Proceedings of the
International conference on
Environmental Monitoring and Management
EMM2020

23rd of October 2020
Center for Environmental Studies
University of Peradeniya
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Center for Environmental Studies
MESSAGE FROM THE VICE CHANCELLOR

It gives me great pleasure in sending this message on the occasion of the 2nd International conference of Center for Environmental Studies, Environmental Monitoring and Management (EMM2020) organized by the Center for Environmental Studies together with International Relations Office (InRO) and Postgraduate Institute of Science, University of Peradeniya.

There is a critical need for a transformational change in the relationship between nature and people in the contemporary world, as managing the environment and understanding its impacts drive increasing regulation and activities to reduce pollution.

The EMM2020 offers a holistic view of environmental performance, to provide a foundation for identifying and analysis of pollutants and their control by decision-making within reasonable time and cost considerations. However, there are implications when moving from screening to implementing the results, especially in measuring and monitoring the effects of different actions.

So this conference will be an excellent opportunity for researchers and academics in different disciplines of Environmental Sciences to present their research findings and to participate in stimulating discussions and propose novel and robust solutions towards efficient environment management and sustainable development.

I extend my sincere appreciation to the members of the Conference Organizing Committee towards their tremendous efforts to make this event a success.

Further, I wish all participants of the Environmental Monitoring and Management a productive and enjoyable experience.

Prof. Upul B. Dissanayake
The Vice-Chancellor
University of Peradeniya
MESSAGE FROM THE CHIEF GUEST

I am deeply honored and thankful to be invited as the Chief Guest for this occasion and I am writing this message with great pleasure on the Occasion of the Conference on “Environmental Monitoring and Management 2020”, the 2nd International conference of the Centre for Environmental Studies of the University of Peradeniya”.

At a time global environment change due to anthropogenic activities is being heavily concerned, and facing numerous challenges in finding remedial measures, initiatives taken by the University of Peradeniya to address environmental related issues through a conference like this by gathering key stakeholder institutes such as relevant Ministries, Departments, Universities, Research Institutes, Private Sector and Non-Government, and Professionals as well as the younger generation who will be the future of the country is greatly appreciated. Such an event would tremendously benefit not only to gather current knowledge on the severity of the issue and sector specific mitigatory discoveries, but also for future networking opportunities as it brings together all relevant professionals.

I thank the organizing committee for their enthusiastic efforts in making an event like this a reality. I wish the conference and the Center for Environmental Studies, University of Peradeniya every success and would be happy to extend the fullest cooperation of the Ministry of Environment for any related future endeavors.

Dr. Anil Jasinghe
Secretary, Ministry of Environment
MESSAGE FROM THE CONFERENCE CO-CHAIRS

With the rapid growth of population, advancing technologies and increase in related waste generations, environmental concerns are receiving a greater attention among the public. We are now experiencing environmental issues which are unknown, and are extraordinary in their magnitude, speed and cruelty. Though such issues concern all countries, developing countries are the most vulnerable.

Second International Conference on Environmental Monitoring and Management organized by the Centre for Environmental Studies (CES) will be held on 23rd October 2020 in collaboration with the Postgraduate Institute of Science (PGIS) and International Relations Office, University of Peradeniya. Due to the present COVID-19 pandemic situation, the organizing committee decided to conduct the event as a virtual conference taking all possible measures to provide utmost convenience for effective participation. We strongly believe that the conference would provide a sound platform to disseminate high quality research outcomes, development of sustainable solutions for environmental issues and productive discussions for shaping future directions for a wider scientific community. This conference covers a wide range of environment related subjects which are extremely critical and important. Some presentations directly highlight the importance of social responsibilities, need of effective and efficient sustainable technologies, regulations, ethics and corporate governance to ensure the environmental sustainability.

We wish to invite intellectuals from Universities and Research Institutes, policy makers from relevant Ministries/Departments, entrepreneurs from Private Sector and Non-Governmental Organizations, and young scientists with interests and looking for a better environment to participate the conference and to collaborate with for future activities.

We hope that you will find the conference is an informative and a memorable one.

Prof. S.P. Nissanka  
Center for Environment Studies

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

Prof. G.B.B. Herath  
Faculty of Engineering
MESSAGE FROM THE DIRECTOR- CES

Environmental issues ranging from local to regional and to global scale with different magnitudes are of significant importance to humankind. The Centre for Environmental Studies (CES) of the University of Peradeniya has been providing training, research and consultancy services with the objective of supporting and possibly improving the nation's ability to address these wide ranges of pressing environmental problems. With its focus on innovative and interdisciplinary approaches, the CES has been accomplishing these goals by bringing together scholars from related disciplines, interested students, leading stakeholders and the wider community beyond the university.

It is with great pleasure that I write this message on behalf of the Board of Management of the CES, that the CES is able to organize the 2nd International Conference on “Environmental Monitoring and Management EMM 2020” in collaboration with the International Relations Office (InRO) and the Postgraduate Institute of Science (PGIS) of the University of Peradeniya. This conference is conducted under the four thematic areas “Policies, the Law, and Social Responsibility in Environmental Management”, “Environmental Hazards, Monitoring, Water Security, and Water Safety”, “Technologies in Pollution Control and Resource Recovery” and “Sustainable Resource Utilization”.

I believe that this conference will provide an excellent opportunity for Sri Lankan and international researchers, local and regional policymakers, and other related organizations to present their research findings, share their knowledge and experiences in an interactive environment. This kind of dialogue among academics, researchers, policy makers and industrial professionals is very much important in developing effective and efficient collaborations and identifying viable solutions to address current environmental issues.

I am glad that this conference has drawn so much interest among key stakeholders and very grateful to all those who have submitted papers and contributed in many ways to make this conferences a success. Dedicated and generous support of the organizing committee, International Relations Office, Postgraduate Institute of Science and the Center for Distance & Continuing Education is greatly appreciated.

Prof. S.P. Nissanka
Director of Center for Environmental Studies
University of Peradeniya
PREAMBLE

The Center for Environmental Studies (CES) of the University of Peradeniya, which was established in 1992, has been offering interdisciplinary environment related research programs, training and consultancy and in addressing pressing environmental problems at the national level. The CES successfully conducted its first International Conference under the theme “Sustainable Environmental Management” on 17th and 18th March, 2016. It is evident that overuse of natural resources, environmental hazards, environmental pollution and degradation are currently major global and local environmental issues that require better monitoring and management through a systematic approach for a sustainable future. As a concerted effort to address the above issues, the CES decided to organize its second International Conference on the theme “Environmental Monitoring and Management (EMM2020)”. The conference was launched and abstracts were called under four thematic areas (i) Policies, the Law, and Social Responsibility in Environmental Management, (ii) Environmental Hazards, Monitoring, Water Security, and Water Safety, (iii) Technologies in Pollution Control and Resource Recovery and (iv) Sustainable Resource Utilization. The main objective of the Conference is to provide an opportunity for researchers in the Environmental Sciences to present their work and interact with local and foreign researchers and share knowledge and experience at an internationally recognized academic forum.

The Conference was planned to be conducted at the Postgraduate Institute of Science (PGIS) on 21st and 22nd of July 2020 in collaboration with the International Relation Office (InRO) and the PGIS of the University of Peradeniya. However, we were compelled to postpone the Conference because of the global Covid-19 outbreak. Subsequently, the conference was rescheduled to be conducted on 23rd October 2020 at which time the Covid-19 health situation in Sri Lanka was expected to be positive and restrictions on public gathering would have been lifted. However, international participants were not expected to be present at the Conference. Therefore, the foreign delegates were invited to contribute their expertise to the Conference through four pre-conference webinars that are conducted on the four themes: Urban Water Management, Advances in Wastewater Treatment, Environmental Impact Assessment and Water Quality Monitoring. However, with the emergence of the latest Covid19 outbreak in the country, the Organizing Committee has decided to conduct the event as a Virtual Conference on the scheduled day in adherence to the health regulations issued by the Government regarding public gatherings. This Virtual Conference will be conducted in collaboration with the Faculty of Engineering, University of Peradeniya, which is probably the first Virtual Conference organized by the University in its history.
The Organizing Committee received a large number of abstracts from both local and foreign authors, which were subjected to double-blind peer review by experts in the respective disciplines. Finally, eighty-nine abstracts were selected for both oral and poster presentations. The Inaugural session will be held in the PGIS with the participation of the Chief Guest Dr. Anil Jasinghe, Secretary of the Ministry of Environment, Keynote speaker Dr. Ananda Mallawatantri, Country Representative of the IUCN and Prof. Upul B. Dissanayake, the Vice Chancellor of the University of Peradeniya. The other distinguished invitees are the Deputy Vice Chancellor, Directors of Postgraduate Institutes and other Centers and Deans of the Faculties of the University of Peradeniya.

The technical sessions of the Conference, organized under four thematic areas, will be conducted completely via the online platform. Each session will contain eight research papers to be presented that will be followed by a common plenary session at the end of the technical session. Two senior academics and an expert from the industry were appointed to the plenary sessions to make it more productive. They will be making comments about the respective thematic areas/sessions and presentations, which we believe will benefit the researchers in their further studies. We hope that this Virtual Conference will be an exciting new experience for all and a great opportunity for researchers to share their work in the scientific community even under this very difficult situation faced by the world.

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Rational and Scales of Monitoring

Development programs and policies aim to create change. Often the changes involve the environment or ecosystem modifications, requiring monitoring and adjusting the plans to suit the new context and continue monitoring. In management, a fundamental assumption is that “if you do not know what you manage, you will not be able to manage it effectively.” Therefore, quantified information on different aspects helps in management decision making, whether we are involved in development, conservation, research, or social science such as poverty alleviation and climate change.

There are multiple levels of monitoring for management. At the global level, the United Nations and international agencies generate products such as “UNDP Human Development Report”, “Global Assessment Report on Disasters” and the likes based on country, regional and global level information. The strength of this analysis depends on the quality of country-level details that are readily available. There are instances where the limitations of worldwide studies have been highlighted due to insufficient data or assumptions. For example, ranking Sri Lanka high as an ocean polluter in terms of plastics and placing Sri Lanka in the 8th place (2018 data) in the Climate Risk Index in 2020 are results of limited data.

On the other hand, “information is power”, especially in the current era. The digital domain and social media thrive on information, and if the information is of inferior quality, so are the conclusions. Therefore, we must focus on monitoring quality, quantity, and related investments to support environmental management and other policy issues.

Scientific Information and Scientist’s Role in Designing

Can we provide quality information to minimize misinformation as well as to support innovative or futuristic research? Are there any global models we can rely on or follow? While there are many, one such model I am familiar with is the United States Environment Protection Agency’s (USEPA) STOrage and RETreival (STORET) system. There the data collected cover air, water, soil and other vital areas and the information is stored in a way that one can first refer to the “Metadata” before deciding on what to obtain from the system. Information retrieval is based on river basins, counties (as our districts or DS divisions), or merely by using boundary coordinates—latitudes and longitudes are available. The system also indicates the quality and reliability of datasets with time durations, parameters, and who collected the data etc.
The significant portion of the data is the regular monitoring data generated and quality assured by Government institutions, in the form of time series of water quality, air quality, stream flow etc. Multiple modalities for access are allowed ranging from free Govt. use, limited fees or free access to researchers and students and on payment for consultants. The critical aspect is that the information is available, digitally downloadable and are in standard formats, irrespective to who wants it.

**Minimum Data Needs and technology**

In environment monitoring, we monitor different phases, namely, air, water, soil etc. Each phase covers hundreds of variables/parameters. Collecting and management of data is costly, especially for a country like ours, yet we need information for our development, conservation, planning and budgeting/policy decisions. To decide on the minimum dataset, we need to identify the parameters to measure, spatial variability or locations to measure? What frequency we should measure and finally the accuracy we need – two decimals or four decimals or no decimals. Therefore, environment monitoring and management could start with a minimum dataset and address data sharing across our fragmented institutional structure. However, it may not be a priority in our country to use public funds to have a minimum dataset measured and coordinated along with other data available with research and industry.

New technologies in sensors, communications and other developments have reduced the costs significantly in monitoring; therefore, earlier assumptions on investing in information generation need to be validated, in the context of the membrane, 5G, remote sensing and non-invasive technologies, among others. Data loggers and storage devices have also transformed into cheaper and efficient pathways, and the affordability has gone up.

**Governance in Monitoring and Information**

There are multiple challenges associated with information related governance, such as a) handling diverse data types; b) quantifying values about the environment; c) convincing public and stakeholders the amount of information and need for investing; d) potential ways to minimize duplication and optimize costs; e) capacity to disseminate data and related governance structures; and the f) security of information and quality, among others. These aspects require the co-operation and collaboration of multiple agencies within the country and partnerships with international agencies. For example, some of the national datasets need “brokering systems” to convert them to international formats. Sustainable financing mechanisms to pay for data collection and storage systems need innovative thinking and sound justifications. Partnerships may bring additional resources or ideas to improve the datasets to suit current demands, and universities and industry linkages could play a vital role in this context.

Further, the information collected using public funds may not be a property of the agency involved, which is the case in Sri Lanka. The cost of not-sharing data is unknown and could be enormous. Lack of access to information restricts innovation,
research, and development planning. Sometimes our data collection designs also cause loss of data. For example, measuring water quality is not adequate without the streamflow or water volume associated with the concentration information to make an inference on the pollution load (weight) during a given period (ex: tons of sediments per annum).

International Collaborations

Many datasets collected by global entities can add value to country data. Our information systems could benefit from NASA, EU, JAXA, Indian and other remotely sensed data sets that extend from images of the earth to sensors measuring moisture, organic carbon, temperature (forest fires), climatic variables etc. Besides these, there are multiple sets of wind profiles, ocean currents and air acidity etc. available for us through partnerships. The creation of and sustaining partnerships is also an art we need to master, and there are good examples already in our universities and private sector but less in Government institutions. For an island country like ours, international datasets are even more valuable to track potential air pollution, risks of oil spills or radioactive leaks etc. Some international datasets come with proposed models. For example, climate models or ocean current phenomena are being studied using a standard set of global tools by scientists, and international collaborations bring in capacity building opportunities.

Use of Information in Management

There are no limits to the use of information. At the global level, most of the conventions use monitoring information such as emission data, biodiversity data etc. For example, without concerted action to reduce greenhouse emissions, the earth could grow warmer by 4 degrees Celsius within this century. The consequences could be devastating with unprecedented heatwaves, droughts, and floods that could put prosperity out of reach for millions of people in developing countries and rollback decades of progress in development. Developing countries need up to $100 billion a year to mitigate and adapt to climate change. This type of challenge requires both local and global data usage to make plans and decisions.

Similarly, there are many new concepts associated with the circular economy and sustainable development based on monitoring. For example, the implementation of the “polluter pay principle” requires full information on water quality, discharges etc. Multi-stakeholder agreement on Total Maximum Daily Load (TMDL) from industries and municipalities to ecosystems is a new concept that requires arrangements by communities and Govt. agencies based on monitoring data. Economic sectors such as apparel and tourism could use monitoring strategically to generate sustainable financing by capitalizing on greening concepts and decarbonization. The project Environment Impact Assessments (EIAs) and implementation of International Finance Corporation (IFC) safeguards are data-intensive in implementing mitigation measures. Carbon trading or biodiversity credits require information measured in the project or at the landscape level. Often insurance schemes operate based on data. The
lack of information on baselines reduces the value of an insurance claim as the damage cannot be assessed without the baseline, irrespective to the area of concern whether it is an oil spill, landslide, or chemical hazard.

Culture of Monitoring and Management

In developing countries, the culture of monitoring for management is a standard and accepted norm. Monitoring also leads to less corruption and high transparency. Monitoring ensures the rights of humans and wildlife and supports the country to capitalize on convention-related funding such as the Global Environment Facility and Green Climate Fund, for example.

Potential benefits of monitoring in management are unfortunately not quantified. This aspect provides room for social and economic researchers to join hands with scientists to compute the advantage of investing in monitoring and highlight the usefulness of monitoring data in innovation and policy planning, among others. The opportunity cost for not having a culture of monitoring and management could be high and worth an extensive discussion and mainstreaming of tracking as part of national development.
Theme 1 - Policies, the Law, and Social Responsibility in Environmental Management
Green Light in a Grey Yard: Challenges towards Green Urban Planning in the City of Kandy through Experts’ Viewpoints

E.G.I. Sevwandi
isurika327@gmail.com
Department of Geography, University of Peradeniya, Sri Lanka

As a central place of production, consumption, and administration, cities are at the forefront of green growth. The eleventh goal of the Sustainable Development Goals also stresses the importance of sustainable cities and communities. Hence, green urban planning approach could be recognized as a promising method of achieving sustainability by increasing the ecosystem services that green infrastructure can supply. Kandy, being a city with unique environmental identity can be easily adapted to green planning concept to improve environmental quality. Yet the upcoming challenges for such ongoing endeavours should be addressed mindfully. Therefore, this research makes an attempt to explore challenges towards green planning interventions in the city of Kandy. The study methodology includes a qualitative inquiry carried out as a descriptive analysis of semi-structured questionnaire survey and key informant interviews. The sampling method includes a purposive sample of officers in the UDA of Kandy selected based on higher involvement in Kandy urban planning. Research findings convinced that there are few major challenges towards green planning in the Kandy urban planning scenario, which are structural as well as institutional. Among them, the pressing challenge is the inadequate fund allocations by the government to introduce environmental-friendly technological advancements. Green infrastructure: a strategically planned network of high quality natural and semi-natural areas designed and managed to deliver a wide range of ecosystem services is not yet locally identified as a cost effective strategy. Moreover, inadequate collaboration between responsible authorities and planners, informational gap between stakeholders and authorities, and lack of perceptions are also unmasked by this study. Thus, it is suggested that experts should be trained on green infrastructure planning. In conclusion, green light is really obscured at the moment in the urban planning mechanism of Kandy. Therefore it is essential to acknowledge green infrastructure planning as an economically and environmentally viable environmental management approach to promote green planning.

Keywords: Green urban planning, Green infrastructure, Challenges, Kandy
Evaluating the Environmental Impacts of Constructing the Central Expressway, Sri Lanka

A.P. Wijesinghe1* and A. Karunarathna2
*ama_shaakya@yahoo.com
1 Postgraduate Institute of Science, University of Peradeniya, Sri Lanka
2 Department of Agriculture Engineering, University of Peradeniya, Sri Lanka

The purpose of this study was to analyze the environmental impacts caused by four 10 km-long sections between Rilloluwa to Rangallepola of the Central Expressway. Three monitoring sessions (baseline, 1st and 2nd periodic monitoring) conducted once in every three months. The impacts were evaluated in terms of air quality, water quality, noise and vibration. All parameters were evaluated with respect to local and international standards. Air quality results indicated that PM10 and PM2.5 values at one location exceeded the maximum permissible levels of 100 µg/m³ and 50 µg/m³, respectively during all three monitoring sessions. The air quality in terms of CO, O₃, SO₂ and NO₂ levels at all locations were within the limit of ambient air quality standards during all three monitoring sessions. The water quality was tested at four different locations of the Kuda Oya, which flows along the construction site. The pH level revealed that it was not suitable for human consumption although fish and other aquatic life were not affected by the pH fluctuations. Turbidity has gradually increased in all monitoring locations and the highest turbidity level was observed in the 2nd periodic monitoring session conducted during major earthwork activities. Results showed that the total coliform count at all monitoring locations exceeded the maximum permissible levels for public water supply (3 colonies/100 ml) as well as individual or small community supply (10 colonies/100 ml). During the 1st periodic monitoring conducted at all four locations, Dissolved Oxygen levels were below the minimum permissible level for fish and other aquatic life (5 mg/l), thus water is not suitable for many types of aquatic organisms. However, BOD levels remained low in all locations and were below the maximum permissible level (4 mg/L) stipulated for fish and other aquatic life. Noise levels were tested at four project locations within Narammala and Alawwa Pradeshiya Sabha areas. Noise levels exceeded the maximum permissible levels (55 dBA - day time) specified for rural residential areas except for two locations during baseline monitoring and one location during the second periodic monitoring. Vibration levels tested at four different locations were well below the maximum permissible levels. It can be concluded that Rilloluwa to Rangallepola area has been affected by construction of the Central Expressway in terms of air quality and water quality as compared to the baseline monitoring data. However, environmental impacts arising from the construction projects can be controlled by maintaining a proper mitigation plan.

Keywords: Environmental monitoring, Air quality, Water quality, Noise
Spatial and Temporal Patterns of the Human-Elephant Conflict in Welikanda, Polonnaruwa

H.B.N. Aathika
aathikahbnawaz@gmail.com
University of Peradeniya, Sri Lanka

Wildlife areas in Welikanda are becoming narrower and isolated by the surrounding areas of human settlements under the Mahaweli settlement project, which increased the Human-Elephant Conflict (HEC). To promote the co-existence between humans and elephants, number of management measures are taking place. Through this study, we analyzed the occurrences of HEC and explored the spatial and temporal factors that influence HEC. The study was conducted using a 3-year dataset from 2016-2019, 60 questionnaires and 6 interviews. The transformation of forested areas into agricultural lands and human settlements play a major role in increasing in HEC. Most of the remaining forest patches in the Mahaweli project areas are disconnected and encroached by people. The study shows that HEC is very severe in the surrounding areas of the Welikanda corridor. HEC in this area is considered as highest as these areas were seasonal route of elephants and now they are encroached and fragmented by human activities. Furthermore, it is found that the crop riding and property damage by elephants are most frequent and high soon after the harvesting seasons of Yala and Maha and mostly between 6.00 p.m. and 7.00 a.m. The farmers in the surrounding areas of the Welikanda corridor and the elephants are the victims of this conflict. To manage HEC successfully in Welikanda, we should consider migration routes of elephants, forest patches occupied, diurnal and seasonal variation in elephant’s movement and human activities in the conflict hotspots. Moreover, the Department of Wildlife Conservation and Mahaweli Authority should work together in development activities in wilderness areas. To reduce the HEC in a productive way, we should conserve the existing elephant habitats, corridors and link habitat patches using new corridors, and should improve the awareness among people and use effective management practices etc.

