

**POSTGRADUATE OF INSTITUTE SCIENCE
UNIVERSITY OF PERADENIYA
SRI LANKA**



**PGIS RESEARCH CONGRESS 2018
PROCEEDINGS
9 - 10 November 2018**

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PGIS Research Congress 2018

Message from the Director, Postgraduate Institute of Science



The Postgraduate Institute of Science (PGIS), University of Peradeniya, contributes to the development of science and technology as well as the society by creating and disseminating new knowledge by conducting postgraduate programmes and scientific research. Through its ten Boards of study in Biochemistry & Molecular Biology, Chemical Sciences, Earth Sciences, Environmental Science, Mathematics, Physics, Plant Sciences, Science Education, Statistics & Computer Science, Zoological Sciences, PGIS has a unique opportunity to launch and promote cross-disciplinary educational and research programs. The Institute as a top priority encourages innovative thinking of its research students and gives its fullest cooperation to fresh graduates to begin their research careers at the PGIS. The research and development activities of the Institute has grown steadily in the recent years proving its identity as an outstanding national institution for science. In the year 2018, University of Peradeniya conferred 196 MScs, 21 MPhils and 18 PhDs on PGIS students and that reflects on the achievements of the Institute.

The annual two-day Research Conference of the PGIS is the prime event in the institute's calendar besides other international and national Seminars and Workshops organized by its Boards of Study. It is a gathering of researchers from all over the country and from other countries and is a regional platform for them to present and discuss their research findings. It combines an inspiring keynote speech by an invited distinguished scientist, with research presentations and discussions in diverse scientific disciplines in a friendly, informal and lively atmosphere. Every year, more than 400 participants comprising scientists from universities, research institutes, senior public-sector officials, industry representatives and postgraduate students attend the conference, and it immensely contributes to promoting and sharing cutting edge research with a stimulating scientific temper.

A conference of this magnitude depends on the contributions of many researchers, organizations and well-wishers, and I would like to acknowledge the efforts of Organizing Committee of RESCON-2018, thank the referees for their invaluable help in the review process and collaboration of the Ministry and Science, Technology and Research of Sri Lanka and the sponsors.

With tremendous pleasure and utmost gladness, I extend a very warm welcome and appreciation to all the dignitaries, researchers, delegates and other stakeholders to the RESCON 2018. I sincerely believe that your presence will add a fresh dimension and glamour to this monumental event.

Prof. H.M.T.G.A. Pitawala

Acting Director

Postgraduate Institute of Science

PGIS Research Congress 2018

Message from the Congress Chairperson



I am indeed privileged and honored to write this message on behalf of the PGIS Research Congress Organizing Committee at the 5th Annual Research Congress (PGIS ResCon-2018). PGIS ResCon is the most important event of the Postgraduate Institute of Science which provides a platform for young postgraduate students and researchers to present, discuss and debate their research findings.

A total of 131 papers were received from postgraduate students and researchers from Sri Lanka and abroad. After peer review under five themes, 100 papers were accepted as oral presentations and 14 papers were accepted as poster presentations. Selected high quality papers will be published in Ceylon Journal of Science as a Special Volume.

The ResCon 2018 program is lined-up for two days as a unique event consist of oral and poster presentations by young postgraduate students and researchers, keynote Lecture by an eminent scientist from the Peoples Republic of China and several invited presentations by eminent scientists. As done in the past four years, this ResCon 2018 wishes to promote the interaction among postgraduate students and researchers while providing an opportunity for them to develop relationships with scientists having diverse background.

The success and sustainability of the PGIS Annual Research Congress over the past 5 years was largely due to the vision and commitments of the past Directors and Congress Chairpersons of the PGIS. I am indebted the present Director Prof. H.M.T.G.A. Pitawala for his excellent support. I take this opportunity to thank Dr. Sarangi Athukorala, the Secretary of the ResCon 2018 and Conveners of the entire sub Committees and respective Committee members for their untiring work during the last few months to make this event a great success. I would also like to thank the generous financial assistance of all the Sponsors.

I wish all the presenters and the participants a very successful and productive ResCon 2018.

Dr. Jagath Gunatilake

Chairperson of the Organizing Committee

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Message from the Editor-in-Chief



We are happy to bring you the Proceedings of the 5th Annual Research Congress of the Postgraduate Institute of Science (PGISResCon-2018), University of Peradeniya.

This year we received a total of 131 submissions under five thematic areas. Most of the authors are affiliated to the PGIS as postgraduate students. All the submissions were subjected to rigorous review by the members of the Editorial Committee and more than seventy referees. The members of the Editorial Committee worked efficiently and responsibly under time constraints to solicit at least two reviews for each abstract. We are pleased to note that we have selected 100 oral presentations and 14 posters for presentation at the PGIS ResCon 2018. The programme includes a keynote talk and several invited talks offered by renowned researchers.

The final outcome would not have been possible without the dedication and hard work of many colleagues. Special thanks are due to the members of the Editorial Committee and to all referees for the excellent reviews, and sense of responsibility and responsiveness under very tight deadlines. I also take this opportunity to thank the authors who responded to our call for papers. We hope that the Proceedings will serve as useful reference material particularly for the postgraduate students.

Prof. B.S.B. Karunaratne

Editor-in-Chief

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A Brief Biography of Professor Pang Zhonghe



Professor Pang Zhonghe received his BSc in 1981 and MSc in 1984 in Hydrogeology and Engineering Geology from Nanjing University, Nanjing, China. Then he completed his PhD in 1987 in Geothermics from the University of Chinese Academy of Sciences (UCAS) in Beijing. He was a Professor and the Head of Lab for Geothermics in Institute of Geology and Geophysics in the Chinese Academy of Sciences in Beijing (IGG-CAS) from 1995 to 1999. From 2000 to 2005 he served as the Isotope Hydrologist, at IAEA in Vienna. He returned to IGG-CAS in 2006 as a Professor of Hydrogeology and held the position till 2013. Professor Zhonghe has been serving as the Director of Geothermal Research Centre, IGG-CAS since 2014 and the Director of Sino-German Geothermal Research Centre since 2016. In 2014 he took up the Professorship and the Head of Department of Hydrogeology and Geothermics at UCAS and continues up to date.

Professor PANG Zhonghe has carried out research on water cycle and water-rock interaction processes in different geological environments, from shallow to deep and local to basin-scale. He has served as principal scientific investigator and took led in completing many research projects supported by national and international funding sources, including the CAS, China Geological Survey (CGS), National Science Foundation of China (NSFC), International Atomic Energy Agency (IAEA) and Ministry of Science and Technology (MOST) as well as SINOPEC. He has supervised many Ph.D. students on various subjects, from groundwater pollution to geological sequestration of CO₂. He has edited 5 books/proceedings and written over 120 peer-reviewed articles in international/domestic journals. He has been a member of editorial boards of international journals such as Hydrogeology Journal, Geothermics and Greenhouse Gases: Science and Technology. He has been involved in the study of global water issues in different continents in particular through his two terms of service, during 1997-2005, with the Water Resources Program of the IAEA in Vienna. As a Chinese scientist with international recognition, he has served as Board Member for a number of international scientific societies such as International Geothermal Association (IGA) and International Association of Hydrological Sciences (IAHS).

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Invited Presentation

INSECT FARMERS

N. Savitri Kumar*

³National Institute of Fundamental Studies, Hantana Road, Kandy, Sri Lanka

*nskumar3@gmail.com

Human beings were ecological pioneers when they changed their nomadic hunter-gatherer life style about 10,000-12,000 years ago, and began discovering and cultivating food crops. With time, wild crops were transformed and production was scaled up to feed entire communities. Agriculture, cultivating food crops, and farming is now central to our survival. Development of new techniques and machinery over thousands of years allowed crop yields to increase and support a growing population.

Cultivating your own food is not unique to human beings. Four groups of insect farmers - attinine ants, macrotermite termites, wood wasps and ambrosia beetles are known to have been cultivating fungi as a food source for more than 40 million years ago. They used the fungi to turn complex plant material such as cellulose and lignin, into a food source which they could digest. Sophisticated techniques are used by these insects to shelter, weed and protect their fungal garden food source. These insects were agricultural wizards and used agricultural techniques to domesticate their crops. Human farmers today are using some of these same techniques to improve agriculture. Agricultural approaches adopted by some insects such as termites, opened up new environments for inhabitation for both the insects and their domesticated fungi, in the same way human agriculture facilitated mankind's spread across the globe.

Ambrosia beetles, members of the family Scolytidae, and their species number several thousand worldwide. The Tea Shot-hole borer beetles, *Xyleborus fornicatus* (Family Scolytidae) known as ambrosia beetles, because they feed on fungal symbionts called ambrosia ("food of the gods") have been causing serious economic losses in the tea plantations of Sri Lanka, for at least 60 years and many studies were conducted at Tea Research Institute (TRI) laboratories. From about 1994, the Tea Shot-hole Borer Infestation (TSHB) of Tea (*Camellia sinensis*) was investigated by the Natural Product Research Group at the Department of Chemistry, University of Peradeniya, in collaboration with the TRI Talawakelle, and was later continued at the National Institute of Fundamental Studies, Kandy. The project at the University of Peradeniya was funded and supported by Uppsala University, Sweden. The significance of the inhibition of TSHB by caffeine, the major alkaloid of tea and, the presence of unusual naphthoquinone metabolites within TSHB galleries will be discussed.

**APPLICATION OF TANK MODEL AND QUANTITATIVE ASSESSMENT TO
PREDICT RAINFALL INDUCED DISPLACEMENT ON LANDSLIDE:
A CASE STUDY ON NAWALAPITIYA LANDSLIDE, SRI LANKA**

A.G.R.P. Weerasinghe^{1,2*}, K.N. Bandara² and J. Gunatilake^{1,3}

¹*Postgraduate Institute of science, University of Peradeniya, Peradeniya, Sri Lanka*

²*National Building Research Organisation, Jawatta Road, Colombo 05, Sri Lanka*

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

**ranjan.weerasinghe@gmail.com*

Although, many identified landslides exist in the mountainous area in Sri Lanka, introducing of advance non-structural methodologies has not been established widely to reduce the impact to the community. A landslide situated at Nawalapitiya was selected for the study. A simple tank model can represent a non-linear flow behavior, and also it can be used for long-term analysis of runoff and groundwater. The tank model is based on analysis of the water balance, a calculation model that considers water flows in and out of the relevant hydrological system. As a modified and advanced version of this model, a multi-tank model was used in this study. Water levels data from gauges from November, 2015 to May, 2016 were used for this study for calibrating the tank model and June, 2016 to November, 2016 data from borewells at Nawalapitiya landslide, were simulated from the calibrated data by using the tank model. Two variables were given to describe the change in displacement and the level of groundwater in the event of heavy rains. The first is the heavy rainfall-induced displacement (HRID) which is defined as the sum of the displacement at an active extensometer location, after a rainstorm. The second variable is the maximum increase in water level (MIWL), which is defined as the difference between highest water level caused by heavy rainfall and average water level. By combining HRID and MIWL relation and the simulated groundwater level from the multi-tank model, calculated heavy rainfall-induced displacement (CHRID) showed a good relationship with the actual rainfall-induced displacement. Therefore, this approach is promising for predicting groundwater level and calculating heavy rainfall-induced displacements. An early warning system can be developed based on this tank model by predicting the groundwater level fluctuation induced by heavy rainfall and hence to issue early warning to the vulnerable communities before a landslide trigger.

Keywords: Groundwater simulation, Nawalapitiya Landslide, Rainfall induce displacement, Tank model.

PRODUCTION OF GRAPHITE OXIDE BASED SUPER SAND FOR DRINKING WATER TREATMENT

R. T. Perera^{1*}, J. A. Liyanage¹, A.R. Kumarasinghe² and R. Weerasooriya³

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

²*Department of Physics, University of Sri Jayewardenepura, Nugegoda, Sri Lanka*

³*National Institute of Fundamental Studies, Hantana Road, Kandy. Sri Lanka*

**ruwantharangaperera@gmail.com*

Drinking water purification process is a very significant and an important process to be carried out using internationally acceptable procedures throughout the country. In particular, low water quality reported areas; the need to have well-established procedure is unavoidable. Sand is considered to be an effective adsorbent for water purification process. Although sand gravels can remove contaminants from water in commercial water treatment plants, there is always a quest to enhance the effectiveness of the sand filtration process. The effectiveness of sand filtration process can be augmented if sand is coated with oxides of graphite which does not occur in nature, unlike sand and graphite. The composite material, where sand gravels are covered by layers of graphite oxide, is called “Super sand”. In this work, production and investigation of surface properties of “such Super sand” material and how such composite material responds to the absorption of fluoride ions from water are reported and discussed. Here, graphite was oxidized using Modified Hammers method and synthesized graphene oxide was coated onto washed sand particles. Repeated coating of graphite oxide on sand resulted in a composite that is more stable in water. FTIR, SEM/EDXA and XRD are used to characterize the composite material as well as individual precursor materials (i.e., sand gravel and graphite). Surface titrations methods are used to evaluate the ion adsorption capacity of sand ravels and “super sand”. FTIR results reveals that, following oxidation, the basal plane of graphite become functionalized with O-H, C=O, C=C groups. Graphite oxide binds to sand via functional groups. SEM images clearly show that the sand gravels are covered with layers of graphite oxide forming a “core-shell structure”. Fluoride adsorption process of the super sand seems a physisorption process at pH = 7. But at the low pH it seems formation of chemical bonds between fluoride and sand surface with the aid of graphene oxide layers and accordingly, 5 times graphite oxide coated super sand has high fluoride adsorption capacity than the single coated super sand.

Keywords: Super sand, Graphene oxide, Water purification.

**PERFORMANCE ASSESSMENT OF A BEACH SAND DERIVED GARNET
FILTER MEDIA FOR TURBIDITY REMOVAL IN WATER**

**K.M.D.P. Kodithuwakku^{1*}, T.H.N.G Amaraweera², G.W.A.R Fernando³
and K.W.S.N Kumari²**

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

²*Department of Science and Technology, Uva Wellassa University, Badulla, Sri Lanka*

³*Department of Physics, Open University of Sri Lanka, Sri Lanka*

**kmdpkoithuwakku@gmail.com*

Filtration is an economical method to remove the turbidity in water. However, efficiency of water filtration units depends on the durability of filter bed and its efficiency of backwashing. Garnet granules have ability of reduction of bed expansion and particle abrasion in multi-media filters due to its high specific gravity and hardness. However, limited attention was given to investigate economical applications of garnet in southeastern coast of Sri Lanka. Consequently, this work focuses on investigating the possibility of using separated garnet from beach sand as a filter media. Garnet for the study was received from the beach sand in southeastern coast of Sri Lanka. Mineralogical analyses of beach sand samples from southeastern coast indicate that beach sand is dominated by garnet (58%), followed by quartz (23%). Grain size distribution and mineralogical analysis of garnet-rich beach sand showed that sand particle size range between 1 – 0.5 mm (49%) and 0.5 – 0.150 mm (48%) can effectively be used as filter material. Garnet from the beach sands, separated by density and magnetic separation were used to prepare filter beds. Performance of filter beds for turbidity reduction was measured. Performance of filter beds during the back washing indicates that the garnet showed three times low bed expansion than quartz. Turbidity resulted due to suspended particles were effectively removed by filtration through garnet filter media. Turbidity removal mainly depends on filtration rate and the particle size distribution of the garnet in filter beds. Under slow filtration condition, filter beds with combined 50 % of 1- 0.5 mm and 50 % of 0.5- 0.15 mm garnet grains showed the more effective filtration. Moreover, this filter bed can effectively remove the turbidity up to 10 repeated filtration cycles. Therefore, garnet of southwestern beach can be value added as a cost effective filter media in reduce turbidity.

Keywords: Garnet, Turbidity, Water filtration.

**SELECTION OF TUNNEL ALIGNMENT FOR PROPOSED BYPASS TUNNEL
TO CONNECT EAST AND WEST OF KANDY CITY AREA**

D.L.C. Pushpakumara^{1,3*} and J. Gunatilake^{2,3}

¹*Engineering Geology Unit, Central Engineering Consultancy Bureau, Digana, Sri Lanka*

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

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

**cecbgeo@yahoo.com*

Heavy traffic congestion within the Kandy City has created numbers of social, economic, environmental and health problems for the people travelling within the city. Numbers of real time traffic surveys have been conducted within the city area to identify the real cause of this traffic congestion and it was revealed that the, insufficient East-West road connectivity create this problem (Kumarage, 2014). Number of proposals for improvements of East-West Kandy city connection were considered and most of the proposals were dropped due to terrain difficulties and heavy urbanized areas. Construction of a road tunnel connecting east-west ends of the Kandy city was considered as the most appropriate proposal to ease the traffic congestions. Detailed pre-feasibility study to identify the best tunnel route has been carried out by the Central Engineering Consultancy Bureau, in collaboration with the Department of Geology, University of Peradeniya. Different tunnel options were studied to identify the most feasible option. A detailed topographical study was carried out using available 1:10,000 topographic maps and GeoEye satellite images. Potential routes were identified considering the elevations and maximum ground cover above the tunnel, feasibility of access from main roads and ground stability at portals. A corridor with 1 km width along each tunnel trace was studied for surface geology, major lineaments, fault zones, dip of the slopes, bedrock outcrops, presence of water bodies and the presence of landslides. Results obtained from field and laboratory experiments were used to compile the engineering geological model with portal locations for preferable entry/exit point of tunnel route options. All the options were evaluated considering tunnel gradient, traffic survey results, surface and sub-surface engineering geological conditions, access roads, social problems, environmental impacts and construction costs. Option 3-tunnel from Tennekumbura (Gallindawatta) to Ampitiya and Ampitiya to Suduhumpola was selected as the most promising option.

Keywords: Traffic congestion, Kandy City, Road Tunnel, Tunnel investigation.

CHARACTERIZAION OF BACTERIA FOR THEIR CELLULASE PRODUCTION

S.K. Jayasekara¹, C.L. Abayasekara² and R.R. Ratnayake^{1*}

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

²*Department of Botany, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka*

**renukar@ifs.ac.lk*

Cellulose being a rich source of fermentable sugars could be utilized as a raw material in industries, such as bioethanol production. Although it is abundant on earth, its complex polysaccharide structure acts as a limitation, as the conversion process is costly. Microorganisms, such as bacteria and fungi, found in nature carry out cellulose hydrolysis efficiently, and could be explored for the presence of novel cellulases which may have a potential to be developed for industrial applications. The objective of the present study was to assess some soil aerobic bacteria for their cellulase production potential. Fifteen bacteria were isolated from garden soil, decaying plant matter, plant rhizobium and the enzyme production by each isolate was compared based on two cellulose substrates *viz*; Microcrystalline and carboxy methyl cellulose. The preliminary observation of cellulose hydrolysis was done by plate culturing. The total cellulase assay was done using Whatman No 1 filter paper as substrate. Endoglucanase assay was done for broth culture extracts obtained after growing bacteria on carboxy methyl cellulose as substrate. Four bacterial isolates exhibited clear zone formation on both microcrystalline and carboxy methyl cellulose plates, indicating cellulose hydrolysis. The highest total cellulase activity (0.0409FPU/m) was given by bacterial isolate NIFS-S-8 utilizing carboxy methyl cellulose as the cellulosic substrate. The highest total cellulase activity (0.0369 FPU/ml) using microcrystalline cellulose also was given by NIFS-S-8 isolate. The highest activity for endoglucanase was observed in NIFS-S-4(1.777 U) and NIFS-S-8(1.776 U) which were not significantly different. The endoglucanases activity was significantly lower when bacteria were cultured on microcrystalline cellulose. The study identified two efficient bacteria (NIFS-S-11 and NIFS-S-8) for the production of cellulases which were more efficient in breaking down carboxy methylcellulose (amorphous cellulose) when compared to crystalline cellulose.

Keywords: Bacterial cellulose hydrolysis, Cellulose, Cellulases activity, Endoglucanases activity.

GROUNDWATER QUALITY ENHANCEMENT AND EFFICIENT WATER MANAGEMENT PRACTICES IN JAFFNA PENINSULA, SRI LANKA

K. Sivendram^{1*} and K.D.W Nandalal²

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

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

**ksivendram@yahoo.com*

The Jaffna peninsula almost wholly depends on groundwater. During the past three decades, the consumption rate of groundwater was rapidly increased. However, the quality of groundwater deteriorated due to increased usage of fertilizer chemicals, rapid change of land-use pattern and an increase in the number of soakage tanks. This study was carried out to study the water resources profile of the Jaffna peninsula and existing water management practices in the area. Subsequently, measures for short-term and long-term water management were suggested. The study is based on available reports and data collected by diverse institutions. Previous studies showed that the quality and quantity of groundwater are not suitable for sustainable human settlement development in the Jaffna peninsula. Due to the geographic setting of the Jaffna peninsula, surface water resources are not available. Therefore, efficient and effective water management and identification of alternative water sources are essential to human settlements in this region. When identifying the alternative sources, consideration given to socio-economic setting is significant because previous attempts on this subject reflect this very well. According to census and statistical data, rainwater harvesting is helpful to reduce the dependency on groundwater in rural areas. However, for urban areas, a Reverse Osmosis plant is necessary to fulfill the demand. Storm water management and rehabilitation of groundwater recharging ponds are essential for ensuring sustainable water supply. Rural settlements partially depend on groundwater since rainwater is not sufficient throughout the year. In the meantime, it is suggested to regularize the extraction, utilization, and recharging of groundwater through the protection of water retention areas in the peninsula.

Keywords: Groundwater stress, Jaffna peninsula, Water management, Water quality.

SYNTHESIS OF MONO-LAYERED ZINC OXIDE NANOPARTICLES ON THIN FILM OF MUSCOVITE MICA: NOVEL ADVANCED VALUE ADDITION TO SRI LANKAN MICA

A. Senthilnathan^{1,2*}, U. G. M. Ekanayake^{1,2} and M.M.G.P.G. Mantilaka^{2,3}

¹*Academy of Sri Lanka Institute of Nanotechnology, Nanotechnology and Science Park, Mahenwatte, Pitipana, Homagama, Sri Lanka*

²*Sri Lanka Institute of Nanotechnology, Nanotechnology and Science Park, Mahenwatte, Pitipana, Homagama, Sri Lanka*

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

**anoja11@gmail.com*

Mica is a group of phyllosilicate mineral which has been attracted the attention to its characteristic layered lattice structure. The reported studies of the value added advanced materials of mica are limited to its wide range of properties. Therefore, this study is mainly focus on the preparation of monolayer of ZnO nanoparticles on mica surface (ZnO-Mica) and the characterization of the prepared product. In this method, 600 μ L, 50 mL of cetyltrimethyl ammonium chloride (CTAC) and 2 M, 50 mL of zinc nitrate hexahydrate were gently stirred using a magnetic stirrer for 30 min. Then, 5 g of cut thin films of mica (0.5 cm \times 0.5 cm) were added to the above solution. Later, a 4 M, 50 mL of NaOH solution was added dropwise to the above solution and continuously stirred for 24 h. The obtained precipitate was washed with distilled water and calcined to a temperature at about 600⁰ C. The calcined material was dried after washing. The field-emission scanning electron microscope revealed that the flower like zinc oxide nanoparticles was deposited on the surface of mica with average particle length and width of 800 nm and 50 nm respectively. X-ray diffraction spectrum revealed that synthesized nanoparticles were of the composition of zincite (ZnO). Energy dispersive X-ray spectroscopy and X-ray fluorescence chemical analysis also confirmed the presence of the ZnO nanoparticles on the surface of the mica. Fourier transform infrared spectroscopy analysis of the synthesized product confirmed the chemical environment. Thermogravimetric analysis of the synthesized material confirmed the thermal stability at the temperature about 1000⁰C. This novel method was used to fabricate flower-like nanoparticles on thin sheet of mica which has potential applications in photo-catalytic dye degradation.

Keywords: Mica, ZnO nanoparticles on mica, flower-like nanoparticles.

APPLICATION OF WATER QUALITY INDEX FOR GROUNDWATER QUALITY ASSESSMENT IN CKDU AREA IN SRI LANKA

W.A.C. Udeshani¹, H.M.K.P. Dissanayake², G.E.M. Wimalasiri³, S.V. Gunatilake⁴ and S.K. Gunatilake^{1*}

¹*Department of Natural Resources, Sabaragamuwa University of Sri Lanka, Sri Lanka*

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

³*Department of Export Agriculture, Sabaragamuwa University of Sri Lanka, Sri Lanka*

⁴*Department of Geology, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka*
**sksg@appsc.sab.ac.lk*

This study investigated the relationship between water quality and Chronic Kidney Diseases (CKDu) using groundwater indices in Moneragala District in Sri Lanka. This study revealed that 29% of CKD patients are belonging to CKDu group, and 80% of the farmers in the age range from 40 to 70 are the most vulnerable group for CKDu. According to the Sri Lanka standard 614, 1983 for potable water, this study showed that 65% of the groundwater is alkaline, Ec of 90% of samples, TDS of 58% of samples, hardness of 53% samples and F of 24.5% samples shown values less than the permissible limits. It is apparent that the groundwater of study area is already being contaminated by high amounts of Fluoride. High Chloride level (18%) in groundwater may have been caused due to contamination with fertilizer and mixing with irrigation water supplied from reservoirs. The main anion in groundwater was serried as $\text{HCO}_3 > \text{Cl} > \text{F} > \text{SO}_4$ while the cations varies as $\text{Mg} > \text{Ca} > \text{Na} > \text{K}$. The computed WQI values range from 1.27 to 333.87. According to WQI, 53% of water samples were found to be of good quality, 47% were of poor quality and 23.29% were of unsuitable quality. The analysis revealed that the dug-well water in the area needs some degree of treatment before consumption, and it also needs to be protected from the perils of contamination. 73% of tube-wells are within the safe limits for drinking purposes. This study revealed that poor groundwater quality areas are the highest vulnerable areas for CKDu in the Moneragala District. Thus, groundwater quality has a direct correlation with CKDu in the area and WQI can be an excellent indicator to detect changes in water quality considering their physico-chemical parameters. This index may be used as a guideline in management of quality of water resources in the other parts of the country.

Financial assistance from Sabaragamuwa University of Sri Lanka, Sri Lanka (Grant No: SUSL/RG/2016/13) is acknowledged.

Keywords: Groundwater, Water quality index, CKDu, Dug-wells.

DETERMINATION OF DESCRIPTOR VALUES FOR SAFROLE USING POLY (DIMETHYLPHENYLSILOXANE) STATIONARY PHASE AND A LIQUID-LIQUID PARTITION SYSTEM

A.W.T.D. Ambagaspitiya¹, C.F. Poole² and J.A.T.C. Ariyasena^{1*}

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

²*Department of Chemistry, Wayne State University, Detroit, MI 48202, USA.*

**ariyasenat@gmail.com*

Safrole (5-prop-2-enyl-1,3-benzodioxole) possesses antibacterial, antifungal and antiviral properties, and is used in many industries including the perfumery and drug industries. Sufficient doses of safrole may cause kidney damage, genotoxicity, cell toxicity and oxidative stress. Therefore, it is important to determine the distribution levels of safrole in environmental compartments for environmental risk assessment procedures. For developing countries like Sri Lanka, experimental determination of distribution levels is difficult due to limited technical, human and economical resources. As a solution to this problem, quantitative structure-property relationships (QSPR) can be used to estimate the distribution level of safrole in environmental compartments. In this study, Abrahams Solvation Parameter Model ($\log SP = c + eE + sS + aA + bB + vV$, where, SP: Free energy related solute property, c : system constant, V : McGowan's characteristic Volume, E : excess molar refraction, S : dipolarity/polarizability, L : gas-liquid partition coefficient for solute in *n*-hexadecane, A : hydrogen-bond acidity, B : hydrogen-bond basicity) is used as the QSPR, and the descriptors of safrole are determined using a gas chromatographic (GC) technique. The poly(dimethylphenylsiloxane) stationary phase was calibrated at temperatures ranging from (80-300) °C at 20 °C intervals and the retention factors for safrole were determined at calibrated temperatures. The partition coefficient for safrole in hexane-acetonitrile was also determined. The descriptor values were assigned using the Solver algorithm in MS Excel, using the system constant values for characterized systems. The determined descriptor values for safrole are, $E = 0.978$, $S = 1.02$, $A = 0.00$, $L = 7.650$, $B = 0.35$ and $V = 1.246$, respectively. The assigned descriptor values can be applied to determine the partition levels of safrole in natural environmental systems, after optimization.

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Keywords: Gas chromatography, Safrole, Solvation Parameter Model.

USE OF BIOFILMS IN BIO SOLUBILIZATION OF EPPAWALA ROCK PHOSPHATE

**J.P.H.U. Jayaneththi^{1*}, G. Seneviratne², H.M.S.P. Madawala³
and M.G.T.S. Amarasekara¹**

¹*Faculty of Agriculture, Rajarata University of Sri Lanka, Mihintale, Sri Lanka*

²*National Institute of Fundamental Studies, Hanthana Road, Kandy, Sri Lanka*

³*Department of Botany, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka*

**harshaniupulika@gmail.com*

Eppawala Rock Phosphate (ERP) has been identified as a good alternative for Triple Super Phosphate (TSP), though its application is restricted due to low solubility. However, ERP has a greater potential to use as a P-rich fertilizer, if the biosolubility is increased. The National Institute of Fundamental Studies (NIFS) has developed biofilm formulations with the potential of solubilizing ERP. Hence, this study was designed to evaluate the efficiency of these biofilm formulations in solubilizing ERP. Two experiments were conducted (a culture broth study and a leaching tube study) under laboratory conditions in a completely randomized design (CRD) with three replicates. Data were statistically analyzed using analysis of variance (ANOVA) followed by mean separation using Tukey's test. In the broth study, four biofilm cultures developed with different bacterial and fungal strains (BF1, BF2, BF3 and BF4) were tested for their efficacy in P solubilization in liquid Low Cost Medium (LCM) containing ERP. Available and water soluble P, microbial biomass C and P, and pH of the medium were analyzed and microscopic observations were taken after two weeks of incubation. In the leaching tube experiment, the recommended dosage of chemical fertilizers for rice was used by replacing TSP with ERP together with biofilms (BF1, BF2, BF3 and BF4) separately. Solubilized P was quantified in the leachate in two-weekly intervals for three months. The broth study revealed that the BF3 solubilized P more efficiently and produced higher microbial biomass in comparison to other tested biofilms. In leachates, the highest cumulative solubilized P was recovered from BF3 too. The results conclude that the BF3 is the most efficient biofilm formulation in solubilizing ERP. Further studies are ongoing to evaluate the efficacy of BF3 in solubilizing ERP under field conditions.

Keywords: Biofilms, Eppawala Rock Phosphate, Phosphorous Solubilization, Triple Super Phosphate.