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Keywords: Corridor, Conservation, Management, Conflict
Investing in Water-Scarce Agricultural Systems: A Framed Decision Analysis

M. Muzni and D.V.P. Prasada*
*pp16252@gmail.com
University of Peradeniya, Sri Lanka

The rain-fed agricultural systems pose limitations on the use of water. In the Sri Lankan Dry zone settings, rain-fed agriculture uses several human-made infrastructures to moderate these limitations. One clear example is the village tank. In this study, a decision analysis is carried out through an experiment which frames the decision to invest in the village tank improvement, village pasture improvement, forest patch improvement, or fish stock improvement. The objective of the study is to identify the tradeoff between private and public gains in a water-scarce setting. The participants in the experiment have to make decisions on the levels of investment as a member of a group of three randomly assigned roles. These roles are paddy farmer, dairy herder and fisherperson. The decision making happens in two stages. The first stage involves investing from a private endowment and the second stage involves investing from a public endowment. From a menu of investment choices that are linked to private and public benefits, participants made choices on how much to invest in each resource from private endowment first and from the residual public endowment sequentially. The findings of the decision analysis from 246 implementations of the experiment reveal several key relationships. Private investments in tank improvement and in pasture improvement are associated positively (P value = 0.001 and 0.016, respectively) with private benefits while investments in forest improvement and fish stock improvement are not significantly related to private benefits on average. The magnitude of partial contribution to private benefit is 1.50 LKR for every rupee invested in tank improvement and 1.36 LKR for every rupee invested in pasture improvement. In contrast, the public benefits are significant only for investments in tank improvement (P value = 0.090). Partial contributions from other three resources to public benefit are not statistically significant. In contrast to private benefits, the magnitude of partial contribution from investments in tank to public benefits is quite low (i.e., 0.49 LKR for every rupee invested in tank improvement). These findings highlight that even in a framing that highlights the connectedness between private and public welfare in tank-based systems, marginal expectations on private gains are approximately three times that of public gains. We conclude that the intensity of private motive hinders the joint improvement of private and public gains in water use.

Keywords: Village resources, Public goods, Simulation, Decision analysis
Evaluation of *Brachybacterium conglomeratum RUH*\textsubscript{1} Mediated Bioremediation of used Lubricant Oil Contaminated Soil using *Allium cepa* Bioassay

M.M. Wijesooriya\textsuperscript{1}, K. Masakorala\textsuperscript{2}\* and S.M.K. Widana Gamage\textsuperscript{2}

\*mas@bot.ru.ac.lk

\textsuperscript{1} Department of Natural Resources, Faculty of Applied Sciences, Sabaragamuwa University of Sri Lanka, Belihuloya, Sri Lanka
\textsuperscript{2} Department of Botany, Faculty of Science, University of Ruhuna, Matara, Sri Lanka

Contamination of soil with Used Lubricant Oil (ULO) has become an emerging environmental threat because of possible negative impacts of ULO on different ecological receptors. Bioremediation has been considered as a green technological approach with a potential to decontaminate ULO contaminated soils. However, bioremediation efficiency and success are species-specific. Further, more toxic compounds might be generated as metabolic intermediates during the biodegradation of ULO. Hence, the reduction of ULO contamination level alone may not be sufficient to assess bioremediation. Therefore, the evaluation of bioremediation by applying bioassay is vitally important. Thus, the aim of the study was to evaluate *Brachybacterium conglomeratum RUH*\textsubscript{1} mediated bioremediation of ULO contaminated soils by applying *Allium cepa* bioassay. Bioremediation was carried out in laboratory-scale microcosms with 1-5\% w/w contamination levels of ULO. At the end of 35 days of experimental time, percentage of ULO biodegradation was calculated and the bioremediated soils and unbioremediated soils taken from the control experiment were used for *Allium cepa* bioassay. The percentages of Root Elongation Inhibition (REI) and percentages of Chromosomal Aberration (CA) were calculated after 48 hours of incubation in triplicates per each contamination level (n=3). The biodegradation percentages of *B. conglomeratum* following 35 days at 1-5\% w/w contamination levels of ULO were 77.63, 66.0, 55.55, 50.86, and 41.66, respectively. The calculated percentages of REI in control soils at 1-5\% w/w contamination levels of ULO were 29.81, 42.79, 71.15, 75.96, and 81.0, respectively and in bioremediated soils were 18.27, 41.83, 43.27, 49.52, and 59.89, respectively. Further, the calculated percentages of CA in control soils were, 2.50, 3.75, 5.0, 6.50, and 7.25 and in bioremediated soils were 1.0, 1.50, 2.25, 3.0, and 3.50, respectively. Thus, the overall results of bioassay showed the contamination level dependent phytotoxicity and genotoxicity. Therefore, results infer the applicability of *Allium cepa* bioassay for the evaluation of *B. conglomeratum RUH*\textsubscript{1} mediated bioremediation of used lubricant oil.

*(Faculty of Science, University of Ruhuna (Grant No. RU-SF-RC-2018-09) is gratefully acknowledged for the financial support).*

**Keywords:** *Allium cepa*, Bioremediation, Genotoxicity, Phytotoxicity, Used lubricant oil
Social Responsibility and Environmental Sustainability in Sri Lanka towards a Green Country

T.P. Weerakoan\textsuperscript{1} and M.T.C. Perera\textsuperscript{2}\textsuperscript{*}

\textsuperscript{*}mtcperera@yahoo.com

\textsuperscript{1} University of Colombo, Sri Lanka
\textsuperscript{2} University of Sri Jayewardenepura, Sri Lanka

Amidst increased emphasis on sustainable development, understanding the sustainability initiatives and practices of the corporate sector has attracted the primary attention of both academia and industry in Sri Lanka. In parallel, social responsibility of the corporate sector has been commonly discussed in the national context; nevertheless, practical measures seem rare. Thus, the objective of this study is to focus on the social responsibility of Sri Lankan citizens without limiting the responsibility of the corporate sector. This may contribute to solving several contemporary issues such as deforestation and global warming, which disrupts our daily lifestyles. In order to achieve the above objective, this study used the available literature and carried out a literature review. Results reveal that currently, the country is facing unprecedented heatwaves, human-made environmental disasters (including coastal disasters), deteriorating air quality, and scarcity of drinking water. Furthermore, inadequate measures taken in waste management is another issue found through this study. They are the consequences of ignorance of our social responsibility. Thus, it is imperative to create better awareness programs for citizens of the country regarding social responsibility in the process of transforming the country towards a green concepts-based nation. Unless and until the citizens are aware of their responsibility, this situation would not be any different. Researchers recommend that adding social responsibility for environmental sustainability in school curricula and higher-educational programs with an emphasis on practical applications. In addition, lawmakers should make adequate laws for citizens to comply with the need, and the relevant authorities should be made aware of this timely perceived deficiency, and they should be assigned to monitor the progress.

\textbf{Keywords:} Social responsibility, Sri Lanka, Environmental sustainability, Green country
Effective Curbing with Crowdsourcing for Sustainable Sand Mining, Transport and Regulation in Sri Lanka

W.M.H.G.T.C.K. Weerakoon1*, W.G.S. Bandula2 and W.G.S. Kokila3

wmhgtckweerakoon@std.appsc.sab.ac.lk

1  Department of Physical Sciences and Technology, Sabaragamuwa University of Sri Lanka, Belihuloya, Sri Lanka
2  Aasa IT Solutions, 146/7, Pasal Mawatha, Attidiya, Dehiwala, 10350, Sri Lanka
3  Geological Survey and Mining Bureau, 569, Epitamulla Road, Pitakotte, 10100, Sri Lanka

Raw materials of construction, such as sand should be extracted in a sustainable manner, so in Sri Lanka the Geological Survey and Mines Bureau (GSMB) imposes Laws and Regulations to maintain sustainability in sand extraction. Because of the high consumption miners try illegal means of extraction and transportation bypassing the law. Considering this, GSMB took initiatives to digitize licensing lifecycle with Mining and Mineral Production (mmPro) solution, a mobile and cloud-based information system that allows recording sand dispatches by the mining license owners directly from their site using mobile application or SMS. Meanwhile anyone including the general public, police officers, GSMB enforcement unit are permitted to check any lorry, anywhere by giving only a lorry number via mobile application or SMS. This study was carried out to assess the progress of the mmPro pilot run and to acknowledge the stakeholders of the sand mining industry on promising feasibility of mmPro for industry sustainability. During this study, the data prior to mmPro were analyzed and compared against the data generated from mmPro, thereby the conclusions were drawn. According to the data prior to mmPro at GSMB, a 50% disparity between the sand consumption and production from 2014-2018 can be traced, which means sand had been extracted through illegal means without being traceable by GSMB. Then with the mmPro’s pilot rollout at Sri Lanka’s largest river sand mining site in Manampitiya, Polonnaruwa shows impactful results in sustainable raw material extraction, dispatch and utilization by managing dispatch of more than 400 Lorries per day without missing any of them. Hence, mmPro’s pilot rollout shows impactful results in sustainable raw material extraction, dispatch and utilization.

**Keywords:** Cloud computing, Crowdsourcing, Effective curbing, Management Information System, Mobile computing, Sustainable nature
Corporate Disclosures on Carbon Emissions in Sri Lankan Public Listed Insurance Companies

M.N.F. Nuskiya* and E.M.A.S.B. Ekanayake
*nuskimnf@pdn.ac.lk
Department of Business Finance, Faculty of Management, University of Peradeniya, Sri Lanka

Carbon emission is considered as one of the root causes for global warming, which has become the most significant environmental challenge to be addressed at present not only by corporates but also by society as a whole. Because of the increase in corporate understanding of environmental responsibilities and increased investors’ demand on corporate legitimacy stimulated companies to disclose carbon emissions voluntarily. However, there is an inconsistency in the extent of corporate disclosures on carbon emissions among companies across periods. Insurance companies appear to be the first industry to disclose carbon emissions around the world. This study aims to investigate trends of Corporate Disclosures on Carbon Emissions. More specifically, it examines whether the disclosure practice on carbon emissions affects the value of Sri Lankan public listed insurance companies to assist investors to evaluate a company’s legitimacy towards environment and society. There is a need to conduct such a study as the ultimate objective of investors to maximize their wealth. This study follows a quantitative approach with a sample of 8 Sri Lankan public insurance companies out of a population of 10 public listed insurance companies listed in the Colombo Stock Exchange of Sri Lanka. This sample selection was based on the companies that existed during the entire period of the study (2012 – 2018). Longitudinal secondary data were collected on the independent variable (i.e., disclosure on carbon emissions), the dependent variable (i.e., firm value), and control variables (i.e., firm size and profitability) from annual reports of the seven financial years. A disclosure score was developed using dummy variables to measure disclosure practices to determine the impact on the firm value, which was measured by market capitalization using statistical techniques of correlation analysis and multiple regression model along with control variables. The findings suggest that the level of disclosure was showing a statistically significant weak positive correlation with firm value. Regression analysis results indicate that there is statistical evidence to prove that carbon disclosures positively impact the firm value. Further, annual average disclosures on carbon emissions of insurance companies display a marginal increase over seven years. Based on such findings, it can be concluded that in the Sri Lankan context, though the insurance companies voluntarily disclose the firm value of the company it is affected by disclosures on carbon emissions.

Keywords: Disclosures on carbon emissions, Legitimacy, Firm value, Sri Lankan listed insurance companies
Corporate Sustainability Reporting: a Review of Literature

R.N.K. Soysa, A. Pallegedara* and D.M. Jayasena

*asankap@wyb.ac.lk
Faculty of Applied Sciences, Wayamba University of Sri Lanka, Sri Lanka

The Sustainable Development Goals (SDGs) comprising 169 targets for 17 global goals have been developed to meet urgent environmental, social, and economic challenges faced by all nations. This study is based on target 6 of the SDG Goal 12: “encourage companies to adopt sustainable practices and to integrate sustainability information into their reporting cycle”. Sustainability reporting has become an important topic among business communities as a means of communicating their sustainability performance on achieving global SDGs. The purpose of this paper is to contribute to the discourse on corporate sustainability reporting practices by reviewing existing literature. This paper provides a review of more than 40 articles extracted from online databases such as Emerald Insights, Science Direct and Google Scholar, from 2005 to 2019 and are presented in academic journals related to various disciplines such as Accounting, Environmental Science and Economics. Based on previous literature, firm size, financial performance, environmental and social performance, ownership structure, corporate visibility, sector affiliation and legal requirements are considered to be determinants of sustainability reporting (SR) by firms. Firms that are pressurized by environmental authorities and consumers have higher quality of sustainability reporting than other firms. Although firms as a whole strive to achieve sustainability, it was revealed that mostly the senior management has a positive attitude towards SR than the lower-level management. Firm’s growth indicators have been moderately affected by SR practices and some studies have concluded that it has a lower capacity of integration within the decision-making process. However, in the Sri Lankan context, it was revealed that firms have a lower level of compliance with Global Reporting Initiative (GRI) guidelines as a standard sustainability reporting framework. Further, literature reveal that firms are more concerned on the social indicators than environmental indicators. This study concludes that policy makers should encourage firms to comply with global environmental standards and guidelines.

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Keywords: Sustainability reporting, Firms, Environmental management, SDGs
International Maritime Law on Managing Environmental Issues: with Special Reference to Indian Ocean

P.K.B. Isuru Premarathna
isurupremarathna100@gmail.com
University of Kelaniya, Sri Lanka

Environmental conservation and management are considered very important concepts in the recent world, where the importance of maritime security and maritime law are major factors. One of the major problems facing the Indian Ocean at present is managing environmental issues. As the research sample, the major countries in the Indian Ocean, India, Sri Lanka and Maldives were studied. The objectives of this research are the identification and study of current marine environmental issues in the Indian Ocean. In addition, study the procedures adopted for the management of environmental issues following international maritime law for current marine conservation. The research problem of this study is to identify the current maritime environmental issues in the Indian Ocean, and environmental management process in the Indian Ocean territory and its major states are under the protection of natural maritime security. This study is qualitative in nature while using both primary and secondary data. To collect primary data, a sample of 30 people has been used in the fields of government, academic, military and other professionals. Secondary data and the main sources of data collection include journal articles, reports, reviews etc. According to the research, at the present, the maritime security has a major impact and there are serious concerns about natural resources and their management. Basically, climate change and environmental degradation, unregulated exploitation of marine resources, impact on mangrove ecosystems, damage to marine resources and exposure to petroleum are also challenges faced today. Furthermore, among the marine issues, coral reef pollution, land runoff, dredging, NO$_x$ and SO$_x$, Ocean acidification, rise of sea level, pollution from ships. Today, maritime security and its law have a broader role within the United Nations (UNCLOS) and basically IMO. Marine environmental pollution- updating the environmental protection act and the IMO have undertaken a number of legal enforcement on maritime issues. Thus, use of new maritime-friendly technologies can be identified as a fundamental international maritime legal reform. Conclusion of the research, at the present maritime problems are raging in the Indian Ocean region. Furthermore, to address the environmental issues, Legal reforms are needed while there are strong legal disclosures in the IMO, it is clear that it is not enough in the Indian Ocean region.

**Keywords:** IMO, Maritime law, Environmental managing, Indian Ocean, UNO
Environmental Sustainability through Green Human Resource Management Practices

Dinusha Dissanayake
dinusha.d.dissanayake026@gmail.com
Research scholar, Sri Lanka

Green HRM involves eco-friendly human resource policies and practices in organizations with the vision of achieving sustainability. The main objective of this study is to find the green HR practices relating to Recruitment (entry), Training and Development, Performance Appraisal and Management, Employee Relations, Pay and Reward, and Leaving (Exit) based on current literature. The methodology of the study was qualitative. Systematic review of literature was conducted by using an archival method. Researcher reviewed 91 articles cited in the online databases of Sage, Google scholar, Springer link, Science Direct, Wiley, and Emerald with green HRM as the topic. Articles published in 1992 and 2019 have been reviewed. Data reduction, data display, and drawing conclusion were the three steps in data analysis. Reduction of data was carried through coding and categorization with respect to six themes mentioned in the objective. Data displayed using a table. The findings overviewed the following, relating to Recruitment (entry) all the articles mentioned that recruit persons with a green mentality was best, when selecting people ask environmental issues/questions in the interview. When it comes to Training and Development found that environmental training was the best way. Considering Performance Appraisal and Management found that managers need to formulate green related measurements to evaluate the employee performance. In Employee Relations found that participative decision making in green related matters. When evaluating the Pay and Reward suggested that green reward management system depends on green performance evaluation. Finally, Leaving (Exit) found that carry out green exit interviews and if the exit was environmental related issues need to improve that area. In Conclusion through green HR functions, it can gain Environmental Sustainability. Finally, it will recommend preparing a green HRM policy to achieve the Environmental Sustainability.

Keywords: Green human resource management, Environmental sustainability, Human resource functions, Human Resource Management (HRM)
Green Bond: A New Debt Instrument for Environmental Resilient Projects

K.G.M. Nanayakkara1* and Sisira Colombage2
*madurikan@kln.ac.lk
1 Department of Commerce and Financial Management, Faculty of Commerce and Management Studies, University of Kelaniya, Sri Lanka
2 Federation Business School, Federation University, Australia

Owing to the agreement around the world regarding the negative effects of climate change and the requirement for high levels of cost-effective debt capital to finance projects that yield environmental benefits, Green Bonds (GB) were introduced to the global capital market in 2007. Despite high expectations on GB in the capital market as a source of financing green projects, the GB market has not been as effective as first expected at addressing the global climate change problem. There is a substantive investment gap worldwide in meeting the financing need of green projects. Therefore, a scientific investigation is essential to find out the reasons that limit the growth of the GB market, which was the objective of this study. The study employed a qualitative research approach to address this timely topic by using content analysis. The study reviewed all key publications of global market players during 2007 to 2019 to identify how stakeholders in the world perceive the GB market. The study has validated the significant findings through opinions of stakeholders in the market using both, interviews and questionnaire surveys. Findings of the study reveal that not only the investor side, but supply side of the market is also not up to scale. Whilst the high administration cost, limited knowledge about the market, limited standardization and difficulties in obtaining credit ratings limit the supply side of the market, absence of large-scale issues, less market liquidity, and fear for green washing due to less market credibility limit the demand side. Streamlining of Green Bond Principles and greater intervention of governments are recommended as the main solutions to overcome these challenges.

Keywords: Green bonds, Green bond principles, Content analysis, Interviews, Questionnaire
Theme 2 - Environmental Hazards, Monitoring, Water Security, and Water Safety
Agricultural Impact on Groundwater in Sandy Aquifers of the Kalpitiya Peninsula, Sri Lanka

Kaushalya Jayathunga* and Rohana Chandrajith
*maduwanthikaushalya123@gmail.com
Department of Geology, Faculty of Science, University of Peradeniya, Sri Lanka

Groundwater in shallow sandy aquifers in the Kalpitiya Peninsula is an essential resource since no other freshwater sources are available in this peninsular. In order to delineate the influence of agricultural activities on the groundwater quality in the region, a comprehensive hydrogeochemical study was carried out to investigate the processes that affect the groundwater quality in the region. Major and trace element content in 43 groundwater samples were measured along with δ¹⁸O, δ²H and δ¹³C signatures. Anions of samples were measured using ion chromatography while cations were quantified by ICP-MS. Water isotopes of δ¹⁸O and δ²H were determined using cavity ring down laser spectrometer while δ¹³C was quantified by isotope ratio mass spectrometer. The groundwater in the peninsula was dominated by Na⁺, K⁺, Ca²⁺, Mg²⁺, NO₃⁻, HCO₃⁻, Cl⁻ and SO₄²⁻. Nitrate-N concentrations recorded up to 186 mg/L, which is well above the WHO recommended limits. It provided evidence for anthropogenic inputs of solutes, most likely from agriculture activities. Among the toxic trace elements, As and Se levels in groundwater were also higher compared to that of the dry zone metamorphic aquifers in Sri Lanka, possibly due to influence of the marine sprays. Except in few wells, saltwater intrusion was not significant. Irrigation return flows and their associated evaporation enriched the solute contents in the aquifer. This was confirmed by the stable isotope composition of groundwater that deviated from the local meteoric water line (LMWL) and formed its regression line denoted as the local evaporation line (LEL). The LMWL can be described by δ²H = 5.51*δ¹⁸O - 3.08. The corresponding δ¹³C_DIC values varied from −13.8‰ to −8.0‰. These isotopes are more typical for carbonate dissolution and equilibration of CO₂ in the aquifer. This study showed that the underlying carbonate system might buffer the aqueous geochemistry of the groundwater in the peninsula. The results of this study indicate that integrated water management is essential and water resources should critically monitor the Kalpitiya Peninsula in order to avoid over-exploitation and seawater inflows.

(The support of Prof. Johannes Barth, Department of Geozentrum Erlangen, University of Erlangen, Germany is greatly acknowledged for isotope analyses).