RAPID SCREENING OF SOURCE WATERS BY INTEGRATED WATER QUALITY INDEX

**A.N. Erangani^{1*}, P.Rukshagini², P. Wijekoon³, S.K. Weragoda²
and R. Weerasooriya⁴**

¹*Environmental Science, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka*

²*Water Safety Plan Advisory Unit, National Water Supply and Drainage Board,
Katugastota, Sri Lanka*

³*Department of Statistics and Computer Science, Faculty of Science, University of Peradeniya,
Peradeniya, Sri Lanka*

⁴*National Institute of Fundamental Studies, Hantana Road, Kandy, Sri Lanka
ruks2007@gmail.com

To date, over 3.8 million people in the dry zone of Sri Lanka suffer without safe water for drinking and domestic requirements. Presently WHO or EPA standards is being used to assess the source water quality. Sometimes this assessment is cumbersome and the synergy among different parameters is often neglected which results in unambiguous water source screening. This research is aimed to develop an integrated water quality index (IWQI) for rapid source water screening. A study was conducted in Mihintale Aquifer. On-site and laboratory assessments measured for most of the physical-chemical parameters. The Inverse Distance Weighted (IDW) technique was used to extrapolate data for spatial mapping. IWQI calculations were carried out by using RStudio 3.1.3 based on 15 parameters (pH, EC, TDS, alkalinity, hardness, Na, Mg, K, Ca, Mn, Fe, F⁻, Cl⁻, NO₃⁻, and SO₄²⁻) with weighted arithmetic water quality index method. The calculated IWQI values were ranged from 18 to 152, and these values were categorized into five different classes (Very Good 0 – 25, Good 26 – 50, Poor 51 – 75, Very Poor 76 – 100, and Unsuitable > 100). Using Hierarchical cluster analysis enabled further classifications according to their IWQI values; a dendrogram visualized the resulted groupings. According to this classification, the source waters in Mihintale Aquifer belong to "Very Poor" category with a mean of 81 IWQI. Since IWQI is a single number, rapid screening of source water can be carried out efficiently. However, refinement of IWAQ is needed by incorporating different chemical species believed to present in water.

Financial assistance from National Research Council (Grant No: TO 16-015), Sri Lanka is acknowledged.

Keywords: Groundwater, Integrated water quality index, Sri Lanka, Water Quality Standards.

ASSESSMENT OF HYDROGEOLOGICAL CONDITIONS USING RESISTIVITY DATA: A CASE STUDY IN MORAGAHAKANDA AREA, SRI LANKA

**A.M.N.P.B. Abeysinghe^{1*}, H.A.M. Prasadani², R.R.G.R. Rajapakse¹,
H.A. Dharmagunawardhana² and J. Gunatilake²**

¹*Water Resources Board, 2A, Hector Kobbekaduwa Mw, Colombo 07, Sri Lanka*

²*Department of Geology, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka*
**abeysingheniranjan@gmail.com*

A resistivity survey was carried out to determine resistivity based hydrogeological properties of sub-surface for a selected Precambrian Terrain in Highland Complex of Sri Lanka. Vertical Electrical Soundings (VES) were carried out using Schlumberger Electrode Array (SEA) and drilling was carried out at selected locations up to 40-60 m depths. Subsurface conditions and lithology were determined using borehole logging. The resistivity method is a reliable alternative in surveying shallow depth for geotechnical investigations. The SEA was adopted for resistivity surveys. Calibration of resistivity data was done corresponding to the findings from boreholes. Interpretation of the VES and borehole data indicates the presence of various rock conditions, overburden depth, groundwater level and an idea about the yield. The lithology of the area is charnockitic gneiss, quartzite and karstic marble. Resistivity values and borehole drilling data were compared and correlated. VES yields a straightforward interpretation of the subsurface structures and these results helped in positioning a trench for fault characterization and identification of subsurface condition. The electrical resistivity of the subsurface materials was dependent on porosity, permeability, mineral composition, weathering state of the bedrock and moisture content. To analyze sub-surface layering and groundwater quality, density maps were prepared using ArcGIS 10.3. The thickness of soil layer is greater in the southern and central parts of the study area. Groundwater yield of the hard rock aquifer is high in the central and western parts of the area. Groundwater level is comparatively shallow along the North South running belt across the central parts of the area which mostly underlain by marble. Electrical conductivity, alkalinity and hardness show almost the same geographic distribution. Geographic distribution of Fe in groundwater is different and an iron rich East West running belt is shown across the central parts of the area. Although, marble rock shows low formation resistivity ranges, rock type specific resistivity range cannot be established using VES alone.

Keywords: Vertical Electrical Soundings, Schlumberger array, Porosity, Permeability.

**GIS BASED ANALYSIS OF UTILIZATION OF CLUSTERED
HOSPITALS IN JAFFNA DISTRICT**

**K.D.N.P. Ranaweera^{1*}, J. Gunatilake², M. Gunawardana³
and K.K.S.A. Withanage⁴**

¹Ministry of Health, Nutrition & Indigenous Medicine

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

³Ministry of Megapolis & Western Development

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

**prasadrana@hotmail.com*

Empanelment of patients in well defined primary catchment areas of hospitals and clustering of primary level hospitals around Apex hospitals were key strategic reforms in Primary Healthcare Strengthening Policy of Sri Lanka. Minimizing bypassing with improvement in utilization of primary level hospitals and reduce overcrowding of major hospitals are key expected outcomes of proposed health reforms. This research was carried out in Jaffna District to propose a GIS-based methodology to cluster primary level hospitals around Apex hospitals to form clusters. Road network and hospital location shapefiles were used to determine the shortest pathways in the process of clustering with ArcGIS software. Primary catchment areas around each hospital were mapped using shapefile of Grama Niladhari Division layer of Sri Lanka. Primary catchment areas were combined according to clusters to form catchment areas of Apex hospitals. Defined catchment areas were validated at a consultative meeting represented by the heads of hospitals of Jaffna District. The accuracy of the methodology was about 80% as considerable changes were observed only in one cluster. Bed occupancy rates, outpatient department visits, hospital admissions and clinic visits were used as basic indicators for spatial analysis of the utilization of clustered hospitals in the study area. BH Point Pedro and BH Tellipalai had similar patterns of use in selected parameters. BH Kytes had the lowest level of utilization of inward facilities but outpatient utilization was higher than expected. The GIS-based methodology of clustering and mapping of catchment areas of hospitals can be implemented in other parts of the country high reliability. In addition, this methodology can be used to assess utilization of hospitals based on clusters instead of individual hospitals.

Keywords: Hospital Clusters, Catchment areas of hospitals. Utilization of hospitals, Primary Healthcare, Empanelment.

**DEMARCATIION OF LAND VALUATION ZONES USING GIS
(CASE STUDY IN GANGAWATA KORALE DSD)**

L.R.T.C. Weeraratne, M.D.N. Chandramali* and J. Gunatilake

Postgraduate Institute of Science, University of Peradeniya, Peradeniya, Sri Lanka
**sadu1989geo@gmail.com*

Land is a scarce resource due to rapidly increasing population in the country. There is a large spatial variation in land prices. The main objective of this study is to investigate the applicability of GIS in demarcation of land valuation zones. This research project designed to determine the market value of a land considered 14 parameters, namely, proximity to city center, distance to main roads, minor roads, railway stations, hospitals, schools, supermarkets, filling stations, government buildings, police stations, fire brigades, recreational areas, current land use and the slope angles of the area. Each parameter was weighted according to the expert's views and Analytical Hierarchical Process (AHP) technique. Most influential factor for land value was "proximity to city center" and least important factor was "proximity to fire brigades". A map was prepared according to land value and categorized into six classes such as very high, high, moderate, low, very low and restricted area. Out of the total area considered, 12.44% of lands depicted as very high in value, and 23.60%, 23.91%, 13.88%, 10.23% are identified as high, moderate, low and very low in value. Final Map was validated by market-value points collected from actual land prices with respect to their locations. Out of total samples, 88.57% were consistent with generated results. Therefore, this model is very practical in selecting land value zones of the area and 11.43% of the lands did not agree with generated map. It may be due to the influence of some other factors which affects land value such as legal, cultural, social and ritual factors that were not considered in this model. This model is very useful in land valuation, as values can pre-determine the value of a particular land.

Keywords: Land Valuation, Geographic Information System, Weighted Sum, Analytical Hierarchical Process.

DETERMINATION AND COMPARISON OF FLUORIDE CONCENTRATION OF DRINKING WATER IN MEEGALEWA AND EPPAWALA AREAS IN SRI LANKA

B.M.S.M. Dissanayaka¹, J.A.T.C. Ariyasena^{1,2} and M.M.A.N. Navaratne^{1,2*}

¹*Department of Chemistry, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka*

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

**ayanthi.pdn@gmail.com*

Fluoride is an essential natural element for human and animal health. But deficiency of fluoride and surplus of fluoride create many health problems. Therefore, awareness on importance of fluoride content in drinking water is very essential to prevent the damages and to identify solutions for the health problems. This research study was conducted to determine and compare the fluoride concentration in drinking water in Meegalawa and Eppawala areas in the Dry Zone of Sri Lanka. In both areas population is mainly represent Mahaweli settlers and they suffer from chronic kidney disease of unknown etiology (CKDu). Due to the anthropogenic activities and natural sources, fluoride comes into the groundwater. The natural sources are related with geological strata and among fluorine-bearing minerals, fluorite (CaF_2), apatite ($\text{Ca}_5(\text{Cl},\text{F},\text{OH})(\text{PO}_4)_3$) and cryolite (Na_3AlF_6) are very common in dry zone of Sri Lanka. The water samples were collected from 20 different dug wells and tube wells distributed in the two areas, over a period of 7 months from February, 2017 to September, 2017. The other monitored water quality parameters were temperature, pH, and conductivity. To determine the fluoride concentration, Fluoride Ion Selective Electrode (FISE) and Suppressed Ion Chromatographic (IC) techniques were used. According to the results obtained, the fluoride ion concentrations in dug wells ($0.61 - 2.76 \text{ mg l}^{-1}$) exceed the accepted fluoride levels according to Sri Lankan standards (0.6 mg l^{-1}) and concentration for tube wells ($1.51 - 2.49 \text{ mg l}^{-1}$) exceed the accepted levels according to WHO standards (1.5 mg l^{-1}), for majority of wells. The fluoride concentration varies significantly within the study period. It was observed that the fluoride concentrations can also vary depending on the rock type, soil profile and water table.

Keywords: Fluoride content, Ion chromatography, Ion selective electrode, Meegalawa.

HYDROGEOLOGICAL AND GEOCHEMICAL INVESTIGATION FOR THE WATER INGRESS IN HEAD RACE TUNNEL OF UMA OYA MULTI PURPOSE DEVELOPMENT PROJECT, SRI LANKA

J.L.G.S. Jayawardena^{1*} and J. Gunatilake^{1,2}

¹*Department of Geology, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka*

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

**jlgjayawardena@gmail.com*

Uma Oya Multipurpose Development Project consists a 15.29 km long Head Race Tunnel (HRT) connecting two reservoirs at Puhulpola and Dyrabaato an underground powerhouse near Karadagolla. Major water ingress into the tunnel was recorded initially on 26th December 2014 and several other water ingresses during the excavation of the HRT. During the investigation of this water ingress problem, several boreholes were drilled to understand the engineering geology, hydrogeology and geotechnical aspects along the HRT. Deep and shallow aquifer groundwater levels were closely monitored from boreholes and domestic wells, springs and lakes around the vicinity of project area. Water inflow into the HRT was mainly through open joint systems through deeply weathered garnet-sillimanite-graphite gneiss (khondalite) rock. Deep and shallow water levels have shown sudden drop responding to these ingresses. Large number of domestic dug wells were dried out and ground subsidence was extensive in the areas where khondalite rock is underlain. Drastic lowering of water levels has been observed in deep boreholes in the area were closely related to the water inflow into HRT. Most of the buildings were cracked and severely damaged due to land subsidence. This extensive land subsidence is mainly attributed to increasing effective stress within the deep overburden of weathered khondalite due to lowering the groundwater table. Stiff diagrams drawn for geochemistry of water samples collected from ingress points of the HRT suggested the possibility that the ingress water is recharged from two distinct aquifers such as deep aquifers and shallow aquifers within the weathered khondalite with remarkably different geochemistry. The results of the shallow and deep groundwater geochemistry further confirmed the two distinct water types in the vicinity of the ingress points along the HRT were either recharged from deep aquifers extended through deep open fractures or shallow aquifers within the deeply weathered khondalite.

Keywords: Water ingress, Land subsidence, Aquifers, Khondalite, StiffDiagram.

**LANDSLIDE HAZARD ZONATION MAPPING USING GIS:
(A CASE STUDY FROM ARANAYAKA DS DIVISION, SRI LANKA)**

D.M.N.P. Dissanayaka^{*} and L. Manawadu

*Department of Geography, Faculty of Arts, University of Colombo, Colombo, Sri Lanka.
^{*}nadeerauoc@gmail.com*

Landslides are one of the serious natural hazards that frequently lead to many problems in hilly areas, resulting to loss of property, human life and bio-diversity. According to the high intensity rainfall along with unplanned human constructions and agriculture activities of Sri Lanka cause many landslides in hilly areas. Therefore, studying the landslide risk and hazard zones can minimize the impacts of landslides. In this exercise of compilation of landslide hazard zonation mapping and analysis, GIS plays an important role. This research is aimed to identify the landslide hazard zones in Aranayaka DS Division, Sri Lanka using GIS tools and methods. Geospatial based Multi Criteria Decision Analysis (MCDA) technique is increasingly used for landslide vulnerability and hazard zonation mapping. The study was mainly carried out using Arc GIS 10.1 software and five main vector layers; slope, geology, soil type, land use and landslide historical data were used to identify the hazard zones in the study area. These factors were evaluated and class weight were assigned to each of the related factors. The Suitability Index (SI) was calculated using MCDA and the susceptible zones were classified into five categories; very high, high, moderate, low and non-hazard. The result of the study revealed that 19 GNDs came under the high hazard zone. It is situated at the South Eastern part of the study area and most of the high and very high landslide hazard zones are located within steep slopes with instable properties (Red-Yellow Podsollic Soils). These Landslide Hazard Zonation Map play a major role in the identification of human settlements and plantations which are threatened by potential landslides, so that, the Local Governments and the Department of Social Services can take an early action to assure the safety of them.

Keywords: GIS, Landslide Hazard Zone, MCDA, GNDs.

FABRICATION OF GRAPHENE ZERO-VALENT IRON ANODE MATERIALS FOR ELECTROCOAGULATION WATER TREATMENT FACILITY

J.U. Halpegama^{1*}, C.A.N. Fernando², H.M.A.M.C. Herath¹ and R. Weerasooriya³

¹Faculty of Applied Sciences, Department of Physical Sciences, Rajarata University of Sri Lanka, Mihintale, Sri Lanka

²Department of Nanotechnology, Wayaba University of Sri Lanka, Sri Lanka

³National Institute of Fundamental Studies, Hantana Road, Kandy, Sri Lanka

*jhalpegama@gmail.com

Electrocoagulation (EC) is a promising technology in the treatment of excess fluoride and hardness in water. In this technique, the coagulant ($\text{Al}^{3+}/\text{Fe}^{2+}$) is generated in situ as the anode material corrodes under the applied potential. Apart from the merits of the EC, passivation of the anode, residual Al^{3+} in treated water and scaling on the cathode are significant issues to be addressed. Iron and its associated species are environmentally benign; therefore, we fabricated graphene zero-valent iron composite in place of Al anode. The preparation of graphene oxide was carried out by a modified Hummers method. Under facile conditions, one step reduction method was used to synthesize the graphite–Fe(0) composites through green tea leaves and sodium borohydride reductants (GO – 1: Green tea reduced Fe^{2+} graphene oxide; GO-2 NaBH_4 Fe^{2+} reduced graphene oxide). 2D Raman bands appeared at 2715 cm^{-1} for GO-1 confirm the presence of multilayer structure while the bands at 2680 cm^{-1} for GO-2 confirm the presence of the single layer structure of graphene. The point of zero charges (pH_{pzc}) measurement of GO-1 and GO-2 samples were found to be 8.71 and 8.58 respectively. The FTIR spectroscopic data obtained for graphene–Fe (0) attribute the removal of oxygen-bearing functional groups during the reduction process. The vibrational absorption bands correspond to -C=O groups have considerably decreased, but the band at 1620 cm^{-1} remains constant. The X-ray Diffraction (XRD) pattern of graphene–Fe (0) suggests not only the presence of zero-valent iron but also iron oxide. Thermogravimetry (TG) analysis showed that the graphene – Fe - (0) composite has much lower thermal stability than natural graphite.

Financial assistance from National Research Council (Grant No: TO 16-015) is acknowledged.

Keywords: Anode, Electrocoagulation, Graphene Oxide, Graphene zero valent iron composite, Passivation.

RELATIONSHIP OF ROCK MASS RATING AND TUNNELING QUALITY INDEX FOR METAMORPHIC ROCKS IN NORTH CENTRAL AND CENTRAL PROVINCES, SRI LANKA

M.P.K.G. Jayathilaka^{*} and J. Gunatilake

Postgraduate institute of sciences, University of Peradeniya, Peradeniya, Sri Lanka
^{}07kanchanagemunu@gmail.com*

Rock Mass Rating (RMR) and Tunneling Quality Index (Q) methods are the most common approaches in rock engineering fields. Therefore, it is necessary to build up a correlation between these common Rock Mass Classification Systems. Thus, the study carried out to build up a best-fit relationship between RMR and Q systems for major rock types in North Central and Central Provinces of Sri Lanka and to build a common equation for metamorphic rocks in the area. The study area consisted of tunnel No.s 1, 2, 3 and 4 of proposed Upper Elahera Canal Project. As study materials, geological maps, 2D resistivity, borehole logs and Lugeon values, UCS data were collected. Correlations between RMR and Q methods were generated using five statistical methods of Exponential, Linear, Logarithmic, Polynomial and Power analysis. Seven major rock types such as charnockitic gneiss, marble, quartzite, khondalite, hornblende biotite gneiss, and biotite gneiss were identified. Seven logarithmic equations for specific rock types and a common equation for all rock types were developed. RMR and Q logarithmic relationship correlates 74.7% for the charnockitic gneiss and 89.7% for the calc gneiss. For quartzites, the correlation is 95.5% and for the khondalites, it is 86.6%. For quartzo feldspathic gneiss, it is 83.6%. Hornblende biotite gneiss showed 80.3% and biotite gneiss showed 84.2% correlation. Best-fit relationship for identified common metamorphic rocks correlated at 82.1% for the study area. The study revealed that the logarithmic relationship is the best-fit relationship for the RMR and Q method for metamorphic rocks in Central and North Central Provinces in Sri Lanka. The derived common equation may be applied for the other rock types of the rest of the metamorphic terrains of Sri Lanka.

Keywords: Metamorphic rocks, Rock Mass Rating, Tunneling Quality Index.

INTERLAYER EXPANSION OF SRI LANKAN VEIN GRAPHITE VIA REDUCTION OF GRAPHITE OXIDE

J.N. Kanagaratnam^{1*}, H.W.M.A.C. Wijayasinghe¹, N.W.B. Balasooriya² and T.H.N.G. Amaraweera³

¹National Institute of Fundamental Studies, Hantana Road, Kandy, Sri Lanka

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

³Department of Science and Technology, Uva Wellassa University, Badulla, Sri Lanka

*jaelnirubha@gmail.com

The growing market for portable electronic devices has fueled the demand for energy storage systems such as rechargeable batteries. Among them, the Sodium Ion Batteries (SIB) have recently drawn significant attention. Graphite has already been introduced as a viable electrode material for extensively used Li-ion batteries. However, ionic radius of Na⁺ being larger than Li⁺, expansion of interlayer spacing of graphite is essential in order to use it for the anode of SIBs. This study aims to expand the interlayer spacing of Sri Lankan vein graphite via thermal, microwave and chemical reduction of Graphite Oxide (GO) synthesized using natural vein graphite. For that, Needle Platy Graphite (NPG) morphological variety was crushed and particle size fraction <53 μm was separated. The powdered sample was first purified via acid leaching and then used to prepare GO by Tour's method using H₂SO₄, H₃PO₄, KMnO₄ and H₂O₂. The synthesized GO was reduced via thermal annealing, microwave reduction and chemical reduction with sodium hydroxide. X-ray diffractograms obtained for purified vein graphite, GO, Micro-Wave Reduced GO (MWRGO), Chemically Reduced GO (CRGO) showed their corresponding *d*-spacing as 3.35, 8.37, 3.65, 3.73 Å respectively. However, interestingly, the Thermally Reduced Graphite Oxide (TRGO) showed *d*-spacing of 6.42 Å, which could favour better Na⁺ intercalation, hence showing its potentiality for SIB anode application. Further, Fourier Transformer Infrared spectroscopic analysis confirms that only few oxygen functional groups were reduced by the thermal treatment while most of the functional groups were reduced by the other two methods. Scanning electron micrographs evidence for the existence of a honeycomb-like structure in the WRGO and a puffed structure in the CRGO but a compact structure for TRGO. Altogether, this study shows that the thermal annealing of GO is the best among the investigated methods to obtain interlayer spacings suitable for SIB anode application from Sri Lankan vein graphite.

Financial assistance from National Research Council (Grant No: 15-007) is acknowledged.

Keywords: Vein graphite, Interlayer expansion, Thermal reduction, Na-ion batteries.

REALITY MODELING IA A REPLACEMENT OF CONVENTIONAL LAND SURVEY PRACTICE - THE CASE STUDY OF A 11 ROAD

K. Thulasivarman*

Monitoring and Evaluation Consultants, Water and Sanitation Improvement Project

**thulasivarman@gmail.com*

A-11 road development project is intended to re-carpet 128 km length of *Marathankadawela* (located 35 km away from *Anuradhapura*) to *Thirukondaimadu* (located 40 km away from *Batticaloa*) Highway (A11) with the Asian Development Bank financial assistance. At planning stage of any infrastructure project, there is a need to do a survey to identify existing conditions, in order to provide primary input to the decision-making process to understand the context within available asset to design, built, and operate. Therefore, a detail topographic survey is essential. Due to time and cost effectiveness, it was decided to use reality modeling technology. Bentley Context Capture is the software used in this case study due to its cost effectiveness in this sector and for its high accuracy output. This software input is the standard photography captured from any digital cameras, whether mounted on UAVs (Unmanned Air Vehicle) or hand-held to produce a highly accurate 3D mesh (Reality Mesh). In reality modeling, it was established ground control points in 400 m intervals to georeference model. For this purpose, Geodetic GPS receivers (*NavCom SF-3040*) were used in post processing method. After photographs captured by UAV (*DJI Phantom 4 Pro*), if any canopy area discovered DSLR camera (*Canon Rebel Ti3*) was used to capture the canopy ground. Finally, photographs processed using Bentley Contextcapture for the development of reality mesh. At the end of this project, it was compared the accuracy with conventional survey practice such as GPS controlled total station topographic survey and split leveling. There was no difference was observed in accuracy. Further, it facilitates to compare the accuracy in third decimal as well.

Keywords: Bentley Context Capture, Reality Modelling, Drone Mapping, Topographic Survey.

**LANDSLIDE SUSCEPTIBILITY ZONING USING OPEN SPATIAL DATA;
A CASE STUDY IN UDUDUMBARA AND MEDADUMBARA DIVISIONAL
SECRETARIATS IN SRI LANKA**

J.W.M.M.P.K. Jayasinghe^{1*}, J. Gunatilake² and N.I.C. Peiris³

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

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

³*National Building Research Organization, Sri Lanka*

**mithilani0106@gmail.com*

Landslide hazard is one of the major issues faced by Sri Lanka which has cost many lives. Kandy District in the Central Highlands in particular, faces severe effects of landslides with the increasing population and its inherent topography. Landslide susceptibility zoning maps can be utilized to identify the vulnerable locations for land sliding which is important in land use planning and development activities. This study aims to utilize cost and time effective method to accurately delineate various hazard zones using open spatial data like Landsat 8 imagery and Aster GDEM. The factors considered for mapping were slope angle, slope aspect, stream and roads buffer, land cover/land use and vegetation cover (NDVI). Different weights were assigned to these factors based on how much they influence landslide occurrence locations in the past. Cross operation of the landslide map and factor maps reveal landslide locations which are used to calculate weights and ranks for each class of each factor. Final weight map was created by adding these individual weights and susceptibility boundaries were delineated through histogram analysis. Final zonation map shows the areas of high slopes (30-45°) adjacent to roads and streams which face NE (escarp slope) with high human intervention and less vegetation show a higher proneness to fail and slide. Also the slope proved to be the most influential causative factor in favor of landslides. Open spatial data are useful in landslide hazard mapping which can be a powerful tool in terms of cost and time for comprehensive landslide studies and mitigations. However, to produce more detailed maps with expensive higher resolution satellite imagery and DEMs have to be employed. Also, integrating rainfall to the map can enhance the accuracy of landslide prediction.

Keywords: Landslide Hazard Zoning, Medadumbara, Open Spatial Data, Ududumbara.

WEBGIS TECHNOLOGIES FOR PROJECT MANAGEMENT AND MONITORING: A CASE STUDY FROM SABARAGAMUAWA PROVINCE

D.A.J.S. Kumara^{1*}, J. Gunatilake² and M. Gunawardhana³

¹*Local Government Enhancement Sector Project (LGESP), Ministry of Provincial Councils, Local Government and Sports, Sri Lanka*

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

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

**janathit@gmail.com*

There were many of foreign funded development projects carried out in the Sabaragamuwa Province over the past decade. This study explored the role of new and emerging technologies, specifically use of WebGIS technologies, for Project information database and Project progress monitoring, and thereby developed a WebGIS prototype. Google Fusion table was chosen to develop the prototype because of its easy maintenance and customization. In the prototype implementation, an interactive user interface was designed and developed. Google Fusion Table was customized to set up and enhance the web interface function. A script was created and assigned to Google sheet for automatically syncing the data collected from site locations to Fusion Tables. Selected project locations (LGESP – Sabaragamuwa) were updated in Google Fusion Tables. To create a spatial project information database and develop a project progress monitoring tool, Google Fusion Tables technology was used. As a result, all the project management staff and beneficiaries (Pradeshiya Sabhas) were able to obtain the required data as and when needed. With the project progress monitoring tool, most of the analysis could be done and those progress reports could be downloaded for printing. Data collection duration was reduced from one week to one day. This study shows Google Fusion Tables system can be used as both project information database and the project progress monitoring tool. Therefore, divisional and national level project management units, stakeholders and funding organizations can use the Fusion Tables system for easy and quick project monitoring, management and data gathering purposes. Recommendations were made to enhance the usage of WebGIS technologies like Google Fusion Tables for funding organizations, local government organizations and other stakeholders for their project monitoring activities.

Keywords: Google fusion tables, Project progress monitoring, WebGIS, Project information database.

**EFFECTIVENESS OF BIOCHAR ON SOIL EROSION POTENTIAL
IN A SLOPE LAND**

K. G. S. Madhushani^{1*} and A. Nandakumaran¹

¹*Department of Bio-Science, Faculty of Applied Science, Vavuniya Campus,
University of Jaffna, Sri Lanka*

**sanjeewanimadhushani@gmail.com*

Soil erosion and desertification are the decline in soil condition caused by improper soil usage or poor soil management. It is a serious environmental problem affecting the productivity of agricultural lands and threatens the food security of an increasing population. Biochar has attracted attention for remediation of degraded soils. The study was undertaken to determine the erosion potential in slope land having soil incorporated with different combination of biochar. The study was carried out in Suduhumpola area in Kandy district. The land was prepared with a plot size of 1.5 m x 2.0 m and each type of biochar made from *Pinus pinaster* (Pinus), *Eucalyptus tereticornis* (Eucalyptus) and *Camellia sinensis* (Tea) were incorporated into the top soil separately. At the bottom of these plots, a ditch was excavated and covered with polythene and collected the eroded soil once in two weeks after the incorporation of different biochar with soil. The Complete Randomized Design was used with four treatments such as soil with tea biochar, soil with eucalyptus biochar, soil with pinus biochar and the control with each four replicates. Duncan's multiple range tests were carried out using SPSS 25.0. Lowest rate of soil erosion $32.34 \pm 0.559 \text{ gm}^{-2}$ showing a significant difference ($P= 0.0000$) with control plot was observed in soil incorporated with tea biochar which was nearly 88% reduction of soil erosion when compared to the control plot. Hence, application of tea biochar as a soil amendment is recommended to reduce the soil erosion in slope land in the hilly area.

Keywords: Biochar, Sloppy lands, Soil erosion.

**UREA ASSISTED NANOPARTICLE DEPOSITED CINNAMON BIOCHAR-A
POTENTIAL MATERIAL FOR WASTE WATER PURIFICATION STUDIE**

**N.B.P.Senanayake^{1*}, D.M.S.N. Dissanayake^{2,3}, U.G.M.Ekanayake², G.W.C.S. Perera¹
and M.M.M.G.P.G. Mantilaka²**

¹*Institute of Chemistry Ceylon, College of Chemical Sciences, Adamantane House
341/22, Kotte Road, Welikada, Rajagiriya, Sri Lanka*

²*Sri Lanka Institute of Nanotechnology, Nanotechnology and Science Park, Mahenwatte, Pitipana,
Homagama, Sri Lanka*

³*Postgraduate Institute of Science, University of Peradeniya, Peradeniya, Sri Lanka
binusenayake123@gmail.com

The stem of the cinnamon wood, a relatively abundant and wasted bi-product of the cinnamon industry in Sri Lanka, can be used to synthesize biochar, an inexpensive raw material which can be used as an efficient adsorbent for the removal of various biological, inorganic and organic contaminants from industrial effluents. This study is an attempt to synthesize property enhanced cinnamon biochar as a potential application in water purification using a nano-technological approach. Cinnamon biochar was produced by “Top lit up draft technique” maintaining the pyrolysis temperature in the range of 500- 600 °C. First, the biochar was ground and sieved to the particle size range 180 - 500 µm and dried. In-situ urea assisted deposition method was used to synthesize some metal oxide nanoparticle deposited cinnamon biochar. In a typical method, water soluble salt of the metal and urea is dissolved in water and heated to 100 °C while condensing, and the biochar is added to the mixture when the required temperature is reached and continued for 12 h maintaining the same temperature. In the study, Fe³⁺, Zn²⁺ and a mixture of the two ions were separately used for the deposition process. To convert the deposited hydroxide nanoparticles into oxide form, calcination was done in an inert atmosphere, after analyzing the optimum temperature by thermo-gravimetric analysis. Metal oxide nanoparticle precipitated char particles were characterized using Fourier Transformed Infrared Spectroscopy (FT-IR), Powder X-ray Diffraction (XRD), Scanning Electron Microscopy (SEM) and Energy Dispersive X-ray Spectroscopy. Data obtained showed effective and homogenous deposition of Fe₂O₃ and the mixture of the two oxides but ZnO was deposited as small clusters in the surface the char particles. Investigation of effective use of these nanoparticle deposited cinnamon biochar in dye adsorption industrial waste is in process.

Keywords: Cinnamon, Biochar, Nanoparticles, Urea, Adsorption.