Keywords: Sandy aquifers, Stable isotopes, Groundwater recharge, Sri Lanka
Study on Climatic Factors Influencing Leptospirosis Transmission in Southern and Eastern Provinces, Sri Lanka

P.H.M.G.C. Priyadarshana1*, A.G.G.C. Bandara2 and S.M.D.A. Imanthiv2

*priyadarshanachathura1@gmail.com

1 Faculty of Science, Horizon Campus, Malabe, Sri Lanka
2 Faculty of Fisheries and Ocean Sciences, Ocean University of Sri Lanka, Tangalle, Sri Lanka

Leptospirosis is a bacterial disease that can be transmitted to humans via contact with rodents, domestic animals, and contaminated water and soil. The disease is an emerging public health problem around the world. Leptospirosis has become one of the notifiable infectious diseases in Sri Lanka in recent years. This study investigates the impact of climate factors (temperature and rainfall) on leptospirosis transmission in the Southern and Eastern provinces of Sri Lanka through a statistical approach. Initially, the climate data and reported leptospirosis cases from 2015 to 2019 were obtained from the Metrological Department of Sri Lanka and the Epidemiology unit in Sri Lanka, respectively. One-way ANOVA test was used considering 0.05 as the mean significant level. There was a significant leptospirosis occurrence between the districts of Southern and Eastern provinces (p=0.000, DF=1, F=105.93). In contrast, there was a significant difference of temperature versus leptospirosis (p=0.008, DF=60, F=1.63). Also, there was a significant difference of rainfall with the leptospirosis occurrence (p=0.048, DF=345, F=2.17). This study shows a substantial synergism between leptospirosis and climate factors in Southern and Eastern provinces of Sri Lanka. It is important to bring together patterns of leptospirosis transmission compatible with long-term data on climate and other social and ecological changes and this would advance forecast of leptospirosis risk associated with climate change. It will provide the essential information for the formulation of better strategies and methods of preventing leptospirosis.

Keywords: Leptospirosis, Sri Lanka, Southern, Eastern, ANOVA
Heavy Metal Contaminated Dust in Kindergartens and Elementary Schools in Kelaniya, Sri Lanka

K.G.A.A. Sudesh\(^1\)* and M.P. Deeyamulla\(^2\)
* sudeshbl@gmail.com
\(^1\) Ministry of Education, Sri Lanka
\(^2\) Department of Chemistry, University of Kelaniya, Kelaniya, Sri Lanka

Toxic heavy metal containing street dust can be accumulated in the human body. Heavy metals pose potentially deleterious effects in young children, who are more sensitive than adults. There is a lack of information related the presence of heavy metals in dust found in kindergartens and elementary schools. The aim of this study was to quantify the amounts of heavy metals in kindergartens and elementary schools in the metropolitan city of Kelaniya, Sri Lanka. Concentrations of Fe, Zn, Cu, Cr, and Pb in dust and soil (i.e., 0-15 cm depth) of 21 kindergartens were analyzed using Atomic Absorption Spectrometry and to calculate the geo accumulation index (\(I_{geo}\)). Minimum Detection Limit (MDL), Instrument Detection Limit (IDL), and Lowest Detection Limit (LOD) were obtained for Cu, Cd, Pb, and Ni to ensure quality control and assurance. The calculated \(I_{geo}\) levels reveal the order as Cu > Pb > Ni > Zn > Cd > Control. The mean concentration order of the studied metals in dust was; \(C_{Pb} > C_{Cu} > C_{Zn} > C_{Ni(control)} > C_{Ni} > C_{Cd} > C_{Control}\). The observed concentration of Cu, Cd, Ni, Pb, and Zn in the dust samples were within the acceptable limits. The calculated \(I_{geo}\) values depict the uncontaminated or moderately contaminated for Pb, Cd, Zn, Ni and \(I_{geo}\) value of Cu depicts moderately or strongly contaminated. Rapid development, increased traffic emissions and industrial activities could be the sources of heavy metal pollution in the area. The findings suggest more attention is required in the future to minimize heavy metal pollution in kindergartens of Kelaniya area.

Keywords: Heavy metals, Contamination assessment, Street dust, Geo accumulation
Risk Assessment of Exposure to Toxic Metals via Drinking Water: a Study in Some CKDu Endemic Areas, Sri Lanka

W.P.R.T. Perera*, W.S.M. Botheju, M.D.N.R. Dayananda and J.A. Liyanage  
*ruwantharangaperera@gmail.com  
Faculty of Science, University of Kelaniya, Kelaniya, Sri Lanka

Heavy metal pollution becomes increasingly severe in Sri Lanka with intensive agriculture and the shortage of clean, freshwater resources. Monitoring water quality is important because the enhanced concentrations of heavy metals in portable water is a threat to human health. Therefore, this research aims to analyze the heavy metal concentrations and assess the quality of drinking water using Heavy Metal Pollution Index (HPI) in CKDu endemic regions including the Wewalketiya Grama Niladhari Division (GND) in the Anuradhapura district, Ambagaswewa GND in the Polonnaruwa district, Naminigama GND in the Matale district and Buddhangala GND in the Ampara district (reference area). Replicated water samples were randomly collected from thirty drinking water wells from each GND and heavy metals (Cadmium, Lead, Chromium, and Arsenic) were analyzed by Inductive Coupled Plasma Mass Spectrometry. In Wewalketiya Cd (3.440±0.072), Pb (5.422±0.687), Cr (11.510±8.360) and As; 0.00 in ppb levels. Heavy metal concentrations in Ambagaswewa GND were Cd (0.178±0.162), Pb (1.229±0.537), Cr (0.203±0.023) and As (0.336±0.014), respectively in ppb levels. Cd, Pb, Cr and As concentrations in Naminigama GND were 0.050±0.006, 0.120±0.016, 0.550±0.077 and 0.330±0.043, respectively in same units. HPIs for Wewalketiya, Ambagaswewa, Naminigama, and Buddhangala GNDs were 91.907, 21.989, 7.267 and 19.423, respectively. The HPI shows the overall quality of water with respect to the content of heavy metals and its critical value is 100. Ambgaswewa and Wewalketiya GNDs have higher HPI values compared to the reference and Naminigama GND. Therefore, the long-term exposure to heavy metal via drinking water may be the major risk factor for renal failures. The differences in HPIs can be attributed to the variations in concentrations of the heavy metals in drinking water and this study has relevance to designing control measures and action plans for reducing pollutants in drinking water in North Central region of Sri Lanka.

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Keywords: HPI, Drinking Water Quality, Heavy Metals, CKDu
Toxicity Assessment of Fungicide Containing Captan 50% WP on Asian Common Toad (Duttaphrynus melanostictus) Tadpoles and Common Onion (Allium cepa)

*pathiraja.lasangi@gmail.com
Faculty of Science, Horizon Campus Malabe, Sri Lanka

Ecotoxicology is a specialized form found in toxicology that focuses more specifically on the toxic substances and its effect on ecosystems. Agrochemicals are used in fields to destroy pests and weeds, which can exert toxic effects to non-target organisms. This study was undertaken to determine the effect of the commonly used fungicide, Captan 50% WP on the Asian common toad (Duttaphrynus melanostictus) and Common onion (Allium cepa) under laboratory conditions. Acute toxicity of fungicide Captan 50% WP was evaluated. In this study Duttaphrynus melanostictus tadpoles were used because they are widely spread. Allium cepa was also tested since they have high absorbent level and high germination rate. After preliminary range finding tests (1 ppm – 500 ppm, 0.2 ppm – 1 ppm, 0.02 ppm – 0.1 ppm, and 0.001 ppm – 0.03 ppm) five days post–hatch Duttaphrynus melanostictus (Gosner stage 25-26; Gosner, 1960) were exposed to five increasing concentrations of Captan (0.010 ppm, 0.0125 ppm, 0.015 ppm, 0.0175 ppm, and 0.020 ppm) for 48 hours and de-chlorinated tap water was used as the control. After 48 hours of exposure, mortality of Duttaphrynus melanostictus increased along concentration gradient. Overall results indicate LC50 value of 0.02187 ppm. Acute toxicity of Allium cepa was evaluated by 72 hours experiment of root growth with range of fungicide concentrations (0.2 ppm, 0.4 ppm, 0.6 ppm, 0.8 ppm, and 1.0 ppm) and using chlorinated tap water as the control. After 72 hours exposure to Captan 50% WP, root growth of Allium cepa was reduced along concentration gradient. Overall results indicate EC50 value of 0.8511 ppm. According to the overall data, tested fungicide Captan 50% WP can be concluded as toxic, but further acute and chronic evaluation must be conducted to determine its exact lethality.

Keywords: Toxicity, Fungicide, Captan 50% WP, Duttaphrynus melanostictus, Allium cepa
Seasonal Variation of Water Quality Parameters in the Embilikala Lagoon in the Bundala National Park of Sri Lanka

K.P.K. Madushani* and M.D. Amarasinghe
*kpkmadushani@gmail.com
Department of Plant and Molecular Biology, University of Kelaniya, Sri Lanka

The Bundala National Park (BNP), the first Ramsar wetland in Sri Lanka, is an important wintering ground for migratory birds. The Embilikala lagoon, one of the three key lagoons in BNP, is affected by the upstream irrigation systems and also recently subjected to the extensive distribution of *Typha angustifolia*. This study is aimed to inquire the seasonal variation of water quality in the Embilikala lagoon.

Water samples were randomly collected from ten sampling locations throughout the lagoon, twice in both dry and wet seasons during 2018/19. Conductivity and pH were measured using Sension+ MM150 Portable Multi-Parameter while nitrate-nitrogen (NO$_3^-$–N), ammonia-nitrogen (NH$_3$–N), total nitrogen (TN), total reactive phosphorus (TRP), and total phosphorus (TP) were measured using spectrophotometric methods. Data were statistically analyzed using IBM SPSS 22 software. Differences in water quality in the two seasons ware analyzed using independent sample t-test at a 95% confidence level. Higher concentrations of NO$_3^-$–N (323.3±66.5 μg/L), NH$_3$–N (243.3±66.5 μg/L), TN (900.0±40.0 μg/L), conductivity (895.83±89.1 μS/cm), and pH (8.59±0.13) were recorded in the wet season than in the dry season NO$_3^-$–N(300.0±69.2 μg/L), NH$_3$–N(230.0±60.8 μg/L), TN(540.0±101.4 μg/L), conductivity(0.39±0.03 μS/cm), and pH( 7.98±0.14). TN, pH and conductivity were significantly different (p<0.05) in the two seasons. Most of the parameters were higher in wet season because of increased surface runoff, sand bar breaching and mixing up the seawater with lagoon water. Higher phosphorus levels in the dry season are related to the upstream agricultural activities with 56% of its total phosphorus is being measured with reactive phosphorous. This study provides an insight into the present status of the Embilikala lagoon and further work is needed for a comprehensive evaluation of water quality dynamics and the impact of the external water and nutrient inputs on the flora of the lagoon.

(National Science Foundation of Sri Lanka (NSF Grant No. RG/2017/EB/03) is gratefully acknowledged for awarding a research grant).

Keywords: Water quality, Embilikala lagoon, Nutrients, Seasonal variation
Study the Anthropogenic Activities that Accelerate Soil Erosion: A Case Study in Wewere GND in Minipe DSD, the Kandy District

D.R.A.K. Danasekara
apsaradanasekara@gmail.com
Department of Geography, University of Kelaniya, Sri Lanka

Soil erosion is one of the natural hazards of the world. However, recently soil erosion has accelerated because of anthropogenic activities. The Wewere GND is selected for this study as there was high consumption of land for agriculture. The main objective of this study is to identify the anthropogenic activities that accelerate soil erosion. The methodology of the research was mixed method under the human ecological approach. Hence to achieve the target, the Wewere GND was divided into 7 land units according to the types of human activities in the area and 1 kg of soil was obtained at a depth of 8 cm from each of the 7 land units through the simple random sampling. Laboratory and field experiments, direct interviews, field observation, and questionnaire survey techniques were used to collect primary data while secondary data were obtained from relevant government institutions. The quantitative and qualitative data were analyzed under statistical and descriptive data analyze methods. The results were represented with maps using Arc GIS 10.3 software and charts, graphs, tables using MS Excel. The soil particle sizes were determined using 2 fractions of 2 mm sieved soil obtained by extracting 100 g of soil from each of the soil samples. The fraction which is more than 2 mm (+2 mm) is selected as results of each samples. Sub forest represented 4.82%, crop cultivation represented 41.36% of soil particles (+2 mm). The result substantiated high soil erosion was represented in crop cultivation (41.36%) due to the human activity and less was represented in sub forest (4.82%). The mismanagement of land, improper land use, and lack of knowledge are the causes of accelerated soil erosion in the area. Vegetative method, structural method, management practices and awareness programs should be executed to the conservation of soil erosion in the research area. The management of agricultural systems must be carried on the sustainable approach and related authorities should pay attention to minimize soil erosion.

Keywords: Soil erosion, Anthropogenic activities, Wewere GND
Improper Chemical Usage and Poor Waste Management Practices in Small Scale Jewellery Sector of Sri Lanka

*nadeeka.mn@gmail.com
Gem and Jewellery Research and Training Institute, Walivita, Kaduwela, Sri Lanka

Sri Lankan jewellery manufacturing industry mainly functions as a small-scale business or as a cottage industry. Though the output is a fascinating product, a considerable amount of carcinogenic, hazardous and harmful chemicals are used in the industry. This study evaluated the chemical usage and waste management practices in Small Scale Jewellery Sector (SSJS) of. In Sri Lanka SSJS is mostly confined to Colombo, Gampaha, Kandy, Badulla, Jaffna, Galle, Matara and Hambanthota districts. This study was conducted through a structured interview and a questionnaire survey among 345 goldsmiths from these districts. It was found that concentrated Nitric acid, concentrated Sulphuric acid, Cadmium-Gold alloy, Potassium Cyanide, Potassium Nitrate, and Mercury are extensively used without any safety precautions. During the process most of these chemicals are heated in open air to high temperatures of about 1100 °C using wind blowing furnaces, which leads to vaporization of chemicals and subsequent mixing with air. In addition, chemical wastes are directly discharged into drainage systems or natural water bodies without proper chemical waste treatment. This improper usage and discharge of chemicals may cause severe environmental problems and serious health issues. Main cause behind this issue is that over 70% of the goldsmiths working in the industry have only studied up to the Ordinary Level or less, so they have little knowledge on the harmful effects of ill-use of chemicals. Very poor ventilation facilities were found in 60% of the inspected workshops, thus increasing the susceptibility of exposure to toxic vapors. An average person engaged in SSJS works around 10 hours per day and 6 days per week. This extended working period with poor level of health and safety measures within the workshops expose them to high workplace risk. We suggest to carry out a bio-monitoring investigation to assess the exposure levels and health impacts of the community engaged in the industry.

(Global Environmental Facility (GEF), United Nations Industrial Development Organization (UNIDO) and Ministry of Environment and Wildlife Resources are gratefully acknowledged for financial and implementing aids).

Keywords: Small Scale Jewellery Sector, Toxicity, Mercury, Chemical Waste, Carcinogenic, Chemical hazard
Transformation of Ancient Water Retention Mechanisms: A Comparative Study of Two Micro-Cascades

P. Kahathuduwa and D.V.P. Prasada*
*pp16252@gmail.com
Postgraduate Institute of Agriculture, University of Peradeniya, Sri Lanka

In water scarce land use systems, the water security was ensured historically by tank cascade systems. Because of various reasons like technological advancements, infrastructure advancement, social and political issues, and change of livelihoods, with time these cascade systems have undergone partial or full abandonment. This study evaluates how the land use, water use, and the economic well-being of the water users have changed over a period of 20 years using a cross sectional farmer and land-use survey. Our approach is a comparative analysis of two micro cascades that lie side by side in a single agro-ecosystem. The aim is to explain the historical transition of two micro-cascades of nearly equal water holding capacity in two different trajectories. The two micro cascades are Mahakanumulla and Ulagalla within the Thirappane system. The survey reveals that even though the connections among the tanks that belong to each micro-cascade still remain intact in both systems, the water holding capacity of Ulagalla cascade as a whole has reduced. In Ulagalla system, the water holding capacity is reduced by half of its initial capacity (i.e., 40 years ago). The main reasons reported by farmers are siltation, abandonment, land use conversion, and invasive species. Due to the reduction of the water holding capacity, paddy cultivated areas within the command area have reduced, especially in Yala season. Based on the farmer response, we find that the gradual abandonment in Ulagalla is due to socio economic transition. For instance, with the establishment of the A9 road though Ulagalla system, financial value of the lands has risen substantively, compelling villagers to sell their land to outsiders who have abandoned conventional land uses. In comparison, Mahakanumulla does not shown such changes due to the greater distance from the A9 route. Overall, the comparative study reveals that external factors can push a microcascade away from agricultural and cascade driven land uses within a period as short as 40 years.

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Keywords: Comparative study, Cascades, Land use conversion, Thirappane
The Socio-economic impact of *Annona glabra* Invasive Alien Species, IAS Special Reference to the Mudun Ela Catchment

H.D.P.C. Premathilake* and M. Jayarathne
*hdpc8332016@gmail.com
Department of Geography, Faculty of Social Sciences, University of Kelaniya, Sri Lanka

Invasive alien species (IAS) have negatively impacted native biota and socio-economic environments worldwide. All major invasions are due to the actions of humans such as deliberate introductions or escapes and hitchhiking with global trade of species to other continents. *Annona glabra* plants highly impact the wetland ecosystems and socio-economic activities of the western part of Sri Lanka. The main objective of this study is to identify the socio-economic impact of the *Annona glabra* plant in the Mudun ela catchment area in the Mahara divisional secretariat division. Primary and secondary data were used for this research and also used to calculate density of invasive plants in this area. Shannon Weiner density calculator was used in calculating the density, so that it could be identified whether IAS growth has affected human activities. Primary data were collected through semi-structured questionnaires, observations, and open discussion while reporting with 30 people in 30 randomly selected families, books, articles and institutional reports have been used as secondary sources. Secondary data have confirmed that the *Annona glabra* plant richness and density were at the highest levels in the study area. It could be identified that the people were not aware of the threats of *Annona glabra* plant to the ecosystem as well as socio-economic activities. Paddy and herbal plant fields have been encroached by this plant, so this area has experienced an increase of reptiles and rats. Therefore, people in this area face a lot of problems such as snake bites and rat damaging electric power instruments and other factory equipment. Moreover the growth of this plant harm to the diversity of plants. Therefore, awareness programmes to control the growth of this plant are needed.

**Keywords:** *Annona glabra*, IAS, Mudun ela catchment, Socio – economic impact.
Effect of Habitat Differences on Morphology, Anatomy and Fecundity of Lichens

E.S.M. Edirisinghe\textsuperscript{1}, A.D.S.N.P. Athukorala\textsuperscript{1}* and K.B. Jayasundare\textsuperscript{2}
\textsuperscript{*}sarangiathu@pdn.ac.lk / sarangi_a@yahoo.com
\textsuperscript{1} Department of Botany, Faculty of Science, University of Peradeniya, Sri Lanka
\textsuperscript{2} Department of Chemistry, Faculty of Science, University of Ruhuna, Sri Lanka

The effect of habitat differences on morphology, anatomy and fecundity of the lichen species have been rarely studied. However, this would help understand the mechanisms by which some lichens thrive while some get eliminated from the habitat. The objectives of the study were 1) to identify the lichen species common to a site in the middle of the Kandy City (KC) and a site inside the University of Peradeniya (UP, 2) to compare their morphology, anatomy and fecundity of common species between sites. Lichen species were randomly sampled from tree barks and fallen branches and identified using standard keys. Morphological and anatomical characteristics of the lichen thallus, sexual and asexual reproductive structures such as number of apothecia, and ascospores were compared between 2 sites using hand lens, dissecting microscope and compound microscope. Among 39 species found in University premises and 15 species around the Kandy Lake, 5 species, \textit{Physcia} sp, \textit{Parmotrema} sp, \textit{Lecanora} sp, \textit{Graphis} sp, and \textit{Lepraria} sp, were common to both sites. As expected, mean thallus area of 4 species, except \textit{Lepraria} was significantly smaller in KC site than UP site. The change of colour in Thallus (green to grey) were significant in all species between KC and UP. Thickness of upper cortex (significant, P=0.041), medulla layer and lower cortex were higher in KC site than UP site in \textit{Parmotrema} sp. while thickness of algal layer is smaller in KC site. A decrease in apothecial number was observed in \textit{Lecanora} sp. at KC site compared to UP site. The current study showed that changes in certain morphological, anatomical and reproductive characteristics can be triggered by the changes in the environment and may attributed to recorded air pollution in KC site suggesting that such species can be used to monitor the quality of the environment.