DENGUE OUTBREAKS IN VAVUNIYA DISTRICT, SRI LANKA

S. Vijitharan^{1*}, A. Nanthakumaran¹ and J. Gunatilake²

¹Department of Bio-Science, Faculty of Applied Science, Vavuniya Campus,
University of Jaffna, Sri Lanka

²Department of Geology, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka
*sarani300@gmail.com

In Sri Lanka, *Aedes aegypti* and *Aedes albopictus* are reported to be the vectors transmitting dengue fever to humans. Socio-economic conditions of the community contribute to mosquito breeding either directly or indirectly. The objective of this study was to assess the influence of social and climatic factors on dengue incidences in Vavuniya District. Data on monthly rainfall, temperature and the dengue incidences were used over the period from 2010 to 2017. Data were statistically analysed using Minitab 17. The result revealed that about 6% of the dengue cases reported in the country was in Vavuniya District in 2017 and the highest number of dengue cases in the study area was 1075 in 2017. Out of them, 80% were recorded in Vavuniya Medical Officer of Health (MOH) area. Some pockets in the study area were identified as dengue prone areas and 50% of the dengue incidences were recorded in those pockets namely Tekkawatha, Katkuli, Thonikkal, Vavuniya town, Vairavapuliankulam, Kurumankadu, Rambaikulam and Soosaipillaiyarkulam. The dengue affected people were mainly males (95%) with the age group of 19 to 37 years. The peak months for positive premises and positive containers were observed in January, February, May and November coincided with high rainfall while no influence of temperature was observed. Positive premises and positive containers were co-existed with *Aedes aegypti* and *Aedes albopictus*. The larval indices such as House index (HI), Container index (CI) and Breteau index (BI) were found to be 5.8%, 6.8% and 5.7% respectively. Specifically the positive containers of flower pots and toilet fitting had the container index of 9.0% and 8.6% respectively. Based on the Breteau index, the study area was categorized as risky. Hence, the continuous monitoring on mosquito breeding sites and appropriate management and the community based awareness programs are recommended to secure the public health.

Keywords: Dengue fever, Entomological indices, Positive containers, Positive premises, Rainfall.

**PLANT-MEDIATED GREEN SYNTHESIS OF IRON OXIDE PARTICLES FOR
CADMIUM REMOVAL IN WASTE WATER**

S.Thevakumar^{1*} and S. Arasaretnam²

¹*Department of Chemistry, Faculty of Applied Sciences, University of Sri Jayewardenepura,
Nugegoda, Sri Lanka*

²*Department of Chemistry, Faculty of Science, Eastern University of Sri Lanka,
Chenkalady, Sri Lanka*

**thevakumars@gmail.com*

Banana leaf mediated Iron oxide particles provide high surface area and specific affinity for the adsorption of Cd (II) metal ion. Cadmium is a great threat to the world population due to its carcinogenic nature. In this study, the Iron oxide particles were synthesized in a simple aqueous based technique using a Banana leaf extract, as a source of both reducing agent and capping agent with a size ranging from 10 nm to 9 μ m. The particles showed the magnetic character and responsiveness to an external magnetic field making separation from solution possibly in less than 1 minute using a strong magnet. Batch tests were used to evaluate the feasibility of the prepared Banana mediated Iron oxide particles for the Adsorption of Cd (II) from cadmium contaminated water. Effect of operational environmental conditions like dose of Iron oxide particles, initial Cd (II) concentration, shaking speed and pH were evaluated at temperature 30⁰C. The data obtained gave a good fit with Langmuir and Freundlich isotherms and the adsorption was conformed to be pseudo-second-order kinetics. Iron oxide particles displayed a high removal efficiency for Cd (II) uptake, with over 85 % of Cd (II) removed and equilibrium in 30 minutes.

Keywords: Magnetic character, capping agent, adsorption, isotherms, cadmium.

EFFECT OF COMPOST AMENDMENTS ON GROWTH AND PHYTOREMEDIATION POTENTIAL OF *IMPATIENS BALSAMINA* L. IN SOIL CONTAMINATED WITH USED LUBRICATING OIL

S.S.Walakulu Gamage¹, K. Masakorala^{1*}, M.T. Brown² and S.M.K.Widana Gamage¹

¹*Department of Botany, Faculty of Science, University of Ruhuna, Matara, Sri Lanka.*

²*School of Biological and Marine Sciences, Plymouth University, Drake Circus, Plymouth, United Kingdom.*

**masakorala12@yahoo.com*

Contamination of soil with used lubricating oil (ULO) has become an emerging concern worldwide. Phytoremediation is a green technological approach to remediate these contaminations. Our previous experiments showed fairly good phytoremediation potential of *Impatiens balsamina* L. for ULO contaminated soil. The aim of the study was to determine the effect of compost amendments (CA) on bioremediation and plant growth performance of *I. balsamina* in soil contaminated with ULO. A pot experiment was conducted by employing soil contaminated with 1%, 2% and 3% w/w ULO amended with compost levels of 5% and 10%. Experiment was designed according to the randomized block design using three replicates per treatment and control. A control experiment was conducted using the same ULO contamination levels without CA. Two seedlings of *I. balsamina* were planted per pot in all treatments and control. At the end of 90 days, plant growth performance, total chlorophyll content, microbial activity (MA) and percentage biodegradation of ULO in the rhizosphere soil were measured. One way ANOVA followed by Tukey's post hoc test was employed to analyze data. Results inferred an enhancement in plant growth performance of *I. balsamina* and percentage biodegradation of oil in compost amended ULO contaminated soil compared to compost un-amended control. All the means of the measured parameters were significantly different from the control ($p < 0.05$). The highest biodegradation (53.4%) of ULO was observed in soil with 1% w/w ULO and 10% compost amendment compared to the biodegradation (38.5%) in 1% w/w ULO contaminated control without compost. Correlation analysis revealed a highly significant ($p < 0.001$) positive correlation ($r = 0.922$) between MA and percentage biodegradation. Therefore, overall results highlighted that the addition of compost positively affects plant growth performance and phytoremediation potential of *I. balsamina* grown in soil contaminated with ULO. Therefore, compost can be effectively used as a soil amendment in phytoremediation of soil contaminated with ULO.

Financial assistance from National Research Council, Sri Lanka (Grant No: 16-144) is acknowledged.

Keywords: Compost amendments, Phytoremediation, Used lubricating oil.

COMPARISON OF SOIL ORGANIC CARBON FRACTIONS OF VEGETABLE AND TEA GROWN SOILS IN THE UPCOUNTRY OF SRI LANKA

**D.D.A.E. Hemamali¹, U.W.A. Vitharana^{2*}, C.P. Attanayake²,
W.S. Dandeniya² and B.L.W.K. Balasooriya³**

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

²Department of Soil Science, Faculty of Agriculture, University of Peradeniya, Peradeniya, Sri Lanka

³Department of Biotechnology, Faculty of Agriculture and Plantation Management, Wayamba University, Makandura, Gonawila, Sri Lanka
*uvithara@pdn.ac.lk

Soil organic carbon (SOC) storage in agricultural soils is an important component of the global carbon cycle. Globally, clearing of natural vegetation for agriculture has resulted in large reductions in SOC levels and it can further decline due to continuous use of land for food production. Therefore, a proper understanding of the impact of land use and management on SOC pool is important to minimize depletion of SOC. In this study assessed the effect of two lands uses i.e. tea plantation and vegetable cultivation, on SOC fractions by quantifying total SOC, permanganate oxidizable organic carbon (POxC) and particulate organic carbon (POC) in soils. Soil samples were collected from the surface (0-30 cm) and subsurface (30-60 cm) at 42 and 44 sampling points at a vegetable grown area (0.9 km²) and tea grown area (1.2 km²), respectively in a sub-catchment in Nuwara-Eliya district. The result indicated that total SOC in the surface layer was not significantly different between vegetable (20.8±6.25 g kg⁻¹) and tea (18±8.14 g kg⁻¹) grown soils. Interestingly, total SOC in the subsurface layer was significantly higher in tea (21.8±5.37 g kg⁻¹) than vegetable (18.2±7.02 g kg⁻¹) grown soils. Conversely, significant higher POxC concentration (0.48±0.14 g kg⁻¹) was observed in the surface layer of tea grown soil. However, subsurface concentrations of POxC were not significantly different between vegetable (0.37±0.15 g kg⁻¹) and tea (0.36±0.13g kg⁻¹) grown soils. Significantly higher contents of POC were observed in surface than the subsurface layer in tea grown soils, which account for 28.5% and 14.2% of SOC, respectively. However, such difference was not observed in vegetable grown soils where surface and subsurface layers contained POC as 20.1% and 17.1% of SOC, respectively. Therefore, this study concludes a significant influence of the land use on the SOC pool, thus the dynamics of soil C in studied vegetable and tea land use.

Financial assistance from National Agricultural Research Policy (Grant No: NARP/16/UP/AG/02) is acknowledged.

Keywords: Carbon fractions, Land use, Soil organic carbon, Tea plantation, Vegetable cultivation.

**COLIFORM QUALITY ASSESSMENT OF GROUND WATER IN
JAFFNA, SRI LANKA**

S. Sivathasan^{*}, S. Saravanan and T. Barathithasan

National Water Supply and Drainage Board, Jaffna, Sri Lanka

**s.thas13@gmail.com*

The Jaffna Municipal Council area (JMC) lies in the Southern part of Jaffna Peninsula. The JMC consists of Jaffna Divisional Secretariat Division and part of Nallur Divisional Secretariat Division. The objective of the study was to define the presence of bacterial contamination of Ground water used for domestic purposes in JMC area. Ninety-one well locations were selected to represent water quality in the JMC area, and the locations include domestic and common dug-wells. The water from these wells were analyzed in December 2014 to February 2015 (during the rainy seasons) and results were compared with Sri Lankan drinking water quality standard (SLS 614:2013). The results showed the presence of coliform bacteria in the water sources requiring some form of treatment of the water before consumption. The mean count of total coliform and faecal coliform ranged from 0 to 705 CFU/100 mL and 0 to 637 CFU/100 mL in water samples respectively. Most brackish water wells of coastal area from Gurunagar, Paasiyoor, Navanthurai and Colombothurai also showed high fecal contamination. The Jaffna Town does not have proper sewerage facilities and every household is having an individual toilet with open dug pit. These open pits are the source of contaminant for the bacterial pollution. The most basic and important factor is the optimum distance / setback distances between the sources of pollution and the water wells. Every household has an individual water well because of the non-availability of pipe-born water supply and most of the people are using the water for their day to day needs as well as drinking water. For adequate determination of setback distances, information on attenuation and transport of pathogens or microbial indicators in groundwater systems are needed. In the larger interests of public health, the implementation of a sewerage scheme for the city is absolutely necessary.

Keywords: E.coli, T.coli, Jaffna Municipal Council.

FABRICATION OF NEW FLOW CELL FOR SURFACE TITRATIONS OF HETEROGENEOUS SOLID SUBSTRATES

P. Rukshagini^{1*}, B.A.Y.B. Jayawardhana², I.P.L. Jayarathne², S.K. Weragoda¹ and R. Weerasooriya²

¹*Water Safety Plan Advisory Unit, National Water Supply and Drainage Board, Katugastota, Sri Lanka*

²*National Institute of Fundamental Studies, Hantana Road, Kandy, Sri Lanka*
**suthankartic89@gmail.com*

Surface titration method is a mainstay technique in environmental and materials characterization laboratories to probe sites' reactivities of solids. Batch experimental methods are conventionally used to obtain surface titration data. It needs homogeneous suspension. However these environmental particulates are heterogeneous; some materials tend to settle in solution due to density variations which result erratic or non-reproducible data. To circumvent this difficulty, a new flow cell particularly suited for rapid surface titrations of heterogeneous particulates that are porous was invented. Particulate materials were stored in the cell (Glass cell with porous material) a solution of desired pH was continuously pumped through the cell and was monitored for different pH-statted conditions. The ion activities of the interface were calculated according to Boltzmann equation. The heterogeneous aquifer is composed of quartz 38.56 %, albiet 16.73 %, orthoclase, 8.1%, ankerite, 1.51 %, and muscovite, 2.84%. In flow cell surface titration curve shows a minimal noise in experimental data. The pH_{zpc} which resulted due aforementioned mineral surfaces is 5.5. Conventional batch technique, data shown in the latter case contains inherent noise largely due to inhomogeneous dispersion of particulates which results non-reproducible data. The data generated by flow cell method are consistent and reproducible. This data is vital in water treatment, fate assessment of sub-surface pollutants, heterogeneous catalysis and soil fertility and weathering.

Financial assistance from National Research Council (Grant No: TO 16-015), Sri Lanka is acknowledged.

Keywords: Surface titration, Aquifer, pH_{zpc} , Flow cell.

IRON OXIDE NANOSPHERES REINFORCED CHITOSAN NANOCOMPOSITE FILMS: PROMISING ALTERNATIVES FOR PETROCHEMICAL PACKAGING MATERIAL

G.T.D. Chandrakumara^{1,2*}, D.M.S.N. Dissanayaka^{1,3}, M.M.M.G.P.G. Mantilaka^{1,3}, R.T. De Silva¹, H.M.T.G.A. Pitawala^{3,4}, K.M.N. de Silva^{1,5} and G.A.J. Amaratunga^{1,6}

¹*Sri Lanka Institute of Nanotechnology (SLINTEC), Nanotechnology and Science Park, Mahenwatte, Pitipana, Homagama, Sri Lanka*

²*Department of Science and Technology, Uva Wellassa University, Passara Road, Badulla, Sri Lanka*

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

⁴*Department of Geology, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka*

⁵*Department of Chemistry, University of Colombo, Colombo, Sri Lanka*

⁶*Electrical Engineering Division, Department of Engineering, University of Cambridge, 9 J.J. Thomson Avenue, Cambridge CB3 0FA, UK.*

**dilharagt@gmail.com*

Biodegradable and nontoxic, chitosan-based packaging films have gained much consideration due to environmental concerns of conventional petrochemical packaging material. However, poor mechanical, chemical and thermal properties of chitosan hinder the applicability of the films and reduce the quality as well as the shelf life of the product. In order to enhance the properties of the films, nanocomposites were fabricated by embedding iron oxide nanoparticles (IONPs) into chitosan matrix. IONPs were synthesized via urea assisted route using ferric ions extracted from powdered natural laterite. Scanning electron micrographs revealed the spherical morphology of nanoparticles of 45 nm average size. The maximum tensile stress was enhanced by 36% and 18% by reinforcing 0.25 and 1 (w/w%) IONPs into chitosan. Moreover, thermo gravimetric analysis was done to investigate the improvement of thermal properties of the composite. As depicted by FTIR spectroscopy, the improvement of these properties may be due to interactions of hydroxyl groups and amine groups of the polymer with nanoparticles. The results obtained from this study propose that the iron oxide reinforced chitosan nanocomposite films with advanced properties be a promising application for eco-friendly packaging material.

Financial assistance from National Research Council (Grant No: 16-123), Sri Lanka is acknowledged.

Keywords: Chitosan, Iron oxide nanoparticles, Nanocomposites, Packaging material.

**GIS-BASED CRIME HOT SPOT MAPPING AND ANALYSIS:-A CASE STUDY
OF MATARA POLICE DIVISION, SRI LANKA**

H.B.T.P. Jayathilaka^{*} and V.P.I.S. Wijeratne

Department of Geography, Faculty of Arts, University of Colombo, Colombo, Sri Lanka.

**prathi@gmail.com*

Increasing population, urbanization and globalization have contributed to growth of crimes at an alarming rate. Therefore, crime has become a major socio- economic problem in the world and every year many people are victimized by crime incidences. In this context, GIS has become a vital tool and plays an important role in crime mapping and analysis. This study was conducted in Matara Police Division (MPD), Sri Lanka which has been identified as the major crimes area in Matara District. More than 50 Grama Niladhari Divisions (GNDs) were considered and this study mainly focused on identifying the crime hot spots in MPD. The analysis was carried out using Arc GIS 10.5 and MS Excel 2013. More than 2,000 crime incidences were analyzed from 2008 to 2017. According to that, the highest number of crime incidences were identified in 2012. The results of this study revealed that, the main hot spot is represented by between 99% to 90% significant value and cold spot represented by between 99% to 90% significant value. Some clusters with negative spatial association were identified which showed 0 significant value. According to that, main crime hot spot were located in southern part of the study area with 99% significant value and the hot spots of different crime types also were located in southern part of the study area with 99% significant value. High population density, road accessibility, high dense settlement areas can be identified in this risk area where the main business area in the Matara District is located. Those factors can be identified as the main causes of this pattern of hot spots. This result can effectively be used to take necessary actions for crime prevention in the MPD in the future.

Keywords: MPD, GNDs, GIS, Hot spots.

APPLICATION OF GIS TO ANALYZE SUITABILITY OF EXISTING SOLID-WASTE DUMPING SITES IN POLONNARUWA DISTRICT

M.D.N. Chandramali¹ and J.R.S.R. Jayakody^{2*}

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

²*Central Environmental Authority, District Office, Polonnaruwa, Sri Lanka*

**sadu1989geo@gmail.com*

Open dumping is the most common method of solid-waste disposal in number of areas in Sri Lanka. The objective of the study was to identify the suitability of existing solid-waste dumping sites using GIS in the Polonnaruwa District. A suitability map of existing Solid-Waste Dumping Sites (SWDS) was created using weighted overlay analysis in GIS. In this study, five (5) map layers such as land use, surface water bodies, roads, forest area and archeological sites were used. SWDS located within home gardens, <100 m distance from main and secondary road, water bodies, archeological sites and <1000 m from forest area were considered as high risk for people and environment. Two hundred people were randomly selected from Thamankaduwa, Lankapura Medirigiriya, Elahera, Hingurakgoda, Dimbulagala and Welikanda divisional secretariat divisions to identify the social issues regarding SWDS. The people were selected within 1 km radius from SWDS. The method of data collection of the study was a structured questionnaire. There are eleven SWDS in Polonnaruwa District and all sites do not have proper dumping systems. Seven SWDS that are distributed in Hingurakgoda, Medirigiriya, Elahera, Lankapura and Thamankaduwa are located within 1000 m radius of the forest area. In the study, 90% of respondents stated that, locating dumping sites marginal to forest areas is one of the main causes of attraction of Elephants to human settlements and thereby human elephant conflicts. There are two SWDS located <100 m distance from the water streams in Hingurakgoda and Thamankaduwa DSDs. Those sites have high potential to contaminate the surface water bodies. Lack of suitable lands, improved technology and experts on solid-waste management, are the key issues for many local authorities are facing in Polonnaruwa District.

Keywords: solid-waste, dumping sites, GIS, weighted overlay analysis.

VIOLATION OF THE INTERNATIONAL MARITIME BOUNDARY LINE BY UNAUTHORIZED BOATS: GIS BASED APPROACH

K.G.C.M. Gamage^{1*} and Jagath Gunatilake^{1,2}

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

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

**koralegams@gmail.com*

This study is aimed to monitor the increasing of the poaching of International Maritime Boundary Line (IMBL) by unauthorized fishermen in Mannar Basin. Presently there is no efficient system with quick reliable reporting and therefore, developing such system will be extremely important. Field survey and analysis revealed that using Naval Radar systems on board ships and ashore bases are technically and practically ineffective because there are some longer time gaps and inefficient recording. During this exercise, IMBL violation by unauthorized fishing boats and their locations were monitored and reported the spatial data using GIS to the authorities via email or hardcopy. The systematic IMBL-VSARS (Violation's Status Analysis and Reporting System) help the local fishing communities to carry on fishing with confidence and the ability for the relevant authorities to control the violation is drastically improved. The system basically uploads the results of the GIS based hotspot analysis as density map in the poaching areas of the Mannar Basin, along with spatial data on to the Google map using WEBGIS. This has been identified as a fast decision-making tool for military, local government and international authorities and quick responses can be made. The developed IMBL-VSARS can effectively identify the poaching areas and analyze unauthorized boat locations by GPS data and uploaded as KML file in WEBGIS. Sri Lanka Navy, then could effectively increase the number of patrols and re-adjust the security measures so that the government authorities can take precautions. The IMBL-VSARS giving comprehensive reports with a proof about boats violating of IMBL as electronic evidences. The expected electronic data will provide precise analysis system about unauthorized boats violating IMBL helps not only quick decision making but also assist in future investigations. Therefore, ArcGIS application can be considered as an ideal tool to provide effective solution for violating of IMBL by unauthorized fishing boats in Sri Lankan Territory.

Keywords: International Maritime Boundary Line, Unauthorized fishing, IMBL-VSARS, electronic evidences.

**CHUNDIKKULAM, NAGAR KOVIL AND ADJACENT AREAS AS
ECOTOURISM DESTINATIONS IN THE JAFFNA PENINSULA, SRI LANKA**

P. Rajkumar^{1*} and C. S. Wijesundara²

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

²*Department of Zoology, Faculty of Science, University of Peradeniya,*

Peradeniya, Sri Lanka

**vpraj82@gmail.com*

Among the different types of natural features used in ecotourism industry, bird watching plays a key role and have a high potential for promotion of ecotourism. Chundikkulam, which has been a bird sanctuary for many years, was upgraded as a national park in 2015. Nagar Kovil and adjacent areas have significant extents of mangroves that are notable for their water bird diversity compared to other parts of Jaffna peninsula. The ecotourism potential of these areas has never been evaluated probably due to the three decade long civil war period during which the areas were within a high security zone. The objective of the present study was to evaluate the ecotourism potential of Chundikkulam, Nagar Kovil, and adjacent areas, mostly based on greater flamingo (*Phoenicopterus roseus*) and other water bird species diversity as well as on mangroves. Analyses of ecotourism potential were carried out based on studies undertaken by us from 2013 to 2017, covering the entire Jaffna peninsula including its main islands. For suitability analysis, Multi Criteria Decision Method (MCDM) and criteria ranking method (GIS) were used, considering greater flamingo areas, other birding areas, sand dune areas, and mangrove areas. The evaluation process for ecotourism sites was conducted based on six criteria *viz.* bird species diversity, tourist preferences, proximity to residential areas, proximity to accommodation, distance from main roads, and scenic beauty. Results indicate that Chundikkulam can be categorized as a high potential area (2.94). Even though Nagar Kovil, Kudaruppu and Mamunai come under the moderate potential (2.60) based on multi criteria analysis in GIS, according to flamingo and other bird species richness, and mangrove analysis in GIS, the areas come under high potential areas (2.94). Natural features such as Thondamanaru and Elephant Pass lagoons, lagoon mouth area, and sand dunes were identified as important habitats for greater flamingo and other water bird species in Chundikkulam. Our recent studies have shown that Nagar Kovil is home to at least 40 species of water birds. Both Chundikkulam and Nagar Kovil areas have a high abundance of greater flamingos, a major avitourist attraction. Nagar Kovil area also has large extents of three true mangrove species, *Excoecaria agallocha*, *Lumnitzera racemosa*, and *Rhizophora mucronata*. Hence, both these areas have a great ecotourism potential. There is also a great potential for the participation of local people in these areas for promotion of ecotourism in the Jaffna peninsula, elevating their standards of livelihood.

Keywords: Chundikkulam National Park, Nagar Kovil, ecotourism potential, greater flamingo, waterbird diversity.

CONSTRUCTION OF GENERALIZED HADAMARD MATRICES OF ORDER p^n , WHERE p IS PRIME AND $n \geq 1$

W. V. Nishadi^{*} and A. A. I. Perera

*Department of Mathematics, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka
vandinisha@hotmail.com

One of the mathematical structures used in coding theory, cryptography, telecommunication, and signal processing is Hadamard matrices, whose entries are ± 1 . This paper concentrates on the generalized Hadamard matrices with entries from finite abelian groups. A celebrated result in this direction is the invention of a new algorithm for constructing a generalized Hadamard matrix of order p^n , where p is a prime. Let G be a finite group of order v and C be a finite abelian group of order w . A $v \times v$ matrix $M = [m_{ij}]$ with entries from C , where w divides v is a generalized Hadamard matrix denoted by $GH(w, v/w)$ over C if, for all $i \neq j$, the sequence of quotients $m_{ij}m_{jk}^{-1}$, $1 \leq k \leq v$, contains each element of C exactly v/w times. Equivalently, if M is a

$GH(w, v/w)$ over C , then $MM^* = vI_v + v/w \left(\sum_{u \in C} u \right) (J_v - I_v)$, where M^* denotes the transinverse matrix of M . If M is a $GH(w, v/w)$ over C and M' is a $GH(w, v'/w)$ over C , the Kronecker product $M \otimes M'$ is a $GH(w, vv'/w)$ over C . Our main aim is to construct generalized Hadamard matrices of prime order p using the multiplication table of a finite group G , where both G and C are the same and is \mathbb{Z}_p . We obtain the general form of $GH(p, 1)$ which has $(p-1)$ variables taken from \mathbb{Z}_p using a recursive algorithm. The method is tested for $p=3$ and $p=5$. The resultant matrices satisfy the equation $M_p M_p^* = pI_p$. The method has been extended to construct $GH(p, p)$. Also, using the Kronecker product recursively, $GH(p, p^n)$ for $n \in \mathbb{Z}^+$ can be computed. Furthermore, the normalized Hadamard matrices of order less than 100 which can be constructed using a recursive algorithm are tabulated and higher values of p will be tested using a computer program.

Keywords: Generalized Hadamard matrix, Kronecker product, Finite Abelian group, Transinverse matrix.

A NOVEL HEURISTIC METHOD FOR SOLVING CAPACITATED VEHICLE ROUTING PROBLEM

M. K. D. D. Sandaruwan¹, D. M. Samarathunga² and W. B. Daundasekara^{3*}

¹*Department of Physical Sciences, Faculty of Applied Science, University of Rajarata, Mihintale, Sri Lanka*

²*Department of Mathematics, Faculty of Science, University of Ruhuna, Wellamadama, Matara, Sri Lanka*

³*Department of Mathematics, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka*
**wbd@pdn.ac.lk*

Vehicle Routing Problem (VRP) is one of the most demanding optimization problems in the field of transportation. The Capacitated Vehicle Routing Problem (CVRP) is a special case of VRP which has been extensively studied in the literature. Since CVRP is NP-Hard, it is impossible to find the exact optimum solution when the number of customers/clients increases. In literature, numerous heuristic methods are proposed to find near-optimal solutions for the CVRP. Our objective is to develop an efficient novel heuristic method to solve CVRP within a reasonable Central Processing Unit (CPU) time. The proposed novel heuristic method consists of two phases. The first phase is an iterative procedure which creates n (number of customers/clients) sets of clusters. In each iteration, all customers are clustered without exceeding the vehicle capacity. Subsequently, a parameter is introduced using the concept of convex hull, which is used to select the best set of clusters. In the second phase, the optimum cluster of the Traveling Salesman Problem (TSP) is found and solved by the Genetic algorithm. The performance of novel heuristic method is measured using thirty benchmarked problems and compared with the most prominent Clarke and Wright heuristic (CWP) method. It is found that 50% of the time the proposed heuristic method produces better optimum solutions than the CWP. It is observed that in comparison with the CWP, the proposed heuristic method needs a fewer number of vehicles for a routing. Also, the convergence rate of CWP is higher than the novel heuristic method for small-scale problems. However, when the number of customers/clients exceeds 60, CWP shows exponential growth of CPU time while the proposed heuristic method remains in the same growth level. It is illustrated that for large-scale CVRPs, proposed heuristic method is more computationally efficient than the CWP.

Keywords: CVRP, CWP heuristic, Genetic algorithm, TSP, Convex Hull.

GENERATION OF THE CYCLIC GRAPHS USING THE NORMALIZED HADAMARD MATRICES

K. D. E. Dhananjaya^{*}, M. A. D. Priyadarshani and A. A. I. Perera

Department of Mathematics, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka
^{*}*kded@pdn.ac.lk*

Hadamard matrix H is a square matrix whose entries are either -1 or 1 such that $HH^T = nI_n$, where I_n is the $n \times n$ identity matrix and H^T is the transpose of H . Hadamard matrices play a major role in design theory. Sylvester's construction, $H_{2^k} = \begin{bmatrix} H_{2^{k-1}} & H_{2^{k-1}} \\ H_{2^{k-1}} & -H_{2^{k-1}} \end{bmatrix} = H_2 \otimes H_{2^{k-1}}$, where \otimes is the Kronecker product, can be used to construct normalized Hadamard Matrices. These normalized Hadamard matrices can be used to obtain special type of graphs. In this work, the suggested algorithm constructs a cyclic graph of order $2n$, where $n \in \mathbb{N}$, using the Hadamard matrix of order 2. This algorithm is based on the above normalized Hadamard matrix and the right shifting Latin squares. The algorithm starts with a Hadamard matrix of order 2, $H_2 = \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix} = \begin{bmatrix} c_1 & c_2 \end{bmatrix}$, where $c_1 = \begin{bmatrix} 1 \\ 1 \end{bmatrix}$ and $c_2 = \begin{bmatrix} 1 \\ -1 \end{bmatrix}$. Next, define $C_i = c_i \cdot c_i^T$, where $i = 1, 2$. Now, replacing 1 to 0 and -1 to 1 in the C_1 and C_2 matrices, we obtain $C_1 = \begin{bmatrix} 0 & 0 \\ 0 & 0 \end{bmatrix}$ and $C_2 = \begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix}$. Here the C_2 matrix can be written as the sum of two square matrices as follows:

$$C_2 = \begin{bmatrix} 0 & 1 \\ 1 & 0 \end{bmatrix} = \begin{bmatrix} 0 & 0 \\ 1 & 0 \end{bmatrix} + \begin{bmatrix} 0 & 1 \\ 0 & 0 \end{bmatrix} = C_2^1 + C_2^2.$$

Using the above matrices; C_1 , C_2 , C_2^1 , and C_2^2 , we can obtain the first and the second rows of the adjacency matrix of the cyclic graph of order $2k$, $[C_2][C_2^1][C_L][C_2^2]$, where $C_L = [C_1 \ C_1 \ C_1 \ \dots \ C_1]_{2 \times 2(k-3)}$. After applying the right shifting method on these blocks, the adjacency matrix of the cyclic graph can be obtained. For example, the adjacency matrix of the cyclic graph with 6 vertices is as follows:

$$\begin{bmatrix} 0 & 1 & 0 & 0 & 0 & 1 \\ 1 & 0 & 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 & 1 \\ 1 & 0 & 0 & 0 & 1 & 0 \end{bmatrix}_{6 \times 6}.$$

This algorithm can also be extended to obtain the wheel graphs.

Keywords: Adjacency Matrix, Cyclic graphs, Latin squares, normalized Hadamard matrix, Sylvester's construction.

MODELLING IMPACT OF MACROECONOMIC VARIABLES ON ALL SHARE PRICE INDEX IN COLOMBO STOCK EXCHANGES

G.K. Thalagoda¹, K.C. Rathnayake² and S.P. Abeysundara¹

¹*Department of Statistics & Computer Science, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka*

²*Department of Mathematics & Statistics, Texas Tech University, Lubbock, TX 79409, USA*
**sachitha@pdn.ac.lk*

Studying the stock market performance of a country is considered an effective alternative for realizing quick profits. One of the major reasons to invest in a stock market is the substantially high growth potential it offers when compared to other investments. Financial policies and macro economic variables such as, inflation rate, exchange rate, and money supply is said to have a consequential impact in the share market performance of a country. The study aims to examine the role of macroeconomic variables on stock prices movement in Sri Lanka. The main objective of the study is to predict the performance of the Colombo Stock Exchange, All Share Price Index (ASPI), based on the other macro economic variables. A regression model with Johansen Co-integration is proposed to predict the behavior of ASPI index in the long run. Systematic errors in residuals are minimized by examining the heteroskedasticity of variables followed by a correlation analysis and stationarity tests for moderately correlated variables. Thereafter, the best lag for the time series variables is chosen using the Vector Auto Regressive model Maximum Eigen Value technique under Johansen Co-integration is applied to model a new co-integrated time series and the stationarity of the residuals of the co-integrated time series is tested at 5% significance level. The stationarity condition of our co-integrated time series is fulfilled. Thus, a regression model is fitted using the Eigen Vector coefficients obtained. Applying the test data set to the suggested model completes the model validation. The residual time series demonstrates a random behavior with mean zero. Stationarity test with a p-value less than 0.05 further confirms the white noise behavior of errors. Therefore the results of the study provide promising results to state with 95% confidence that there exists a long-run cointegration regression relationship between ASPI and other macro economic variables.