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\textbf{Keywords:} Lichens, Thallus morphology and anatomy, Fecundity
Optimum Conditions for Adsorption of Aqueous Manganese (II) by Bamboo Wood Based Activated Carbon

I.S. Pathirathne¹, D.C. Herath², N.S. Jayasinghe², L. Weerasekara²,³, S.K. Weargoda²,³,* and D.T. Udagedara¹

¹Department of Science and Technology, Faculty of Applied Sciences, Uva Wellassa University, Badulla, Sri Lanka
²China Sri Lanka Research Grant Project, Ministry of City Planning, Water Supply and Higher Education, Sri Lanka
³Water Safety Plan Advisory Unit, National Water Supply and Drainage Board, Sri Lanka

The presence of excessive amounts of Manganese in water creates substantial issues both in health and industrial sectors. Activated carbon is being used extensively in the remediation of contaminated water, as an effective and economically viable solution. This study was conducted to examine the optimum conditions for the adsorption of Mn (II) onto activated carbon derived from Bamboo wood. Bamboo Wood Activated Carbon (BAC) was prepared by chemical activation by impregnation with potassium hydroxide (KOH) at 1:1 ratio followed by pyrolysis at 800 °C for 2 hours. The estimated cost of BAC production was 0.26 US$/kg. Batch adsorption studies were conducted to investigate the influence of contact time, pH, and adsorbent dose on the adsorption process while using Commercial Activated Carbon (CAC) as a reference. Both BAC and CAC have obtained the maximum removal efficiency (equilibrium) by 5 hours of contact time with 50.3% and 95.0%, respectively where the saturation of adsorption sites obtained. The optimum removal efficiency (RE) of Mn (II) was observed at pH 6 for BAC and CAC, which is 58.0% and 87.0%, respectively while RE of BAC was 57.0% and RE for CAC was 91.0% at pH 7. Although it showed highest REs (59.0% for BAC and 99.0% for CAC) at pH 9 but this was neglected since Mn (II) removal occurs due to precipitation at this condition. The highest RE showed at adsorbent dose of 5.0 g/L for BAC (89.0%) and 7.0 g/L for CAC (98.0%) for the study. Accordingly, it can be concluded that the aforementioned optimum conditions could be used for effective remediation of Mn (II) through adsorption onto BAC with lesser production cost than CAC (1 US$/kg). The results from the study can be applied for optimizing an isotherm model for the adsorption of Mn (II) onto BAC and can be extended for increasing the Mn (II) removal efficiency and adsorption capacity by using different activating agents and activating temperatures.

Keywords: Manganese, Bamboo, Activated carbon, Pyrolysis, Optimum conditions
Challenges Influencing Domestic Water Consumption in the Dompe GN Division

G.N. Kaushalya*, L. Manawadu and V.P.I.S. Wijeratne
*gnnipuni011@gmail.com
Department of Geography, University of Colombo, Sri Lanka

Water is essential to life. It serves as the base for social and economic development of any country in the world and domestic water is a fundamental requirement for human welfare and a better living standard. As a result of urbanization and population growth, more water is likely to be demanded for domestic proposes, and it has become the third largest water consumer from total water consumption after industry and agriculture. The aim of this study was to identify the major challenges associated with the water consumption in the urban and semi urban sector the in Dompe GN Division. Research data collection was mainly conducted through a questionnaire survey (N=100). The sample was selected based on main drinking water source (groundwater and tap water) using stratified random sampling method. In addition, focus group discussions were conducted to identify the major problems and challenges influencing domestic water consumption in the study area. The Problem Tree Analysis, ranking methods, inferential analyses and spatial point pattern analyses become the main data analysis method for identifying the major problems related to water consumption. All analyses were carried out using ArcGIS 10.1 and Excel 2013 software. The study of 392 domestic ground water wells reveal that the distribution density of groundwater wells was 0.4274. The daily average water consumption of the study area is 119.44 liters person per capita per day. In the wet season the majority of household (65%) use groundwater resources for their daily activities, but in the dry season most of them used the government water supply for their daily activities. In this situation the households face different problems such as lack of drinking water sources, poor water quality, spatial and temporal drinking water quantity etc. The analyses of the questionnaire survey reveals that the majority of household (80%) face the problem of inadequate the water storage during the dry season. Finally, the result of the study would benefit the sustainable water resource development and to provide an adequate water supply to the study area.

Keywords: Domestic water consumption, Problem tree analysis, Point pattern analysis, ArcGIS 10.1
Comparative Study on Determination of Water Quality Using Physicochemical Parameters and Benthic Macroinvertebrates of the Sarasavi Oya, University of Peradeniya, Sri Lanka

A.M.T.I. Amandakoon\textsuperscript{1,2} and A.C.A. Jayasundera\textsuperscript{1,2}\textsuperscript{*}
\textsuperscript{*}acaj@pdn.ac.lk
\textsuperscript{1} Postgraduate Institute of Science, University of Peradeniya, Peradeniya, Sri Lanka
\textsuperscript{2} Department of Chemistry, University of Peradeniya, Peradeniya, Sri Lanka

Water pollution affects the water quality and the biodiversity of the aquatic community. The present study determines the water quality using benthic macroinvertebrates and physicochemical parameters of the Sarasavi Oya, University of Peradeniya, Sri Lanka at three locations (X, Y and Z) of the 400 m stream stretch for a period of three months from March to May in 2019. Physicochemical parameters such as temperature, pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Biological Oxygen Demand (BOD$_5$), Dissolved Oxygen (DO), nitrates and orthophosphates were measured with three replicates. Macroinvertebrate community were studied along a five meter line transect at the locations. Weighted Arithmetic Water Quality Index (WAWQI) for physicochemical parameters and relative abundance, Shannon-Wiener Index (SWI) and Simpson Index (SI) for biological indicators were calculated. The mean values of temperature, pH, EC, TDS, DO, BOD$_5$, nitrates and orthophosphates in the Sarasavi Oya were 24.1°C, 6.98, 0.08 mS cm$^{-1}$, 0.03 g L$^{-1}$, 5.30 mg L$^{-1}$, 1.96 mg L$^{-1}$, 0.43 mg L$^{-1}$, and 0.04 mg L$^{-1}$, respectively. However, these values do not exceed the maximum limits of water suitability for aquatic life introduced by Central Environment Authority (CEA). WAWQI (X=8.52, Y=17.42, and Z=23.97) indicate that A-grade water (excellent water quality) is available in the Sarasavi Oya. The macroinvertebrates recorded with the highest relative abundance in X, Y, and Z locations were water strider (\textit{Geris adelaidis}), Water stick insect (\textit{Ranatarafiliiformis}) and Fresh water crab (\textit{Paratelphusa sp.}), respectively which indicate the better water quality at X than in Y and Z. SWI (X=2.05, Y=1.84, and Z=1.93) and SI (X=0.14, Y=0.18, and Z=0.16) explains that the highest diversity in sampling locations. SWI has been found with a positive correlation with DO, whereas negative correlation with BOD$_5$, EC, TDS, nitrates, phosphates and WAWQI. SI has been found with a negative correlation with DO and positive relationship with BOD$_5$, EC, TDS, nitrates, phosphates and WAWQI. The results also reveal that there is a direct relationship between physicochemical parameters and the macroinvertebrate diversity and the water quality was suitable for healthy growth of macroinvertebrates in the stream.

\textit{Keywords:} Shannon-Wiener Diversity Index, Simpson Diversity Index
Treatment of Reverse Osmosis (RO) Reject Water Using Modified Adsorbent from Drinking Water Treatment Sludge

L.I.U. Kavindi¹, A. Kularathne², N.S. Jayasinghe², S.K. Weragoda², ³*, M. Prabaharan¹ and S. Thushyanthi¹
*skwera7@gmail.com
¹Department of Agricultural Engineering, Faculty of Agriculture, University of Jaffna, Kilinochchi, Sri Lanka
²China Sri Lanka Research Grant Project, Ministry of City Planning, Water Supply and Higher Education, Sri Lanka
³Water Safety Plan Advisory Unit, National Water Supply and Drainage Board, Sri Lanka

Both, reject water of Reverse osmosis (RO) plants and alum sludge of drinking water treatments cause a challenging threat to the environment. Accordingly, in this study alum sludge in drinking water treatment was used to modify an improved adsorbent material to absorb fluoride, chloride, bromide, nitrate, and sulphate ions in the RO reject water. In addition, one-month and two-month-old separate samples from each sludge lagoon in the Kandy-South water treatment plant were obtained in chronological order to investigate the impact of exposure time of sunlight in drying effects on the adsorption ability. Furthermore, the sludge samples were oven-dried and pyrolyzed for 300 °C, 400 °C, 500 °C, 700 °C, 800 °C, and 900 °C temperatures. Initially characterized RO reject water was allowed to come in contact with the modified adsorbent material for the ion removal experiment. Above mentioned ion concentrations were analyzed in the filtrate solution. The adsorption experiments were carried out by varying contact time (20-90 hours) and adsorbent dosage (0.1-5 g). Ion Chromatograph (Eco IC, and Metrohm) for analyzing ion concentrations in filtrates and the scanning electron microscope (SEM) for the characterization of the developed adsorbents before and after physical activity were used. The analyzed results showed that the fluoride removal could achieve up to 55% while 1% removal of Nitrate and Sulphate in one-month-old and two-month-old oven-dried adsorbent material. Accordingly, there was no effect on the time factor for oven-dried material. Finally, it could be concluded that the adsorption ability of oven-dried material for fluoride ions is prominent. Further, it can suggest that this is an easy and environment-friendly method to treat the RO reject water.

Keywords: RO reject, Sludge, Oven-dried, Environment
Performance Assessment of a Wastewater Treatment Plant in a Textile Industry: A Case Study

S.B. Croos, I.M.N.D. Bandara, J.K.P.N.D. Jayakody, P.N. Jayanetti, W.A.I. Subashini and B.G.N. Sewwandi*

*sewwandidh@kln.ac.lk

Department of Zoology and Environmental Management, Faculty of Science, University of Kelaniya, Dalugama, Kelaniya, Sri Lanka

The wastewater discharged from the textile industries consists of various chemicals and dyes that can cause serious environmental issues. This study was carried out to assess the performance of a wastewater treatment plant operating in a textile industry in Colombo. The existing wastewater treatment plant in the industry is operated as an intermediate treatment process, which has two pathways as DAF method and Clarifier method including the units of equalization tank, cooling tank, DAF, clarifier tank, and filter press etc. The treatment process is carried out to meet the discharge requirements given by the BOI before sending it to the central wastewater treatment plant. The objectives of the study were to analyze the physico-chemical parameters of the wastewater at different locations of the treatment plant and to determine the removal efficiencies of physico-chemical parameters. Samples were collected at the points selected from different locations at the wastewater treatment plant for the measurements of color (red, yellow and blue), TDS, TSS, COD and heavy metals using standard methods. The temperature, pH, and electrical conductivity were measured onsite on a weekly basis. The removal efficiencies of COD, Fe, Cd and TSS were 68%, 71%, 57% and 75%, respectively. The results of the study show that the pH, temperature and COD of the effluent of the treatment plant meets the BOI discharge standards. However, the concentrations of TDS, TSS and color of the effluent of the wastewater treatment plant exceed the standard discharge limits to the central wastewater treatment plant. Therefore, the conclusion of the study was that the performance of the existing wastewater treatment plant is acceptable for pH, temperature, electrical conductivity and COD removal. Further, the treatment plant has to be improved specially at the point of adding FeSO₄ and decolorant and at the effluent discharging point. This is mainly to achieve a better performance in removing TDS, TSS to meet the required BOI standards and especially for the color removal since it affects the treatment performance of the central wastewater treatment plant.

**Keywords:** Color, COD, Performance assessment, Removal efficiency, Textile wastewater
Environmental Monitoring and Risk Assessment: A New View Using Diffusive Passive Sampling Technique (DGT and DET)

Nadeeka Rathnayake Kankanamge1*, Peter Croot1, Peter Teasdale3,4, David Welsh2, Jianyin Huang3,4 and William Bennett2

1 Earth and Ocean Sciences, School of Natural Sciences and Ryan Institute, National University of Ireland Galway, Ireland
2 Environmental Futures Research Institute, Griffith University, Gold Coast campus, Queensland, Australia
3 Natural and Built Environments Research Centre, School of Natural and Built Environments, University of South Australia, South Australia 5095, Australia
4 Future Industries Institute, University of South Australia, SA 5095, Australia

* Nadeeka.rathnayake@nuigalway.ie

Regulatory environmental monitoring is mainly based on the spot sampling of water, sediment, soil, and biota and conventional analysis. These well-established ex-situ conventional methods have limitations and the analysed samples may not accurately reflect the in-situ concentrations due to the artefacts resulting from spot sampling, sample oxidation and changes in temperature. Diffusive passive samplers (diffusive gradients in thin films (DGT) and diffusive equilibration in thin films (DET)) overcome these limitations. The research to date in this field has clearly demonstrated the power of applying DGT and DET samplers to investigate contaminant biogeochemistry in water, sediment, and soil systems. We have developed and applied several DGT and DET methods for the analysis of trace metals, sulfate, iron (II), and nutrients in water/sediment/soil. Here we present various examples of the monitoring application of DGT and DET methods to investigate contaminant biogeochemistry in water and sediments. These examples range from the investigation of metal (loid) concentrations in marine sediment pore waters, the measurement of elevated concentrations of iron (II) and sulfide in different habitats. Methods including the Chelex binding layer DGT for measuring trace metals and REEs in marine water, Chelex-Metsorb mixed binding layer DGT for measuring trace cations and oxyanions in sediment pore waters, and the colorimetric iron (II) and sulphide DET methods for the measurement of high-resolution pore water iron (II) and sulfide concentrations are discussed. This work consider current approaches for the assessment of bioavailability of metals in water and sediments, and how DGT stands as a step forward in suite of tools available. These studies demonstrate that the DGT technique has strong potential link chemical monitoring and ecotoxicology to predict contaminant risk.

(Environmental Protection Agency, Ireland, Marine Institute, Ireland, and School of Environment and Sciences, Griffith University, Australia are gratefully acknowledged for awarding research grants).

Keywords: Diffusive Gradients in Thin films (DGT), Diffusive Equilibration in Thin films (DET), Conventional methods, Contaminant biogeochemistry, Sediment porewater.
Toxicity Assessment of Fungicide Containing Thiram 80% WP using *Eisenia fetida* and *Allium cepa* as Indicator Species

R.A.H. Dilrukshi* and M.P. Gunawardena
*dilrukshi8harsi46@gmail.com
Faculty of Science, Horizon Campus, Malabe, Sri Lanka

Ecotoxicology is the science of contaminants in the biosphere and their effects on the components of the biosphere. Predicting the exposure and effect of contaminants is difficult for all relevant ecological entities. Agrochemicals are used extensively in fields to kill pests and weeds, which may exert toxic effects on other non-target species including earthworms and common onion. This research was conducted to evaluate the acute and chronic toxic effects of a commercial fungicide containing Thiram 80% WP, which is carbamate, on *Eisenia fetida* (earthworms) and *Allium cepa* (Common Onion). Earthworms are better indicators of the health of the soil because 60% - 80% of soil biomass represents earthworms. In this study earthworm species, *Eisenia fetida* was used because they can be bred within two weeks. *Allium cepa* is used in this study because they have a high absorbent level and high root growth rate. *Eisenia fetida* was exposed directly to aqueous solutions in five different concentrations (6 mg/L, 8 mg/L, 10 mg/L, 12 mg/L, and 14 mg/L) while distilled water was used as the control. Six *Eisenia fetida* were used in each sample and three replicates were performed. After 48-h exposure to Thiram 80% WP mortality of *Eisenia fetida* increased along the concentration gradient. Overall results of the acute toxicity test of *Eisenia fetida*, indicated an LC50 value of 12.636 mg/L and any behavioral changes could not be observed. Acute toxicity was evaluated to *Allium cepa*, by 72-h experiment of root growth with a range of fungicide concentrations (40 mg/L, 80 mg/L, 120 mg/L, 160 mg/L, and 200 mg/L) and tap water was used as the control. After 72-h exposure to Thiram 80% WP, root growth of *Allium cepa* was reduced along concentration gradient and overall results indicated an EC50 value of 22.183 mg/L. Recommended formulations of fungicide Thiram 80% WP of 640 g/hectare – 1600 g/hectare, and LC50 value for earthworms is 560 mg/kg of soil. According to the results fungicide Thiram 80% WP can be concluded as toxic, but further studies should be conducted to evaluate the acute and chronic effects.

**Keywords**: Toxicity, Fungicide, Thiram 80% WP, *Eisenia fetida*, *Allium cepa*
Adaptation Strategies for Flood Victims on Major River Basins of Sri Lanka: Case Study from the Megoda Kolonnawa GN Division of the Kelani River Basin

K.B.I.S. Ranwella*, N. Sakalasooriya and B.M.S.M. Basnayaka

*indunilranwella@gmail.com
Department of Geography, Faculty of Social Sciences, University of Kelaniya, Sri Lanka

Recently, it has been witnessed that flood is the growing catastrophe in Sri Lanka when compared with all the other calamities. Depending on the temporal and regional intensity and the broad spectrum of destruction, it has been recognized as one of the most predominant disasters in Sri Lanka. The awareness of victims living in the endangered area and launching strategies for avoiding significant impacts are required to adapt to disasters. Accordingly, victimized proportions of the flood have vigorously adapted to vulnerable situations rather than leaving their homelands and disrupting their daily routines. This study becomes significant in providing theoretical and validated impulses beyond any limits, typically imposed by a culture of safe and exemplifies the essential elements to provide adaptive strategies to flood victims in the Megoda Kolonnawa GN division practiced prior the incident, at the moment and after the incident. The Kolonnawa DS Division was found to be the largest flood-affected DS Division in Sri Lanka. Out of 46 GN divisions of the Kolonnawa DSD, “Megoda Kolonnawa – A” GND has been identified as the most vulnerable area to flood disasters. A sample of 3% of the total population, which is 2347 households of the GND were selected for the study. The stratified sample method was used to select GN Division and the Simple Random Sampling method was used to select 70 units of households from the GN Division. The study was carried out using primary and secondary data collected using questionnaires, interviews and observations. Quantitative and qualitative methods were used to analyze the data. This study revealed the fact that “Identifying the strategies of adapting to the flood” is becoming the main approach of the villagers as well as the government and non-government offices. Initiating communication with each other to gather at a safe place where the government has approved in vulnerable situations is the most common strategy. Similarly, increasing the physical values of the buildings and coordination with the government engineers to get the appropriate building plans are the most common strategies recorded within the past few decades.

Keywords: Flood, Vulnerability, Adaptation strategies, Community
In this study, an environmental DNA (eDNA) metabarcoding methodology was applied in two different agro-ecological regions of Sri Lanka to understand the eco-epidemiology of leptospirosis and to disclose diversity of environmental microbiome of each eco-agriculture region. Irrigation water samples were collected from the Kandy District (wet zone mid-country region 2) and Girandurukotte in the Badulla District (intermediate zone low-country region 2) to explore the environmental microbiome especially for the presence of pathogenic leptospires and other terrestrial and aquatic vertebrate animal residuals. Concisely, extracted environmental DNA amplified for high-throughput sequencing of multiple amplicons through next-generation sequencing. The analysis disclosed diverse environmental microbiome in both regions including a higher diversity of *Leptospira* species and many other known pathogenic bacterial species. The number of sequence reads of pathogenic *Leptospira* species associated with published *Leptospira* species from clinical cases such as *L. interrogans*, was higher in Kandy than in Girandurukotte. Kandy also revealed a high diversity of pathogenic bacterial species than Girandurukotte, which were associated with many peridomestic animals. An unexpectedly high level of human eDNA was detected which showed the high level of residents’ interaction with irrigation water. Furthermore, eDNA of marine fish sequences were detected, which appeared to be derived from canned foods consumed in the sampling regions (i.e., *Scomberomorus commerson* and *Thunnus albacares*). The great *Leptospira* species diversity in Kandy detected in this study shows that the etiological agents of leptospirosis in Sri Lanka might be underestimated. The eDNA metabarcoding method is suggested to be used as a tool for evaluating human activities and monitoring potential biological environmental pollution.

**Keywords:** Microbiome, Biological pollution, eDNA, Next generation sequencing
Variation in Diversity of Macro-Invertebrates in Relation to the Water Quality Status of the Kaakkaithivu Coastal Waters, Jaffna Estuary, Northern Province, Sri Lanka

A. Vithusha* and P. Sivakumar
*Vithusijaanu4@gmail.com
Department of Zoology, Faculty of Science, University of Jaffna, Sri Lanka

The present investigation was conducted with the aim of documenting the variation in diversity of macro-invertebrates in relation to the water quality status of the Kaakkaithivu coastal waters, Jaffna estuary, Northern Province, Sri Lanka. Samplings were made on a fortnightly basis from July 2018 to January 2019 and water quality parameters were measured at the selected sampling sites of the Kaakkaithivu coastal waters. During the present study, twenty macroinvertebrates were identified based on their morphological characteristics using standard keys. Macroinvertebrates were Terebraliapalustris, Cerithideacingulata, Murex virgineus, Volegaleasp,Littorariaundulata, Morulamargariticola, Cypraeasp, Clypeomorussp, Cardita bicolor, Donaxsp, Dosinialincta, Portunuspelagicus, Thalamitacrenata, Metopograpsussp, Gammaruslocusta, Penaeusmonodon, Penaeuslatisulcatus, Penaeussemisulcatus, and Cassiopeapictaand Acromitussp. According to the Shannon Wiener and Simpson indices, the highest species diversity value (2.716) was found at the site-3, followed by site-2 and site-1. Terebraliapalustris (21.35%) and Cerithideacingulata (20.05%) were the most abundant species. Selected sites were in three different conditions; therefore, these sites have different correlation with the species and their distribution. They were significantly correlated with the distribution of Terebraliapalustris, Cerithideacingulata, Volegaleasp, Littorariaundulate and Donaxspat at site-1; Cerithideacingulata, Morulamargariticola, Clypeomorussp, and Cardita bicolor at site-2; Volegaleasp,Cardita bicolor, Portunuspelagicus, Metopograpsussp, Gammaruslocusta, Penaeusmonodon, Penaeuslatisulcatus, Penaeussemisulcatus, and Cassiopeapictaat at site-3 (p˂0.05). Terebraliapalustris showed a significant difference with the most of the water quality parameters such as temperature, salinity, Dissolved Oxygen (DO), Total Dissolved Solids (TDS) and Oxidation Reduction Potential (p˂0.05). Among the water quality parameters, the salinity, pH, DO, TDS, and Electrical Conductivity significantly influenced the abundance and diversity of the species at three sampling sites. Terebraliapalustris showed tolerant to change in water quality. Results of the present study are important in ecological assessments and it will be useful in estuary-based management and restoration process of the Jaffna estuary.