Keywords: Cointegration, Share Price Index, Macro Economic Variables, Time Series Regression, Stationarity.

MEAN SQUARE ERROR COMPARISON BETWEEN RIDGE AND LASSO ESTIMATORS IN THE MISSPECIFIED LINEAR REGRESSION MODEL

M. Kayanan^{1,2*} and P. Wijekoon³

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

²*Department of Physical Science, Vavuniya Campus of the University of Jaffna, Vavuniya, Sri Lanka,*

³*Department of Statistics & Computer Science, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka.*

* *mgayanan@vau.jfn.ac.lk*

It is well-known that the Ridge Estimator has been used as an alternative estimator for Ordinary Least Squared Estimator (OLSE) to handle multicollinearity problem in the linear regression model. However, it introduces heavy bias when the number of predictors is high, and it may shrink irrelevant regression coefficients, but they are still in the model. As a solution for this problem, Least Absolute Shrinkage and Selection Operator (LASSO) has been used to make the variable selection and shrinking the regression coefficients simultaneously. Further, the misspecification of the model due to excluding relevant explanatory variable in the linear regression model is considered as a severe problem in statistical research, and it will lead to bias and inconsistent parameter estimation. The performance of Ridge and LASSO estimators under a correctly specified regression model was well studied in the literature. This study intends to compare the performance of Ridge and LASSO estimators in root mean square error (RMSE) criterion under the misspecified regression model using a Monte-Carlo simulation study. In addition to that, a real-world example was employed to support the results. The analysis revealed that LASSO outperformed Ridge estimator in both the correctly specified model and the misspecified model. However, LASSO failed to outperform Ridge estimator in some situations under high multicollinearity.

Keywords: Ridge Estimator, LASSO, Misspecified model, Multicollinearity, Variable selection, Mean square error.

IMPLEMENTATION OF A WIRELESS SENSOR NETWORK ROUTING PROTOCOL ON NS-3

B.G.M.P. Banneggedara, R. Siyambalapitiya and H.R.O.E. Dayaratna*

*Department of Statistics & Computer Science, Faculty of Science, University of Peradeniya,
Peradeniya, Sri Lanka.*

**iru049@gmail.com*

Increasing trend of Internet of Things (IoT) creates the necessity of the Wireless Sensor Networks (WSNs). The classical wireless routing protocols are not effective because of the high energy consumption during the routing process. LEACH (Low Energy Adaptive Clustering Hierarchy) is one of the WSN routing protocols and it is the base protocol for most of the WSN protocols such as PAGASIS and S-LEACH. But, there is no implementation of LEACH protocol on NS-3 network simulator where as NS-3 is the most popular open source network simulator which uses C++ and python in core implementation. The implementation of the LEACH protocol is the first implementation of a WSN protocol on NS-3. LEACH protocol is implemented as a new module to the NS-3 development tree and it can be used by the other users to simulate their own WSN that uses LEACH as the routing protocol. All the underlying dependencies like MAC sub layer support, communication protocol support, physical layer support, and support for other layers are already given to the users through this implementation. To provide above services, the LEACH module is implemented as a collection of associated classes. Therefore, the users can simply change the parameters and configure their networks according to their needs. Since NS-3 comes under GNU General Public License (GPL) Version 2 (V2) category, any valid, accurate change to the module is accepted. For the evaluation of the implementation, the response times for several functions and parameters such as average number of rounds before the first node drains and average number of rounds before last node drains were recorded by simulating different network environments. The values recorded were compared with the values from normal wireless communication. The results obtained by the simulation of the LEACH protocol after the implementation tally with the previously reported work. Thus, proves the accuracy of the implementation. The extended versions of LEACH protocol like V-LEACH, S-LEACH, Multi-hop LEACH protocols can also be implemented in future by benchmarking the implemented LEACH protocol.

Keywords: Wireless Routing Protocols, Sensor Networks, LEACH protocol, NS-3 Simulator.

GROUP GRAPH MEASURES OF BRAIN NETWORKS: NEW CONCEPTS AND DEFINITIONS

S. Vinayakavaseekaran¹, A.A.I. Perera^{2*} and N. Ratnarajah¹

¹*Department of Physical Science, Vavuniya Campus, University of Jaffna, Vavuniya, Sri Lanka*

²*Department of Mathematics, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka*
**athula103@yahoo.com*

Brain networks consist of cortical and subcortical regions as nodes and connections between them as edges. These brain networks convey a huge amount of information that has been almost unexplored previously and the fundamentals of brain network analysis arrived from graph theory. Graph theoretical approaches have been used by many studies to investigate the human brain network related to health. Different aspects of global and local brain connectivity are characterized by graph measures of brain networks. However, the full potential of the graph theory on brain network has not been fully exploited by the research community as studies have used the same measures and techniques. All published local graph measures, such as centrality are intended to apply for a single node and the global graph measures such as efficiency have been applied for the whole-network. But a group of nodes such as a lobe would be benefited from a formulation that applies to group of nodes rather than a single node or the whole network. A question such as “which brain-lobe is more structurally central in the normal brain?” could be answered to some extent by the application of a centrality measure that applied to a group of nodes. In brain asymmetric studies, global metrics have been applied to left and right hemispherical networks separately by considering only intra-hemispheric edges. However, for the valid comparison, global measures must include the inter-hemispheric edges as well. The concept of group graph measures has the potential to solve such problems. Here, we develop novel definitions for group graph measures based on the existing graph measures to the group context and these group measures make sure the proper generalization of the corresponding single node or whole network measure. These group measures are evaluated on structural brain networks of Alzheimer’s and healthy subjects and obtained number of significant results. The new outcomes of this study will push forward the understanding of the brain connectivity.

Keywords: Alzheimer, Brain network, Group graph measures.

A MODEL TO CLASSIFY SOCIAL MEDIA TEXTS FOR PHARMACOVIGILANCE

S. T. Jarashanth¹ and R. D. Nawarathna^{2*}

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

²*Department of Statistics & Computer Science, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka*

**ruwand@pdn.ac.lk*

The use of social media for sharing and seeking health-related information is overgrowing. Recent studies have used social media data for health monitoring tasks using Natural Language Processing (NLP) and Machine Learning. Pharmacovigilance refers to the post-marketing surveillance of pharmaceuticals, primarily to identify unreported Adverse Drug Reactions (ADRs). An ADR is an unwanted or harmful reaction, caused by an intervention related to the use of medication under regular doses. ADRs are a significant health burden, representing one of the leading causes of morbidity and mortality in healthcare. Mining social media data for healthcare imposes several challenges such as highly informal sentences, nontechnical medical concepts, frequently misspelt words and ambiguity. This study explores NLP techniques for generating representative features from drug-related social media data and utilizing them in a Support Vector Machine classifier for classifying ADR assertive texts. The main contribution of this work is the introduction of two ADR-specific features to represent ADR assertive sentences, namely, ADR-specific word embedding and Apache Lucene based lexicon matching. In addition, the model includes five other features: N-grams, change of phrases, word clusters, sentiment scores and synonymous terms expansion. We examined the performance of our model on a publicly available Twitter dataset that contains manually annotated tweets of ADRs. We also used another manually annotated adverse drug effect (ADE) dataset taken from medical case reports to compare the effectiveness of our model on a well-formulated dataset. We compared the performance of our model with the state-of-the-art method proposed by Diego Lab, Arizona State University that gives the highest F1-score for ADR classification which we call the ‘baseline’ method. Our model performs significantly better than the baseline method and achieves F1-scores of 0.58 (baseline: 0.51) and 0.87 (baseline: 0.81) for Twitter and ADE datasets, respectively. Our experimental results strongly indicate that the newly added features contribute significantly to improve the performance of ADR classification.

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Keywords: Adverse Drug Reactions (ADRs), Pharmacovigilance, Social Media Texts, Natural Language Processing, Machine Learning, Classification.

REGULAR EXPRESSIONS BASED APPROACH TO DETECT SQL INJECTIONS

R. Senthana^{1*}, E.Y.A. Charles² and S.R. Kodituwakku³

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

²Department of Computer Science, University of Jaffna, Jaffna, Sri Lanka

³Department of Statistics & Computer Science, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka

*krsenthana@gmail.com

Database Management Systems (DBMS) and Web applications are vulnerable to a variety of security threats. SQL Injection Attacks (SQLIA) are one of the most significant of such threats. The resulting security violations can include identity theft, loss of confidential information and fraud. SQL Injection occurs when an attacker is able to attach a series of malicious SQL statements in one of many possible forms as input for a query in the DBMS. The DBMS is tricked to execute this malicious code while processing the original query. Insufficient validation of user input is the main cause of SQL injection vulnerabilities. Even though guidelines for defensive coding have been made available, in practice it was found to be difficult due to human errors. A number of studies have been carried out and many solutions have been proposed for handling SQL Injection attacks. Detection using regular expression is one among them. However, its effectiveness in detecting all types of attacks has not yet been established and this work attempts such a study. By analysing the literature on SQLIAs and a data set of 185 queries (160 malicious and 25 benign), four cases of patterns of malicious queries were identified.

Case 1: A tautology $s=s$ follows the keyword *or*.

Case 2: Malicious code follows the *select* keyword.

Case 3: Keyword *or* is followed by malicious code.

Case 4: Certain keywords are followed by malicious code.

Regular expressions were created for the above four cases and tested on all 185 queries. The regular expressions were able to identify 152 cases out of 160 SQLIA queries correctly (95%). Out of 25 benign queries 16 were identified correctly. The accuracy of the proposed approach can be improved further by fine tuning the regular expressions. The salient feature of the proposed approach is that it detects SQLIA queries with very low resources and execution time.

Keywords: Database management system, Web application, SQL Injection attack, Regular expression.

**A PRODUCTION PLAN FOR A BISCUIT MANUFACTURING PLANT USING
INTEGER LINEAR PROGRAMMING**

D.K. De Silva^{*} and W.B. Daundasekara

Department of Mathematics, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka
**dilishiya.kalpani@gmail.com*

Effective planning, scheduling, and synchronization of all production activities are the key responsibilities of the management of a manufacturing plant. Therefore, it is necessary for the management of the plant to design the production process so that the total production cost is minimized subject to the available resources that cannot be compromised. In this study, a biscuit manufacturing plant is selected and an integer linear programming (ILP) model is formulated to determine the number of batches that the plant should produce from each product per month, so that the monthly demand is satisfied with the available resources. The objective is to minimize the monthly production cost of the plant. The necessary data are collected from the production plant for a particular month from which the objective function and constraints are formulated. The management has given a paramount importance in satisfying the demand so that there will not be any unsatisfied customer. Any feasible solution that is obtained by the model must satisfy the demand. Therefore, the demand constraint is considered as a hard constraint. The management is repeatedly adjusting the labour and machine requirements according to the monthly demand. Thus, the labour and the machine hour constraints are considered as soft constraints. The formulated ILP model is implemented as a spreadsheet model in Excel and is solved using the Excel solver. It uses the simplex algorithm and incorporates the integer requirement of the model when finding the optimal solution. Total labour and machine hours can be changed within a particular range until a feasible solution is found. The solved model determines the number of batches to be produced from each product and the corresponding minimum cost per month. Additionally, the machine and labour idle times and the needed overtime hours can be identified using the solved model while the additional overtime cost will be added to the monthly production cost.

Keywords: Integer Linear Programming, Soft constraints, Hard constraints.

**A DEPTH FIRST SEARCH BASED APPROACH TO IMPROVE THE
MOLECULAR PATHWAY SEARCH**

W.M.L.M. Wijesundara, R. Siyambalapitiya* and P.M.P.C. Gunathilake

*Department of Statistics & Computer Science, Faculty of Science, University of Peradeniya,
Peradeniya, Sri Lanka
ruwanthini@gmail.com

Molecular pathway analysis has become significant and gained greater value in bioinformatics due to improvements of computation hardware. Molecular pathways can be defined as a network of molecules within a cell. The reactions between molecules are important as the results directly relate with the health. Pathways can be represented as graphs and analysis can be performed mathematically. However, the number of pathway maps are substantial therefore, required computation resources are also high. Thus, with this method, analysis of Molecular Pathway Search (MPS) runs several days or even weeks depending on the computation capacity of the machines. The accuracy against the computation time is considered to be the most important factor in the context. Researchers are yet to address this problem completely with lack of sufficient computation resources. The most of previously developed graph related algorithms are executed sequentially and sequential algorithms do not fit well with high performance computing. One of the main objectives of this work was to enhance MPS with the help of parallel computing techniques. The Depth First Search (DFS) algorithm was used to implement the MPS. Which divides into a set of individual search tasks and perform DFS and execute parallelly. When there is a large number of nodes (molecules) and connections (interactions) in the graph, the traditional DFS techniques need a very high computation power. As the number of pathway maps are large, the accuracy of the analysis should be high. A new parameter, where value depends on the required accuracy was introduced to the DFS to control the termination condition. A cluster computing system was used to evaluate the proposed method with the proposed termination condition, all the previously unterminated computations were completed with different accuracy levels.

Keywords: Parallel computing, Molecular pathways, Cluster computing, Graph search, Bioinformatics.

STOCHASTIC MODELING OF LOTKA-VOLTERRA COMPETITION MODEL WITH ALLEE EFFECTS

T. M. M. De Silva^{1*} and S. P. D. S. S. K. Karunarathna²

¹*Department of Basic Sciences, Sri Lanka Technological Campus, Padukka, Sri Lanka*

²*Department of Mathematical Sciences, Wayamba University of Sri Lanka, Kuliyaipitiya, Sri Lanka*

**mihirid@sltc.edu.lk*

We propose models of continuous-time Markov chain (CTMC) and Ito stochastic differential equations (SDE) of population interactions based on a deterministic system of Lotka–Volterra competition model of two populations where one population is subject to Allee effects. The Allee effect, referring to the reduced fitness or the decline in population growth at low population densities or sizes, was first observed by Allee. There has been a rebound of interest in Allee effects recently due to fragmentation of habitats, invasions of exotic species, biological control of pests, etc., all involved with small populations. In the literature, interesting biological motivation and many mathematical models of Allee effects are examined deterministically. Stochastic models of Lotka-Volterra competition model with Allee effects on the other hand have not received much attention. The CTMC model is formulated first as a birth and death process and the derivation of the SDE model is then based on the CTMC. The transition probabilities of the CTMC satisfy the forward Kolmogorov differential equations and theoretically the moments of the random variables of the populations can be derived based on the moment generating functions of the distribution of transition probabilities. We apply the Euler-Maruyama numerical method to approximate the Ito stochastic differential model. There are many SDE models that correspond to the same ODE system, and in this work, we consider two different birth and death rates. It is found that the theoretical results established in the deterministic setting may not be valid in the stochastic models due to random effects of the birth and death process imbedded in the populations. From our numerical simulations, we obtain sudden population extinctions in the stochastic models that cannot be captured in the deterministic systems. Moreover, it is concluded that the variability of the population interactions depends on the formulated birth and death rates.

Keywords: Allee effects, Continuous-time Markov chain, Ito stochastic differential equations, Lotka-Volterra competition model.

MATHEMATICAL MODELING OF SPREAD OF DENGUE FEVER

D. M. N. K. Dissanayaka^{*} and T. H. K. R. de Silva

Department of Mathematics, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka
^{}dissanayaken273@gmail.com*

Dengue fever is a mosquito borne viral infection which can be transmitted to humans by infected female Aedes mosquitoes. In this paper, we develop a SIR (Susceptible, Infected, Recovered) model that describes the population dynamics of humans and mosquitoes during a Dengue fever epidemic. We consider the possible vertical transmission of Dengue infection among Aedes aegypti mosquitoes. In addition to the natural death, we consider death of the infected people due to disease as well. Some of the parameter values in our model are collected from previous studies and we estimate the transmission rate of Dengue fever to humans, the transmission rate of Dengue fever to mosquitoes, and the birth rate of mosquitoes using fmincon solver in MATLAB to best fit the simulated data with available dengue epidemic data in Kandy District, Sri Lanka in 2009. Using our proposed SIR model we find and estimate the basic reproduction number (R_0) which is the most important estimate in forecasting a spread or die out of an infectious disease. Our model fits fairly well with the real data and the calculated $R_0 = 1.1816 > 1$ shows that Dengue fever can spread in the community. We also perform a sensitivity analysis to determine the relative importance of the model parameters to R_0 . Sensitivity analysis results show that transmission rate of Dengue fever to humans and the death rate of mosquitoes are the most sensitive parameters of R_0 and by increasing the death rate of mosquitoes, and/or by decreasing the transmission rate of Dengue fever to humans, R_0 can be reduced. This qualitative and quantitative analysis of the model can be used in identifying strategies to control the transmission of Dengue fever in Sri Lanka.

Keywords: Fmincon solver, Reproduction number, SIR model, Vertical transmission.

EFFECT OF PACKING MATERIAL AND MOISTURE CONTENT AT PACKING ON SEED GERMINATION AND VIGOR OF THREE POPULAR RICE VARIETIES OF SRI LANKA

A.A.C.B. Alahakoon^{1,2*}, D.S.D.Z. Abeyesiriwardena³, J.W. Damunupola^{1,2} and N.S. Gama-Arachchige^{1,2}

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

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

³*CIC Agri Business Center, Pelwehera, Dambulla, Sri Lanka*

**chamindaalahakoon6@gmail.com*

The rapid loss of vigor in paddy seeds during storage in polysac (perforated, woven polyethylene) bags is a common problem faced by rice farmers. This study was conducted to understand how rice seed vigor is affected during storage by seed moisture content (SMC) at packing and packing material. Seeds of three popular improved rice varieties (Bg 300, Bg 352 and Bg 358) adjusted to two moisture contents (11% and 13%) were stored in polythene (gauge 300) and polysac bags under ambient conditions. The experiment was factorial with a 3×2×2×10 (variety × SMC × packaging material × storage time) treatment structure in a CRD with four replications. Samples were drawn from four packets of each treatment combination at monthly intervals and standard germination (SG) and field emergence (FE) tests were conducted. For FE test, four replications of 400 seeds were germinated in a paddy field. Normal seedlings were counted after seven days. Normal seedlings (%) in FE test was always lower than in SG test. Seed moisture content remained unchanged in polythene and fluctuated in polysac bags. Initially, all three varieties showed >80% germination and >50% FE and remained the same in Bg 300 and Bg 352 throughout the study period when stored in polythene at 11% SMC while in Bg 358, germination and FE significantly dropped after 8 months. Both % germination and % FE began to drop after eight months in polythene at 13% SMC and were <50% after ten months. In polysac, both % germination and % FE start to drop significantly (P<0.05) after four months of storage and were <10% in all three varieties after ten months. Thus, high seed germination and vigor of Bg 300, Bg 352 and Bg 358 can be maintained more than twice longer (>8 months) when stored at 11% SMC in polythene than in polysac bags.

Financial assistance from Sri Lanka Council for Agricultural Research Policy (Grant No: NARP/16/UP/SC/01) is acknowledged.

Keywords: Germination, Rice, Seed vigor, Storage.

**MORPHOMETRIC ANALYSIS OF THE GENUS *SALACIA* (CELASTRACEAE)
OCCURRING IN SRI LANKA**

W.I.N.S. Senevirathne^{1*}, P.L. Hettiarachchi² and D.M.D. Yakandawala³

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

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

³Department of Botany, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka
nirodha.sewwandi@gmail.com

Salacia is a well-known genus for its medicinal value that comprises of nearly 200 species of woody lianas, scandent or erect shrubs distributed in tropical countries. According to the Flora of Ceylon, four species have been recorded in Sri Lanka namely *S. reticulata*, *S. oblonga*, *S. diandra* and *S. chinensis* while a fifth species, *S. acuminatissima* was added during the recent Red listing. Therefore, the present study was carried out with the aim of determining the species limits of the genus *Salacia* occurring in Sri Lanka. Eighty two morphological characters (30 vegetative and 52 reproductive characters) were recorded for 66 samples collected from 12 administrative districts and cluster analysis was performed using PAST version 3.2 software. The resulted dendrogram identified two main clusters and each of these clusters sub-divided very early where six main clusters could be identified. The dendrogram unambiguously supports the two species *S. reticulata* and *S. chinensis* as distinct species. *S. oblonga* and *S. diandra* forms a largecluster which is subdivided into two, one of which is subdivided into three clusters, of which two corresponds to *S. oblonga* and other is *S. diandra*. Thus, one morphotype of *S. diandra* is closely similar to *S. oblonga*. *S. acuminatissima* clustered with *S. diandra*. According to the SIMPER, leaf length, petiole length, nature of the leaf margin and leaf width have been identified as characters for species identification in the field. Although *S. reticulata* and *S. chinensis* could be identified using morphometric characters, *S. oblonga*, *S. diandra* and *S. acuminatissima* needs further studies with molecular data to determine their species limits.

Financial assistance from Rajarata University of Sri Lanka, (Grant. No: RJT/RP+HPC/2013/APP/R/01) is acknowledged..

Keywords: *Salacia*, Cluster Analysis, Morphometric, Species limit.

ANTIBIOTIC RESISTANCE AND PHYLO-TYPING OF *ESCHERICHIA COLI* FROM NATURAL WATER AND HOSPITAL WASTE WATER SOURCES

M.I.F. Ishara^{1*}, C.L. Abayasekara², B.N. Dissanayake³, B.N.L.D. Rangama² and E.W.M.A. Ekanayake³

¹Department of Zoology, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka

²Department of Botany, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka

³Department of Microbiology, Faculty of Medicine, University of Peradeniya, Peradeniya, Sri Lanka

*mreeza619@gmail.com

Escherichia coli is known to acquire resistance to antibiotics, which is one of the most significant current global health challenges. The objective of this study was to investigate the antibiotic resistance and the phylo-group distribution of *E. coli* in natural water and hospital waste water. A total of 63 natural water and 17 hospital waste water samples were collected from selected areas in the Central Province. Subsequent to membrane filtration, the isolates were incubated on a fecal coliforms broth (mFC broth), and colonies were confirmed as *E. coli* on Citrate agar. Antibiotic susceptibility testing was performed for nine selected antibiotics belonging to five antibiotic groups. Isolates were characterized by a quadruplex PCR for target genes *chuA*, *yjaA*, *TspE4C2* and *arpA*. *Escherichia coli* was isolated from 26 (41.27%) of natural water and 17 (100%) of hospital waste water samples, indicating fecal contamination. Highest resistance was noted for ciprofloxacin in both natural (65.3%) and hospital isolates (76.4%). Resistance to cefatoxime and at least one β lactam- β lactamase agent was identified in 11.5% of natural water and 35.3% of hospital waste water isolates ($P < 0.05$). Carbapenem resistance was statistically different ($P < 0.05$) among natural water (7.7%) and hospital waste water (82.3%) isolates. *Escherichia coli* isolated from natural water predominantly belonged to phylo-group B1 followed by D, E, B2, A, C, F and cryptic clade I, and those from hospital waste water belonged to strains of phylo-group B1 followed by A, C, D, E, and cryptic clade I. Significantly higher antibiotic resistance in *E. coli* isolated from hospital waste water compared to natural water, indicates that the level of exposure to antibiotics, results in different antibiotic resistance patterns rather than its phylo-group. Occurrence of antibiotic resistant *E. coli* in water raises a serious public health concern and highlights the importance of alternative disposal methods especially of hospital effluents.

Keywords: *Escherichia coli*, Antibiotic resistance, Phylo-typing, Natural water and Hospital waste water.

**ENCAPSULATION OF CINNAMON LEAF OIL WITHIN CHITOSAN:
FORMULATION AND CHARACTERIZATION**

U.G.P.P. Subasinghe¹ and S. Wickramarachchi^{2*}

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

²Department of Chemistry, University of Kelaniya, Kelaniya, Sri Lanka

*suranga@kln.ac.lk

Synthetic pesticides are often used in large scale food industry to extend shelf life and storage time. However, it has become an economical and ecological challenge due to its harmful effects. Botanical pesticides could be a better alternative as they pose no or minimum threat to the environment and human life. Essential oils can be used for this purpose due to their useful properties such as antioxidant, anti-inflammatory and antimicrobial activities. However, their full potential is not harnessed yet. Encapsulation of oil is one of the best solutions to overcome some issues related to their use and to obtain a sustained release. In this study, chitosan microcapsules (MCs) containing cinnamon leaf oil as an active ingredient were formulated by ionotropic gelation of chitosan, cross linking with Sodium tripolyphosphate (STPP). The effect of varying amounts of polymer, cross linker and oil load on encapsulation efficiency (EE), and also the oil content and release rate was determined. Gas Chromatogram of cinnamon oil indicated the presence of eugenol (93.9%) as the major constituent. According to optical microscopic images, the formulated MCs are spherical in shape and their size varies from 38.66 ± 0.46 to 96.33 ± 0.05 μm . Scanning electron micrograms of the oil-loaded capsules imaged clear spherical shaped MCs with smooth surfaces while empty capsules with a layered structure. The particle size and EE increased with increasing oil load, polymer concentration and cross linker concentration. The EE decreased when the viscosity of the solution is too high. The thickness of the wall of capsules increased with the increasing polymer and crosslinker concentration while decreasing the oil release rates from capsules. The release rate increased with increasing oil load. The formulated MCs can be used as an effective natural antimicrobial substance as well as a botanical pesticide.

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Keywords: Chitosan, Cinnamonoil, Essentialoil, Encapsulation, Microcapsules.

**POLYAMINE-INDUCED NITRIC OXIDE PRODUCTION
IN *ARABIDOPSIS THALIANA***

R. Wimalasekera^{1*} and G.F.E. Scherer²

¹Department of Botany, University of Sri Jayewardenepura, Gangodawila, Nugegoda, Sri Lanka

²Institute for Horticultural Production Systems, Leibniz University of Hannover,
Hannover, Germany

*rinukshi@yahoo.co.in

Polyamines (PAs) are growth regulators that are implicated in plant development and abiotic and biotic stress responses. PA catabolism is crucial in regulating PA levels. PA catabolizing diamine oxidases (DAO) and polyamine oxidases (PAO) play important roles in stress tolerance. Nitric oxide (NO) is an important second messenger in numerous growth-related and stress responsive functions. The common functions of PAs and NO speculated that NO may be a link between PA-mediated stress responses. The aim of the study was to investigate potential involvement of PAs in NO biosynthesis emphasizing contribution of DAO and PAO. PA-induced NO biosynthesis was investigated in *Arabidopsis thaliana* wild type (WT) and T-DNA insertional knockouts of DAO/PAO. Quantification of NO was done by fluorometry and fluorescence microscopy using NO-sensitive fluorophores. Compared to the mock-treated controls, the WT seedlings showed 30-50% increase in NO biosynthesis when treated with PAs, 1 mM of putrescine, spermidine and spermine. A rapid 50% increase of NO release was observed in spermine treated seedlings. PA-induced NO release of the DAO and PAO knockouts showed 20-60% less NO production compared to WT. Fluorescence microscopic analysis showed PA-induced NO biosynthesis in the cotyledons, leaves, shoots and roots. Compared to WT, PA-induced NO production was mainly impaired in the root tips of the knockouts. Post-translational modification of proteins, *S*-nitrosylation, is a key regulatory function of NO. Biotin switch assay was performed to investigate *S*-nitrosylated proteins. In comparison to the *S*-nitrosylated protein profiles of mock-treated control seedlings, enhancement of *S*-nitrosylated protein profiles was observed in 1mM putrescine, spermidine and spermine treated seedlings. Taken together, the results suggest role/roles of PA in NO biosynthesis in *Arabidopsis*. NO biosynthesis as a result of catabolism of PA by DAO and PAO direct or in an indirect mechanism can be one potential pathway responsible for PA-mediated NO biosynthesis.

Keywords: Amine oxidases, *Arabidopsis thaliana*, Nitric oxide, Polyamine.

EXOGENOUS *MORINGA OLEIFERA* LEAF EXTRACT AS A BIOSTIMULANT IMPROVES GROWTH AND PHYSIOLOGICAL ATTRIBUTES OF RUBBER (*HEVEA BRASILIENSIS*) UNDER SUB-OPTIMAL CLIMATIC CONDITIONS

N.M.C. Nayanakantha^{*}, B.M.S.S. Panditharatne, S.A. Nakandala, W. Karunathilake and P. Seneviratne

Rubber Research Institute of Sri Lanka, Dartonfield, Agalawatta, Sri Lanka
^{*}nayanakanthachamil7@gmail.com

Cultivation of *Hevea* is being extended to nontraditional areas of Sri Lanka where extreme climatic conditions like drought and high temperature are the major impediments limiting the growth of rubber clones grown at present. Therefore, it is essential to do priming (pre-conditioning) rubber plants to improve growth under sub-optimal climatic conditions. Moringa (*Moringa oleifera*) leaf extract (MLE) has been widely used as a biostimulant for enhanced growth and yield in crop plants under abiotic stresses. Here we studied the efficacy of foliar applied MLE to evaluate the response of *Hevea* to sub-optimal climatic conditions. Rubber plants of clone RRISL 203 cultivated in Mawathagama (Intermediate Zone) were spray treated (primed) with MLE at 5, 10 and 15% concentrations at monthly intervals for a period of six months. Control plants were kept without priming treatments. The girth was measured before and after 3 and 12 months of treatments. Physiological attributes *viz.*, net photosynthesis (Pr), chlorophyll content (Cc), stomatal conductance (gs) and leaf water potential (Ψ) were recorded after three months. A significantly higher girth (7 cm) was recorded from plants treated with MLE at 15% after 3 months, although the highest girth (11.5 cm) was recorded with MLE at 5% after 12 months. A significantly higher Pr ($19.5 \mu\text{mol m}^{-2} \text{s}^{-1}$) was recorded from plants treated with MLE at 15% as compared to the control ($14.4 \mu\text{mol m}^{-2} \text{s}^{-1}$). Significantly higher Cc values were recorded from plants treated with MLE at all concentrations than the control. No significant differences were observed in stomatal conductance and Ψ values in rubber plants treated with MLE as compared to the control. Therefore, MLE can effectively be utilized as a zero cost and an environment-friendly biostimulant for growth improvement in rubber under sub-optimal climatic conditions.

Keywords: Abiotic Stress, Growth, Moringa Leaf Extract, Rubber.

OVER-DOMINANCE OF *BAMBUSA BAMBOS* ALTERS STRUCTURE AND COMPOSITION OF NATIVE FORESTS: A STUDY FROM TROPICAL MOIST EVERGREEN FORESTS IN SRI LANKA

**M.P.T. Wijewickrama¹, W.A.I.P. Karunaratne², D.S.A. Wijesundara³
and H.M.S.P. Madawala^{4*}**

¹Postgraduate Institute of Science, Peradeniya, Sri Lanka

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

³National Institute of Fundamental Studies, Hantana Road, Kandy, Sri Lanka

⁴Department of Botany, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka

*sumedham@pdn.ac.lk

Far-reaching consequences of the over-dominance of native species have drawn less attention from the scientists. Some native bamboos have shown to expand their populations altering the structure and composition of native forests. *Bambusa bambos* (L.) Voss. is a native showing over-dominance in Dry and Intermediate Zone forests in Sri Lanka. The present study evaluated the impacts of *Bambusa bambos* in a tropical moist evergreen forest (TMEF) near Moragahakanda in Sri Lanka. Bamboo-dominated (BD) and non-bamboo (NB) plots were established in three forest patches viz., Galboda (GAL), Moragolla (MOR) and Maragamuwa (MAR). A vegetation survey (> 2 m in height) was conducted along three transects with six 100 m² quadrats placed at distances from the forest edge (0 m) towards the forest interior (20, 40, 60, 80 and 100 m). All individuals were identified and their numbers were recorded. Completely or partially dead individuals were also noted. The culm density of *B. bambos* decreased towards the forest interior at GAL. Of 127 species (69 trees, 28 shrubs and 30 woody climbers), 72 species (57%) were common to both forest types, while 28 and 16% were exclusive in BD and NB, respectively. At MAR, a higher density and richness of liana species were recorded in NB than in BD, indicating site-specific differences. Light-loving, early successional species were more abundant and frequent in BD forests while shade-loving, late successional species were more prevalent in NB. The mortality of forest species was significantly greater in BD than in NB. Overall results indicate that the over-dominance of *B. bambos* has altered the structure and composition of TMEFs significantly, possibly due to higher mortality incidences. The study highlights the importance of speedy action to mitigate the negative impacts caused by the over-dominance of *B. bambos* in natural forests in Sri Lanka.

Financial assistance from National Research Council, Sri Lanka (Grant No: 16-054) is acknowledged.

Keywords: Bamboo, mortality, native species, over-dominance.

ESTABLISHMENT OF VARIETAL IDENTITY OF SELECTED EXPORTABLE AND MEGA PRODUCTION RICE GENOTYPES IN SRI LANKA USING DNA FINGERPRINTING

W.W.M.U.K. Wijesundara¹, G.K.S. Ananda¹, S.K. Kannangara¹, S.I. Karunrathne¹, L.T. Ranaweera¹, U.A.K.S. Udawela², C.K. Weebadde³ and S.D.S.S. Sooriyapathirana^{1*}

¹*Department of Molecular Biology and Biotechnology, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka*

²*Rice Research and Development Institute (RRDI), Bathalagoda, Ibbagamuwa, Sri Lanka*

³*Department of Plant, Soil and Microbial Sciences, College of Agriculture and Natural Resources, Michigan State University, East Lansing, Michigan, USA*

**sunethuop@gmail.com*

The improved rice varieties with the best quality attributes are required to reach the export market for the development of rice industry in Sri Lanka. Rice Research and Development Institute (RRDI) of Sri Lanka has developed five exportable rice genotypes; At362, Bg94-1, Bg360, Bg1165-2 and Bw-Bs-1-2-31. However, due to the unavailability of a standard procedure for varietal identification, RRDI cannot claim for the varietal ownerships (type of a patent) for these genotypes. Thus, the present study was conducted to establish a procedure for the discrimination of the five exportable rice genotypes from the mega varieties (most commonly grown) such as Bg352, Bg300, Bg358, Bg359, Bg357, Bg379-2 and At353, based on DNA fingerprinting. The other cultivars in addition to the mega varieties were not considered in the present analysis as they are rarely grown in Sri Lanka. The rice genotypes (five exportable and seven mega) were grown in a greenhouse using breeder-seeds and the DNA was extracted from leaves. The PCR of 24 SSR markers yielded polymorphic bands. A cluster analysis using Minitab 16 was carried out to discriminate rice cultivars. Out of 24 SSR, a minimum of six markers; *RM206*, *RM246*, *RM251*, *RM335*, *RM475* and *RM23744*, were selected based on the polymorphic bands for individual genotype discrimination and clear PCR amplification. The selected markers were tested for multiple plants per genotype and no intra-varietal variation was observed. Thus, RRDI can employ the six selected SSR markers to claim the varietal ownership for exportable rice genotypes. With the varietal ownership, RRDI can claim a share of the profit from the revenues generated from rice exports to fund research and breeding programs without depending on the treasury funds.

Financial assistance from National Research and Development Institute (Grant No: URG/2016/59/S) of Sri Lanka is acknowledged.

Keywords: Improved rice varieties, Rice varietal ownership, Rice SSR markers.

INVESTIGATION OF THE STABILITY OF ANTIGEN-FUNCTIONALIZED METAL NANOPARTICLES FOR IMMUNODIAGNOSIS OF ANTI-LEPTOSPIRAL ANTIBODIES

**D.M.M.H. Dahanayake¹, C.D. Gamage², N.M.S. Sirimuthu³
and A.C.A. Jayasundera^{4*}**

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

²*Department of Microbiology, Faculty of Medicine, University of Peradeniya, Peradeniya, Sri Lanka*

³*Department of Chemistry, Faculty of Applied Sciences, University of Sri Jayewardenepura, Nugegoda, Sri Lanka*

⁴*Department of Chemistry, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka*
**acaj@pdn.ac.lk*

Due to superior optical and chemical properties, nanoparticles are used in immunodiagnosics, which are functionalized using proteins such as antibodies or antigens. The interaction between protein and nanoparticle should be reliable and the protein must be in its biologically active conformation. This interaction can be identified by surface plasmon resonance of metallic nanoparticles in the UV-visible region. In this analysis, antigens are used for the functionalization of nanoparticles to detect antibodies against leptospirosis, which is an emerging, infectious, zoonosis in Sri Lanka. The objective of the study was to determine the stability of antigen-functionalized silver nanoparticles at optimum environmental conditions for the identification of anti-leptospiral antibodies in blood samples of humans. Silver nanoparticles of 80 nm were incubated with different concentrations of rLigA (recombinant leptospiral immunoglobulin-like protein A) antigens for 1 hour at different temperatures and pH levels. rLigA-functionalized nanoparticles were characterized by UV-visible spectroscopy, FT-IR spectroscopy and SEM. For the efficient functionalization, 1.5 $\mu\text{g ml}^{-1}$ was selected as the optimum concentration of rLigA, and temperature of 25 °C and pH of 7.0 as optimized experimental conditions, according to UV-visible spectroscopy and SEM data. FT-IR spectra verified that nanoparticle-rLigA interaction was taken place through electrostatic interactions with carboxylate groups of the protein. Furthermore, three samples of human sera containing IgG (Immunoglobulin-G) anti-leptospiral antibodies (group-A) and another three samples without IgG anti-leptospiral antibodies (group-B) were tested with functionalized nanoparticles. SEM confirmed the aggregation of nanoparticles in group-A, compared with group-B. No significant difference in UV-visible absorption was observed between group-B and functionalized nanoparticles, whereas group-A showed a significant reduction in absorption compared with group-B. According to experimental results, we can conclude that rLigA-functionalized silver nanoparticles are stable at 25 °C and pH of 7.0 and can be used to detect anti-leptospiral IgG antibodies in human sera using UV-visible spectroscopy.

Keywords: Immunodiagnosis, Leptospirosis, Surface plasmon resonance, UV-visible spectroscopy.

DETECTION OF *MECA* GENE AND METHICILLIN RESISTANCE IN STAPHYLOCOCCI ISOLATED FROM HUMAN ORAL CAVITY

**W.M.D.A. Wijesundara¹, J.A.M.A. Jayatilake², R.G.S.C. Rajapakse^{1*}
and J.A.M.S. Jayatilake³**

¹Department of Molecular Biology & Biotechnology, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka

²Ministry of Health, Colombo, Sri Lanka

³Department of Microbiology, Faculty of Dental Sciences, University of Peradeniya, Peradeniya, Sri Lanka

*sanathr@pdn.ac.lk

Staphylococci consist of medically important bacteria that produce hospital associated infections and they often develop antimicrobial resistance. *Staphylococcus aureus* which produces coagulase is primarily a commensal organism of the human skin. Similarly, coagulase negative staphylococci (CoNS) have emerged as pathogens among medically compromised dental patients. Both types of staphylococci are common human commensals that develop methicillin resistance (MR) which has become a serious challenge faced by the clinicians. *MecA* gene encodes penicillin binding protein-2a (PBP2a) which confers antimicrobial resistance and detection of *mecA* gene has been identified as the gold standard in determining MR. MR has been assessed in staphylococci isolated from skin, blood, sputum, urine and wounds using cefoxitin disc diffusion test (CDDT) and polymerase chain reaction (PCR) detection of *mecA* gene. However, studies that have assessed MR in oral staphylococci are rare. Aim of this study was to demonstrate MR in staphylococci isolated from human oral cavity using CDDT and PCR with an internal control *16S rRNA*. The identity of twenty-five oral isolates of staphylococci used in the study were confirmed using colony morphology, Gram stain, catalase test, and the coagulase test. According to the morphology and biochemical tests, there were 07 (28%) isolates of *Staphylococcus aureus* (coagulase positive) and 18 (72%) of coagulase negative staphylococci (CoNS). CDDT revealed that 02 (08%) of the CoNS samples were methicillin resistant while 92% were methicillin sensitive isolates. Furthermore, these two cefoxitin resistant CoNS samples were positive to *mecA* gene. This study indicated that majority of oral staphylococci are CoNS. Moreover, results showed the possibility of *S. aureus* and CoNS with or without MR in colonizing the human oral cavity. Hence, rational use of antimicrobials and meticulous infection control practice are essential in order to prevent opportunistic infections and transmission of antimicrobial resistance by staphylococci during oral and maxillofacial procedures.

Keywords: Methicillin resistance, Oral cavity, Staphylococci, *16S rRNA*.

SPATIAL AND TEMPORAL VARIATIONS OF TOXIC ELEMENTS IN CULTURED AND WILD OYSTERS *CRASSOSTREA MADRASENSIS* IN PUTTALAM LAGOON, SRI LANKA

M.M. Subasinghe¹, B.K.K.K. Jinadasa², A.N. Navarathne^{1,4*} and S. Jayakody³

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

²Analytical Chemistry Laboratory, National Aquatic Resources, Research and Development Agency, Colombo 15, Sri Lanka.

³Department of Aquaculture and Fisheries, Faculty of Livestock, Fisheries and Nutrition, Wayamba University of Sri Lanka, Makandura, Sri Lanka

⁴Department of Chemistry, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka
*ayanthi.pdn@gmail.com

The Oyster *Crassostrea madrasensis* is abundant in Kala Oya estuary. This edible oyster is collected from both wild and cultures in Sri Lanka. As filter feeders, they are well known to accumulate toxic metals from the surrounding environment hence, quantifying non-essential trace metals and understanding spatial and temporal variations is essential. Accordingly, samples collected from wild (n=195) and cultures (n=195) in Ganagewadiya of Kala Oya and cultures (n=195) in Kandakuliya of Puttalam were analyzed for lead (Pb), cadmium (Cd), arsenic (As) and mercury (Hg) monthly from July 2014 to July 2015 using Atomic Absorption Spectrophotometer. Results were reported on a dry weight basis and were compared with the published international standards. Monthly variations in trace metal concentrations between groups were analyzed using the General Linear Model and One-way ANOVA. The mean Hg (ii), Pb(II), Cd (II) and As(III) concentrations in wild were 0.14 mg/kg, 18.33 mg/kg, 6.21 mg/kg, 2.75 mg/kg and in those of cultured were 0.11 mg/kg, 27.15 mg/kg, 6.51 mg/kg, 3.16 mg/kg respectively in Gangewadiya sample site. Same measurements for above metal ions of cultured oysters in Kandakuliya sample site were 0.12 mg/kg, 24.11 mg/kg, 5.73 mg/kg, 3.39 mg/kg respectively. The results showed no significant differences ($p>0.05$) of trace metal concentrations between cultured and wild samples of oysters. Mean concentrations of Hg (0.23 ± 0.02 mg/kg) and As (8.32 ± 0.82 mg/kg) were high in July 2014 and mean Pb (72.31 ± 2.65 mg/kg) and Cd (11.33 ± 0.59 mg/kg) concentrations were high in March 2015. As per the results of this study, mean Hg, Cd and As concentrations were well below the standards of WHO, European Union (EU), Australia, New Zealand Food Standards Code (FSANZ) while the mean Pb concentrations were slightly higher than the said standards.

Keywords: *Crassostrea madrasensis*, Puttalam lagoon, Toxic metals.

SOLUBLE SILICA IMPROVES THE QUALITY OF 'EMBUL' BANANA DURING STORAGE

N. G. D. N. Nikagolla¹, M. Y. Udugala-Ganehenegge² and W. A. M. Daundasekera^{3*}

¹Post graduate Institute of Science, University of Peradeniya, Peradeniya, Sri Lanka

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

³Department of Botany, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka

*malkantheid@pdn.ac.lk

Sri Lanka experiences considerable postharvest loss of banana due to improper handling and fungal rots. Soluble silica, a GRAS (Generally Regarded As Safe) compound, is known to control many postharvest diseases. As we have reported previously, shelf life of banana can be extended (two-fold vs. control) by dipping in 1500 $\mu\text{g mL}^{-1}$ silica solution for 20 minutes. Aim of this study was to determine efficacy of soluble silica (Si) in enhancement of storage quality of 'Embul' banana. Mature, fungicide-free, bananas were harvested from Mawanella. Separated banana 'hands' were immersed for 20 minutes in 1500 $\mu\text{g mL}^{-1}$ potassium silicate solution and distilled water (control). They were packed in corrugated fiber board boxes and stored under 13.5 ± 1 °C and 94% relative humidity (RH) for 7 days and then transferred to ambient temperature (28.0 ± 3 °C) and RH (60%). Each treatment comprised of three boxes containing five 'hands' in each. The boxes were arranged in Complete Randomized Design. Shelf life (time to reach eating-ripe stage), time taken to develop 5% (of fruit area) fungal rots were assessed. At eating-ripe stage, fresh weight loss (FWL), firmness, % titratable acidity (%TA) and total soluble solids (TSS) content were measured. Data were analyzed by two sample T test. Si-treated fruits exhibited significantly longer shelf life (17.5 days) vs. control fruits (13.5 days), significantly delayed development of anthracnose (21.5 days) vs. control fruits (16.7 days), no effect on crown rot development, significantly higher fruit firmness and reduced rate of FWL, possibly due to Si deposition beneath the cuticle, while their %TA and TSS remained unchanged. Si deposits may have formed a mechanical barrier against pathogen invasion and extended shelf life through reduced ethylene production rates in Si-treated fruits. Silica can be suggested as a quality enhancer for boxed 'Embul' bananas without affecting their organoleptic properties.

Financial assistance from National Science Foundation (Grant No NSF/RG/2016/AG/03) is acknowledged.

Keywords: Anthracnose, Banana, Crown rot, Silica, Storage.

**PHYSIOLOGICAL CHARACTERIZATION AND GENETIC DIVERSITY
ANALYSIS OF THE RHIZOBIAL POPULATIONS INHABITING
GLIRICIDIA SEPIUM FROM SELECTED LOCATIONS OF
ANURADHAPURA DISTRICT, SRI LANKA**

V.R.R.U. Udapamunuwa¹, P.W.I. Nawanjana² and R.G.S.C. Rajapakse^{2*}

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

²Department of Molecular Biology & Biotechnology, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka

*sanathr@pdn.ac.lk

The symbiotic association between *Rhizobium* and leguminous species plays a significant role in sustainable agricultural systems as it contributes higher amounts of fixed nitrogen to soil through biological nitrogen fixation. *Gliricidia sepium* is one of the most commonly cultivated agro forestry trees in the world. This leguminous tree is widely distributed throughout Sri Lanka. A very limited number of studies are available on *G. sepium*–*Rhizobium* symbiosis in Sri Lanka. The main objective of this study is to isolate and identify the stress tolerant *Rhizobium* sp. in *G. sepium* as the initial step to use Rhizobial strains for cross inoculation of crop legumes in order to minimize the use of chemical nitrogen fertilizers. The root nodules of *G. sepium* were collected from seven sites in *Anuradhapura* district, which is located in the dry zone of Sri Lanka. A total collection of 34 strains was tested for tolerance to different stress conditions, namely pH, salinity, drought and temperature. Fifteen of the 34 Rhizobial strains showed high tolerance when grown under a wide range of stress conditions. When these 15 stress tolerant Rhizobial strains were grown under combined extreme conditions (pH-8.0, salinity 3.0%, drought 0.4%, and temperature 36°C) which mimic the adverse environmental conditions they often experience in their natural habitat, 12 strains could survive well. DNA fingerprinting with *ERIC* 1R and *ERIC* 2R was carried out to analyze the genetic diversity of these 15 Rhizobial strains. The results showed that these 15 strains are genetically diverse as they belong to 9 clusters at 71% similarity level.

Keywords: Symbiotic association, Biological Nitrogen fixation, *G. sepium*, *ERIC*DNA fingerprinting, *Rhizobium*.

PEOPLE'S KNOWLEDGE, ATTITUDE AND PRACTICES TOWARDS DENGUE INFECTION AND PREVENTION IN A SEMI URBAN AREA, SRI LANKA

**W.L.S. Perera¹, P.K. Perera², A.M. Ambagahawita³, C. Wijesundara³
and K.O. Bandaranayaka^{4*}**

¹*Management and Science University, Malaysia*

²*Institute of Indigenous Medicine, University of Colombo, Rajagiriya, Sri Lanka*

³*Ministry of Health, Sri Lanka*

⁴*Management and Science Institute, Colombo 03*

**kalpanee.b@gmail.com*

Dengue is the most prevalent mosquito-borne viral infection in the world. Over the time, dengue has affected many countries including developed countries and developing countries like Sri Lanka. A cross-sectional study was conducted to assess level of knowledge, attitude and practice among the households of Ja-Ela MOH area, Sri Lanka using an interviewer administered questionnaire (n=510). Attitude and practices were assessed through a likert scale. Data analysis was done using SPSS statistical software version 21. Administrative and ethical clearance (ERC no: NIHS/ERC/17/03-R) was obtained from relevant authorities prior to the study. Majority of respondents (50.8%) were females and more than two third of respondents were married. The study showed that 56.7% respondents had an excellent knowledge, 67.6% had an excellent attitude and majority of the respondents reported to have good practices especially towards prevention. Respondents who had G.C.E. O/L qualification had a significantly higher knowledge, attitude and practices than other respondents. A statistical significance was found between the total knowledge and the total practices where higher the knowledge, better the practices towards dengue prevention. Respondents between 18 – 28 years of age had a significantly higher knowledge on the vector, signs and symptoms of the dengue followed by a significantly higher attitude and practice towards dengue prevention. However, overall knowledge on vector biting time, signs and symptoms were insufficient. Even though females were having a significantly higher knowledge, the study shows that cultural background plays a major role in decision making, thus their practices were significantly lower than males especially when third parties are involved. Furthermore, self-experience in dengue disease resulted in better attitudes and practices. Educating people with proper knowledge makes dengue control efficient and building women empowerment regarding making decisions plays a major role in dengue prevention at least in the studied population.

Keywords: Dengue, Knowledge, Attitude, Practices.

IMPROVEMENT OF SEED QUALITY THROUGH HYDRO-PRIMING AND THE BEST STORAGE TREATMENT FOR TWO TRADITIONAL RICE VARIETIES OF SRI LANKA, BATAPOLA-EL AND SUWENDAL

M.O. Galappaththi^{1*}, K.M.G.G. Jayasuriya^{1,2} and N.S. Gama-Arachchige^{1,2}

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

²*Postgraduate Institute of Science, University of Peradeniya, Peradeniya, Sri Lanka*
**mogalappaththi91@gmail.com*

Although, traditional rice varieties have increased in demand, their low germination and vigour have posed difficulties in cultivating them. The study was conducted to establish a hydro-priming method and a proper storage method to improve the seed quality for two traditional rice varieties, 'Batapola-el' and 'Suwendal'. Seeds were soaked for 0, 24, 48 and 72 hours and dried under ambient laboratory conditions until the initial weights were reached. Performance of primed and unprimed seeds was tested under laboratory and glasshouse conditions. Four replicates of 100 seeds each were used. Seed quality was evaluated using seed germination, seed vigour (root and shoot length) and seedling emergence. Three replicates of 100 g of seeds each were packaged separately in gunny, plastic and polythene (gauge 100) bags and stored under 27, 25 and 8 °C for 2, 4 and 6 months. Seed quality was evaluated using seed germination and vigour (conductivity test). Data were arcsine transformed and analyzed using one-way ANOVA. Seeds of both 'Batapola-el' and 'Suwendal' varieties hydro-primed for 72 hours, germinated to a significantly higher percentage (98±0.3% and 98±0.6%, respectively) than non-primed seeds (91±1.4 and 89±0.6%, respectively). Root and shoot lengths were significantly higher in seedlings of both varieties developed from 72 hours primed seeds than those from non-primed seeds. Seeding emergence was 79% and ~76% of the non-primed 'Batapola-el' and 'Suwendal', while that was significantly higher (> 90%) when the seeds were primed with distilled water for 72 hours. Seeds stored in polythene bags at 8 °C for 6 months germinated to higher percentages (91±0.6 and 89±1.1%, respectively) than those stored under other methods (P < 0.001). Thus, hydro-priming for 72 hours could be recommended to improve the seed quality of 'Batapola-el' and 'Suwendal' varieties. The storage of seeds in polythene bags at 8 °C could also be recommended.

Keywords: Emergence, Germination, Hydro-priming, Vigour.

PRACTICAL APPLICABILITY OF THE GLUCOSE OXIDASE METHOD IN ASSESSING α -AMYLASE ACTIVITY

R. Visvanathan^{1,2}, **C. Jayathilake**², **R. Liyanage**^{2*} and **R. Sivakanesan**³

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

²National Institute of Fundamental Studies, Hantana Road, Kandy, Sri Lanka

³Department of Biochemistry, Faculty of Medicine, University of Peradeniya, Peradeniya, Sri Lanka

* ruvinill@yahoo.com

Glucose oxidase (GOx) is an enzyme widely used in glucose monitoring systems owing to its high specificity towards glucose. According to literature, the enzyme GOx is specific for glucose and there is no significant reaction with other mono- or disaccharides. In our previous work, maltose was found to show significant interaction with GOx and based on this observation, a novel microplate based method was developed to assess α -amylase inhibitory activity using GOx (GOD method). However, several concerns regarding the interaction of GOx with maltose limited the widespread use of the GOD method in assessing α -amylase activity. Thus, the present work aimed at studying the applicability and reliability of GOx in assessing α -amylase activity. The purity and interaction of maltose with GOx was determined using HPLC studies. HPLC results confirmed the absence of glucose in the maltose standards thereby confirming the interaction of maltose with GOx. In addition, the hydrolysis products of starch after α -amylase action were also confirmed to interact with GOx. The application of the adapted method in assessing α -amylase and α -amylase inhibitory activity was studied using 10 different flour types and medicinal plants, respectively. Hydrolyzing rates of the starches for α -amylase ranged from 0.23 ± 0.01 to 12.52 ± 0.10 μ M maltose/min. The highest hydrolysing rate was observed in wheat flour while lowest was observed in soy flour. The α -amylase inhibitory activity of the herbal extracts ranged from 0.37 ± 0.002 to 109.41 ± 3.21 mg/mL (IC_{50}). Among the tested extracts, Nelli and Ranawara showed significantly high inhibitory activity against amylase. However, none of the extracts were as effective as acarbose (5.50 ± 0.07 μ g/mL) in inhibiting the activity of α -amylase. In summary, it can be said that the GOD method is an accurate and reliable method for quantifying α -amylase activity and there is no doubt on the interaction of GOx with the products of α -amylase.

Financial assistance from the National Institute of Fundamental Studies, Kandy, Sri Lanka is acknowledged.

Keywords: α -Amylase activity, Glucose oxidase method.

NEW LOCALITY RECORD AND FOOD HABITS OF ENDEMIC AND CRITICALLY ENDANGERED FISH *LABEO FISHERI* (JORDAN AND STARKS, 1842) (TELEOSTEI: CYPRINIDAE: CYPRININAE) IN SRI LANKA

K.G.D.D. Thilakarathne^{*}, G.N. Hirimuthugoda and K.B. Ranawana

Department of Zoology, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka
**dinelkat@yahoo.com*

Labeo fisheri is an endemic and critically endangered benthic freshwater fish which is known to be restricted to the rocky areas with strong water currents in the upper parts of the Mahaweli River (Polgolla, Lewella, Gatambe around Hakkinda islands and Moragolla around upper part of the Gampola area) in Sri Lanka. New locality record of a species with limited distribution is vital for its conservation. Present study reports an accidental record and new locality of *L. fisheri* in the Victoria reservoir with its food habit. Samples of *L. fisheri* were collected from the fisherman's catch in the Victoria reservoir from January 2017 to August 2017. Some fishermen in the reservoir set their gill nets (minimum mesh size 9 cm) near the bottom in shallow regions of the reservoir targeting bottom inhabiting species. Collected fish were photographed and the morphometric and meristic measurements were taken for identification purpose. Collected dead fish were dissected to separate the guts. Each gut was crushed and its content was separated into 10 ml of distilled water. Ten 0.05 ml drops of crushed solution of each individual were observed under Zeiss Primo-star light microscope. Different types of plankton species were identified and photographed using a Zeiss Primo-star inverted microscope with camera attachment. During the study period, a total of seven mature *L. fisheri* specimens were found in the Victoria reservoir, the new locality of *L. fisheri*. Dorsal fin comprised of three spines and 10-12 rays. Anal fin comprised of three spines and five rays and pectoral fin with one spine and 15 branched rays. It has a complete lateral line with 40-42 lateral line scales, 16-18 pre dorsal scales (D III.10-12; A III.5; P I.15; V I,8; LL 40-42; L. lat 7 ½ /5 ½). The average total length of the body of captured fish was 24.8±4.3 cm and the standard length was 19.7±3.8 cm. The average body weight of the captured ones was 197.686±10.124 g. According to the food habit analysis, *L. fisheri* depends on phytoplankton and the algae. The most dominant food types of *L. fisheri* were *Aulacoseira* sp. (29%), *Staurastrum* sp. (8%), *Chroococcus* sp. (9%) and diatoms (14%). According to literature they are known to feed on algae but according to our study they are feeding on both algae and phytoplankton. *Labeo fisheri* is one of the critically endangered species in Sri Lanka and according to the global red list, this is an endangered species. Therefore, proper conservation measures are needed to protect the remaining favorable habitats of *L. fisheri* in Sri Lanka.

Keywords: *Labeo fisheri*, New locality, Endemic, Critically endangered, Victoria reservoir.

NON-TOXIC MONTMORILLONITE CLAY COMPOSITES OF *LIMONIA ACIDISSIMA* LEAF HEXANE EXTRACT AND THEIR ANTIBACTERIAL ACTIVITY AGAINST *ESCHERICHIA COLI*

B.H. Madhushini¹, N.C. Bandara², I.S.K. Vithanage² and B.M.R. Bandara^{1,2*}

¹Department of Chemistry, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka

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

*bmrbandara@gmail.com

The possibility of trapping the antibacterial constituents of a hexane extract of *Limonia acidissima* L. (woodapple) leaf into H⁺- and Al³⁺-exchanged montmorillonite (MMT) to furnish non-toxic antibacterial clay composites was examined. MMT has a layered structure and can intercalate organic molecules into its expandable interlayer nano-space (1 - 3 nm). Powdered *L. acidissima* leaves were extracted into hexane using a Soxhlet apparatus. A dichloromethane solution of the concentrated extract was separately stirred with Mⁿ⁺-MMT (Mⁿ⁺ = H⁺ and Al³⁺) and β-CD-Mⁿ⁺-MMT to furnish extract-Mⁿ⁺-MMT and extract-β-CD-Mⁿ⁺-MMT, respectively; Mⁿ⁺-MMT was prepared by stirring Na⁺-MMT in aqueous HCl or AlCl₃ and β-CD-Mⁿ⁺-MMT by stirring Mⁿ⁺-MMT with β-cyclodextrin (β-CD) in water. MMT clays and their composites were characterized by FT-IR and XRD methods. The release of phytomaterial from the clay composites at pH 1.2 and 7.4 further confirmed the successful intercalation. The percentage of intercalated phytomaterial was as follows: extract-H⁺-MMT (25%), extract-Al³⁺-MMT (47%), extract-β-CD-H⁺-MMT (25%) and extract-β-CD-Al³⁺-MMT (35%). The antibacterial activity of the samples against *Escherichia coli* (ATCC 25922) was determined by estimating the LR-CFU (log reduction in colony forming units per mL) of the respective samples by the broth micro-dilution assay. The LR-CFU values of the clay composites were high (1.30 - 7.18) and the ones recorded for extract-β-CD-H⁺-MMT (5.18) and extract-β-CD-Al³⁺-MMT (7.18) were higher than that for the extract (3.22) indicating that β-CD substantially potentiates the antibacterial activity of the clay composites; β-CD did not, however, enhance the extent of intercalation. The clay composites were not cytotoxic in the brine shrimp lethality assay against *Artemia salina* having high LC₅₀ values (4,176 – 9,824 ppm), compared to the neat extract (605 ppm). In conclusion, the extract was successfully intercalated into H⁺-MMT and Al³⁺-MMT clays to furnish non-toxic composites that had considerable antibacterial activity against *E. coli*.

Keywords: *Limonia acidissima*, Montmorillonite-clay-composites, Antibacterial.

SURVEY OF ANOPHELINE MOSQUITO FAUNA IN A VIRGIN FOREST IN DAMBANA: THE FIRST RECORD OF *ANOPHELES BARBUMBROSUS* IN BADULLA DISTRICT

D.M.C.J. Dissanayake¹, S.N. Weerakoon^{1*}, I.S.P. Amarasinghe¹, T.C. Weeraratne² and S.H.P.P. Karunaratne²

¹*Anti Malaria Campaign, Regional Office, Badulla, Sri Lanka*

²*Department of Zoology, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka*
**snweerkn@gmail.com*

The mosquito fauna of Sri Lanka is rich with 141 species reported through morphological identifications and several sibling species disclosed *via* cytological and DNA barcoding studies. Using morphological tools, the present study aimed to identify the mosquito fauna in a virgin forest in Dambana in the Badulla district. During December 2017 to July 2018, mosquitoes in Dambana virgin forests (7°23'33.1"N, 81°04'55.7"E) were surveyed using standard collecting methods; cattle baited trap collection (CBTC), window trap collection (WTC), indoor and outdoor partial night human landing collection [HLNC(P) *in* and HLNC (P) *out*] and larval surveys (LS) by dipping. A total of 1244 adults and 163 larvae of anopheline species were collected. According to morphological characterization, the collection comprised of 13 anopheline species. Among them was *Anopheles barbumbrosus*; 27 individuals (2.2%) collected from CBTC and 9 individuals (5.5%) from LS and the single individual collected from indoor HLNC (P) was also *An. barbumbrosus*. This is the first record of *An. barbumbrosus* from Badulla District in Sri Lanka. *Anopheles barbumbrosus* (Strickland and Choudhury) belongs to the barbirostris group. According to reports it has a very limited distribution in Sri Lanka. *Anopheles barbumbrosus* larvae were found only in the margins (waterway margin) of Maduru Oya and Dehiaththawa Oya. Sand pools (shaded with canopy vegetation but with clear water) were the most preferred breeding site of this species. These locations had mean temperatures of 27.1 ± 0.6 °C and relative humidity of 70.8 ± 3.06 . Other anopheline species collected included rare species such as *An. pseudojamesii* (1.1% in CBTC) and *An. karweri* (0.1% in CBTC). Studies are in progress for DNA barcoding and molecular characterization of these anopheline species for evaluation of their genetic structure.

Keywords: *Anopheles barbumbrosus*, Badulla District, Entomological investigations, Mosquito sampling.