Keywords: Coastal waters, Diversity, Estuary, Macro-invertebrates
Why Farmers are Reluctant to Apply Adaptation Strategies of Climate Change: A Case Study in the Mahakanadara agro-eco system, Dry Zone of Sri Lanka

W.M.P.W. Wickramasinghe¹ and S.P. Gunarathne²*

¹ Department of Environmental Management, Faculty of Social Sciences and Humanities, Rajarata University of Sri Lanka
² Department of Community Medicine, Faculty of Medicine and Allied Science, Rajarata University of Sri Lanka

Agriculture in the dry zone of Sri Lanka is directly affected by Climate Change (CC), so Agricultural Adaptation Strategies (ADS) are required to face the adverse impacts of CC. The present study is aimed to identify the status of using ADS for CC. The study design has three parts: the first part is a comprehensive literature search to identify the ADS in developing countries and to develop the study tool that used in the second phase of the study, which is a cross-sectional study, conducted in the Mahakanadara agro-eco system, North Central Province, Sri Lanka. Data were collected through an interviewer-administered questionnaire from 60 farmers selected using the stratified sampling method and analyzed by using descriptive statistical methods and correlation analysis. The third part is an in-depth interview to identify the special features of success stories of using ADS. According to the literature search, ten adaptation strategies were identified and the survey was focused on finding the status of practicing those approaches. Results revealed that the majority does not employ those strategies due to major constraints such as lack of capital, barrier to access the technology and financial support, and being trapped in cultural beliefs. The correlation analysis revealed that there is a positive significant relationship (r=0.63) between the factor of being trapped in cultural beliefs and the education level of farmers. Besides two success stories were interviewed and the results revealed that the reasons for the success with adverse CC impacts were the following: financial and technological strength, highly consideration of weather pattern when selecting the type of crop, working on a scheduled timeline and ability to face in sudden shocks, having information sources in terms of market, new varieties of seeds/plants and testing different varieties before applying to the field, etc. In the conclusion, even though there are major barriers for formulating viable ADS such as technology and financial abilities and being trapped in cultural beliefs can be overcome by learning lessons from the farmers who succeed in the same field with entering a new era of farming.

Keywords: Adaptation strategies, Agriculture, Climate change, Constrains, Success stories
Effect of Physical and Chemical Modifications of Sawdust for Removal of Cr (III) from Textile Industry Effluent

*chandimag@pdn.ac.lk
Department of Civil Engineering, Faculty of Engineering, University of Peradeniya, Sri Lanka

Textile wastewater discharge contains heavy metals such as Chromium, Copper, Zinc and Lead. Harmful levels of Chromium in these effluents causes the majority of the negative impacts as a non-bio degradable and bio-accumulative toxic substance. Abundantly available sawdust can be used efficiently as an alternative adsorbent to remove heavy metals from textile effluent. Hence, objectives of this study were to modify sawdust as an adsorbent while investigating the heavy metal adsorption behavior of different forms of adsorbents using batch experiments. Thermal modification of Raw Sawdust (RSD) was carried out at 400 °C pyrolysis condition producing biochar in order to increase the surface area of the adsorbent. Furthermore, two separate chemical activation processes were carried out on biochar using 0.1M H\textsubscript{2}O\textsubscript{2} and 0.1M KOH. Chemical modifications of biochar produced at low temperature increases oxygen containing carboxyl functional groups and hydroxyl groups on the surface of biochar. Kinetic study was carried out for 7 hours with an initial Cr (III) concentration of 5 ppm, adsorbent dosage of 2 g/l and a neutral pH in the system. The results indicated optimum contact time as 40 minutes. Adsorption capacities of the adsorbents were 2.2 mg/g, 2 mg/g, 1.8 mg/g and 1.7 mg/g and percentage removal of Cr (III) was identified as 86%, 83%, 72% and 70% for H\textsubscript{2}O\textsubscript{2} modified biochar, raw biochar, RSD and KOH modified biochar respectively according to the kinetic experiments. Biochar showed a higher adsorption capacity than RSD. The H\textsubscript{2}O\textsubscript{2} modified biochar showed enhanced Cr (III) adsorption ability than KOH modification. This study is expected to be continued further by conducting isotherm studies and characterization of adsorbents. Findings from present work indicate the potential application of biochar as an effective, economic and environmentally friendly adsorbent for the removal of heavy metals from industrial wastewater effluent in providing solutions to minimize water pollution.

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Keywords: Adsorption, Wastewater treatment, Sawdust, Biochar, Heavy metals
Hydrogeochemistry of Tank Cascade Systems: A Study from the Siwalakulama Cascade in Galenbindunuwewa

D.T.G.L. Subasinghe¹, K.M. Premathilaka² and Rohana Chandrajith¹*

*rohanac@pdn.ac.lk

¹ Department of Geology, University of Peradeniya, Peradeniya, Sri Lanka
² National Water Supply and Drainage Board, Telewala Road, Ratmalana, Sri Lanka

Tank Cascade Systems (TCS) are a water conveyance system developed in ancient times in Sri Lankan to supply water throughout the year for agricultural and domestic purposes. It also acts as a source for groundwater recharge. Due to various reasons, TCS are now abandoned or destroyed. It is believed that TCS are an important component for the sustainability of groundwater in the dry zone region of Sri Lanka. The aim of this study is to investigate the geochemical behavior of groundwater in a TCS based on hydrogeochemistry and environmental isotopes of $\delta^2$H and $\delta^{18}$O. For the study, the Siwalakulama Cascade located in the Galenbindunuwewa region was selected. Water sampling were carried out in both dry (n=14) and wet (21) seasons and analyzed for their major ions, trace metals, and isotopes ($\delta^2$H and $\delta^{18}$O). Higher levels of fluoride (mean=1.5 mg L$^{-1}$), chloride (mean = 238 mg L$^{-1}$), hardness (mean = 357 mg L$^{-1}$), and nitrates (mean = 5.68 mg L$^{-1}$) were found in groundwater while Ca–HCO$_3$ type water was predominant in this region. The $\delta^{18}$O and $\delta^2$H signatures of the most groundwater and surface water in the area deviated from the local meteoric water line indicating higher rate evaporation. It also suggested that the shallow groundwater in the cascade is mainly recharged by the second inter-monsoon rain. Anthropogenic activities such as excessive rates of abstraction of groundwater through agro-wells possibly affected both ground and surface water in the study area. The present study suggested a need of proper groundwater management plan for the area for the eco-hydrological sustainability of the TCS.

*Keywords: Isotopes, Groundwater management, Sustainability, Agro-wells*
The Estimation of Return Levels of Extreme Rainfall: A Case Study of Watawala

S.H. Shajitha¹* and K. Perera²
*shajithash@seu.ac.lk
¹ South Eastern University of Sri Lanka, Sri Lanka
² University of Peradeniya, Sri Lanka

Watawala is located in the Nuwara Eliya District in the Central Province of Sri Lanka, which covers a total area of 32.82 km². Since the location’s annual average rainfall goes beyond 5000 mm, it is considered as one of the wettest places in the country, where the local economy is largely based on growing tea. Therefore, study on occurrences of future rainfall is beneficial for enhancing water management and planning crop growing. Daily rainfall (mm) for the period from 2008 to 2017 was used for the analysis. In this study, Block maxima (BM) method and Peak over threshold method (POT) were applied using extreme value theory. The objectives of the study are to fit the best distribution using both methods and to estimate the return levels of daily rainfall using the more suitable method. Generalized Extreme Value (GEV) distribution and Generalized Pareto Distribution (GPD) are the standard distributions corresponding to BM and POT methods, respectively. In BM method, monthly maximum rainfall was studied while rainfall exceeding a specified threshold was studied in POT approach. Dependency of events exceeding the high threshold was tested using extremal index and auto-tail dependence function. Maximum likelihood estimation method was used to determine the parameters in each method. The study reveals that the monthly maximum rainfall fits well with the Frechet distribution and rainfall exceeding the threshold fits well with the GPD based on the sign of the shape parameter. Diagnostic plots: quantile plots, density plot and return level plot were used to test the goodness of fit of GEV distribution and GPD. Comparatively, POT gave better fit than the BM method. Return levels of 3, 5, 7 and 10 years were estimated using POT approach. A rainfall of 283.3 mm or more on average once in every 5 years with probability 0.2 can be expected for Watalawa.

Keywords: Block Maxima, Generalized Extreme Value distribution, Maximum Likelihood Estimation, Generalized Pareto Distribution, Peak Over threshold
Does the Drought have an Effect on Agriculture? Farmers’ View in the Dry Zone of Sri Lanka

K.A.N.L. Kuruppuarachchi1,2, D.C. Gunawardhana2,3 and S.P. Gunaratne2,4*

*Sajaanpraveen7@gmail.com

1 Agribusiness Centre, Faculty of Agriculture, University of Peradeniya, Sri Lanka
2 Post Graduate Institute of Agriculture, University of Peradeniya, Sri Lanka
3 Department of Mathematics, Faculty of Science, University of Peradeniya, Sri Lanka
4 Department of Community Medicine, Faculty of Medicine and Allied Science, Rajarata University of Sri Lanka

Drought refers to a period when an area undergoes below normal precipitation that has a negative effect on regular life of living beings. With the objectives of recognizing the impacts of drought on agriculture and the perception of farmers on the influences of drought, the study was conducted aiming at North Central Province, which is located in Dry Zone of Sri Lanka. The Anuradhapura district was selected as a case and through stratified random sampling procedure, representative sample of 560 farmers in eight divisional secretariat divisions were selected to collect data. A self-administrated questionnaire including questions with 5-point Likert scale was carried out to observe the perception of the farmers on the impacts of drought on agriculture. The study design was a cross-sectional study. At the initial stage, a desk review was conducted to gather the information available in the literature and 22 impacts were brought together which are effects of drought in different aspects both in the local and global settings. Five impacts among all were selected that are related to agriculture in the Sri Lankan context. Those summarized influences are decreasing harvest, decreasing cultivable lands, changing the land use pattern, increasing the animal attacks and biodiversity degradation. The data were freely distributed. Therefore, non-parametric analysis Sign test with normal approximation was done to evaluate the perception of farmers on the above influences. According to the results, all the above influences are negatively affected by the drought and it is statistically proved (Z> 1.96) with Sign test. Therefore, it can be concluded that, according to the farmers’ view, agriculture in the dry zone is adversely affected by the drought.

Keywords: Agriculture, Drought, Dry zone, Impacts, North Central Province
Effect of POEA-15, Surfactant of Glyphosate Formulation on Soil Properties

G.G.D.P. Jayawardhene and A.N. Navaratne*
*ayanthi.pdn@gmail.com
Department of Chemistry, Faculty of Science, University of Peradeniya, Sri Lanka

The extensive use of agrochemical has led to environmental pollution. Glyphosate formulations have been very popular as a total weed killer. Glyphosate formulations are more toxic than glyphosate alone due to the toxicity of POEA-15 surfactant. The aim of this research is to determine the effect of POEA-15 surfactant on soil properties by treating paddy soil with glyphosate formulation and extracted POEA-15 from the commercial formulation of glyphosate. POEA-15 surfactant was extracted into dichloromethane and characterized. The FTIR spectrum of standard POEA-15 was comparable with the spectrum of extracted POEA-15. Paddy soil was treated with different POEA-15 concentrations of glyphosate formulation solutions and different masses of soil. Then the tank concentration of POEA-15 was used to treat paddy soil. The effects on soil properties such as soil pH, electric conductivity, cation exchange capacity, soil organic matter content and soil porosity were analyzed by comparing with a control sample, which was treated with distilled water. The data were analyzed using multiple comparisons testing in analysis of variance (ANOVA). Soil pH was significantly affected by POEA-15 and glyphosate formulation. Electric conductivity of soil has been affected only by glyphosate formulation. Organic matter content has not changed by both glyphosate formulation and POEA-15. POEA-15 may not be degraded by microorganisms within experimental time period. Cation exchange capacity is decreased over time for both glyphosate formulation and POEA-15. However, it has not significantly affected by POEA-15. Soil porosity has increased due to glyphosate formulation and POEA-15. But, the contribution of POEA-15 on soil porosity is more prominent. Furthermore, sorption of glyphosate molecule on to the soil may affect for soil properties, especially soil pH. Thus it may affect the changes of other properties such as cation exchange capacity, electric conductivity, and soil porosity. Finally, it can be concluded that both POEA-15 and glyphosate change some soil properties of tested soil with time and it may pose long lasting effects on soil.

Keywords: POEA-15, Surfactant, Glyphosate, Weed killer
IoT Based Environment Condition Monitoring for Agricultural Fields

R.T. Wakkumbura\textsuperscript{1}, D.A.H. de Silva\textsuperscript{1,*} and M.W.P. Maduranga\textsuperscript{2}
\textsuperscript{*}himahansiakshi@gmail.com

\textsuperscript{1} Department of Computer Science, General Sir John Kotelawala Defense University, Rathmalana, Sri Lanka
\textsuperscript{2} Department of Computer Engineering, General Sir John Kotelawala Defense University, Rathmalana, Sri Lanka

Sri Lanka is a fertile tropical country that maintains the economic life of agriculture. 25\% of Sri Lankans work in the agricultural sector. Weather and agriculture cannot be separated into two separate facts. Environmental factors have changed rapidly and randomly over the past few years. This problem has caused various damages to the agricultural sector. By using technology, the Internet of Things (IoT) based real time monitoring system could help to improve the productivity of agriculture. In this project, we designed and implemented an IoT based monitoring system to monitor humidity and temperature, which are two main factors for measuring environmental conditions in weather station design. In this design, a sensor node includes an ESP8266 microcontroller, DHT 11 sensor and a rechargeable battery to power the sensor node. Real-time data were collected using IoT sensor nodes and transmitted to a remote IoT cloud called Thinger.io, making it an IoT-based weather station that can monitor weather conditions from anywhere using a digital device with the internet.

Testing involved two sensor nodes placed in two different places in an outdoor environment and data collected for five consecutive days. Received data saved on IoT servers to achieve temperature and humidity monitoring. In the data preprocessing stage, we filtered all the raw data using moving average filters and computed basic statistical parameters and standard distribution of temperature and humidity data. Average result of the humidity and temperature captured by the system is 93 \% and 31.8 °C. According to results, data variations of two nodes are not uniformly distributed and it concludes the efficiency and accuracy of the weather station. Moreover, created data sets can be used to create Machine Learning based predictive models for different applications. In addition, systems can be developed by focusing more on safety constraints for specific farms or crops.

\textit{Keywords:} Internet of Things (IoT), Smart agriculture, Wireless Sensor Networks (WSN), Temperature, Humidity
Assessment of the Impact of Semi-Intensive Shrimp Farming on Water Quality of the Mundal Lagoon, Sri Lanka

N.D. Hettige*, J.K.P.C. Jayawardane, R.H.N.S. Alwis and K.A.W.S. Weerasekara

*naeeshahettige7@gmail.com

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

The main objective of this study was to determine the water quality status of the Mundal lagoon and provide suitable recommendations to minimize lagoon pollution. Eight sampling locations were selected including sea mouth canal to Udappuwa, Dutch canal end and surrounding shrimp farms. Water samples were collected from February to July 2018 at monthly intervals. Physico-chemical parameters of water were measured using portable meters and standard laboratory methods. Water temperature (>30°C), salinity (>50 ppt) of lagoon water were significantly high during the dry period i.e., February, March and April recording hypersaline conditions. Average salinity was 15.5 ±1.4 ppt in May with the receipt of heavy showers and it was gradually increased up to the average salinity of 30.3±17.3 ppt. Mean pH value of water was 8.35±0.75 and DO level recorded was more than 6 mg/L. Mean concentrations of nitrate-N, nitrite-N and dissolved phosphorous were within the acceptable range. However, average BOD (10.14 ± 8.73 mg/L) and COD (497.83 ± 381.34 mg/L) were relatively high. Principal Component 1 and 2 explained 57.7% of cumulative variance and the sampling locations were clearly separated to 5 clusters. ML 1 (Udappuwa sea mouth end) was identified as the location with higher BOD and nitrates where the effluent water from shrimp farms flows into the lagoon as the sea mouth is closed more often. Locations from the middle part of the lagoon showed less organic and inorganic pollution. Also, higher dissolved phosphorous, water temperature and hypersaline conditions were recorded during the dry period. Dutch canal end was identified as the most polluted location, where the high number of shrimp farms were operated at the time. In conclusion, shrimp farm effluents discharge into the lagoon could cause eutrophic conditions and variations of lagoon water quality in the long run. Thus, continuous monitoring of shrimp farms adherence to existing water discharge regulations are thoroughly recommended.

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Keywords: Lagoon, Water quality, Pollution, Hypersaline
Benthic Macroinvertebrates Diversity in the Kokkilai Lagoon: A Preliminary Survey

N.D. Hettige* and W.D.N. Wickramaarachchi
*nadeeshahettige7@gmail.com
Environmental Studies Division, National Aquatic Resources Research and Development Agency (NARA), Crow Island, Colombo 15, Sri Lanka

The Kokkilai lagoon is an estuarine lagoon, which is located in the Mulathivu and Trincomalee Districts, northeast of Sri Lanka. There were few studies conducted on the aquatic biodiversity in northeastern lagoons. The main objective of this study is to identify the diversity of benthic macroinvertebrates in the Kokkilai lagoon. The study was conducted in October 2017 and sediment samples were collected from nine randomly selected sampling sites in the Kokkilai lagoon. Collected sediments samples were wet sieved and identified using standard identification keys. Diversity index of macroinvertebrates was calculated. A total of 1769 individuals of benthic macroinvertebrates belonging to three phyla (Mollusca, Annelida and Arthropoda), four classes (Gastropods, Bivalves, Polychaeta and Crustaceans) and 24 families were recorded from the Kokkilai lagoon. Class gastropods were found to be abundant in the total composition of benthic macroinvertebrates and nine families of gastropods were recorded. Littorinidae were the most abundant gastropod (67.44%) family followed by Cerithiidae (8.14%) and Haminoeidae (4.75%) from the total abundance of benthic macroinvertebrates. Among the eight bivalve families recorded, Veneridae was the most dominant family (4.58%). Four families of Polychaeta namely Nephtyidae, Nereididae (0.40%), Pilargidiidae and Opheliidae were detected and Penaeidae, Gammaridae and Balanidae (0.17%) were identified among crustacean families. The overall Shannon wiener diversity index of the lagoon was 1.41. In conclusion, this index confirmed that the aquatic health of lagoon is in moderately poor condition and low species diversity of the lagoon. Furthermore, the lagoon is dominated by the class gastropod. The findings of the study can be used as baseline data of the aquatic biodiversity of the lagoon.

*(National Aquatic Resources Research and Development Agency and International Union for Conservation of Nature, Sri Lanka (Grant No. 2017/1.17) is gratefully acknowledged for awarding a research grant).

Keywords: Kokkilai lagoon, Benthic macroinvertebrates, Diversity and Sediment
Measuring Traffic-Related Air Pollution Using Smart Sensors: Before and During a New Traffic Plan

S.M.D.M.C. Senarathna1*, T.M.S. Priyankara1 and G. Bowatte1,2
*smdmaheshchamika@gmail.com
1 National Institute of Fundamental Studies, Hantana Road, Kandy, Sri Lanka
2 Department of Basic Sciences, Faculty of Allied Health Sciences, University of Peradeniya, Peradeniya, Sri Lanka

Change in traffic flow in a city can cause increased, decreased or no change in overall air pollution. Air pollution levels may vary significantly in some street segments compared to others and this variation may not get accurately captured by stationary monitors. In this study, we aimed to measure air pollution before and during a New Traffic Plan (NTP), Kandy, Sri Lanka using smart sensor technology. Air pollution data (PM$_{2.5}$, PM$_{10}$ and NO$_2$) were collected using a mobile air quality sensor unit mounted to a Police traffic motorbike, four times a day before and during the NTP (2019-03-02 to 2019-03-07). After data collection, roads were divided into segments according to road length, geographic features and road traffic conditions using GIS software. Air pollution in each segment of roads was compared before and during the NTP. Trends of air pollution at different times of the day was compared using data from a stationary smart sensor. During the NTP majority of the road segments had higher mean levels of air pollution compared to before the NTP. For any given time (Morning, Mid-day, Afternoon and Evening), and any given period (before or during NTP), the highest PM$_{2.5}$ and NO$_2$ concentrations were observed at Station Road Kandy. The PM$_{2.5}$ concentrations were moderately correlated with NO$_2$ and positively correlated with PM$_{10}$, before and during the NTP. PM$_{2.5}$ concentrations during the NTP means were statistically significantly higher than the before NTP (p=0.0067 < 0.05). PM$_{2.5}$ concentrations at roads of the Kandy city were much higher than the WHO standards. Mean NO$_2$ concentrations were not significantly different before (109.87 ppb) and during NTP (104.73 ppb). The recent change in the Kandy city traffic plan might have caused an increase of PM$_{2.5}$ levels. Proper development of road infrastructure with compatible traffic plan could reduce air pollution in urban areas.