**POTENTIAL OF PREDATORY LARVAE OF *ARMIGERES SUBALBATUS*
(DIPTERA: CULICIDAE) FOR BIOLOGICAL CONTROL OF
VECTOR MOSQUITOES**

W.G.D. Chathuranga^{1,2*}, S.H.P.P. Karunaratne¹ and W.A.P.P. de Silva¹

¹*Department of Zoology, Faculty of Science, University of Peradeniya, Peradeniya, Peradeniya, Sri Lanka*

²*Postgraduate Institute of Science, University of Peradeniya, Peradeniya, Sri Lanka*
**dilanchathuranga9@gmail.com*

The predatory nature of *Armigeres subalbatus* larvae was examined to determine the possible use of this mosquito species in controlling co-occurring vector mosquitoes. Both predator (*Ar. subalbatus*) and prey (*Aedes albopictus* & *Culex uniformis*) larvae were collected from the natural habitats and reared in larval trays (1000 ml) in the insectarium (25°C). They were fed on fish food (0.05 g) twice a week. Larvae of *Ae. albopictus* and *Cx. uniformis*, that share breeding sites with *Ar. subalbatus* were used as prey. Rate of prey consumption of individual predatory larvae were recorded every 24 hours for total of 120 predatory larvae. The rate of change of cannibalism of *Ar. subalbatus* larvae was assessed for availability of food (fish food throughout, fish food once, fish food first five days, and non-fed), space (100 ml & 1000 ml), and density of larvae (10, 25, 50, and 100 individuals per container). Results revealed the voracious predatory nature of both 3rd and 4th instar larvae of *Ar. subalbatus*. The mean consumption of prey by a single predatory larva was 47.3 ± 7.6 (*Ae. albopictus*) and 33.6 ± 4.4 (*Cx. uniformis*). A significant difference in predatory rate of *Ar. subalbatus* larvae was observed with the type of meal provided ($p < 0.001$). A high pupation rate in *Ar. subalbatus* was observed when larvae were fed on both fish food and prey larvae (*Ae. albopictus*: 70% & *Cx. uniformis*: 72%). A positive correlation between larval density and rate of cannibalism was observed ($p < 0.05$). Larval density has a significant impact on natural deaths ($p < 0.05$), rate of pupation ($p < 0.05$), and rate of adult emergence ($p < 0.05$) in predatory larvae. The findings provide important information on the predatory efficiency of late instar larvae of *Ar. subalbatus*, which are critical in understanding the suitability of *Ar. subalbatus* as a biological controlling agent of co-occurring vector mosquitoes.

Financial assistance from National Research Council, Sri Lanka (Grant No: NRC 16-059) and National Science Foundation, Sri Lanka (Grant No: NSF 2016 EB /05) are acknowledged.

Keywords: Breeding sites, Cannibalism, Co-existence, Dengue, Predatory mosquito larvae.

**DIVERSITY AND CONSERVATION OF LESS KNOWN LEAFY
LIVERWORTS OF SRI LANKA**

B. M. S. K. Bandaranayake¹ and S. C. K. Rubasinghe^{2*}

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

²*Department of Botany, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka*

**srubasinghe@pdn.ac.lk*

Leafy liverworts are one of the poorly known groups of plants in Sri Lanka. They also represent one of the taxonomically difficult taxa among bryophytes (mosses, liverworts, hornworts). The present study was carried out to explore the diversity of leafy liverworts in Sri Lanka and to identify their habitats. Fresh samples including vegetative and reproductive structures of leafy liverworts were collected from all possible geographic localities in Sri Lanka. Morphological, anatomical and ultra structural characters of spores were observed using dissecting, compound (Olympus CX21), stereo (Zeiss, Primo Star, Germany) and Scanning Electron (Evo LS 15 Zeiss, Germany) microscopes. Characters were recorded for each specimen. Specimens were identified up to specific/ generic level using taxonomic keys, monographs and illustrations. Twenty one families, 46 genera and 132 species of leafy liverworts were identified with 9 new records to Sri Lanka. A high diversity of leafy liverworts was observed in montane and lowland rainforests. They are mainly found on tree barks, decaying logs, leaves, rocks and soil in shady moist habitats. Due to the lack of a proper cuticle or water absorbing structures, they are sensitive to pollutants and micro-climatic changes. The epiphytic taxa have high water retention capacity, thus act as indicators of pollution and changing environmental conditions. Deforestation and environmental pollution destruct their habitats threatening their survival. The study emphasizes the necessity of conserving these habitats to protect the rich leafy liverwort flora of the country.

Financial assistance from National Science Foundation (Grant No: RG/2016/EB/01), Sri Lanka is acknowledged.

Keywords: bryophytes, leafy liverworts, habitats, conservation.

SOFTENING OF HARD WATER USING ACTIVATED COCONUT COIR

W.G.S.S. Gunarathne¹, M.N.S. Kottegoda² and A.D.L.C. Perera^{1,3*}

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

²*Department of Chemistry, Center for Advanced Materials Research,
University of Sri Jayewardenepura, Nugegoda, Sri Lanka*

³*Department of Chemistry, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka
chandanip@pdn.ac.lk

Activated carbon is widely used as a filter material in water purification. However, commonly used coconut shell activated carbon has not shown promise in water softening applications. This research focuses on development of a low cost filter material based on activated carbon derived from coconut coir dust for water softening applications. Activated carbon (ACC) was synthesized by activating raw coconut coir dust with 50 % (w/w) phosphoric acid followed by pyrolysis at 450 °C under N₂ (g) flow for 1 h. ACC was modified with an alginate coating to improve the adsorption efficiency and to make a bead-like filter material. The water softening efficiencies of ACC powder, ACC granules and ACC-alginate beads were compared using water samples collected from different locations in Sri Lanka. Hardness of water samples was analyzed by HATCH spectrophotometer. Single filtration through ACC-alginate gel beads yields softening of natural hard water to the values of: Jaffna (Ca-136.0→20.0 ppm, Mg -214 →143.5 ppm), Panduwasnuwara (Ca -185.0→42.0 ppm, Mg -200.0→82.0 ppm), Kiullinda (Ca -201.0→49.0 ppm, Mg -300 →74.0 ppm) and Polonnaruwa (Ca -200 →63.5 ppm, Mg -172 →71.0 ppm). Single filtration of the same hard water samples through ACC powder results in the values of: Jaffna (Ca -20.0 ppm, Mg - 36.0 ppm), Panduwasnuwara (Ca -30.0 ppm, Mg - 47.0 ppm), Kiullinda (Ca - 21.0 ppm, Mg - 60.0 ppm) and Polonnaruwa (Ca -30.0 ppm, Mg - 27.0 ppm). Water softening capacity of ACC granules is about 50% less than ACC powder. Thus, ACC powder has the highest water softening capacity in a single filtration. Therefore, coconut coir dust based activated carbon would be a promising low cost candidate for future water softening applications.

Keywords: Coconut coir dust, Chemical activation, Water hardness, Adsorption.

**DETERMINATION OF FUNDAMENTAL PROPERTIES OF CZTS
SEMICONDUCTOR MATERIAL DEPOSITED BY THE SPRAY
PYROLYSIS METHOD**

A.M.K.L. Abeykoon^{1,2} and J. Bandara^{1*}

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

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

^{*}*jayasundera@yahoo.com*

Copper zinc tin sulfide (CZTS) which is a p-type, kesterite, semiconductor material with a narrow band gap around 1.5 eV is a promising and an ideal light-harvesting material for thin film solar cells. In recent years, there is a wide interest on CZTS based thin film solar cell as CZTS harvests solar energy from UV to far IR regions. The electronic and physical properties of CZTS are highly dependent on the atomic ratio of the elements in which sulfur in CZTS plays a significant role in determining the properties of CZTS. As such, in this experiment, we carried out fundamental properties such as material type, band energy positions, band gap, crystal structures, etc of a CZTS semiconductor material when the variation of sulfur content in CZTS. The CZTS was synthesized by a two-step process in which, metal salts and different ratios of thiourea are dissolved in dimethyl sulfoxide (DMSO) and the precursor solution was sprayed on FTO followed by sulfurization at nitrogen environment at 500 °C. Mott–Schottky plot is used to determine the flat-band potential and type of material. UV-Visible spectrometry and powder X-ray diffraction were used to determine the band gap and crystal structure of the material respectively. The Mott–Schottky plots confirm the complete p-type nature of the CZTS while the flat band potentials negatively shifts from 0.66 V to 0.03 V and charge carrier density decreases from $2.38 \times 10^{16} \text{ cm}^{-2}$ to $3.36 \times 10^{15} \text{ cm}^{-2}$ with the increase of the sulfur ratio in CZTS. These results offer guidance to improve the properties of CZTS and their applications in solar energy conversion applications.

Keywords: Copper zinc tin sulfide, Semiconductor, Flat band potential.

TRENDS IN ENCAPSULATION CAPACITY OF DENDRIMERS WITH VARYING CORE-FUNCTIONALITY AND GENERATION

N.P.N.R. Kumarachchi¹, Z. Dunajova^{1,2} and R. J. K. U. Ranatunga^{1,3*}

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

²*Department of Chemistry, Masaryk University, Brno, Czech Republic*

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

**udyranatunga@pdn.ac.lk*

Dendrimers are highly branched synthetic polymers, with a symmetrically-layered, three-dimensional structure. Dendrimers are particularly attractive because of viable control of their architecture, through several structural parameters. Even though structural parameters such as core-functionality, generation, terminal length and chemical composition affect physicochemical properties, these cannot be readily studied experimentally. Here we use computational simulations to investigate the influence of structural parameters on entrapment capacity. Dendrimers, represented using the SDK coarse-grained force-field of generation (G) 3 - 5, and core-functionality (C) 1 - 6 were simulated. Simulations, at ambient temperature and pressure, were carried out separately in water and phenol, to observe trends in size and shape. The retention capacity, radius of gyration (R_g) and bead density data were obtained from analysis of trajectories. Results suggested increasing core-functionality yields higher R_g values, while the dendrimers are more expanded in phenol than in water. Finally, the dendrimers, loaded with phenol, were inserted into the water region of a water-phenol biphasic system and allowed to equilibrate, allowing phenol to diffuse out while tracking the number of entrapped molecules. The mass of molecules retained was fitted to an exponential decay function to evaluate the equilibrium retention capacity and release rates. It was found that both the release rate and the loading capacity are influenced by generation and core-functionality. In the case of loading capacity, increasing G enhances capacity, while for C, there seems to be an optimum value. In our studied system C_1 shows almost no loading capability, while the capacity was highest for C_5 dendrimers. For the release rate, the relationships seem to be driven mainly by steric effects.

Keywords: Dendrimers, Generation, Coarse-grained simulations, Core-functionality.

**FACILE FABRICATION OF OMNIPHOBIC SURFACES ON
POLYESTER FABRIC**

U.G.M. Ekanayake^{1,2*}, N. Rathuwadu¹ and M.M.M.G.P.G. Manthilaka¹

¹*Sri Lanka Institute of Nanotechnology, Nanotechnology and Science Park, Mahenwatte,
Pitipana, Homagama*

²*Postgraduate Institute of Science, University of Peradeniya, Peradeniya, Sri Lanka*
**mihirie@slintecacademy.lk*

Omniphobic surfaces have been widely used in many applications due to their self-cleaning performance. In this study, omniphobic polyester fabric with water contact angle of 152° has been produced using ZnO seed layer and polymerizing 3,3,4,4,5,5,6,6,7,7,8,8,8-tridecafluorooctyl methacrylate to decrease surface free energy of the surface. The fabric with and without seed layer was analysed using contact angle goniometer. The water contact angle of the fabric without seed layer is 142°, which is lower than the fabric with the seed layer. The oleophobicity of the fabric was analysed using SAE 40 motor oil and the treated fabric shows 130° contact angle while non-treated fabric shows 0° contact angle. Scanning electron microscope (SEM) characterization was done for morphological analysis of the treated and non-treated fabrics and according to that particle size of the seed layer applied fabric ranging from 100-300 nm and after application of fluoropolymer it was lower than 100 nm. Elemental dispersion spectroscopy (EDS) and X-ray fluorescence (XRF) analyses were done for elemental characteristics and FTIR for bonding analysis. Elemental analysis showed presence of fluorine and FTIR confirmed the polymerization of 3,3,4,4,5,5,6,6,7,7,8,8,8-tridecafluorooctyl methacrylate. Thermal analysis using thermogravimetric analysis (TGA) and differential scanning calorimetry (DSC) confirmed the polymerization of fluoromonomer. The durability of the fabric was tested by 1.5 h washing and 50 cycles of abrasion and the contact angle did not change throughout the test. The prepared fabric is robust and the colour of the fabric did not change upon the treatment. Moreover, the preparation method of the fabric is also simple, inexpensive and less time consuming.

Keywords: Fluorinated, Omniphobic, Robust, ZnO.

A STUDY OF THERMAL CONDUCTIVITY OF COMPOSITE BUILDING MATERIALS AND VERIFICATION OF MAXWELL'S THEORETICAL MODEL

A.V.D.C. Vithanage^{1*} and K. Premaratne²

¹*Department of Physics, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka*

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

**dcvith@gmail.com*

A large percentage of energy delivered to buildings is consumed for space heating or cooling processes. Thermal insulation of buildings reduces heating or cooling requirement by decreasing heat loss or gain through building envelopes. The thermal insulation process requires an extensive understanding of thermal conductivity of building materials such as bricks and concrete. This study investigates the thermal conductivities of various compositions of cement mortar, having river sand, granite chips and fly ash as constituent components and thermal resistances of layered structures. Samples were made into thin discs of cement mortar and tested in dry state. Applicability of Maxwell's theoretical model in predicting effective thermal conductivity of cement mortar was investigated using Lee's disc technique. The results show a non-linear continuous increase of thermal conductivity of cement mortar with increasing volume fraction of river sand, granite chips and, fly ash shows a non-linear continuous decrease. This is due to the simple fact that thermal conductivities of river sand and granite are higher than that of pure cement, whereas fly ash has a thermal conductivity lower than that of cement. Results indicate that Maxwell's model is applicable to predict thermal conductivity of cement mortar. Validity of thermal resistance equation for layered structures in series was also investigated, for mortar-brick layers and for layers of mattress materials. Double-layered structures are in good agreement with theory, while precise validation of the equation cannot be verified for three-or more-layered structures. This could be due to the increase of heat loss from the circumferential area of the disc with the number of layers used. In our work this loss has been neglected as thin discs of material were used in most of our work.

Keywords: Thermal conductivity, Composite building materials, Thermal resistance, Maxwell's model.

**ENHANCING THE THERMAL CONDUCTIVITY OF BASE FLUIDS BY
INCORPORATING GRAPHITE**

V.A.S. Sumanasinghe¹, T.P. Ranawaka^{1,2} and B.S. Dassanayake^{1,2}

¹*Department of Physics, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka*

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

^{*}*buddhid@gmail.com*

Inefficient heat transfer in conventional commercial coolants leads to early combustion, deformation, unnecessary noise and vibrations in engines; thermal runaway in transformers and poor performance in hydronic systems culminating in heavy economical losses and debilitating the machinery. Production of coolants with enhanced thermal conductivities (TC) is a solution to overcome these drawbacks. Thus, determination of TC of coolants is of utmost importance. The standard instruments available for TC measurements of fluids are extremely expensive. An alternative approach to alleviate the cost factor of standard instruments such as the transient hot wire method (THWM) requires expensive platinum wire as the hot wire (HW). In this study, platinum was replaced by a copper wire which is readily available and inexpensive envisaging reduction of cost by a huge margin. Transient hot wire apparatus (THWA) with copper wire as the HW produced appreciable accuracy in TC measurement at 27 °C with a percentage error of 7.14% (Experimental : $0.574 \text{ W m}^{-1} \text{ K}^{-1}$, Standard: $0.615 \text{ W m}^{-1} \text{ K}^{-1}$) for deionized (DI) water. When graphite (average particle size: 210 nm) was incorporated to DI water, an optimum enhancement in TC ($0.694 \text{ W m}^{-1} \text{ K}^{-1}$) of 17.33% was obtained for 5 wt% of graphite incorporation. This was attributed to provision of a higher surface area by incorporating graphite, facilitating an enhanced mechanism for heat transfer within fluid medium. Incorporating 5 wt% of graphite in a water-based STR Radiator Coolant produced an increment of TC by 6.01% (0.556 to $0.589 \text{ W m}^{-1} \text{ K}^{-1}$) and viscosity by only 1.77%. Thus, rheological properties were not significantly altered by incorporation of graphite. Consequently, as a pioneering study conducted in Sri Lanka, it can be suggested that incorporating trace amounts of finer graphite particles in nanometre and micrometre range can be used in coolants for enhancing thermal conductivity in heat generating appliances.

Keywords: Thermal conductivity, Coolants, THWM.

PERFORMANCE EVALUATION OF A LITHIUM RECHARGEABLE CELL WITH THE THICKNESS OF CONDUCTING POLYMER CATHODE

W.A.D.S.S. Weerasinghe¹, K.P. Vidanapathirana^{1*}, K.S. Perera¹, A.K. Arof² and M.A. Careem²

¹*Department of Electronics, Wayamba University of Sri Lanka, Kuliypitiya, Sri Lanka*

²*Department of Physics, University of Malaya, Malaysia*

**kamalpv41965@gmail.com*

During recent decades, conducting polymers, such as polypyrrole (PPy), polyaniline (PANI), polythiophene (PTH) and their derivatives, have been extensively studied as electrode materials because of their high electronic conductivity and reversible redox chemistry. In electrode design, electrode thickness, electrode porosity and chemical composition are important. In this study, effect of thickness of PPy cathode on the performances of Li rechargeable cell was investigated. Sodium dodecylbenzenesulphonate (SDBS) and a standard non-aqueous Li⁺ electrolyte mixture of 1 M LiPF₆ in ethylene carbonate (EC) with dimethyl carbonate (DMC) were used as the salt and the electrolyte. Cells were fabricated in the configuration of Li / [LiPF₆ : EC: DMC] / PPy : DBS varying calculated thickness of PPy cathode and they were characterized using cyclic voltammetry and continuous charge-discharge tests. Soon after a cell was fabricated, the initial open circuit voltage (OCV) was measured. Cyclic voltammetry tests were performed in the potential window of 2.0 V to 3.5 V at the scan rate of 20 mV s⁻¹. Continuous charge-discharge cycles were obtained in the potential window of 2.5 V to 4.2 V under a constant charge-discharge current of 0.6 mA for 500 cycles. OCV of the cells were around 2.5 V indicating that there is no significant effect on the OCV with the thickness of the cathode. Cyclic voltammograms showed that as the thicknesses of the cathodes were increased, peak positions shifted towards higher potentials indicating that thicker films required more energy to obtain the maximum capacity. The highest discharge capacity value of 29.3 mAh g⁻¹ was obtained for the cell with the cathode thickness of 1 μm. Charge retention of it was more than 95% of the initial value after 500 continuous charge-discharge cycling. So it is clear that, with the thinner electrodes, higher discharge capacities could be obtained.

Financial assistance from National Science Foundation Sri Lanka (Grant No: RG/2014/BS/01 and RG/2015/EQ/07) is acknowledged.

Keywords: Polypyrrole, Rechargeable cell, Cyclic voltammetry, Galvanostatic charge-discharge.

MODIFICATION OF HIGHLY FLUORESCENT CdTe QUANTUM DOTS UNDER ATMOSPHERIC CONDITIONS

**M.M.E. Munasinghe¹, Y.B. Jayawardhene², A.M.M.H. Athapaththu³,
W. Abeywickreme⁴ and L. Jayarathna²**

¹*Molecular Medicine Unit, Faculty of Medicine, University of Kelaniya, Sri Lanka*

²*National Institute of Fundamental Studies, Hantana Road, Kandy, Sri Lanka*

³*Biotechnology Unit, Industrial Technology Institute, Sri Lanka*

⁴*Department of Para Clinical Sciences, General Sir John Kotelawala Defense University, Sri Lanka*

**erandieran@hotmail.com*

In the recent years, researchers have paid more attention for constructing distinctive varieties of nanosystems such as quantum dots, nanowires, nano-rods, nanotubes and nano-films. The potential use of these materials is determined by its size, ranging from 2- 10 nm in diameter. Zeolite is a micro porous allumino-silicate mineral which serves as a molecular sieve and are currently used in many new industrial applications. Zeolite was used as a trapping agent during CdTe quantum dots synthesis with the aim of maintaining inert conditions in the synthesis media. In the current study, L-Cysteine capped CdTe QDs were synthesized in zeolite media under atmospheric conditions, maintaining the molar ratio of Cd²⁺: Te²⁻: Cysteine as 1: 0.24: 4. During synthesis, the sample was refluxed at different reaction time intervals and was visualized under ultraviolet light and was characterized using FTIR and SEM analysis. Synthesized L-cysteine capped CdTe quantum dots presented bright yellow-orange and red colors at 365 nm wavelength and the size of synthesized CdTe nano crystals are determined as 3 - 3.5 nm for 1 hour and 2 hours reaction times. FTIR analysis exhibited successful synthesis of CdTe QDs. The modified IONP-QD complex can be further developed to be used in diagnostic assays.

Financial assistance from the National Research Council (Grant No: NRC TO 14/04), Sri Lanka is acknowledged.

Keywords: CdTe, Quantum dots, Zeolite.

ENHANCING EFFICIENCY OF DYE-SENSITIZED SOLID-STATE SOLAR CELLS USING ALKYL-FUNCTIONALIZED ORGANIC DYE

**D.N. Livanage^{1,2}, A.C.A. Jayasundera⁴, K. Tennakoon³,
K.D.M.S.P.K. Kumarasinghe^{1,2} and G.R.A. Kumara^{2*}**

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

²National Institute of Fundamental Studies, Hantana Road, Kandy, Sri Lanka

³Department of Physics, Georgia state University, Atlanta GA 30303, USA

⁴Department of Chemistry, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka
*grakumara2000@yahoo.com

Since mid-nineteen nineties, a number of attempts have been made in the field of Dye-sensitized Solid-state Solar Cells (DSSCs) which circumvent the problems associate in wet type Dye-sensitized Solar Cells (DSCs). However, the photovoltaic efficiency is lower with compare to that of DSCs. When considering the configuration of DSSCs n-type semiconductor/dye/p-type semiconductor would lead to rise the recombination rate. The structure of the photo sensitizer can effect for the photovoltaic performance as well as the recombination rate of the cell. Alkyl-functionalized organic dye namely MK-2, comprises Donor- π spacer-acceptor morphology which can reduced the recombination rate by providing long distance for charge separation. DSSC was prepared by using TiO₂ and Culas n-type and p-type semiconductor respectively with adding triethylaminethiocyanate as a crystal inhibitor and sensitized with MK-2 dissolved in acetonitrile / tert-butyl alcohol (1:1 volume ratio) and toluene. The optimum photovoltaic performance of DSSC sensitized by MK-2 dissolved in acetonitrile / tert-butyl alcohol, with 15 μm thickness of TiO₂ film has shown 0.496 V open circuit voltage, 16.14 mA cm⁻² current density, 0.42 fill factor with overall efficiency 3.33% under 1.5 AM illumination. The UV-visible and IPCE results showed that MK-2 dye able to absorb board range in visible spectrum and more than 50% photons convert to electrical energy. As such, MK-2 dye would be suitable for sensitize DSSCs with CuI as a p-type hole conductor.

Financial assistance from National Institute of Fundamental Studies is acknowledged.

Keywords: Alkyl-functionalized organic dye, Copper iodide, Dye-sensitized solid-state solar cells.

GROWTH AND CHARACTERIZATION OF SEED ASSISTED, $\text{Cd}_{(1-x)}\text{Zn}_x\text{S}$ WITH EDTA TREATMENT

W.G.C. Kumarage^{1,2}, R.K.K.G.R.G. Kumarasinghe^{1,3}, W.K.D.A.U. Wijesinghe¹, R.P. Wijesundera⁴, V.A. Seneviratne^{1,3}, C.P. Jayalath^{1,3} and B.S. Dassanayake^{1,3}

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

²Department of Science and Technology, UvaWellassa University of Sri Lanka, Badulla, Sri Lanka

³Department of Physics, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka

⁴Department of Physics, University of Kelaniya, Kelaniya, Sri Lanka
*buddhid@gmail.com

A detailed study on chemical bath deposited CdS (CBD-CdS), Zn incorporated chemical bath deposited CdS ($\text{Cd}_{(1-x)}\text{Zn}_x\text{S}$) and seed assisted Zn incorporated surfactant ethylenediaminetetraacetic acid (EDTA) added CdS (ED/CBD/EDTA+Zn-CdS) is reported here. The CBD-CdS films were deposited on FTO glasses using 1 mmol dm^{-3} CdSO_4 , 2 mmol dm^{-3} $\text{CS}(\text{NH}_2)_2$ and 1.1 ml of ammonia solution in 140 ml of de-ionized water. The $\text{Cd}_{(1-x)}\text{Zn}_x\text{S}$ films ($x=0.3$ in the solution) were fabricated using $0.47 \text{ mmol dm}^{-3}$ CdSO_4 , $0.53 \text{ mmol dm}^{-3}$ ZnSO_4 and the remaining reaction solution was kept similar to the CBD-CdS bath. The CdS seed layer was electrodeposited (ED) using 0.05 mol dm^{-3} CdCl_2 and 0.05 mol dm^{-3} $\text{Na}_2\text{S}_2\text{O}_3$ at a bath temperature of 60°C for 3 minutes under potentiostatic conditions of -600 mV against the Ag/AgCl_2 electrode, keeping pH between 1 and 2. In order to fabricate the ED/CBD/EDTA+Zn-CdS films, seed deposited FTO glasses were placed in the reaction solution described for $\text{Cd}_{(1-x)}\text{Zn}_x\text{S}$ with 0.2 mmol dm^{-3} EDTA added to it. The CBD processes for all the depositions were carried out at a temperature of 80°C and similar thickness $\sim 80 \text{ nm}$ were maintained for all the grown samples. The $\text{Cd}_{(1-x)}\text{Zn}_x\text{S}$ and ED/CBD/EDTA+Zn-CdS films showed a blue shift in absorption edge and resulted optical band gap values of 2.42 and 2.50 eV respectively compared to 2.35 eV obtained for CBD-CdS. GIXRD results reveal absence of any impurities in the fabricated thin films. Highest V_{OC} (363 mV), J_{SC} ($141 \mu\text{A cm}^{-2}$) and V_{fb} (-692 mV) of the sample are of 1 cm^2 in the PEC cell (FTO/sample/ $0.1 \text{ M Na}_2\text{S}_2\text{O}_3/\text{Pt}$) and E_g values were shown by ED/CBD+EDTA- $\text{Cd}_{1-x}\text{Zn}_x\text{S}$ potentially due to uniformity of clusters ($\sim 110 \text{ nm}$ spherical by SEM), better adherence of CdS to the FTO, and improved carrier concentration.

Financial assistance from the Solar Edu-Training Project of the Ministry of Science, Technology and Research, Sri Lanka is acknowledged.

Keywords: CdS, Seed assisted, Zn.

NANOCOMPOSITES OF CATION-EXCHANGED MONTMORILLONITE CLAYS, β -CYCLODEXTRIN AND α -TOCOPHERYL ACETATE

M.R.S.S.B. Gunasekera¹, N.C. Bandara² and B.M.R. Bandara^{1,2*}

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

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

*bmrbandara@gmail.com

α -Tocopherol (vitamin E) provides numerous health benefits. In dietary supplements, α -tocopherol is often present as α -tocopheryl acetate (α -TA) because the ester is more resistant to oxidation on storage; α -TA is hydrolysed to α -tocopherol in the gastrointestinal tract. β -Cyclodextrin (β -CD) protects α -tocopherol from thermal decomposition. β -CD has a hydrophobic central cavity (0.8 nm) and a hydrophilic outer surface. The photo/dispersion/thermal stability of compounds may be improved by trapping them in the expandable interlayer space (1-3 nm) of montmorillonite (MMT). We examined the possibility that cation (M^{n+})-exchanged MMT clays can intercalate β -CD which will then form inclusion complexes with α -TA to give α -TA- β -CD- M^{n+} -MMT nanocomposites. α -TA, isolated from commercial vitamin E capsules by flash chromatography, showed ¹HNMR peaks, UV-Vis spectral data and TLC behaviour consistent with the literature data. Each cation-exchanged clay, M^{n+} -MMT ($M^{n+} = H^+, Al^{3+}$ and Na^+), prepared from MMT by treating with aqueous MCl_n , was stirred separately with β -CD in water and α -TA in dichloromethane to obtain β -CD- M^{n+} -MMT clays and α -TA- M^{n+} -MMT clay composites, respectively. Treating β -CD- M^{n+} -MMT clays with α -TA afforded the respective α -TA- β -CD- M^{n+} -MMT composites. The clays and the clay composites were characterized by FT-IR spectroscopy and XRD measurements. The amount of α -TA intercalated into M^{n+} -MMT (9-18%) increased by 2- to 4-fold (29-70%) when the clays already had β -CD in the interlayer space. The highest % α -TA intercalation (70%) was observed for β -CD- Al^{3+} -MMT. Al^{3+} -exchanged MMT appears to attract more β -CD molecules and thus β -CD- Al^{3+} -MMT accommodates more α -TA molecules than α -TA- β -CD- H^+ -MMT and α -TA- β -CD- Na^+ -MMT. The clay composite α -TA- β -CD- H^+ -MMT released 79% of the intercalated α -TA at pH 1.2 after 3 h, and α -TA- β -CD- Al^{3+} -MMT 45% after 24 h. In conclusion, α -TA was successfully intercalated into β -CD- M^{n+} -MMT ($M^{n+} = H^+, Al^{3+}$ and Na^+) clays and the highest amount of intercalation was observed in α -TA- β -CD- Al^{3+} -MMT, which released α -TA at gastric acidity.

Keywords: α -Tocopheryl acetate, β -Cyclodextrin, Montmorillonite-clay-composites.

**A STUDY OF THE PERFORMANCE OF CHENODEOXYCHOLIC ACID WITH
TiO₂ BASED DYE-SENSITIZED SOLAR CELLS**

**L.W.M.S. Jayathilake^{1,4}, B.M.K.Pemasiri^{2*}, W.M.N.M.B.Wanninayake³
and K. Premaratne²**

¹*Department of Materials Technology, Faculty of Technology,
Rajarata University of Sri Lanka, Mihinthale, Sri Lanka*

²*Department of Physics, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka*

³*Horizon Campus, Malabe, Sri Lanka*

⁴*Postgraduate Institute of Science, University of Peradeniya, Peradeniya, Sri Lanka*
^{*}*bmkp@pdn.ac.lk*

One of the major drawbacks of the Dye-Sensitized Solar Cells (DSSCs) is the dye aggregation which lowers the light-to-current conversion efficiency of solar cells. There are three different types of dye aggregations namely J, H and herringbone aggregations which lead to inefficient electron injection from the photoexcited dye molecules to the conduction band of the semiconductor electrode of DSSCs. In this study, chenodeoxycholic acid (CDCA) was employed as a co-absorber in order to reduce the aggregation of dye molecules. DSSCs were composed of CDCA based dyed TiO₂, I₃⁻/I⁻-based liquid electrolyte and Pt counter electrode. There was an efficiency enhancement of 20.5% and 16.5% respectively for CDCA/N719 (molar ratio of 1:5) and CDCA/D149 (molar ratio of 1:15) systems compared to their corresponding devices made without CDCA. This increase can be attributed to the reduction of intermolecular interaction of dye molecules and void filling due to the presence of CDCA which has lower steric hindrance.