Keywords: Air quality, Mobile air quality sensors, Particulate Matters, Road traffic
Fluctuations of Airborne Bacterial Community in November 2019 Haze Event in Kandy, Sri Lanka

*dhammika.ma@nifs.ac.lk
National Institute of Fundamental Studies, Hantana Rd, Kandy, Sri Lanka

Human activities such as industrialization and deforestation have led to deterioration of air quality and climate related adversities. The haze events that occurred in November 2019, in New Delhi, India and in Sri Lanka could also be cited as a consequence of such human activities. This study focuses on the airborne bacteriology during the haze event in Sri Lanka, which has not been previously explored. Air samples were collected in Kandy, Sri Lanka during hazy days (06/11/2019-09/11/2019) and on a non-hazydays using three methods: natural sedimentation method (NSM)—(12 h, Whatman 5), PM$_{2.5}$ fine particulate air sampler (FPAS)—(1 m$^3$/hr, 30 min) and a laboratory designed air sample collector (ASC)—(Whatman 5, 50 ml/round). Bacteria collected on filter papers were extracted into sterile Milli-Q water and DNA was extracted using Boom’s method followed by real-time PCR. The Bacterial load (cells/µl) was quantified with comparison to a standard curve generated by *Escherichia coli* DNA. Isolated bacterial cultures were identified using Sanger sequencing by amplifying 16S rRNA gene. As per NSM, during daytime, the highest bacterial load was observed on 07/11/2019— a very hazy day (1.89x10$^6$) followed by 08/11/2019—a moderately hazy day (2.79 x10$^5$). During night time, the highest bacterial load was observed on 06/11/2019—a very hazy day (5.83x10$^5$) followed by 07/11/2019 (5.18 x10$^5$) and 08/11/2019 (3.5x10$^5$), which complied with the other two methods. Accordingly, the bacterial load gradually decreased with the reduction of haziness. Also, compared to the control of each method, the hazy days showed a high bacterial load. *Exiguobacterium acetyllicum*, *Burkholderia multivorans*, *Bacillus megatarium*, *Phytobacter diazotrophicus*, *Pantoea deleyi*, *Acinetobacter modestus*, *Chryseobacterium gleum*, and *B. paramycoides* were identified in air collected on hazy days and *B. cereus*, *Ochrobactrum intermedium*, and *P. wallisii* were observed on both hazy days as well as non-hazy days. Fluctuations of airborne microbial composition and presence/absence of certain bacteria could be used as important monitoring tools of air quality and pathogenicity of bacterial isolates needs to be explored further to identify potential hazards.

**Keywords:** Haze event, Airborne bacteria, Bacterial load, Air quality monitoring
Dust generated from manufacturing asbestos related products may become a respiratory health hazard to the workers. Therefore, characterizing dust and the presence of asbestos fibre in the atmosphere of an asbestos roofing factory can be used to co-relate with the possible health risks faced by the workers during their working hours. An asbestos roofing factory with two production sections was selected for the study. Five sampling sites were selected from each production section, which included: sheets loading area, broken sheets dumping area, sheets cutting area, and sites closer to pulverizing machine and cement silo. Deposition samples were collected using dry deposition sampling apparatus, once a week for 6 times (a total of 30 samples). Samples were observed under SEM to visualize the physical properties and EDX (Energy Dispersive X-Ray Analyzer) was used to identify the composition of the atmospheric particles. The samples were analyzed for toxic heavy metals by acid digestion and subjected to ICP-OES searching for the trace metals (Cd, Zn, Cr, Pb, Cu, As, Ni, and Hg) in the atmospheric dust, which may have been in the raw materials. The samples observed under the SEM confirmed the presence of asbestos fibers in the atmospheric depositions. EDX revealed that Mg, Si, Ca, Fe, S, Al and K were observed as major elements in the composition of the atmospheric particles inside the factory. The average concentrations of the trace metals in the samples in units of mg/kg were Cd- 2.74, Pb- 17.18, Ni- 46.68, Cr- 81.01, As - 7.12, Co- 6.77 and Cu- 43.04. However, Hg was not detected in the samples. Zn, Al, Mg and Fe showed high concentrations in the deposition samples: 0.2-12, 1.9-4.8, 57-163 and 12-112 g/kg, respectively. The presence of asbestos fibers and toxic heavy metals in the atmospheric depositions inside the factory implies necessity of strict safety measures for the workers.

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Keywords: Asbestos, Deposition samples, Heavy metals, ICP-OES, SEM
A Review of GIS/RS Based Soil Erosion Modelling in Sri Lanka

I.D.U.H. Piyathilake1*, E.P.N. Udayakumara2 and S.K. Gunatilake2

*iduhasantha@gmail.com

1 Faculty of Graduate Studies, Sabaragamuwa University of Sri Lanka, Sri Lanka
2 Department of Natural Sciences, Faculty of Applied Sciences, Sabaragamuwa University of Sri Lanka

Soil erosion is a global environmental concern that is influenced by both natural and anthropogenic factors. Thus, the modelling provides a quantitative and consistent approach to estimate soil erosion and sediment yields under a wide range of conditions that are needed to guide the comprehensive control of soil erosion. Over the years, various soil erosion models have been developed and the application of these models have been carried out for different regions in the world with different types of models that differ in their complexity and input requirements. Thus, this study reviews various GIS/RS based soil erosion models that have been applied in Sri Lanka focusing more on the most widely applied models: The Universal Soil Loss Equation (USLE), The Revised Universal Soil Loss Equation (RUSLE) and Integrated Valuation of Ecosystem Services and Tradeoffs, Sediment Delivery Ratio (InVEST SDR) model. The method used for this research is a review of academic articles, conference papers and publicly available materials that published in the last 20 years on soil erosion models. We examine and compare various methodologies in deriving soil erosion model components, analysis methods and applications with special reference giving to Sri Lanka. The results of this study revealed that most soil erosion models have been applied for the assessment of rill/ inter rill erosion and sediment yields at the catchment or whole country scale by using different methods of the derivation of soil erosion model components viz. soil erodibility factor (K), rainfall erosivity factor (R), slope gradient factor (LS), crop management factor (C) and support practice factor (P). Moreover, the study indicated that most previous authors have used the empirical models due to the paucity of data and parameter inputs. However, recommendations of the study include the expansion of the USLE, RUSLE and InVEST SDR models should be investigated for the simulation of gully erosion and sediment processes; researchers should explore better ways of deriving K factor, C factor, and P factor in soil erosion models for future research studies. Finally, validation of the soil loss using reference data is also a valuable input towards improving the accuracy of the results.

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Keywords: GIS, InVEST, Models, RUSLE, Soil Erosion, USLE
Application of GIS for Rehabilitation of a Water Distribution System

A.P.U.M. Pathirana, P.D.P.O. Peramuna* and H.K. Nandalal
*oshini.peramuna@eng.pdn.ac.lk
Faculty of Engineering, University of Peradeniya, Sri Lanka

Most of the countries use pipe networks to provide water of good quality to meet the demand with an acceptable pressure while conserving the amount of water remaining in the planet. One of the main problems of such networks is leakage of water. Hence, it is of utmost importance to effectively rehabilitate and renovate water distribution network. However, it is not practical to rehabilitate the whole system at the same time. Thus, one of the objectives of the research is to identify the effective rehabilitation model for a pipe network. This study is based on physical parameters of a pipe network such as pipe age, pipe diameter, pipe material and pipe length, and operational parameters such as water pressure and burst record history. The Thottipallama water distribution network situated in the Kandy Municipal area is used as a case study area in this research since a high record of pipe breakages have been reported from this area. The methodology is developed to locate the water network spatially using Geographic Information System (GIS) including the information from the hydraulic model developed in WaterGems software and to model the prominent rehabilitation method using GIS. To identify the prominent pipes for the rehabilitation, a deep feedforward neural network, a type of an Artificial Neural Network is trained with the parameters. The result obtained shows that the pipe breakage history is the prominent parameter of the rehabilitation model for the effective rehabilitation of this network. The results of the research can be used in planning and managing the rehabilitation of the water distribution networks in the area. Furthermore, this methodology can be extended to the water distribution networks in other districts of Sri Lanka to identify the rehabilitation priority.

Keywords: Pipe network, Pipe breakage history, GIS, WaterGems, Rehabilitation model, Deep feedforward neural network
Effect of Benzenesulfonamide Based Herbicide Formulation (Granite®) on Soil Inhabiting Nostoc sp.

G.Y.H. Weerasinghe*, K. Masakorala and R.D.A. Gunasekara

*mas@bot.ruh.ac.lk
Department of Botany, Faculty of Science, University of Ruhuna, Matara, Sri Lanka

Granite is a systemic herbicide formulation that is widely used as a post emergent weed killer by paddy farmers in Sri Lanka at an initial vegetative growth phase of paddy. The active compound in Granite is 2-(2,2-difluoroethoxy)-N-(5,8-demethoxy[1,2,4]triazolo[1,5c]pyrimidine-2-yl)-6-trifluoromethyl) benzenesulfonamide and it inhibits Aceto Lactate Synthase (ALS) enzyme of target grass and broad leaf weeds and thereby destroy weeds. As a nitrogen fixing soil inhabiting dominant cyanobacterial group, Nostoc spp. play an important role in rice field soil ecosystem through improving soil fertility and structural properties. Paddy soil inhabiting Nostoc spp. are considered as a non-target group of soil microorganisms with sensitivity to herbicides. Therefore, the present study is aimed to determine the effect of Granite on rice field inhabiting Nostoc sp. The Nostoc sp. was isolated from a paddy growing soil by using N free BG-11 agar medium and the isolate was exposed to a concentration series of Granite (2.5, 5.0, 10, 15, and 20 mg/L of Granite) prepared in N free BG-11 broth and solidified medium. A control experiment was carried out in N free BG-11 medium. Three replicates were used for both treatments and control. Measurements on morphology, growth and photosynthesis were taken at the beginning of the experiment and after every 24 hours up to five days. The calculated mean filament length, cell width, number of specific cells and photosynthetic pigment (Chlorophyll a, b and total chlorophyll) content and colony morphology of Nostoc sp. exposed to Granite showed concentration dependent, significant (p < 0.05) irreversible negative impacts compared to that of the control. The recommended rate for the field application (2.37 ppm/m²) of active compound of granite is more similar to the lowest concentration (2.5 ppm) used in the experiment. Thus, the overall results infer possible inhibitory effects of Granite on rice field inhabiting Nostoc spp.

Keywords: Nostoc sp., Granite, Herbicide concentration, Rice fields
Radioactive Challenges in Exploration and Extraction of Rare Earth Elements (REEs) in Sri Lanka

N.P. Dushyantha1*, N.M. Batapola1, H.M.R. Premasiri1, A.M.K.B. Abeysinghe1, L.P.S. Rohitha1, D.M.D.O.K. Dissanayake1, I.M.S.K. Ilankoon2, N.P. Ratnayake1,3 and P.G.R. Dharmaratne1

*nimila.dush@gmail.com

1 Department of Earth Resources Engineering, University of Moratuwa, Sri Lanka
2 Discipline of Chemical Engineering, School of Engineering, Monash University Malaysia
3 Ocean University, Mattakuliya, Sri Lanka

Rare Earth Elements (REEs) govern the modern life style of people, although many people are not aware of such a scenario. REEs are consumed in various high technological and green applications due to their unique chemical and physical properties. Since the demand for REEs is rising continuously, the world will be vulnerable to a future REE scarcity. Although many REE deposits are found around the world, only handful of mines currently process rare earth ores because of the environmental and social concerns. The radioactivity of the associated elements such as Thorium (Th) and Uranium (U) in rare earth minerals is the critical environmental concern, which brings the social resistance towards the processing of REEs. In the Sri Lanka context, although there are no commercial level explorations, mining or extraction of REEs, geological setting implies the presence of probable commercially viable primary REE sources (e.g., apatite in carbonatites and hydrothermal veins) and secondary REE sources (e.g., mineral sand and laterite deposits). In this regard, radioactivity was measured in few samples from different geological origins prior to assessing their true REE potential of the source and develop a sustainable REE extraction technique. Once the radioactivity was reported higher (500-900 cpm from Geiger counter in the Pulmoddai beach sand) than the permissible level, precautions were taken during the explorations and certain lab-scaled steps were developed to remove the radioactive content during the extraction process. However, radioactive elements were also enriched during the processing of rare earth minerals because of their chemical similarity with the REEs. Therefore, in order to mitigate the adverse effects on human health and environment due to radioactive contaminants, improved measures, such as advanced mining and processing techniques, protective storage facilities and suitable waste disposal methods are required in REE industry to maintain long-term social sustainability fostering the United Nation’s sustainable development goals (SDGs).

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Keywords: Rare Earth Elements (REEs), Radioactivity, Exploration, Extraction
Aquatic plants species play an important role in the removal of heavy metals from contaminated water. *Bacopa* (Scrophulariaceae) locally called *Lunuvila* is an important aquatic medicinal plant frequently used in Sri Lanka for traditional medical preparations. Thus, the aim of this study was to investigate the heavy metal accumulation potential of *B. monnieri* and to determine its morpho-physiological changes that occur to cope with heavy metal contaminated environments. The information will be evaluated to determine the potential use of species in phytoremediation and the safeness of using *B. monnieri* in traditional medicine. The plants were raised in a glass house and separately treated with 0, 2, 5, 10, 20, and 50 mg L\(^{-1}\) concentrations of Cd\(^{2+}\) and Pb\(^{2+}\) solutions. Plants were observed for their morphological changes for one month. The efficiency of Photosystem II was measured at seven-day intervals using a fluorometer. Plants were uprooted to observe anatomical changes and to measure wet and dry masses and heavy metal content using Atomic Absorption Spectrometer. The photosynthesis efficiency of the plants was significantly reduced by Cd\(^{2+}\). Significant growth retardation was caused by both Cd\(^{2+}\) and Pb\(^{2+}\) when they were abundant in the habitat. 11.5, 34.1, 49.5, 52.4 and 67.0 mg/kg of Cd\(^{2+}\) and 4.2, 8.2, 7.4, 9.3 and 13.8 mg kg\(^{-1}\) of Pb\(^{2+}\) were accumulated in plants treated with 2, 5, 10, 20 and 50 mg L\(^{-1}\) of Cd\(^{2+}\) and Pb\(^{2+}\) concentrations, respectively. Any Cd\(^{2+}\) or Pb\(^{2+}\) were not detected in the control plants. Further, *B. monnieri* had higher Cd\(^{2+}\) accumulation potential compared to Pb\(^{2+}\) accumulation potential. Only little morpho-anatomical changes were observed in plants that were grown in contaminated water. Thus, *B. monnieri* is suitable to use in phytoremediation of heavy metal contaminated wastewater because of its adaptive potential to grow in heavy metal-rich environments. However, the use of this aquatic plant for medicinal preparation could lead to a health hazard.

**Keywords:** *B. monnieri*, Heavy metal, Phytoremediation, Wastewater
Study of the Olfactory Communication Signals in Sambar Deer (*Rusa unicolor unicolor*) at the Horton Plains National Park of Sri Lanka

Danushka S. Weerasekera*, S. Samarasekara Thadhani¹, N.U. Jayawardana², Sandun J. Perera³ and K.B. Ranawana⁴
danushw2@gmail.com

¹Postgraduate Institute of Science, University of Peradeniya, Sri Lanka
²Department of Agriculture Biology, Faculty of Agriculture, University of Peradeniya, Sri Lanka
³Department of Natural Resources, Faculty of Applied Sciences, Sabaragamuwa University, Belihuloya, Sri Lanka
⁴Department of Zoology, Faculty of Science, University of Peradeniya, Sri Lanka

Olfactory glands produce scents that are used for communication by sambar deer. The olfactory communication signals of 10 randomly selected adult sambar deer (5 stags and 5 hinds) were studied over a period of 5 months from May to September 2018. The focal animals were observed continuously for two hours in the morning (0630-0900 hrs), or evening (1600-1800 hrs) at the Horton Plains National Park (HPNP) in montane Sri Lanka. Identification of the olfactory glands and the different occasions of their use is helpful in understanding sambar behavior and this knowledge can be important in sambar deer management, when visual or auditory cues are difficult to use. An individual sambar was followed for two hours during observations and the number of times different olfactory glands were used was recorded, this was followed by data analysis using the mean frequency per hour ± standard deviation. It was observed that both sexes of this species of deer depend considerably on olfactory cues during various social interactions. The tendency to snit the marked sites was more frequent among stags than among hinds. Both the stags and hinds used their back-leg hooves to rub their preorbital glands, forehead and ear pinnae. Rubbing the forehead against objects for olfactory signaling was observed only with stags. Thumping was observed in sambar deer for scent marking by pedal glands. Frequency of olfactory signaling by preorbital glands was 0.23 ± 0.02 times per hour for an individual stag while it was 0.05 ± 0.01 times per hour for a hind. The frequency of olfactory marking by forehead rubbing against objects was 0.22 ± 0.02 times per hour and the rubbing of forehead with back leg hooves was 0.11 ± 0.02 times per hour in stags, while it was interesting to note both these modes of olfactory marking was not observed among the sambar hinds in HPNP. The average frequency of olfactory signaling by pedal gland thumbing were 0.06 ± 0.01 times per hour in stags and 0.04 ± 0.01 times per hour in hinds.

Keywords: Horton Plains National Park, Olfactory signals, Scent marking, Sambar deer
An Assessment on Difficulties Faced by Farmers of the Matara District in Paddy Cultivation due to Flooding

J.K.A.S. Srimali
kankanamsamu@gmail.com
University of Ruhuna, Sri Lanka

Paddy is the second largest cereal produced in the world and nearly 90% of the world’s rice is produced and consumed in Asian countries. The research is focused on identifying the impact of flood risk in paddy cultivation of Wellethota and Katuwangoda GN Divisions in the Matara District of Sri Lanka. Another objective of this research is to identify the Physical Problems and socio–Economic problems faced by Paddy farmers: e.g., Non-seasonal rains, Monsoon delays, Floods, and Failure to sow because of Flood in the particular season, destroying the harvest destroyed by flood, migration among youth and farmers to other sectors, increasing the cost of labours etc. A mixed methodology consists of primary and secondary data collection has been used in this study. Within the primary facts, data was collected by interviews, questionnaire and field inspection. Secondary data used in this research were acquired from the Gowijanasewa office and the Gowiniyamaka. The prepared questionnaire was given to 30 framers in the study area. Quality and quantity methods were used to analyze these facts along with methods such as charts and graphs. Farmers’ knowledge about the paddy cultivation were entered into the GIS system. According to the findings, most of the paddy field in study area were at risk of flood. As a result of that farmers faced physical and socio-economic problems. Some farmers followed mitigation option to reduce flood (Introducing pumping water system, introducing flood warning systems). Also, the study has resulted, the most farmers in Pahala Baduluwel yaya, used “maavee” seed as an Adaptation method. The study revealed that all the paddy fields in the Wellethota and Katuwangoda GN Divisions were at risk of floods.

Keywords: Flood, Paddy cultivation, Socio-economic, Mitigation
Remotely Controlling and Maintaining Membrane Water Treatment Plants using a Smart Phone Application

Zhiguo Wu¹,²,³, A.C.A. Jayasundera¹, Ming Zhu⁴, Yu Huang⁵, Xing Chen⁶, and Rohan Weerasooriya³,⁶*

*rohanw@pdn.ac.lk

¹ Department of Chemistry, University of Peradeniya, Sri Lanka
² Wuhan Newfiber Optoelectronics Co., LTD, Wuhan 430074, Hubei, P.R. China,
³ National Institute of Fundamental Studies, Kandy20000, Sri Lanka
⁴ School of Electronic Information and Communication, Huazhong University of Science and Technology, Wuhan 430074, Hubei, P.R. China
⁵ Chongqing Institute of Green and Intelligent Technology, Chinese Academy of Sciences, Chongqing 400714, P.R. China
⁶ Industry and Equipment Technology Institute, Hefei University of Technology, Hefei 230009, Anhui, P.R. China

To solve acute water stress in the dry zone of Sri Lanka, we developed an intelligent mobile application (commonly known as “NRC-WNO app”) to demonstrate the control of a membrane treatment plant, remotely. Using our new technology, a water professional can address services and routine maintenance of the treatment plant remotely without community intervention. The routine maintenance includes backwashing of sand and activated carbon filters, membrane cleaning and conditioning, emergency shutdown, and technical error detection required for on-site repairing. Our device can be used to control the unit processes (i.e. activated carbon, sand, reverse osmosis, and nanomembranes) independently. The different water quality data can be received on mobile phones, and the whole plant can be operated via wireless technology. A high-precision monitoring sensors of water quality are installed at different stages via the NRC-WNO app. The remote-control unit was built on the Java platform, and the mobile app was developed by using OOC language. The NRC-WNO app is currently operational as a demonstration at the laboratory scale plant. Scaling up of the control technology to a community-level membrane treatment plant is currently in progress.

(National Research Council, Sri Lanka (NRC Grant No. To-16-015) is gratefully acknowledged for awarding a research grant).

Keywords: Water purifier, Real-time monitoring, Intelligent control, NRC-WNO app
Impact of Climate Change and Irrigation Water Management Strategies of the Dry Zone Paddy Cultivation of Sri Lanka: A Case Study in the Ampara Uhana Divisional Secretariat

R.M.S.M. Rathnayaka
shanurathnayak42@gmail.com
Department of Geography, university of Ruhuna, Sri Lanka

Climate change and water management are inextricably linked. Climate is changing world – wide. Climate change is expected to influence rainfall. This research is focused on impact of climate change and irrigation water management strategies in the dry zone paddy cultivation. The dry zone is highly vulnerable to diminishing precipitation and drought season. Dry zone paddy cultivation is mainly based on the irrigation-based complex water management system. The Ampara district contributes significantly to the national paddy production. However, paddy cultivation is vulnerable to drought season and diminishing precipitation in the study area. This study has been carried out with the focus on impacts of climate change and water management strategies by paying attention to the village of Himidurawa under the Himidurawa Great irrigation and the Mahakandiya village under the minor irrigation (Pansalagala) of the Uhana Divisional Secretariat in the Ampara district. The research followed the embedded design in the mixed method research approach. Data were collected through secondary data and primary data. Secondary data were collected through books, internet, research papers and articles. Primary data were collected through three structured interviews, group interviews, field observation and sample of 10% of the farming families in the study areas were selected. Collected data have been analyzed and presented under detailed analysis. Farmers mainly use ‘Mura’ method under the Himidurawa irrigation. Limited water storage and water distribution strategies have been adopted for the systematic distribution of water due to inadequate rainfall caused by climate change in study area. Water management strategies in great and minor irrigation can be identified as changing and are related to climate change.

Keywords: Water, Water management, Farmer, Irrigation, Climate change
Modeling and Evaluation of Salinity Changes in the Matara Coastal Area

C.J. Hettiarachchi 1*, M.P. Gunawardena2 and G.P.T.S. Hemakumara3
1*chandulajanithhettiarachchi@gmail.com
1 Nature Beyond the Horizon -The Environment Society of Horizon Campus, Malabe, Sri Lanka
2 Department of Biotechnology, Faculty of Science, Horizon Campus, Malabe, Sri Lanka
3 Department of Geography, Faculty of Humanities and Social Sciences, University of Ruhuna, Matara, Sri Lanka

The demand and use of water resources is rapidly increasing while the quality of water is deteriorating. Urban groundwater has emerged as one of the world’s most challenging problems at present. More importantly the quality of available groundwater near the coastal areas have degraded enormously as a result of increasing levels of salinity. Therefore a study was conducted to assess the salt water intrusion in the coastal area of Matara. The salinity of ground water in wells of the Matara district’s coastal area was investigated in terms of chloride ion concentration of samples collected from 36 different sites. Twelve sampling sites were located at three distance ranges 80-100 m, 300-600 m and 800-1200 m from the mean sea level. The water samples were subjected to chlorine titration and the chloride ion concentration of the samples was used to calculate the salinity of the water. GPS locations were taken at the sampling sites to prepare the salinity variation map in the study by using ArcGIS commercial software. The lowest salinity was observed from the Talalla - Kottegoda (0.039 ppt) area and highest salinity was observed from the Polhena - Thotamuna (0.249 ppt) area. The average salinity of the coastal area of Matara was 0.130 ppt. According to the interpolated map of salinity variation the salinity values at the sampling points do not demonstrate a distinctive relationship to soil type or to water bodies. The salinity reduces when moving from the coastal area to the inland area. The elevation of the area, height from the sea level, anthropogenic activities, presences of aquifers near sampling sites, vegetation and population of the area were the major factors which affect the changes in salinity of the Matara district’s coastal area. Therefore the study must be continued for several years representing all the seasons of the year to find the complex relationship between other factors and the salinity of the coastal area of Matara.

Keywords: ArcGIS, Groundwater quality, Salinity
Kinetics of Fluoride Adsorption onto Natural Crystalline Apatite: A Laboratory Simulated Study

*Dilki Ekanayake and Rohana Chandrajith  
dilkiemn@gmail.com  
Department of Geology, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka

Groundwater is the prime source of drinking water for many communities in the tropical equatorial region. However, in some regions the groundwater contains fluoride concentrations above the permissible level, causing numerous health issues. Hence, introducing an economically viable and easy-to-use sorbent for the removal of fluoride from drinking water at the household level, particularly for rural communities, is extremely important. Numerous methods have been introduced to defluoridate drinking water of which adsorption is the most commonly used and the most economical technique. However, looking for an effective and low-cost sorbent that can be used easily is a challenge. In this study, natural apatite crystals, which are available in large quantities in Eppawala located in North Central province of Sri Lanka was tested as an absorbent material to remove fluoride. The adsorption of fluoride as a function of pH, adsorbent dose, initial fluoride concentration and contact time were investigated under laboratory conditions. The results showed that rapid adsorption of fluoride occurred within 10 minutes of the contact time. The highest adsorption percentage was recorded at the neutral pH (i.e., 7) condition. It was also noted that 1.0 g/L apatite powder indicated the optimum absorption of fluoride from the aqueous media. The optimal removal percentage of 84% was achieved under the optimized condition. Materials were characterized by X-ray diffraction, Fourier Transform Infrared (FTIR) and surface titration techniques. The FTIR data suggested that fluoride adsorption occurred due to the exchange of the OH group with \( \text{F}^- \) ions. The adsorption equilibrium is well fitted with the Langmuir models and followed the pseudo-second order kinetic model. The study revealed that apatite crystals from Eppawala can be used effectively to remove excess fluoride in groundwater into a desirable level.

Keywords: Adsorption, Fluoride, Defluoridation, Natural apatite, Eppawala
Effect of Counter Ions on Removal of Cr (III) in Wastewater using Phytoremediation

E.M.A.S. Ekanayake1*, C.V. Hettiarachchi1 and H.M.S.P. Madawala2

*anusandaren93@gmail.com
1 Department of Chemistry, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka
2 Department of Botany, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka

Wastewater is a mixture of cations, anions and various other organic compounds. Interactions among them can affect the removal of cations using aquatic plants. The present study was aimed at investigating the effects of different associated counter ions such as acetates, nitrates, fluorides and chlorides on phytoremediation potential of Cr (III) using two macrophytes, *Eichhornia crassipes* and *Pistia stratiotes*. Besides identify the most effective anionic species which can support the Cr (III) removal process efficiently.

Two young plants of equal size from each species were grown in plastic basins for 10 days. Each basin contained 3 L of 10 mg L⁻¹ Cr(III) salt solutions prepared with Cr(CH₃COO)₃, Cr(NO₃)₃, CrCl₃ and CrF₃ salts and initial counter ion concentrations were 26, 35, 18 and 10 mg L⁻¹, respectively. Solutions were collected from each container on 1st, 2nd, 5th and 10th day for analysis of Cr (III) and chlorides, fluorides, nitrates concentrations using Atomic Absorption Spectrophotometer and suppressed ion chromatography, respectively. Each experiment was triplicated. On 10th day, the average Cr (III) removal by *Eichhornia crassipes* in presence of acetates, nitrates, chlorides and fluorides were 0.73, 0.56, 0.67 and 0.42 mg g⁻¹, respectively with the above mentioned anion concentrations, respectively. For *P. stratiotes*, in presence of above anions were 3.15, 2.28, 3.03 and 0.33 mg g⁻¹, respectively. The anion concentration of all were increased to 35 mg L⁻¹, which was similar to the initial concentration of nitrates, while keeping Cr(III) concentration at 10 mg L⁻¹. Under these conditions, the average Cr (III) removals were obtained as 0.83, 0.71 and 0.55 mg g⁻¹ for *E. crassipes* in presence of acetates, chlorides and fluorides, respectively. They were 3.56, 0.88 and 1.07 mg g⁻¹, respectively for *P. stratiotes*. Thus, acetate is the most supportive counter ion in removing Cr (III) effectively using both macrophytes. Results indicate that Cr (III) removal is influenced by the type and the concentration of the associated anion in the solution. This information could be used to enhance the efficiency of Cr (III) removal in wastewater treatment plants using macrophytes.

(University Research Grant No. URG/2017/51/S is gratefully acknowledged for providing funds to carry out this study).

Keywords: Phytoremediation, Counter ions, *Eichhornia crassipes*, Wastewater, *Pistia stratiotes*
A Hybrid Mobile Ad-hoc Wireless Sensor Network: An Automatic Water Pollution Detection System

S. Mathitheepan¹* and M. Kukapalini²
*mathitheepan@gmail.com
¹ Postgraduate Institute of Science, University of Peradeniya, Sri Lanka
² Lansing Community College, USA

Water pollution in Sri Lanka is identified as a serious issue that must be solved urgently to avoid the effects of polluted water. We need a robust and rapid scheme to solve this issue, even though several useful ways and solutions are taking a major role to identify pollution levels. The sample-collection based monitoring water quality involves a significant amount of human resources and is a time-consuming process. This ineffective scenario can be resolved by utilizing the existing tools and technologies to detect water pollution and provide a rapid alarm. Our research study suggests a hybrid mobile ad-hoc wireless sensor network (WSN) to monitor water quality. The tree based WSN can be established on the water body with sensor vertices that can detect relevant physical and chemical parameters. This tree topology WSN system consists of sensor vertices in leaves, sub-base stations on the intermediate vertices and the main base-station on the top root vertex. The sensor vertex is a device that is normally equipped with sensing, processing and communication capabilities and is responsible for measuring the water quality parameters. The sub-base stations are responsible for capturing and providing access to all measurement data from the sensor vertices to transfer the main station that connects to the ad-hoc mobile network. A mobile app designed to connect our system receives the alert by the automatic alarm system and shows the fluctuation as a graphical model. The mobile application creates a self-awareness to protect the people with themselves from water pollution issues. Since the model enables early warning capability to ensure timely response to water contamination, the WSN system leveraged to the mobile application is a prominent model for water pollution detection. Additionally, these networks require relatively low start-up and maintenance costs and hence show great potential for numerous monitoring applications.

Keywords: Hybrid structure, Mobile application, Wireless sensor network, Water pollution, Auto detection system, Mobile ad-hoc
Theme 3 - Technologies in Pollution Control and Resource Recovery
evaluation of tertiary treatment of sanitary landfill leachate using subsurface horizontal flow constructed wetland

M.W. Jayaweera and J.S.S. Devi*
*devjeg@gmail.com
Department of Civil Engineering, University of Moratuwa, Sri Lanka

The varying nature of the typical characteristics of landfill leachate requires a two-stage leachate treatment system with a constructed wetland at the final stage has been identified to make its treatment successful. In the Sri Lankan context, many studies on constructed wetlands and leachate treatment have been carried out. However, further investigations on the potential of both locally available native plants and low-cost sorbent materials in the treatment of landfill leachate are considered beneficial. Therefore, this pilot scale study was conducted at the sanitary landfill, Dompe, Sri Lanka, to evaluate the performance of a Subsurface Horizontal Flow (SSHF) constructed wetland for tertiary treatment of landfill leachate. A continuous flow wetland unit was constructed (length-1.5 m, depth- 0.71 m, and width- 4 m, where width was sectioned into 20 connected columns with an average width of 13 cm) in a manner that the influent flows in a zigzag way to utilize the space efficiently as well as function as a subsurface horizontal flow constructed wetland. The gravel medium was used in the inlet and outlet zones; the rest of the constructed wetland bed was filled with 25-50 mm Calicut tiles media and planted with 20 young plants of Phragmites karka. The study period was from June to August 2017. The study was conducted in two phases: Acclimatization phase and Operation phase. At the operation phase, sixty liters of diluted pre-treated leachate (i.e., containing 80% of the pre-treated leachate (effluent of the sequencing batch reactor by volume) was fed per day. Influent and effluent samples were collected once in 3 days and the removal efficiencies of BOD$_5$, COD, TSS, NO$_3$-N and PO$_4^{3-}$-P were evaluated. Concentration based mean removal efficiencies of this constructed wetland during the operation phase was 63% for BOD$_5$, 62% for COD, 96% for TSS, 49.11% for NO$_3$-N and 85.28% for PO$_4^{3-}$-P showing a significant reduction of mean concentration of the tested parameters in the outlet compared to the inlet of the system. The results predicted that this SSHF constructed wetland system can be utilized for the tertiary treatment of BOD$_5$, COD, TSS, NO$_3$-N and PO$_4^{3-}$-P in landfill leachate.

(Central Environmental Authority is gratefully acknowledged for awarding a partial research grant).

Keywords: Landfill leachate, Subsurface Horizontal Flow, Phragmites karka, Calicut tile
Utilization of Clay based Construction and Demolition Waste: Effective Removal of Pb (II) by Used-rooftiles

Chamindu Gunarathne and Nadeesha H. Koralegedara*

Department of Geology, University of Peradeniya, Peradeniya, Sri Lanka

Management of construction and demolition waste is a growing problem in Sri Lanka because of the increasing rate of urbanization. A significant amount of construction and demolition waste such as used rooftiles, bricks and ceramics manufactured using clay materials are being accumulated at dumpsites every day. The clay minerals are well known to be good adsorbents of heavy metals. We expect to utilize these waste materials in water purification. Hence, the aim of this is to study the applicability and efficiency of used-rooftiles to treat Pb contaminated aqueous media. Factory fresh roof tiles and their raw materials were collected from three main rooftile manufacturing plants in Dankotuwa and Mahiyanganaya, Sri Lanka. Used rooftiles made by the same factories were collected from households. First, all the materials were characterized for chemical composition (X-Ray Fluorescence spectrometry and Inductively Coupled Plasma-Mass Spectrometry (ICP-MS)), morphology (Scanning Electron Microscopy) and mineralogy (X-Ray Diffractometry). Lead removal efficiency of the powdered-materials was tested using Pb solutions of known concentrations. Both adsorption and desorption experiments were carried out as batch tests for total 48 hours of contact time. Samples were collected at different time intervals (2, 4, 6, 8, 12, 24 and 48 hours) for ICP-MS analysis. The results showed that more than 90% of Pb removal was achieved by raw clays, fresh-rooftiles and used-rooftiles within 6-8 hours of contact time at 10 mL/g liquid/solid ratio. More than 95% of the up taken Pb is retained in the rooftiles in an agitated condition even after 48 hours of contact time. Kaolinite and Montmorillonite were the main types of clays present in the rooftiles. Fourier-transform Infrared analysis suggested the Pb adsorption to the Si-O bond of tetrahedral layer of Kaolinite and to both inter and intralayer -OH of Kaolinite and Montmorillonite. Hence, the used rooftiles can be employed to treat Pb contaminated water effectively.

(Financial support by University of Peradeniya Research grant (URG/2018/42/S) is gratefully acknowledged).

Keywords: Used-rooftiles, Lead adsorption, Water purification, Kaolinite, Montmorillonite
A Review of the Importance of Soil Microorganisms for Bioremediation of Pesticides

*chameenrandika@gmail.com
1Faculty of Graduate Studies, Sabaragamuwa University of Sri Lanka, Sri Lanka
2Faculty of Technology, Sabaragamuwa University of Sri Lanka, Sri Lanka
3Faculty of Applied Sciences, Sabaragamuwa University of Sri Lanka, Sri Lanka
4Faculty of Agricultural Sciences, Sabaragamuwa University of Sri Lanka, Sri Lanka

Pest control is of utmost importance in agriculture to maximize the harvest and thereby the profit. However, the indiscriminate usage of pesticides has threatened the environment and the humans by accumulating pesticide residues in the natural ecosystem. Hence, it is timely to find ways of mitigating this ill effect caused by pesticides. In this scenario, bioremediation using microbes has taken global attention as microbes are known to play a major role in biodegrading the pesticide residues. This review critically evaluates the pesticide biodegradation by different soil microorganisms, thereby unraveling the research gaps in this area. More than 40 literature findings showed the presence of 17 bacterial genera with the ability of degrading various pesticides: they are Flavobacterium, Sphingobium, Sphingomonas, Agrobacterium, Pseudomonas, Serratia, Enterobacter, Burkholderia, Novosphingobium, Rhodococcus, Bacillus, Stenotrophomonas, Acinetobacter, Klebsiella, Arthrobacter, Lysobacter, Stenotrophomonas) and 09 fungal (Phanerochaete, Trametes, Pleurotus, Aspergillus, Ganoderma, Trichosporon, Verticillium, and Trichoderma, Acremonium). Among these microbes, some bacteria and fungi have shown selective degrading ability towards the major classes of pesticides such as organophosphates, carbamates, organochlorines and pyrethroids. There is a potential of using above microbes in bioremediation of Profenofos, Quinalphos, Chlorpyrifos, Diazinon, Chlorothalonil, Pyraclostrobin like pesticides belonging to these major classes and commonly used in Sri Lanka. However, other than the aptness of the organism, some other supportive factors seem to affect the bioremediation potential. This study reveals that different microbes isolated from different geographical area possess distinct abilities in degrading pesticides. Though the other countries carry out research on bioremediation of pesticides by different microbes, there are hardly any reports in Sri Lanka. Because Sri Lanka is a country that has a heavy usage of pesticides, it must investigate the use of bioremediation of pesticides by different microbes to protect humans and the environment.

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Keywords: Bioremediation, Pesticide residues, Soil microorganisms
Current Waste Management Practices in the Matale Municipal Area and Problems Faced by the General Public

A.M.P.E.K. Atapattu* and U. Edirisinghe
*prabashia@yahoo.com
Post Graduate Institute of Science, University of Peradeniya, Peradeniya 20400, Sri Lanka

Open dumping is the common waste disposal method used within the Municipality of Matale. Moreover, 17 tons of wastes are daily disposed at the open dumping site in Wariyapolawatta. The overall objective of this study was to identify the problems in collection, recycling and dumping of municipal solid waste. A garbage dump of area 400 m² and 1,000 m long polluted tributary of the Suduganga were identified as the study sites. Twenty-five settlers residing in the study area were randomly selected for the questionnaire survey. Data were collected from May 2017 to present from the Municipal Council and Integrated Resource Recovery Centre (IRRC), Matale. Observations revealed that the underprivileged community around the study area discharged waste water into the stream and disposed degradable waste, which has even affected the soil quality. Waste water from the residents and animal faeces increased the nutrient content, which lead to increased turbidity in water. Workers in and around dumpsite have suffered from respiratory problems because of bad odor. IRRC collected recyclable wastes into separate containers. Organic wastes were stored in ventilated boxes at 55-60 °C to produce compost. The main weaknesses in IRRC project was that they did not collect polythene because of economic issues and the total space of compost plant was insufficient to treat the daily collection of degradable wastes. Different colours of waste dumping bins had been distributed among the government institutions and the residents, which led to direct involvement of people for the separation of solid wastes and compost production to some extent. In order to make this a sustainable project a co-management should be implemented incorporating the underprivileged community around the study area, which would finally up-lift their economy as well.

Keywords: Matale, Municipal area, Waste management practices, Open dumping site
Polycyclic aromatic hydrocarbons (PAHs) are a group of chemicals found in crude oil. Phytoremediation is the use of plants to absorb and remove pollutants from crude oil spill sites has emerged as a cheap and eco-friendly alternative to chemical remediation. We hypothesized that *Eichhornia crassipes*, a free-floating aquatic plant known as water hyacinth, may absorb PAHs. The main objective of this study was to investigate if *E. crassipes* absorbs carcinogenic naphthalene, fluoranthene, phenanthrene, and anthracene PAHs, using high performance liquid chromatography.

*E. crassipes* plants were collected from oil spill sites located at the Kittampahuwa canal near Orugodawatta oil installation. Plants collected from uncontaminated fresh water were used as a control to evaluate background PAHs level. Some control plants were grown in 12.5% crude oil mixed water for 7 days to evaluate PAHs uptake. Plant roots were separated, cleaned, and freeze dried. PAHs were extracted using 1:1 dichloromethane: acetone mixture with sonication. Extracts were further purified using silica columns and evaporated by a gentle nitrogen flow. Reversed-phase C-18 column was used for PAHs separation with acetonitrile: water mobile phase.

According to the results, plants collected from oil spill site recorded 0.041 ± 0.005 mg naphthalene per kg plant dry weight (p < 0.0001), while plants grown in 12.5% crude oil mixed water had absorbed 0.055 ± 0.003 mg/kg of naphthalene (p < 0.0001). Moreover, 7.7 and 11.4-fold increase in fluoranthene was observed in oil spill site plants and the plants grown in 12.5% crude oil-containing water, respectively. Significant increase in phenanthrene (p < 0.0001) and anthracene (p < 0.05) uptake was observed in plants grown in 12.5% crude oil mixed water. We concluded that *E. crassipes* plant can absorb naphthalene, fluoranthene, phenanthrene, and anthracene PAHs. Further research is needed to characterize phytoremediation ability of *E. crassipes* to cleanup PAHs from crude oil contaminated water.

**Keywords:** PAHs, Phytoremediation, Water hyacinth, High Performance Liquid Chromatography
The Effective Mechanism for Resources Recovering Through Environmental Technologies: Experience by the Sri Lankan Hotel Industry

W.M.U. Lakmali* and G.T.A.M.D. Karunarathna

*udaraweerasundara@gmail.com
Department of Environmental Management, Faculty of Social Sciences and Humanities, Rajarata University of Sri Lanka, Mihintale, Sri Lanka

To achieve the eco-friendly concept most of hotels in Sri Lanka actively commit towards environmental conservation through resource recovering. Resource Recovery is when energy, a material, or product which is taken from waste and then used. Today most of the hotel industries are over-consuming energy, water and materials that is why there is a need to recover the resources. The objective of the study was to analyze the effective methods for resource recovering through environmental technologies of hotel industry in Sri Lanka. To fulfill the objective both primary and secondary data were used. Primary data were collected by direct observation and interviews with managers. Nearly hundred luxury hotels with over 99 rooms were selected for the study. The secondary sources were data from books and internet related to the hotel industry. Results reveal that hotels mainly use sewage treatment plants to recover resources. Before disposing the waste water all the Sri Lankan hotels remove the contaminants through a scientific process and produce environmentally safe treated water. Sewage treatment mechanisms are largely based on computerized systems and only one or two employers have to search the system in action. As a by-product of STP is usually a semi solid waste or slurry used as fertilizer. Producing biogas is also a resource recovering method. The waste form washrooms and kitchen are used and it automatically fill into tanks. After the processing the hotels use it for electricity and heat generation. Composting (recycling of organic waste) is also a preferred solid waste mechanism, where kitchen waste and sewage are collected and then managed under conditions that help it to breakdown naturally. The compost is then used for their hotel gardens. Therefore, the study recommended for strengthening the resource recovery mechanisms and promote Sri Lankan hotel industry to practice environmental technologies effectively.