Keywords: Dye-sensitized solar cells, Chenodeoxycholic acid, Dye aggregation.

ENHANCING ADSORPTION EFFICACY OF ACTIVATED CARBON BASED ON COCONUT COIR DUST FOR WATER DEFLUORINATION APPLICATIONS

A.A.A.W.K. Rathnapala¹, M.N.S. Kottegoda² and A.D.L.C. Perera^{1,3*}

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

²*Department of Chemistry/ Center for Advanced Materials Research,
University of Sri Jayewardenepura, Nugegoda, Sri Lanka*

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

**chandanip@pdn.ac.lk*

Desalination, deflourination, removal of heavy metals and toxins are important aspects of water purification. This study focuses on enhancing adsorption efficacy of activated carbon prepared using coconut coir dust (ACC) by optimizing experimental conditions for synthesis. ACC was prepared by varying pyrolysis temperature (450 °C - 600 °C), temperature ramping, concentration of phosphoric acid (PA) (50% and 70% (V/V)) and pyrolysis environment (with and without N₂(g) atmosphere). ACC thus prepared were characterized by methylene blue number and iodine number tests and Scanning Electron Microscopy (SEM). Ion chromatography was used to determine the fluoride ions in water samples. Experimental conditions were optimized using standard NaF solution to obtain the highest fluoride ion removal capacity. SEM images of ACC sample show the presence of both microporous and mesoporous structures. The highest methylene blue value (292 mg g⁻¹) and iodine value (1018 mg g⁻¹) were obtained for ACC prepared by coconut coir dust treated with 50 (V/V) % PA, pyrolysed under N₂(g) atmosphere with a temperature ramp of 10 °C min⁻¹ and keeping 15 min each at 150 °C, 250 °C, 350 °C and 1 h at 450 °C. In addition, the highest set adsorption capacity was yielded from the particles of sizes < 300 μm. It was found that under optimized conditions, 2.000 g of ACC (particle size < 300 μm) per 100.00 ml of standard 1.00 ppm NaF solution, with 30 min agitation time yielded 50% of fluoride ion removal in single filtration and repeated filtration enhanced it up to 60%. The percentage fluoride ion removal by the same ACC from natural water samples was 25% in single filtration and 65% in repeated filtration. The improved efficacy of ACC signifies its suitability as a filter material for removal of fluoride ions in drinking water.

Keywords: Activated carbon, Defluorination, Adsorption, Coconut coir dust.

**DEVELOPMENT OF A PROTOTYPE COMPUTERIZED DRIVING SYSTEM
FOR THE LOCALLY MADE NEWTONIAN TELESCOPE**

**K.G. Samararathna, H.D.S. Amaradasa, G.D.K. Mahanama^{*}, S.S. Abeywickrama
and E.M. Ranatunga**

Department of Physics, University of Ruhuna, Matara, Sri Lanka
**mahanama@phy.ruh.ac.lk*

A telescope driving system is an intricate and precise mechatronic design which allows to point the optical tube of the telescope towards stellar objects accurately. For a research grade telescope, a mechanical driving system is designed uniquely to match the optical and physical parameters of the telescope. This research project was carried out with the aim of studying the methods used in motorizing and computerizing Newtonian telescopes and upgrading the previously made manually driven Newtonian telescope. The telescope developed in the project is a 0.25 m, F/10 Newtonian optical design with a Dobsonian mount. This mount allows the telescope to be driven in altitude and azimuth axes, therefore two separate motorizing designs with different resolutions were fabricated. Friction and torque of the previous mount was considerably high therefore major structural modifications were done to minimize the torque exerted on motors. The mechanical driving system consists of unipolar stepper motors, gearboxes with worm drives and rubber wheels. A single board computer was used with driver modules to control the stepper motors and an accelerometer was used to detect the angular direction of the telescope. The telescope was driven to a given angle and errors related to stability and resolution of the driving system were analyzed. The completed system with computerized driving system is capable of positioning the telescope to a given angle with the accuracy of 0.42 degrees around vertical axis and 0.03 degrees around horizontal axis.

Financial assistance from Science Faculty Research Grant (Grant No: RU/SF/RP/2016/08) is acknowledged.

Keywords: Newtonian telescope, Driving system, Motorized.

A STUDY ON GEL POLYMER QUASI SOLID STATE MAGNESIUM ION-BASED ELECTROLYTE

R.M.I.G.C.A.K. Ranathunga¹, V.A. Seneviratne^{1,2*} and D.M.D.V.Bandara¹

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

²Department of Physics, University of Peradeniya, Peradeniya, Sri Lanka

*sene7403@yahoo.com

The modern anticipation in portable devices, such as flexibility, manufacturing integrity, enhanced endurance have made the need for commercialization of gel polymer electrolytes (GPEs) incorporated electronic devices such as electrochromic devices, batteries, super-capacitors, solar cell etc. In this study, having the idea of making an alternative to Li-ion conducting electrolytes, attention was given to make an environmentally friendly magnesium ion conducting GPE. The volumetric capacity for Mg is 3.833 Ah cm^{-3} and that of Li is 2.046 Ah cm^{-3} for Li. Higher safety due to Mg ion's divalent nature, low manufacturing cost is the main driving forces to engage the Mg. In this study, first liquid electrolytes (LEs) were prepared by dissolving magnesium perchlorate $\text{Mg}(\text{ClO}_4)_2$ in a mixture having ethylene carbonate (EC) and propylene carbonate (PC) in a 1:1 weight ratio. The amount of salt ($\text{Mg}(\text{ClO}_4)_2$) was varied to have samples with different Mg:O molar ratios (Mg:O = 1:10, 1:20, 1:30, 1:40, 1:50 and 1:60). Poly(ethylene oxide) (PEO) was added to make the LEs into GPEs, and the amount of PEO added per sample was 5% of the total weight of EC, PC and $\text{Mg}(\text{ClO}_4)_2$. Analysis of the prepared samples showed a highest room temperature conductivity of $6.22 \times 10^{-3} \text{ S cm}^{-1}$ for the sample with Mg:O molar ratio 1:30. Calculated activation energies from the temperature dependent impedance studies of GPEs reveal that the same ionic conductivity mechanism is responsible for ion migration in the studied GPEs. Showing the electronic transference number over 0.97 (>0.99) evidenced the predominant ionic conducting nature of the GPE and FTIR studies confirm clear Mg ion coordination with the oxygen atoms of EC and PC solvent molecules.

Keywords: Fumed silica, Gel polymer electrolytes, Ionic conductivity, Magnesium perchlorate, Transference number.

ELECTROCHEMICAL REDUCTION OF CARBON DIOXIDE USING COPPER BASED METAL ORGANIC FRAMEWORK AS AN ELECTROCATALYST

K.N. Devindi^{*} and M.Y.U. Ganehenege

Department of Chemistry, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka

**kndevindi1993@gmail.com*

Even though carbon dioxide is a major greenhouse gas produced by intense human industrial activities, it is a necessary compound for the plant growth and many industrial processes. Therefore, either reducing or converting CO₂ into useful entities is necessary. In this regard, electrochemical reduction of CO₂ is a promising method. In general, homogeneous metal based electrocatalysts are directly employed for the electrocatalytic reduction of CO₂. This introduction of homogeneous electrocatalyst ultimately causes difficulty for product isolation. Thus, several methods are being investigated to overcome this problem. Introduction of heterogeneous electrocatalyst is one of the alternatives. In the work reported herein, Cu₃(1,3,5-benzenetricarboxylate)₂ (Cu₃(BTC)₂) metal organic framework was coated on a carbon rod and used, as the working electrode, for the electrocatalytic CO₂ reduction. Cu₃(BTC)₂ was synthesized electrochemically. Spray pyrolysis was used to coat Cu₃(BTC)₂ on the carbon rod. The electrode prepared in this way was used as a working electrode in the cyclic voltammetric study. The resulting cyclic voltammogram showed distinct redox peak potentials at -0.79 and -0.62 V vs SCE, indicating the reversible reduction (Cu(II)/Cu(I)) and oxidation (Cu(I)/Cu(II)). Since Cu(II) to Cu(I) reduction potential is responsible for CO₂ reduction, bulk electrolysis was done at constant potentials of -0.70, -0.80, -0.90, -1.00 V vs SCE for 40 minutes. The aliquots collected at each potentials were analyzed using UV spectroscopy and Gas Chromatography. Data revealed formation of oxalate and further analysis is underway in order to confirm the mechanism suggested for the oxalate formation.

Keywords: Cu₃(BTC)₂, Metal organic framework, Cyclic voltammetry, Bulk electrolysis.

COMPUTATIONAL STUDY ON FREE ENERGY PROFILES OF PASSIVELY CELL PENETRATING PEPTIDES IN DIOLEOYLPHOSPHATIDYLCHOLINE (DOPC) LIPID BILAYER

**B.T. Kumara¹, P.W.C.M. Purijjala¹, P.V.G.M. Rathnayake¹
and R.J.K.U. Ranatunga^{1,2*}**

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

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

**udyranatunga@pdn.ac.lk*

Cell penetrating peptides (CPPs) are short peptide structures that can penetrate into cells and can induce cellular uptake of various molecules. CPP translocation can progress through both passive and active pathways, and can involve many steps and stages. The mechanisms of passive permeation of CPPs are not fully understood, particularly the chemical interactions between the peptides and the membrane; structural features of the peptides which allow translocation; and, collective dynamics of membrane lipids. Here we show, for a range of CPPs, that for isolated peptides at DOPC bilayer membranes, most peptides spontaneously adsorb to the membrane surface, although they do not favor spontaneous insertion into the bilayer. Coarse-grained (MARTINI) molecular dynamics simulations of six CPPs (Penetratin, CCMV Gag, C6, Transportan, Grb2, K-FGF) were carried out to represent cationic, amphipathic and hydrophobic peptides. Umbrella sampling simulations were carried out to calculate the free energy profile of the CPP across the bilayer membrane. The calculated free energy profiles showed that cationic CPPs show a monotonously repulsive profile, while both amphipathic and hydrophobic CPPs showed free energy minima in their profiles. The minima indicated favourable adsorption onto the bilayer surface. Furthermore, free energy calculations were carried out varying the temperature, and tangential pressure. The effect of temperature varied with peptide, while the lowering of applied tangential pressure augmented the probability of insertion. These findings imply that the passive translocation of CPPs observed experimentally may be due to more complex phenomena than the passage of isolated peptides through a neutral lipid bilayer. Moreover, peptide adsorption at the membrane surface may lead to concentration of peptides at the peptide surface and lead to synergistic pathways for entry.

Keywords: Cell penetrating peptides, Free energy profiles, Membrane translocation, Molecular dynamics.

HYDROTHERMAL SYNTHESIS OF HIERARCHICAL TiO₂ MICROSPHERES FOR PHOTOANODES IN DYE-SENSITIZED SOLAR CELLS

S. Senthuran^{1,2,3*}, M.A.K.L. Dissanayake^{1,2} and G.K.R. Senadeera^{1,4}

¹National Institute of Fundamental Studies, Hantana Road, Kandy, Sri Lanka

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

³Department of Physics, University of Jaffna, Jaffna, Sri Lanka

⁴Department of Physics, The Open University of Sri Lanka, Sri Lanka

*senthur803@gmail.com

Dye sensitized solar cells (DSSCs) have emerged as a viable alternative to the conventional silicon-based solar cells due their relatively high power conversion efficiency, low cost, easy roll to roll fabrication and tunable aesthetic features, such as colour and transparency. The surface morphology and internal architecture of photoanode plays a crucial role in the overall power conversion efficiency of DSSCs. The efficient photoanode should have large surface area, well-connected internal pores and efficient light scattering property. Usually, these requirements are simultaneously achieved by employing double-layered or triple-layered photoanodes. In this work, we have succeeded in designing a single layer, hierarchically structured TiO₂ photoanode consisting of sub-micron size TiO₂ spheres composed of aggregates of TiO₂ nanoparticles of size around 10 nm. These mesoporous TiO₂ microspheres were successfully synthesized by hydrothermal method and characterized by scanning electron microscopy (SEM) and X-ray diffraction (XRD). XRD data revealed that as-sintered TiO₂ microspheres poses anatase phase. Subsequently, DSSCs were fabricated and characterized by current-voltage (*I-V*) characteristics, and electrochemical impedance spectroscopy (EIS). The power conversion efficiency of microsphere-based DSSC was 6.23% whereas the efficiency of P25-based was 5.62%. This overall efficiency enhancement of about 10.85% is evidently due to the enhanced photocurrent by the increased dye loading due to the larger specific surface area of TiO₂ microspheres as well as due to the improved light harvesting by scattering of long wavelength radiation by the sub-micron size TiO₂ spheres. This structure also exhibits a low interfacial resistance between photoanode layer and FTO.

Keywords: Dye-sensitized solar cells, Hierarchical TiO₂ microspheres, Light scattering, Hydrothermal synthesis.

**ENHANCEMENT OF THE EFFICIENCY OF A DYE-SENSITIZED
SOLID-STATE SOLAR CELL BY ELIMINATING EXCESS IODINE IN CuI**

A.W.M.V. Ekanayake¹, G.R.A. Kumara^{2*} and R.M.G. Rajapaksa³

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

²*National Institute of Fundamental Studies, Hantana Road, Kandy, Sri Lanka*

³*Department of Chemistry, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka*

**grakumara2000@yahoo.com*

Conversion of solar energy into electricity is commonly succeeded by the p-n junction photovoltaic device designs. Besides the use of silicon in solar cell industry, new trend of using TiO₂ as the n-type semiconductor material is prominent in dye-sensitized solar cells(DSCs) due to its low cost and easiness in preparation when compared to silicon. Intension of this research was to enhance the efficiency of a dye-sensitized solid-state solar cell, which uses the Indoline D-149 dye as the sensitizer, by eliminating the excess iodine dissolved in the CuI saturated Acetonitrile solution. TiO₂ films have been prepared on the Fluorine doped Tin Oxide (FTO) glass substrate with a thickness < 20 μm by the deposition of Degussa P-25 TiO₂ nanoparticles in a TiO₂ colloidal suspension. These TiO₂ films were used to configure the Dye-sensitized solid-state solar cells (DSSC) in the form of FTO/TiO₂/D-149 Dye/CuI (with low Iodine)/Pt/FTO. Removal of excess iodine in the saturated CuI acetonitrile solution was done by adding refined, oxide free Cu powder. The optimum efficiency (η) of 2.11% was obtained for the excess iodine eliminated CuI saturated acetonitrile solution, with the corresponding cell parameters of open circuit photovoltage (V_{oc}) of 475 mV, short circuit current density (J_{sc}) of 12.7 mA cm⁻² and a fill factor (FF) of 35%.

Keywords: Semiconductor, dye-sensitized, Iodine, Titanium Dioxide.

CUTTING EDGE PROTEIN AND CARBOHYDRATE-BASED MATERIALS FOR DRUG DELIVERY

**W. R. A. P. J. Ratnavake^{1,5}, J.W. Damunupola², A. L. C. J. Liyanage³,
R. G. S. C. Rajapaksha⁴ and A. C. A. Jayasundera^{5*}**

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

²Department of Botany, University of Peradeniya, Peradeniya, Sri Lanka

³Department of Food Science & Technology, Faculty of Applied Sciences,
Sabaragamuwa University of Sri Lanka, Sri Lanka

⁴Department of Molecular Biology & Biotechnology, University of Peradeniya,
Peradeniya, Sri Lanka

⁵Department of Chemistry, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka
*acaj@pdn.ac.lk

Utilization of biologically derived materials for the state-of-the art drug delivery vehicles such as hydrogels and nanoparticles in the field of bio-nanomedicine is rapidly growing. Drug vehicles with combination of carbohydrate (cellulose/alginate/chitosan) and protein (albumin/gelatin/collagen) proved very effective according to recent literature. Fabrication of a model system using bacterial nanocellulose (BNC) hydrogel and a protein drug bovine serum albumin (BSA) as a drug delivery system is systematically investigated. Hydrogel prepared by freeze dried bacterial nanocellulose (fd-BNC) synthesized by *Gluconacetobacter* species is used as drug delivery matrix. Different BSA concentrations of 2, 5, 10, 20 mg/ml in phosphate buffer adsorption and releasing from a preswollen fd-BNC hydrogel at predetermined time points under shaking conditions of room temperature were maintained. The UV absorbance results at 278 nm indicated mean loaded BSA amounts of 1.65, 3.02, 7.04, 13.52 mg after 48 hours for 2, 5, 10, 20 mg/ml respectively. Regression coefficient (r^2) of equilibrium loading isotherm was 0.9965 giving the linear correlation between the loaded BSA (mg/g BNC) with equilibrium BSA concentration (mg/ml). Higher BSA adsorption observed due to the fine network of nanofiber structure in BNC. The uptake capacity of studied BSA-fd-BNC system was $96 \pm 0.94\%$. Drug loading stabilized within initial 8 hours and was controlled mainly by diffusion whereas no saturation effects observed. Release profile indicated a 'burst release' during initial 8 hours followed by a controlled release. The mean released amount from 2 to 20 mg/ml BSA concentrations were 1.12, 2.89, 5.59 and 10.37 mg respectively. Ritger-Peppas power law indicated that studied drug delivery system is non-Fickian (anomalous) in which overlay of diffusion and swelling controlled release could be observed. Present study renders the significance of biopolymer BNC as a suitable carrier for active protein drugs like BSA and future invention of non-toxic and non-biodegradable drug delivery matrix.

Keywords: Albumin, Anomalous diffusion, Bacterial nanocellulose, Drug delivery.

**VOLATILE COMPOUNDS AND PHYSICO-CHEMICAL PROPERTIES OF
COCONUT TODDY AND SPIRIT**

D.M.D.A. Bandara, K.B. Jayasundera* and A.B. Thollabugolla

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

**keerthibj@chem.ruh.ac.lk*

Production and utilization of alcoholic beverages have been associated with mankind from the beginning of the civilization. As a result, it has become an important as well as an essential feature of most of the cultures in the world. The main active component of all alcoholic beverages is ethyl alcohol and it is produced via fermentation of sugars. In addition to ethyl alcohol, the final fermentation product may accumulate many other organic compounds. These compounds not only give a pleasant aroma and a flavour but also can cause serious threats to human body depending on the dosage. Therefore, it is essential to perform a comprehensive chemical and physico-chemical analysis during the process of developing an alcoholic beverage. This research is focussed on investigating chemical and physiochemical parameters that are important in producing a safer alcoholic beverage by fermentation of coconut sap. Initially, a detailed physico-chemical characterization of fresh and fermented (toddy) coconut sap was conducted. The results indicated suitable parameters that can be utilized to confirm successful fermentation of coconut sap. Further, major volatile compounds present in coconut toddy and rectified spirit were analysed qualitatively and quantitatively using gas chromatography. The absence of harmful compounds in the spirit in high levels ensured the safety of using coconut toddy for the production of alcoholic beverages. Furthermore, a comparison study between natural coconut toddy and synthetic toddy (sugar mixture) was also conducted. The results revealed the variation patterns of different volatile compounds during the fermentation of coconut toddy and synthetic toddy. The differences can be used to distinguish synthetic toddy from natural coconut toddy which is an important aspect in beverage industry. Overall, the study provided an efficient methodology to ensure a safer alcoholic beverage production from coconut sap.

Keywords: Coconut sap, Toddy, Spirit, Gas chromatography.

ELECTRICITY GENERATION FROM SOIL

**S.P. Karunaratne^{1*}, M.M.D. Anuradha¹, P. Ekanayake², R. G. S. C. Rajapaksha³
and V.N. Seneviratne¹**

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

²Department of Physics, Universiti Brunei Darussalam, Brunei.

³Department of Molecular Biology and Biotechnology, University of Peradeniya,
Peradeniya, Sri Lanka.

*sachinikarunaratne@gmail.com

Lack of access to electricity for more than one billion people in the developing world is a stumbling block which has impacted range of development indicators such as health, education and trade. A study was undertaken to explore the use of different soil types as a medium for electron flow in earth batteries. An earth battery contains two electrodes: an anode and a cathode, which are usually made from zinc and graphite while soil is used as the ion transport medium. A number of experiments were conducted to improve the efficiency of the power output of these batteries by varying different parameters such as the distance between electrodes, type of electrodes (Zinc/Graphite, Aluminium/Graphite, Zinc/Copper), pH of soil (pH 2.00-7.30) and soil salinity (with 0.1–2 mol dm⁻³ NaCl solution). A single unit from the laboratory model designed under optimized conditions can produce ~0.5 mW of harvestable power. To investigate the potential of microbes on electricity generation, the invasive plant Japan Jabara (*Eichhorniacrassipes*) was incorporated to the setup. The efficiencies of earth batteries have demonstrated that they depend on type of soil due to their ion concentration, water content, soil reactivity and differences in microbial communities (Bacteria, Fungi) involved. Experimental techniques such as inductively coupled plasma mass spectrometry, *I-V* characteristic curves, X-ray fluorescence spectroscopy were used to characterize the soil samples. The amount of exchangeable bases, effective cation exchange capacity (ECEC) and base saturation were used as the chemical methods for the soil sample characterization. Microbial studies of Japan Jabara plant incorporated setup revealed that fungi to be the most dominant microbe present. The optimized setup designed using compost as the soil medium (Graphite/ Zinc electrodes, pH 7.06, 2 moldm⁻³NaCl) was used to power a set of seven LED bulbs.

Keywords: Earth battery, Environmentally clean energy, Low cost energy sources.

FLUORESCENCE SPECTROSCOPY AS AN ANALYTICAL TOOL FOR IDENTIFYING OIL DEGRADATION

R.A.B.M. Ranawaka¹, N.M.S. Sirimuthu¹ and C.N.K. Patabendige^{2*}

¹*Department of Chemistry, University of Sri Jayewardenepura, Nugegoda, Sri Lanka*

²*Faculty of Technology, University of Sri Jayewardenepura, Nugegoda, Sri Lanka*

**cpatabendige@sjp.ac.lk*

Identification of oil degradation in turbo machines and automobile industry is a huge problem which has been prevailing from past decades to up to now. Many research have been conducted to solve this problem. In the present study, several used wind turbine gear oil samples were analyzed by UV-visible, Fourier-transform infrared (FTIR) and fluorescence spectroscopic methods. Promising results were obtained for the fluorescence method when compared to other two spectroscopic methods. Motor oil samples which were subjected to artificial aging in the laboratory conditions by heating them up to different temperatures at different time periods were analyzed with fluorescence spectroscopic method. Clear variation in fluorescence emission intensities was observed with oil aging. Results show that fluorescence spectroscopic method can be used as a good analytical tool to identify oil degradation. This method can be developed as a novel potential sensor to detect the quality of oil.

Keywords: Lubricant oil, Oil degradation, Fluorescence spectroscopy.

HIGH PERFORMANCE ACTIVE COCONUT SHELL CHARCOAL COUNTER ELECTRODE FOR DYE-SENSITIZED SOLAR CELLS

K.D.M.S.P.K. Kumarasinghe^{1,2*}, G.R.A. Kumara¹ and R.M.G. Rajapakse^{1,3}

¹National Institute of Fundamental Studies, Hantana Road, Kandy, Sri Lanka

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

³Department of Chemistry, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka

*spkkumarasinghe@gmail.com

Current studies on dye-sensitized solar cells (DSCs) are mainly focused on fabricating low-cost cell with high performances. DSCs are consists with three main parts, working electrode (WE), redox shuttle and counter electrode (CE). Platinum (Pt) coated substrates are widely used as CEs in DSCs. Since Pt is one of the most precious elements, Pt coated CEs takes more than 40% of the device cost. Therefore finding low-cost alternative CEs with high catalytic activity, good electrical conductivity and good chemical stability necessitate for the development of DSCs. Activated coconut shell charcoal (ACSC) is a promising CE material for DSCs due to its excellent conductivity and high catalytic activity. This research has been focused on preparation of low-cost ACSC CE using spray pyrolysis method to replace the standard Pt electrode. The ACSC CE was made using ACSC powder, polyvinyl Acetate (PVA) as binder and Triton X-100 as a surfactant. The X-ray diffraction pattern for ACSC powder indicated two intense peaks corresponding to the crystalline reflections from (002) and (101) planes. Scanning electron microscope images showed the porous nature and homogenous distribution of pores within the film. Energy dispersive X-ray spectroscopy (EDX) spectra revealed that ACSC CE contains minor quantities of oxygen. The TiO₂ WE was also prepared by spray pyrolysis deposition and it was soaked in an N719 dye solution overnight. The space between the WE and CE was filled with a liquid electrolyte (I⁻/I₃⁻) and solar cells performance was measured. Electrochemical impedance spectroscopy (EIS) was used to analyze the charge transfer resistance and electron life time of solar cells. Under simulated sunlight (AM 1.5 at 100 mW cm⁻²), ACSC CE based DSC showed power conversion efficiency of 7.67% which is comparable to 9.23% of Pt CE based solar cells.

Financial assistance from National Institute of Fundamental Studies is acknowledged.

Keywords: Activated coconut shell charcoal, Counter electrode, Dye-sensitized solar cell.

FREQUENCY COUNTER FOR THE SONOMETER STRING USING OPTICAL PICKUP METHOD

Y.M.N.W.Y. Abeyrathna^{*} and L.R.A.K. Bandara

¹*Department of Physics, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka*
^{*}*nivarthana.abeyrathna@gmail.com*

In the music industry, electrical guitars whose sensor units are mounted directly under the strings are playing a noticeable role. There, magnetic pickups will cause damping of the original string vibration, thus changing the original note. Consequently, the idea to develop a frequency counter using a non-destructive sensing method arose. Under this work, a frequency counter was developed to display real time mechanical vibrational frequency of a string using the optical pickup method. The sensor development was done by constructing a sensor driving circuit; incorporate with an amplifier unit and a filtering circuit. An automatic signal processing unit of the circuit was allowed to calculate and display the vibrational frequency of the string. The sensor, with an Infrared light emitting diode and an Infrared detector diode, was tested in both the reflective mode and transmission mode and the sensitivity of the sensor was monitored using an oscilloscope. The transmission mode was selected for further development considering its ability to overcome the ambient background noise due to surrounding light sources. Both the circuit design and the simulation were performed with Proteus software. For signal processing and frequency display stages, *Arduino Uno* and *Arduino* software were used. The performance of the constructed device was checked using a set of tuning forks with known frequency and a sonometer with metallic and non-metallic strings. Metallic string resonated with 256.00 Hz tuning fork, was produced the reading of 255.94 Hz with an error of 0.02%. The sensor was able to capture the vibrations of metallic strings as well as of non-metallic string with low percentage errors. From the results which were obtained, it can be seen that using this low cost device it is possible to perform reliable data collection and analysis of different modes of a vibrating string.

Keywords: Frequency counter, Optical pickup, Sonometer.

COMPARATIVE ASSESSMENT OF Cl ACTIVATION ON CBD-CdS THIN FILMS; CdCl₂ AND MgCl₂

**W.G.C. Kumarage^{1,2}, R.K.K.G.R.G. Kumarasinghe^{1,3}, R.P. Wijesundera⁴,
V.A. Seneviratne^{1,3}, C.P. Jayalath^{1,3} and B.S. Dassanayake^{1,3*}**

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

²Department of Science and Technology, UvaWellassa University of Sri Lanka,
Badulla, Sri Lanka

³Department of Physics, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka

⁴Department of Physics, University of Kelaniya, Kelaniya, Sri Lanka

*buddhid@gmail.com

The reporting study is on CdCl₂ and MgCl₂ solution treatment on chemical bath deposited CdS (CBD-CdS). The chemical bath used for the deposition of CBD-CdS thin films contained 0.001 mol. dm⁻³ CdSO₄, 0.002 mol. dm⁻³ CS (NH₂)₂ which were titrated throughout the experiment and 1.1 ml of NH₄OH was used in 140 ml of de-ionized (DI) water. The CBD process was carried out at a bath temperature of 80 °C for one hour on FTO (TEC 10) glass substrates. For the CdCl₂ and MgCl₂ treatment, fabricated CBD-CdS thin films were dip-coated in a saturated methanol solution of CdCl₂ and MgCl₂ respectively. Later the Cl treated samples were cleaned with DI water and annealed at 200 °C for one hour in a tube furnace (BüchiTo-51). The improved electrical parameters obtained for the photoelectrochemical cell (CdS/0.1 M Na₂S₂O₃/Pt) such as V_{OC} (328.7 and 341.5 mV) and J_{SC} (136.8 and 131.1 $\mu\text{A cm}^{-2}$) for MgCl₂ and CdCl₂ treated CBD-CdS thin films respectively, compared to V_{OC} (254.0 mV) and J_{SC} (93.3 $\mu\text{A cm}^{-2}$) of untreated CBD-CdS thin films, were found to be due to the higher carrier concentration and improved effective area as well as grain boundary passivation. Chlorine treatment was found to increase the cluster size of CdS thin films and the formation of clusters was identified to be due to coalescence of small clusters. Additionally, the flat band potential (V_{fb}) value was found to be tunable with CdCl₂ and MgCl₂ treatment durations. An improvement of J_{SC} about 20% was observed for the CdS films which underwent Cl treatment. According to these results, it can be concluded that MgCl₂ is environmentally friendly and economical alternative for the traditional CdCl₂ treatment.

Financial assistance from the Solar Edu-Training Project of the Ministry of Science, Technology and Research, Sri Lanka is acknowledged.

Keywords: Activation, MgCl₂, CdCl₂, CdS.

**SYNTHESIS OF ATMOSPHERIC STABLE ZERO VALENT IRON
NANOPARTICLES ON RADIATION-INDUCED GRAFTED GRAPHENE OXIDE
THIN FILMS**

**K.A.S. Jayasekara¹, T.P. Ranawaka¹, K.R.C. De Silva², A.G.R. Kumarasinghe^{3*}
and S.V.R. Weerasooriya⁴**

¹*Department of Physics, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka*

²*Sri Lanka Atomic Energy Board, Orugodawatta, Wellampitiya, Sri Lanka*

³*University of Sri Jayawardhanapura, Nugegoda, Sri Lanka*

⁴*National Institute of Fundamental Studies, Hantana Road, Kandy, Sri Lanka*

**argk@sjp.ac.lk*

Atmospherically stable zero valent iron nanoparticles (nZVI) were stabilized on radiation-induced polyacrylic acid grafted graphene oxide thin films. Graphene oxide thin films were synthesized by a modified Hummers method using a rare form of graphite. Polyacrylic acid was grafted on to the surface of the graphene oxide thin films by exposing to Co-60 γ radiation. nZVI were synthesized by reducing Fe (III) in FeCl₃ by NaBH₄ and stabilized by adsorbing on to the polyacrylic acid grafted graphene oxide thin films. The stabilized nZVI adsorbed graphene oxide thin films were characterized by Fourier transform infrared – attenuated total reflectance (FTIR-ATR) spectroscopy, X-ray diffraction (XRD), scanning electron microscopy (SEM) and energy dispersive X-ray (EDX) analysis. The SEM images revealed that polyacrylic acid was grafted properly on to the surface of graphene oxide during irradiation and that nZVI were well dispersed on the surface of the polyacrylic acid grafted graphene oxide thin films. EDX analysis confirmed the presence of nZVI on the surface of polyacrylic acid grafted graphene oxide thin films. Supplementary evidence for proper grafting of polyacrylic acid was shown by the XRD and FTIR-ATR analysis. Furthermore, FTIR-ATR analysis showed that nZVI were adsorbed on to the carboxylate groups in polyacrylic acid with a monodentate configuration. Therefore, it could be concluded that synthesized nZVI by this method was stable under ambient conditions.

Keywords: Graphene oxide, Nano zero valent iron, Polyacrylic acid, Radiation grafting.

**DEVELOPMENT OF A COLORIMETRIC SENSOR SELECTIVE FOR Cr³⁺
USING POLY(VINYL ALCOHOL) FUNCTIONALIZED SILVER
NANOPARTICLES**

P.B.G. Dhanushka, K.A.A. Sarangi, M.U.S. Kulathunga and N.M.S. Sirimuthu *

Department of Chemistry, University of Sri Jayewardenepura, Nugegoda, Sri Lanka

**nmssirimuthu@sjp.ac.lk*

Recent developments of methodologies for the detection and quantification of heavy metal ions such as Cd²⁺, Hg²⁺, Pb²⁺ and Cr³⁺ have drawn much attention due to their adverse health effects associated with them. In this study, synthesis of Silver Nanoparticles (Ag-NPs) was carried out using NaBH₄ as the reductant and poly(vinyl alcohol) (PVA) as the functionalizing agent. The selectivity of PVA-AgNPs to Cr³⁺ was analyzed with 10 ppm metal ion standards upon varying dilution factors of the nanoparticles. The effect of matrix ions was analyzed with matrices containing number of different metal ions. Selectivity of PVA-AgNPs to over 14 metal ion standards of 1 ppm and the sensitivity up to 600 ppb for Cr³⁺ was also analyzed with the development of a calibration plot for the quantification of Cr³⁺. Upon analysis of 10 ppm metal ion standards with 10 folds diluted PVA-AgNPs, only Hg²⁺, Mn²⁺, Cr³⁺, Pb²⁺ and Fe³⁺ displayed selectivity while Cr³⁺ indicated the appearance of a new peak centered between 500-550 nm giving a sharp color change from yellow to orange in its presence. When the concentration of Ag-NPs was increased the selectivity of PVA-AgNPs to Cr³⁺ was also enhanced. Control experiments with the addition of over 14 metal ions such as Na⁺, K⁺, Ca²⁺, Mg²⁺, Pb²⁺, Mn²⁺, Cu²⁺, Ni²⁺, Hg²⁺, As³⁺, Fe³⁺, Cd²⁺, Zn²⁺ and Fe²⁺ did not result in any distinct change in spectrum or the color of the PVA-AgNPs. Quantification of an unknown sample containing Cr³⁺ was achieved with the calibration plot developed. At higher concentrations of PVA-AgNPs the interferences from all other ions analyzed were negligible making the probe selective and sensitive only for Cr³⁺ and hence, the overall objective of developing a selective probe for Cr³⁺ was accomplished with the possibility of detection of trace concentrations of Cr³⁺ visually even in the presence of many other matrix ions.

Keywords: Poly(vinyl alcohol) functionalized silver nanoparticles, Chromium(III) selectivity, Colorimetric sensor.

IMPROVING THE PERFORMANCE OF CdS QUANTUM DOT – SENSITIZED SOLAR CELLS BY TiO₂ NANOPARTICLE/ NANOFIBER PHOTOANODE

T. Jaseetharan^{1,2,3*}, M.A.K.L. Dissanayake¹ and G.K.R. Senadeera^{1,4}

¹National Institute of Fundamental Studies, Hantana, Kandy, Sri Lanka

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

³Department of Physical Sciences, South Eastern University of Sri Lanka, Sammanthurai, Sri Lanka

⁴Department of Physics, The Open University of Sri Lanka, Sri Lanka

*jasitharan@gmail.com

Semiconductor quantum dots have been studied under various research areas especially in optoelectronic devices including solar cells, infrared light emitting diodes (IR LEDs), photo conductors, infrared detectors and lasers. These devices have excellent and unique optoelectronic properties such as high molar extinction coefficient, tunable energy gap due to quantum confinement effect and the ability of multiple exciton generation (MEG). In dye – sensitized solar cells, expensive inorganic dyes are generally used as the sensitizers. Quantum dot – sensitized solar cells (QDSSCs) are emerging as the viable, cost – efficient alternative for the dye sensitized solar cells. In this work, CdS quantum dots were deposited on the TiO₂ nanostructure by using successive ionic layer adsorption and reaction (SILAR) method. In order to enhance the power conversion efficiency through the effective light scattering process, a TiO₂ nanoparticle (NP)/ TiO₂ nanofiber (NF) double layer was used for the photoanode. QDSSC with NP/NF nanostructure shows an efficiency of 3.5% with a higher short-circuit current density of 12.83 mA cm⁻² under the illumination of 100 mW cm⁻² with AM 1.5 spectral filter. The corresponding CdS sensitized solar cell made with TiO₂ nanoparticles (NP) only shows an efficiency of 2.41%. The enhancement in overall power conversion efficiency of the CdS QDSSC with double layer photoanode relative to the single layer TiO₂ NP photoanode was about 45%. This can be attributed to improved light harvesting by effective light scattering process in the composite double layer photoanode combined with efficient electron transport with less recombination.

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Keywords: Quantum confinement effect, Extinction coefficient, Quantum dot – sensitized solar cell, Tunable energy gap.

**Zn/NATURAL GRAPHITE RECHARGEABLE CELL WITH AN IONIC LIQUID
BASED GEL POLYMER ELECTROLYTE**

K.W. Prasadini, K.S. Perera* and K.P. Vidanapathirana

Department of Electronics, Wayamba University of Sri Lanka, Kuliypitiya, Sri Lanka

**kumudu31966@gmail.com*

Energy production and storage have become a hot topic in the scientific community due to the increasing thirst for power at an alarming rate. Though Li rechargeable cells are very popular in the market as a class of efficient energy storage devices, many studies have exploited and revealed the hazardous nature of Li. With this, focus has been diverted towards developing environmental friendly, low cost rechargeable cells based on other materials than Li. Main objective of the present study is to design a rechargeable cell having Zn and natural graphite electrodes with an ionic liquid based gel polymer electrolyte. A circular shape Zn electrode was used as the anode. Natural graphite mixed with polyvinylidene fluoride was made into a slurry incorporating acetone as the solvent. It was cast in a stainless steel dice and solvent was allowed to evaporate. Gel polymer electrolyte consisting with poly(vinyl chloride), zinc trifluoromethanesulfonate and 1-ethyl 3-methyl imidazolium trifluoromethanesulfonate were mixed well using tetrahydrofuran as the solvent. Thin, bubble free electrolyte films were prepared using solvent casting method. A circular shape electrolyte film was sandwiched in between the two electrodes. Open circuit voltage was about 1.1 V. Cell was characterized using Cyclic Voltammetry technique. Continuous cycling was done at the scan rate of 10 mV/s at room temperature. Initial capacity was about 2.25 mA h g⁻¹. During 50 cycles, it had reduced down to 2.15 mA h g⁻¹. The percentage of reduction is rather low. The results showcase the suitability of the electrolyte / electrode materials to be employed in rechargeable cells. Further studies are in progress to improve the cell performance.

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Keywords: Ionic liquid, Gel polymer electrolyte, Rechargeable cell, Cyclic voltammetry.

**LEARNER PERCEPTIONS ON DISTANCE LEARNING: A CASE STUDY AT
THE CENTRE FOR DISTANCE AND CONTINUING EDUCATION,
UNIVERSITY OF PERADENIYA, SRI LANKA**

A.M.R.S. Bandara¹, W.D. Chandrasena^{2*} and M. Pinnawala³

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

²*Science Education Unit, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka*

³*Centre for Distance and Continuing Education, University of Peradeniya, Peradeniya, Sri Lanka*

**wdchand@pdn.ac.lk*

As higher education in the state universities in Sri Lanka is highly competitive, learners are much aware on alternative paths to fulfill their higher education needs. This situation is critical in undergraduate education and as such the distance learning is used extensively through higher education institutes (HEIs). The Centre for Distance and Continuing Education (CDCE) of the University of Peradeniya is one of such institutes. In order to upgrade and update educational programmes offered by the CDCE, a need assessment study was conducted. The objective of this study is to identify perceptions of stakeholders with special reference to their educational needs. Thus, the aspects such as mode of delivery, employability, and the new programmes to be launched to facilitate learners through distance mode were investigated. Study used a qualitative approach and the sample consisted of 250 respondents including school teachers, high school students, current CDCE students, current university undergraduates, university staff members, bank officers, and other general public. Data were collected through open responses survey and analyzed through thematic and content analyses. Results show high demand in courses such as computing and English language. Learners preferred hybrid mode of delivery in which both face-to-face and online approaches are used. Identified themes from the responses based on thematic analyses include: enhancement of efficiency of learner supportive services through the web; launching of job oriented courses; commencement of short courses on demanding disciplines; commencement of diversified courses that are useful in day-to-day life; and building strong links with other industries and organizations. Thus, in distance learning the factors mentioned above have to be considered in designing and developing programmes to satisfy learner needs to enhance their intrinsic motivation on continuing education to prepare the citizenry to meet challenges successfully in their life so as to contribute in national development.

Keywords: Distance Learning, Need, Demanding programmes, Mode of delivery.

INVESTIGATION OF TEACHER PERCEPTION ON ISSUES AND REMEDIAL MEASURES IN CONDUCTING G.C.E. (A/L) BIOLOGY LABORATORY PRACTICALS: A CASE STUDY IN SOUTHERN PROVINCE

K.H.N. Prasad¹ and W.D. Chandrasena^{2*}

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

²*Science Education Unit, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka*

**wdchand@pdn.ac.lk*

Biology education is a part of science education. As biology is a practical subject, how these practical classes are conducted in schools could affect students' achievement and their performance. As there is a dearth of research on biology education in Sri Lanka the aim of this study is to investigate teacher perception on issues and potential remedial measures in conducting G.C.E. (A/L) biology laboratory practical. This is a mix methods study consisting both quantitative and qualitative approaches. A questionnaire administered with biology teachers was the major data collection instrument. It covered descriptive information on biology laboratories, practical sessions, physical and human resources, biology teachers' perspectives etc. Quantitative data were analyzed using SPSS for descriptive statistics and qualitative data were analyzed according to thematic and content analyses. Study reveals that 5% schools had all the specimens, chemicals and instruments. Approximately 98.59% teachers possessed a syllabus. All teachers had a Teachers Instructional Manual (TIM) while 95.8% teachers had practical guides. Respondents (78.9%) used text books as other resources in teaching process. About 49% of teachers had not participated any teacher training session and only 35.2% of teachers had participated only one session in the last year. The suggestions proposed to enhance the quality of practical work at school level included: enhancement of infrastructure facilities; conducting repairs and maintaining buildings; making furniture and instruments available; and providing teaching aids, other resources, modern facilities etc. Thus, the above factors are to be considered in developing and enhancing biology education in Southern province. Hence, the existing practices in biology teaching and learning process are to be re-evaluated with the aim of facilitating students' meaningful learning through practical based approach to enhance their biology performance.

Keywords: Biology education, Laboratories, Practical, Teacher perceptions.

TEACHER PERCEPTIONS ON TEACHER MOTIVATION AND USE OF EFFECTIVE TEACHING METHODS IN G.C.E. (O/L) SCIENCE

W.D. Chandrasena^{1*}, A.C.A. Jayasundera² and A.M.R.S. Bandara¹

¹Science Education Unit, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka

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

*wdchand@pdn.ac.lk

In spite of the importance of science education, percentage of school students studying science is alarmingly low. This situation could be due to many inter-related factors including teacher characteristics. Thus, enhancing teacher motivation with pedagogical skills is extremely important. Hence, present study aimed at investigating science teacher perceptions on teacher motivation and effective methods of teaching science at G.C.E. (O/L). Teachers' perceptions were collected using a questionnaire (six-point likert scale) in Ibbagamuwa educational zone at the end of one-day G.C.E. (O/L) science teacher training programme held for 54 teachers. Basically learner centred approach was used in this programme. Themes used in sessions were science teacher motivation, effective teaching-learning process for fundamental chemistry concepts, application of self-determination theory in science classroom, and enhancing students' creativity through student centred learning process. The major factors considered in the questionnaire were characteristic of the content of the training programme, characteristic of the trainers, motivation towards the training programmes, and application of experience gained in science classrooms. Quantitative data were analyzed using SPSS 17.0. Among the above factors teachers had highly rated the ability of applying learnt matter during the programme. All four factors showed a positive correlation with each other. The motivation gained by the teachers through this programme and application of learnt matter showed the strongest positive correlation ($r = 0.780$; $p < 0.05$). Application of learnt matter was well predicted by motivation ($r^2 = 0.609$; $p < 0.05$). Science teachers possessed the view that they should be motivated and supported continuously to enhance teaching-learning process. Above results show the importance of empowering teachers by increasing their intrinsic motivation through necessary support. Hence, it is suggested to conduct teacher training programmes with motivational aspects to uplift the science education status at G.C.E. (O/L).

Keywords: Perceptions, Motivation, Effective Teaching.

INVESTIGATING THE EFFECTIVENESS OF USING SELF-DETERMINATION THEORY IN TEACHING BIOLOGY FOR GRADE TEN STUDENTS

H.P.R. Menike¹ and W.D. Chandrasena^{2*}

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

²*Science Education Unit, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka*

**wdchand@pdn.ac.lk*

Biology is a very important discipline as it focuses on structure and functions of living organisms in this world. Hence, it has become a significant area of study in school curriculum and it is also a main subject discipline in the Grade 10 science syllabus in Sri Lanka. Although, biology is perceived as an easy discipline to study compared to other disciplines in science, students' achievement in biology is not satisfactory. Thus, there may be different reasons for students' poor achievement in biology. The literature shows that the practices based on Self-Determination Theory (SDT) could be used in biology classrooms to enhance enthusiasm of students towards learning. According to SDT people have three innate psychological needs: competence, relatedness, and autonomy. If these universal needs are met, the theory argues that people will function and grow optimally. However, there is a dearth of research and practices in Sri Lankan school classrooms using SDT to facilitate students' learning. Hence, the unit of "Classification of Organisms" in Grade 10 syllabus was selected to study the effectiveness of SDT in teaching biology for Grade 10 students. This is an experimental study and two groups of students were used as control and experimental groups. Experimental group was taught using the SDT and the control group was taught according to the traditional methods. During the lessons observations were collected while maintaining the records of field notes. The collected data were analyzed using the Thematic analysis technique. Students' motivation, engagement, enthusiasm, and performance in both groups were compared. The results of the study showed that the above characteristics are higher in the experimental group compared to the control group. Thus, the classroom practices based on the SDT can be used as a good technique in teaching biology in order to enhance the students' intrinsic motivation.

Keywords: Biology, Education, Intrinsic motivation, SDT, Grade 10 science.

KNOWLEDGE AND ATTITUDES ON FIRST AID AMONG G.C.E. ADVANCED LEVEL STUDENTS IN GOVERNMENT SCHOOLS OF GAMPAHA EDUCATION ZONE, SRI LANKA

P.V. Alahakoon¹, P.K. Perera^{2*}, C. Wijesundara³ and K.O. Bandaranayaka⁴

¹*Management and Science University, Malaysia*

²*Institute of Indigenous Medicine, University of Colombo, Rajagiriya, Sri Lanka*

³*Ministry of Health, Sri Lanka*

⁴*Management and Science Institute, Colombo 03, Sri Lanka*

**kalpanee.b@gmail.com*

First aid is an initial care given in an emergency until patients are given proper medical care. To assess the knowledge, attitudes, and practices on first aid among G.C.E. Advanced Level (A/L) students in government schools in Gampaha educational zone, a descriptive cross-sectional study was conducted among five schools (n=510) using a probability proportionate multistage cluster sampling technique. A self-administered questionnaire was used to assess knowledge and attitudes towards first aid. Data analysis was conducted through SPSS statistical package version 21. Out of the population only 16.9% students were previously trained in first aid. Students' overall mean of the first aid knowledge was (57.4 ± 13.5) where 61.4% were having good knowledge and 7.1% were having an excellent knowledge. Overall attitude towards first aid was positive and most of the students (98.8%) believed it is essential to possess first aid knowledge. Further, students' willingness to provide first aid for emergency situations was positive (77.1%). It was also found that higher the first aid knowledge better the positive attitudes towards first-aid practices ($r = 0.134$, $p = 0.003$). Biological stream students were having a significantly higher knowledge than all other streams ($\chi^2 = 31.7$, $p < 0.001$) on first aid practices. Moreover, the students who had followed health science in their G.C.E. (O/L) had a significantly higher knowledge score when compared to others ($\chi^2 = 12.4$, $p = 0.006$). However, previous training on first aid had no significant relationship with their knowledge ($\chi^2 = 7.2$, $p = 0.064$). Incorporating first aid education as a practical subject for the school curriculum will improve a better outcome in first aid knowledge among school students, which will positively impact the first aid practices in Sri Lanka.

Keywords: First-aid, Knowledge, Attitudes.

**READINESS OF STUDENTS AND TEACHERS FOR E-LEARNING IN BIOLOGY
EDUCATION IN G.C.E. (A/L) IN NATIONAL SCHOOLS IN HOMAGAMA
EDUCATIONAL ZONE**

P.H. Dhammika^{1*} and T.M.S.S.K. Yatigammana Ekanayake²

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

²*Department of Education, Faculty of Arts, University of Peradeniya, Peradeniya, Sri Lanka*

**hh2010sri@yahoo.com*

According to the recent research literature, the use of Information Communication Technology (ICT) towards e-learning has been considered in schools and other educational institutions. Thus, the aim of this research is to find out the readiness of students and teachers to use e-learning in biology teaching and learning in National Schools of Homagama Educational Zone in Colombo District. The sample consists of 116 biology students and 7 biology teachers. Mixed methods approach was used. The data were collected using questionnaires, semi- structured interview schedules, and observation schedules. Quantitative data were analyzed using SPSS 17.0 software and the thematic analyses technique was used for qualitative data analysis. The findings showed that environmental, technological, and equipment and content readiness of the use of ICT were poor in biology education. Further, the study habits related to the use of the internet were poor among the students. However, the students had positive attitude about the use of ICT for biology learning. The teachers and the students had identified the constraints of learning G.C.E (A/L) biology using ICT. The teaching approaches of these schools were mainly limited to chalk-and-talk or paper-and-pencil method. It was also found that even though these schools are financially sound enough, they were not ready to empower e-learning for the G.C.E (A/L) biology education. Thus, it is needed to pay attention on the problems, difficulties and suggestions expressed by teachers and students on the use of ICT in order to develop biology education through e-learning.

Keywords: Biology education, E-learning readiness, Students, Teachers.

MOTIVATION OF UNDERGRADUATES THROUGH POSITIVE PSYCHOLOGY AND SELF-DETERMINATION THEORY

W.D. Chandrasena^{1*}, A.C.A. Jayasundera² and A.M.R.S. Bandara¹

¹*Science Education Unit, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka*

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

**wdchand@pdn.ac.lk*

Motivation is a key factor determining success of many aspects of life including learning and achievement of students. Self-determination theory is a major theory in motivation. It explains that innate psychological need of autonomy, competence and relatedness enhances achievement of goals compared to externally created interests or motivation. Since students possess an innate tendency for learning it can be enhanced to improve their achievements and success in academic life. This paper investigates the perception of a group of undergraduates of the Faculty of Medicine, University of Peradeniya, Sri Lanka on a discussion on aspects related to self-determination theory, importance of education and positive thinking. This qualitative study was conducted analyzing the feedback given by 179 first year undergraduate students soon after a two hour discussion on above aspects. Feedback were collected as written documents and analyzed using the thematic analysis technique. Five themes were identified. They are; discussion contained facts which are inspirational and effective for students in planning a successful life, students have developed confidence to face challenges positively in future, students have received guidance on how to achieve goals in life with positive attitudes, the discussion has lead to think in a different way about life with positive attitudes and motivation, and students have engaged in the discussion well due to its relevance to their personal life and mode of delivery. It is evident that these students need guidance with respect to motivation and positive thinking in order to develop their future academic life and career as medical doctors. Discussions on positive attitudes and motivation would develop self-initiation and self-directed engagement of learners in educational activities even some activities are not enjoyable as expected. Further this type of discussions would support students to cope with stresses, both related to academic and day-to-day life.

Keywords: Motivation, Positive thinking, Self-determination theory.

**FACTORS AFFECTING MATHEMATICS PERFORMANCE OF GRADE
ELEVEN STUDENTS IN THUNUKKAI EDUCATION ZONE**

C. Volantine¹ and W.D. Chandrasena^{2*}

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

²*Science Education Unit, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka*

^{*}*wdchand@pdn.ac.lk*

Mathematics is a very important subject for all as it helps people in many ways to improve their logical thinking and facing challenges in day-to-day life. However, students' performance in G.C. E. (O/L) mathematics in Thunukkai Education Zone is not up to the expected levels. The Thunukkai Education Zone is situated in Northern Province and it has sixty one schools. Approximately 500 students of Thunukkai Education Zone sit for the G.C.E. (O/L) mathematics examination. Every year only around 200 students pass the mathematics subject. Moreover, only a few students (about 20) continue their studies in G.C.E. (A/L) mathematics stream. This prevailing situation could be due to many factors. However, there is a dearth of research on this issue in Thunukkai Education Zone. Thus, this study was aimed at investigating the factors related to low performance in G.C.E. (O/L) mathematics in Thunukkai Education Zone. This is a mixed methods study where both quantitative and qualitative approaches were used. The sample consisted of 150 G.C.E. (O/L) students in Thunukkai Education Zone. The respondents were selected using convenience sampling technique. Data were collected through a questionnaire and documents. Quantitative data were analyzed using SPSS 17 software and qualitative data were analyzed by the thematic analysis technique. Findings of the study reveal that the factors affecting the students' mathematics performance were as parents' education level, family income, the nature of the curriculum, teaching methodology, pedagogical skills of teachers, facilities available in the school, methods of learning, students' academic abilities, and students' engagements in learning. Thus, mathematics teaching-learning process has to be re-evaluated and updated while paying attention to the above issues with the aim of supporting the students' learning towards high performance in G.C.E. (O/L) mathematics in Thunakkai education zone.

Keywords: G.C.E. (O/L), Mathematics, Mixed methods, Performance.

**STUDENT PROBLEMS IN PERFORMING CHEMICAL CALCULATIONS ON
THE CONCEPT OF MOLE AT G.C.E. (A/L)**

W.M.K.R. Seneviratne¹ and W.D. Chandrasena^{1,2*}

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

²*Science Education Unit, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka*

**wdchand@pdn.ac.lk*

Chemistry educationists have identified the terminology “*Mole*” to be a confusing factor for students. Thus main purpose of this study was to investigate the problems encountered by students in understanding and performing the chemical calculations on the concept of mole. The sample of this study included 100 Grade twelve students from three separate classes, taught in Sinhalese medium of a school in Kandy education zone, Sri Lanka. The sample also comprised of six chemistry teachers from the same school. Students were instructed by the same teacher for two weeks according to recently designed instructions given in Teachers’ Instructional Manual which was implemented from year 2014. At the end of the instructions an achievement test was administered to the whole group in order to investigate their performance and to assess their issues of the concept of chemical calculations on the concept of mole. The level of the students’ competencies, mathematics abilities and the problems related to the concept of basic chemical calculations on mole were examined. In order to investigate their perceptions towards basic chemical calculations, student focus group discussions, teacher semi-structured interviews and surveys for both groups were conducted. The collected quantitative data were analyzed using SPSS 22.0 for descriptives. Qualitative data were analyzed using thematic and content analyses. Based on the findings, a positive relation between performance of students in related mathematics and chemical calculations was revealed. In addition to comprehension of mole concept students encountered different issues in chemical calculations such as confusion of problem solving in complex sums, use of relations between chemical and mathematical concepts, weaknesses in basic mathematical skills and comprehension of chemical concept. Teachers’ perceptions revealed that the classroom practices on chemical calculations using mole concept to be re-evaluated to enhance performance of students through automatically supportive environment.

Keywords: G.C.E. (A/L), Chemical calculations, Mole, Performance, Mathematics.

THE IMPACT OF SCIENTIFIC LITERACY AND MOTIVATION OF GRADE 11 STUDENTS ON THEIR PERFORMANCE IN SCIENCE

N.W.L. Narangoda^{1*}, W.D. Chandrasena^{1,2} and W.A.P.P. De Silva^{1,3}

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

²*Science Education, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka*

³*Department of Zoology, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka*
**wathsi.nwl@gmail.com*

This study was carried out to investigate the importance of scientific literacy, motivation towards students' performance in science of Grade 11 students of Dehiowita Educational Zone. The sampling technique was convenience sampling and sample consists of 205 students and 10 teachers of six selected schools. The level of scientific literacy and the motivation were investigated through motivation questionnaire and a science question paper. The qualitative data were collected by semi-structured interviews, focus group interviews and open ended questions. Data analyses were performed using SPSS 17.0 and thematic analysis. The results revealed the presence of strong positive correlation between level of scientific literacy and students' performance ($r=0.775$) indicating a significant contribution of scientific literacy on students' science performance. There was no significant difference on scientific literacy between male and female students. These students showed high intrinsic motivation for overall science subject (mean=4.55) and for biology component (mean=4.43). However, mastery motivation and ego motivation were high for chemistry (mean=4.23) and physics (mean=4.22). However there was no significant difference between overall science performance and motivation between male and females ($p>0.05$). The relationship between students performance and level of motivation showed low positive association ($r = 0.138$). The derived themes on teachers' perception showed that practical based teaching and use of new technologies in teaching and learning positively affect the students' performance. The extra knowledge as well as teachers' dedication in teaching and learning process was the other identified influential factors of students performance. The findings of the study proposed the importance of enhancing the level of scientific literacy and motivation to improve their science performance in Grade 11 students. Thus classroom practices are to be re-evaluated with the aim of enhance students' performance in science through the development of students' scientific literacy and motivation in science.

Keywords: Scientific literacy, Motivation, Performance.

**AN INVESTIGATION OF STUDENTS' SELFCONCEPTS AND MOTIVATION
ON DIFFERENT TEACHING METHODS IN G.C.E. (O/L) PHYSICS**

S.A.B. Maheshinee^{1*}, W.D. Chandrasena² and J.P. Liyanage³

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

²*Science Education Unit, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka*

³*Department of Physics, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka*
**bhagyamaheshinee@gmail.com*

Based on the G.C.E. (O/L) science syllabus in Sri Lanka students in Grade 10 and 11 have to learn Biology, Chemistry and Physics. Experiences of classroom practices depict that some students' performances in physics is not satisfactory. Past researches have shown that this situation is due to several factors such as self-efficacy, self-concepts, motivation, students' academic abilities, misconceptions, and teaching methods. However, there is a dearth of research in the relations of students' physics self-concepts and motivation with the teaching methods. Thus, the purpose of this study is to investigate the relations of G.C.E. (O/L) students' science self-concepts, motivation with the teaching methods. The four different teaching methods used for this study were problem based learning, practical based learning, cooperative learning, and integrated learning. This study was conducted in an educational zone in the North Western Province, Sri Lanka. A sample of 185 Grade 10 students and 5 teachers selected using convenience sampling from two schools was used in the study. The quantitative data were collected using physics self-concepts scale and physics motivation scale. A pre-test was administered to check the students' level of achievement. The final assessment test paper was administered after the intervention to find out students' level of achievement. The results revealed that the increment of the mean value of self-concepts after the intervention is 0.07 and it takes 0.26 in motivation in integrated method. The results of final assessment paper also indicate that integrated method is the best method to teach lessons on force. However, practical approach was highly admired by the students and teachers. Thus, classroom practices in the G.C.E. (O/L) physics teaching are to be re-evaluated with the aim of facilitating meaningful learning of students.

Keywords: G.C.E. (O/L), Self-concepts, Motivation, Teaching method.

KEY FACTORS AFFECTING SCIENCE PERFORMANCE IN DIMBULAGALA EDUCATION ZONE

W.N. Rukmalee^{1*} and W.A.P.P. De Silva²

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

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

**n.rukmalee@gmail.com*

Students of the Dimbulagala Education zone show considerably low performance in Science Examinations. This study was designed to identify the key factors that affect students' performance in science subject in Dimbulagala Education zone. The study sample was consisted of students (N=120), their parents (N=120) and science teachers (N=20) of four selected schools. Thirty students were selected from each school representing equal number of males and females. Three questionnaires were used to collect data. From student questionnaire, students' self-concepts, nature of science subject, problems in home environment and their choices of selecting subjects in G.C.E (A/L) pathway were determined. Term test marks were obtained from respective schools. Attitudes on science and socio-economic status of the parents were also obtained from parents' questionnaire. Teachers' attitudes towards motivating students for science streams and the issues along with other concerns of chosen science teachers were determined by teachers' questionnaire. The results revealed a strong positive relationship between students' self-concepts on science and their performance in science examinations (for male students $r=0.790$ and female students $r=0.852$). There were no gender based differences in science performance and self-concepts ($p=0.191$, $p=0.14$ respectively). Parents' attitudes and science performance of the students were also positively correlated ($r=0.753$). Poor socio-economic aspects, low performance for G.C.E. (O/L) examinations, lack of proper career advisory programmes, poor mathematics skills, abstract nature of science subject, lack of proper lab experiences, negative attitudes of parents, teachers and school administration were identified as significant factors that had influenced decision of students for not selecting G.C.E. Advanced Level science stream. Teachers' attitudes and responsibilities as well as lapses in the science curriculum were identified as critical factors that need urgent attention of authorities in the field of education. Overall, this study provides useful information for parents, teachers, students and education authorities to consider in improving science performance in rural areas of Sri Lanka.

Keywords: Science performance, Self-concepts, Socio-economic status, Attitudes of science teachers.

A REVIEW OF RESEARCH ON PROJECT BASED LEARNING

P.M.J.R. Pivatissa¹ and W.D. Chandrasena^{2*}

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

²*Science Education Unit, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka*

**wdchand@pdn.ac.lk*

Project based learning (PBL) is important for developing the 21st century skills in students. Project based learning involves assignments that lead toward a production of a process or product design, a computer code or simulation, or the design of an experiment followed by the analysis and interpretation of the data. This literature review on PBL was aimed at addressing the trends and gaps observed in PBL. In this study three distinct phases were followed such as search and inclusion, individual study review, cross study comparison and analysis. It was revealed that on a shorter time scale, the repetition of action negotiation dialogues, student questioning dialogues, and action feedback dialogues with the students enabled the teacher to provide active guidance in the functioning. It has also been found that students' involvement in environmental projects had a statistically significant positive impact on their environmental knowledge and science attitudes. The scientific-technological PBL has elevated pupils' motivation and self-image along with affective learning. A study on an interdisciplinary standard focused PBL approach has revealed that the students were benefited with the academic, social, and emotional gains while becoming aware of the connections between the academic knowledge and its applications in real life. Moreover, one of the weaknesses in PBL is that different individual factors induced different types of conflicts as most of the groups experienced more than one type of conflict simultaneously during project based learning in groups. Thus, it could be stated that a significant attention should be paid on the requirements on implementing PBL. However, there is a dearth of research in PBL in science education in Sri Lanka leaving a gap in the literature. Hence, it needs further investigations on the applications of PBL in teaching science subjects such as biology, chemistry, physics and mathematics to facilitate meaningful learning Sri Lanka.

Keywords: Project based learning, Science education.

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