(The support from the managers and technicians of the selected hotels are greatly acknowledged).

Keywords: Resource recovery, Biogas, Waste, Organic waste, Mechanism
L - Cysteine Functionalized Silver Nanoparticles as a New Rapid Colorimetric Sensor For Cd$^{2+}$ and Ni$^{2+}$ Ions.

R.A.N.R. Jayasekara and A.C.A. Jayasundera*
*acaj@pdn.ac.lk
Department of Chemistry, University of Peradeniya, Peradeniya, Sri Lanka

Inappropriate agricultural practices caused many environmental catastrophes. Agrochemicals and industrial waste mainly cause increased levels of Cd$^{2+}$ ions in the water reservoirs. When cadmium enters the renal epithelial cells, it can cause toxicity in the kidney. An excess of nickel ions in an organism can lead to serious illness such as malignant tumors and dermatological diseases. The detection and quantification of heavy metals is based on spectrophotometric and potentiometric methods. However, the selectivity and sensitivity of the above methods towards individual elements becomes a real challenge. Therefore, metal nanoparticles can be used for sensing heavy metals in aqueous media because of their strong surface plasmon resonance property. Silver nanoparticles were prepared using chemical reduction method and the maximum absorption wavelength is obtained at approximately 415 nm. The prepared silver nanoparticles were functionalized by using L-cysteine molecules that attach to the surface of the silver nanoparticles through sulfur atoms that make the nanoparticles stable. The prepared L-cysteine functionalized silver nanoparticles tend to aggregate together upon addition of Cd$^{2+}$ or Ni$^{2+}$ ions because of the strong bond between Cd$^{2+}$ or Ni$^{2+}$ ions and –COOH, NH$_2$ of L-cysteine. The aggregation leads to a significant shift in the absorption spectrum with a concomitant visible color change from yellow to deep orange, which provides a simple and inexpensive means for the determination of Cd$^{2+}$ and Ni$^{2+}$ ions. The limit of detection of this L-cysteine functionalized silver-nanoparticle based detection system is 1 ppm for both Cd$^{2+}$ and Ni$^{2+}$ ions. At the optimized conditions, this detection system has no interference towards the Cd$^{2+}$ or Ni$^{2+}$ ions detection when 10% of Cd$^{2+}$ or Ni$^{2+}$ ions are present.

**Keywords:** Cadmium and Nickel detection, Nanoparticles, Functionalization, Aggregation, Interference
Removal of Heavy Metals (Cu, Pb, and Cd) in Synthetic Greywater using Water Hyacinth (*Erchhornia crassipes*), Pothos Plant (*Epipremnum aureum*) and Coconut Husk

W.M.A.M. Karunarathne1*, S. Wijetunga1, G.M.P.R. Weerakoon2 and M.I.M. Mowjood3

*achinikarunarathne1@gmail.com

1 Department of Agricultural Engineering, Faculty of Agriculture, University of Ruhuna, Mapalana, Kamburupitiya, Sri Lanka
2 Department of Civil Engineering, Faculty of Engineering, University of Peradeniya, Peradeniya, Sri Lanka
3 Department of Agricultural Engineering, Faculty of Agriculture, University of Peradeniya, Peradeniya, Sri Lanka

Uncontrolled discharge of greywater into the environment and surface water resources pollutes the environment with various pollutants including heavy metals (Cu, Pb, and Cd). Phytoremediation is a good option for the removal of heavy metals in greywater. This study was conducted to assess the removal of Cu, Pb and Cd in synthetic greywater using Water hyacinth (WH) and Pothos plant (PP) with Coconut husk (CH) system. It also aims to find the relationship between heavy metal removal rate with root length of WH and PP. The experiment was conducted under a protected house in vertical A-frame hydroponic system. The experiment was performed in two sessions (batch and continuous flow). Free floating, same maturity stage WH and 3-4 leaves with two nodal cuttings of PP were selected. Synthetic greywater with the initial concentrations of 12.5 mg L⁻¹, 1.2 mg L⁻¹ and 7.0 mg L⁻¹ for Cd, Pb and Cu, respectively were prepared with other required nutrients and applied at the rate of 0.02 L s⁻¹. Hydraulic retention time was 3 days for batch system and 2 days for continuous flow system. Water quality and plant growth parameters were measured for 25 days in batch system and 16 days in continuous system. Data were statistically analyzed using t-test and regression. In the batch experiment Cu removal rate was higher in PP (77.6±1.5%) than WH (67.5±2.0%). However, Pb and Cd removal rates were significantly higher in WH (62.7±2.4% and 29.9±1.6%). A significant positive relationship was observed in between ion removal rates and root lengths (P <0.05). In continuous flow system, Cu removal rate (54.0±3.6%) was significantly high in PP. However, Pb and Cd removal rates were significantly high in WH (41.7±4.2%, 11.5±2.1%). Further, it was revealed that significant relationship between Pb and Cd removal rates and root length (R²=0.74). The heavy metal removal rate of coconut husk in two systems (batch and continuous) were not significant. Based on the results of this study, it can be concluded that the water hyacinth with coconut husk-based hydroponic system can be used as a reliable treatment method for the removal of heavy metals in greywater.

**Keywords**: Greywater, Heavy metals, Phytoremediation, Pothos plant, Water Hyacinth
Perceived Noise Annoyance and Urban Green Spaces as Psychological Buffer: A Cross-Sectional Study in the Kandy Lake Area, Sri Lanka

S.K. Kulathunga¹, R.M.S.R. Chamara¹*, G.D. Kapila Kumara² and C.K. Beneragama¹

*ruwanchamara034@gmail.com

¹ Department of Crop Science, Faculty of Agriculture, University of Peradeniya, Peradeniya, Sri Lanka
² Department of Export Agriculture, Faculty of Agricultural Sciences, Sabaragamuwa University of Sri Lanka, Belihuloya, Sri Lanka

Noise pollution interferes with work performance, can cause hearing impairment, alters social behavior and causes annoyance. Annoyance is a major psychological impact arisen from noise, which is still growing environmental hazard though information is scant. Highly populated and congested city of Kandy, particularly around the lake, is considered to be one of the most noise-pollution affected cities in Sri Lanka, owing to its geographic setting. The present study was conducted to identify the perceived noise annoyance, effect of greenery as a psychological buffer, sources of noise and techniques to mitigate through greenery in the city limits of Kandy. A total of 416 respondents in Kandy lake area, either dwelling or travelling though, were interviewed face-to-face using a pre-tested structured questionnaire, of which, 376 respondents were with adequate dwelling information for accurate prediction of association between noise annoyance and greenery. The key questions were enclosed with perception of respondents on annoyance levels, presence of greenery, air pollution, dust, vibration and the knowledge about sound-absorbent trees. The questions were answered on a five-point response scale with verbal endpoints. In addition, the actual noise measurements were taken at several points. Results revealed that females are highly sensitive to sound annoyance than males. The peak annoyance period during the weekdays was between 12 noon to 3 p.m. at 68 dB noise level. School children, office workers, and permanent residents are most affected. Areas where the presence of vegetation such as large trees, the level of sound annoyance seemed less compared to the areas where they are absent. Some people believe surrounding plants are useful to reduce the noise annoyance. This study describes the current practices and some suggestions to mitigate noise pollution and related annoyance. The findings could help decide urban green settings as a psychological buffer in areas where residents are exposed to chronic noise pollution.

Keywords: Noise Pollution, Noise, Annoyance, Tree-belt, Greenery
Nitrogen Removal in Landfill Leachate using Hybrid Constructed Wetlands with Rice Straw as an External Carbon Source

J. Tharaniya, G.M.P.R. Weerakoon* and K.B.S.N. Jinadasa
*prabhaw@eng.pdn.ac.lk
Department of Civil Engineering, University of Peradeniya, Sri Lanka

Nitrogen removal in constructed wetlands (CWs) happens through various complex mechanisms, out of which nitrification and de-nitrification processes are the main pathways. In general, these processes can be enhanced by creating favourable environments for them. Thus, this research evaluated the removal of nitrogen from landfill leachate using hybrid CWs consisting a vertical subsurface flow (VSSF) wetland followed by a horizontal subsurface flow (HSSF) wetland. To facilitate the de-nitrification process in HSSF wetlands, rice straw was used as an external carbon source. The experimental system had four sets of hybrid wetland units with different volumetric ratios of rice straw (0% (control set up), 10%, 15% and 20%, respectively) in the HSSF wetland unit. The substrate used in this study was 15 – 30 mm gravel and the plant species used was umbrella palm (*cyperus alternifolius*). The synthetic leachate was prepared according to the composition given by Jamie et al., in 2004 and fed to the vertical systems at 28 cm$^3$/cm$^2$.d hydraulic loading rate (HLR). Samples were collected from the influent and effluents of each wetland system at one-week interval and tested for 5-day biochemical oxygen demand (BOD$_5$), Chemical oxygen demand (COD), total nitrogen (TN) and total organic carbon (TOC) concentrations. Results showed that the highest removal efficiencies of BOD$_5$, COD and TOC of 90%, 81% and 70%, respectively were obtained in the hybrid system with 10% rice straw while 20% rice straw system showed the highest TN removal of 80%. At 10% rice straw the TN removal efficiency was 75%. Accordingly, hybrid system with 10% rice straw showed best Nitrogen removal potency.

(NORAD – WaSo Asia Project is gratefully acknowledged for awarding this research grant).

Keywords: Hybrid constructed wetlands, Landfill leachate, Nitrogen removal, Rice straw, External carbon source
Comparison of Different Types of Vertical Subsurface Flow Constructed Wetland Arrangements for Heavy Metal Removal from Landfill Leachate

V. Rajkumar, T. Sainadaraj and G.M.P.R. Weerakoon*
*prabhaw@eng.pdn.ac.lk
Department of Civil Engineering, University of Peradeniya, Sri Lanka

Leachate is a fluid generated from solid waste landfills containing higher concentrations of pollutants including heavy metals, which can cause various adverse effects to human beings, animals and entire ecosystems when discharged to the environment without an appropriate treatment. Constructed wetlands (CWs) have successfully been used as a cost-effective technology to remove various types of pollutants. Out of many types, vertical sub-surface flow constructed wetlands (VSSF CWs) have exhibited an ability to remove an array of pollutants occupying relatively less land area. In this study, effects of broken bricks on removal of three different heavy metals, Zinc (Zn), Iron (Fe) and Copper (Cu) present in landfill leachate were evaluated using VSSF CWs. The Experimental setup comprised with four cylindrical shape VSSF CW units of size, 0.4 m x 0.45 m (diameter x height). Broken bricks and gravel were used as the substrate media. They were arranged with different gravel to broken bricks ratios: (i) 100% gravel, (ii) 75% gravel + 25% brick, (iii) 50% gravel + 50% brick and (iv) 25% gravel + 75% brick. Size of the gravel and broken bricks were from 10 – 20 mm and the selected plant species for the study was Cyperus alternifolius (umbrella palm). The wetland units were then batch-fed with synthetic leachate, at four-day hydraulic retention time (HRT). Influent and effluent samples were collected at four-day interval. pH, electrical conductivity (EC) and concentrations of Zn, Fe and Cu were analyzed using standard methods. Then removal performances of Zn, Fe and Cu, between different wetland arrangements were compared. Results showed that 25% gravel + 75% brick system has the best removal efficiencies of 98.23%, 98.63%, 98.82% for Fe, Zn and Cu, respectively, showing brick has a positive effect on heavy metal removal.

(Financial assistance by Norad-WaSo Asia Project of the University of Peradeniya is greatly acknowledged)

Keywords: Landfill leachate, Vertical subsurface flow constructed wetlands, Broken bricks, Heavy metals, Cyperus alternifolius
Technologies in Pollution Control and Resource Recovery: Minimizing the Water Pollution in the Kandy Lake using Natural Water Purification Technologies

H.M.Y.L.P. Herath and T. Rajapaksha*

*thathsarana05@gmail.com

1 Department of Environmental Management, Rajarata University of Sri Lanka, Sri Lanka
2 London Metropolitan University

The Kandy Lake, which was built in 1807, transforms the hill capital into a place of beauty and is a magnificent legacy that speaks of a bygone era and. This was a creation of the last king of Kandy, Sri Wickrama Rajasinghe (1798-1815). It collects water from all the mountains around the lake. Further, water from the entire drainage system is collected in the Kandy Lake. In earlier days, the water carried in the drainage system was not much polluted. Even the king, queens, Bikkus used this water for their day-to-day needs. However, the current situation is totally different. In 2009, a massive fish die-off was reported in the Kandy Lake. The maximum number of dead fish was as high as 150 fish per day. As per the literature gathered the researchers were able to identify that dissolved Oxygen, nutrients, heavy metals could have caused the die-off the fish. Observations were carried out as the primary research methodology while the secondary data were collected via the data available publicly on the internet and from the regional irrigation department. Natural water purification technologies can be implemented to the Kandy Lake environment to reduce the water pollution in the lake. Especially the Infiltration basins of Artificial Groundwater Recharge technology is an example. Natural purification effects within filter layers and in the subsurface are caused mainly by filtration, sedimentation, precipitation, oxidation-reduction, sorption-desorption, ion-exchange and biodegradation. Infiltration basins often have sizes ranging from 100 to 10,000 m. The thickness of the uppermost layer of filter sand ranges from 50 to 100 cm, and the grain size should be less than 3 mm. The water to be infiltrated passes over a cascade in order to enrich its oxygen content. Then it percolates the sand filter and the unsaturated zone and finally reaches the lake. The slopes of infiltration basins can be stabilized with concrete or designed in a natural mode. The quantitative efficiency of the filter sand layer is influenced by the permeability of the filter sand, the mode of rain fall, the growing up of algae, etc. Therefore, establishment of infiltration basins supporting all the main water streams to the lake would be supportive towards the natural water purification of the lake. Through this paper the researchers may assess the feasibility and discuss the importance of implementing these technologies for promoting resource recovery and pollution control relating them to the Water pollution which is taking place in the Kandy Lake.

Keywords: Water purification, Kandy Lake, Water pollution, Purification technologies
Effluent Treatment Efficiency Assessment of Rubber Glove Industry Using *Daphnia Magna* and *Allium Cepa* Bioassay and Physio-Chemical Analysis

K.A. Dilrangi* and M.P. Gunawardena
*dilrangi003@gmail.com
Faculty of Science, Horizon Campus, Malabe, Sri Lanka

Water pollution caused by industrial waste and toxicity assessment of industrial discharge is a major concern worldwide. Therefore, this study was conducted to assess toxicity levels of the effluent of the rubber glove industry at different stages of the effluent treatment process. The toxic effect of effluent was studied using two indicator species, *Daphnia magna* and *Allium cepa* along with water quality parameters. Seven stages of the wastewater treatment were selected to assess the toxicity and distilled water used as the control. In *Daphnia magna*, 24 hours and 48 hours acute immobilization test were conducted. The highest mortalities (100%) were observed at the equalization tank and chemical clarifier tank. In the aerobic tank and the final outlet, the mortality was 0%. In *Allium cepa* bioassay, the toxicity was determined by the inspection of root growth inhibition and the mitotic stage abnormalities. The root growth inhibition and mitotic abnormalities were found in the initial tanks of the treatment process. The highest root growth inhibition was in chemical clarifier tank. Nevertheless, when the effluent was treated, there was less root growth inhibition and mitotic abnormalities detected in the outlet tank. The initial and final of water quality parameters of pH were 6.6 and 7.0, temperatures were 32.5 °C and 33 °C, turbidities were 58.9 NTU and 1.7 NTU, conductivities were 1821 µs/cm and 132 µs/cm, BODs were 960 mg/L and 27 mg/L, CODs were 984 mg/L and 2 mg/L and TSSs were 50 mg/L and 15 mg/L, respectively. The initial tanks, which were less treated effluent have had affected the root germination of onions and the survival of daphnids; however, when the effluent was sent through primary and secondary treatments, it induced the germination of root in onions and also the survival of daphnids. This research illustrates the vital requirement of wastewater treatment and the efficiency of the wastewater treatment process.

**Keywords:** Toxicity, Effluent, *Daphnia magna*, *Allium cepa*, Wastewater
Cadmium Cd (II) and Lead Pb (II) Removal Behavior of Chemically Synthesized Vaterite Nanoparticles

D.D.T.T.D. Senarathna¹, K.H.D.N. Abeysooriya², W.M.H.K. Wijenayake¹ and R.M.G. Rajapakse³*

*rmgr@pdn.ac.lk

¹ Department of Aquaculture and Fisheries, Faculty of Livestock Fisheries and Nutrition, Wayamba University of Sri Lanka, Makadura, Gonawila, Sri Lanka
² Environmental Science Degree Programme, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka
³ Department of Chemistry, Faculty of Science, University of Peradeniya, Peradeniya, Sri Lanka

In the current scenario, water pollution caused by heavy metals such as cadmium and lead has become a serious problem throughout the world. The US EPA has established a maximum contaminant level of 0.005 mg/L for cadmium and 0.015 mg/L for lead in drinking water. Cd (II) and Pb (II) pose severe health problems, so they should be removed from drinking water. To achieve this, we developed a vaterite polymorph of porous calcium carbonate nanoparticles and used them to remove cadmium and lead ions in water. In this study, the vaterite polymorph of calcium carbonate nanoparticles were synthesized chemically using calcium acetate and sodium bicarbonate in a water-ethylene glycol soft-template medium at 100 °C in a reaction time of 24 h. Synthesized nanoparticles were characterized by the X-Ray Diffractometry and the Fourier Transform Infrared Spectroscopy, which show the presence of vaterite polymorph of CaCO₃. Average size of the synthesized particles was 25.5 nm when measured using Dynamic Light Scattering in solution. The Scanning Electron Microscopy coupled with Energy Dispersive X-Ray Analysis shows the spherical vaterite nanoparticles and the presence of only calcium, carbon and the oxygen, respectively. Furthermore, the cadmium and lead removal efficiencies of synthesized nanoparticles were tested with different initial concentrations, pH levels, adsorbent dosages, and contact times. Atomic Absorption Spectroscopy was used to analyze the metal concentrations in water samples. The maximum cadmium and lead removal percentage of 100% was obtained with 30 min of contact time, 50 mL of 45 mg/L cadmium and lead solutions with 0.15 g and 0.10 g of the particle dosages, respectively. It was found that both cadmium and lead adsorptions by synthesized vaterite nanoparticles are less sensitive to pH variations. According to the optimization results, the study presents a viable option for removing cadmium and lead in water to avoid its harmful effects on the environment. The kinetic study, Isotherms study, competitor ions effect study and reusability study will be continued in the future.

Keywords: Adsorption, Cadmium, Lead, Vaterite, Nanoparticles
Removal of Excess Phosphate Ions in Water using 1-D Magnesium Oxide Nanowires

K.M. Indeewari*, K.H.D.N. Abeysooriya and R.M.G. Rajapakse
*malshaindeewari@gmail.com
Department of Chemistry, University of Peradeniya, Peradeniya, Sri Lanka

In the recent few decades, the rate of phosphorous cycling has been increased because of rapid development in agriculture and industries causing more wastewater generation. When untreated wastewater containing phosphate is discharged into water bodies such as lakes and tanks it can cause eutrophication, which leads to harmful effects on the ecosystem and human health. Hence, phosphate removal is important in the control of eutrophication. Adsorption is one of the effective and economical methods for the removal of phosphates. This study focuses on a simple, low-cost and a novel approach towards the removal of excess phosphate ions from aqueous solution by adsorbing on to one dimensional (1D) Magnesium Oxide Nanowires (MONWs). The nanowires were synthesized via hydrothermal method using urea and magnesium acetate at 180 °C for 2 h. The synthesized MONWs were characterized using X-ray diffraction, Fourier transform infrared spectroscopy, particle size analyzer and scanning electron microscopy. Additionally, the phosphate removal efficiency was studied using ion chromatography technique. The optimum removal percentage (99.5%) was obtained with 50 ml of 3 mg L⁻¹ phosphate solution and 0.075 g of synthesized MONWs. Phosphate adsorption is found to be less sensitive to the pH variations. Moreover, adsorption data were fitted with Freundlich isotherm with an R² value of 0.952. Adsorption kinetic data were fitted to the pseudo second-order model and yield an R² value of 0.995 suggesting that the adsorption process is chemisorption. Furthermore, phosphate removal efficiency influenced by the presence of competitor ions. This study found that MONWs have a potential application for wastewater treatment.

Keywords: Adsorption, Magnesium oxide nanowires, Phosphate, Removal
Comparison of Environmental Technological Practices on Pollution Abatement of Hotels in Kandy, Sri Lanka

G.T.A.M.D. Karunarathna* and W.M.U. Lakmali
*dinushikakarunarathna96@gmail.com
Department of Environmental Management, Faculty of Social Sciences and Humanities, Rajarata University of Sri Lanka, Mihintale, Sri Lanka

The environmental pollution caused by the hotel industry significantly impacts humans and nature. Environmental technology aims to protect the environment through offering ways to lower the pollution in a sustainable manner and provide new ways to avoid depletion of natural resources. This study aims to compare how hotels in Kandy district abate the environmental pollution with and without environmental technologies. Both primary and secondary data were used to fulfill the objectives of this study. Primary data were mainly collected through key informants discussions with chief engineers of hotels and questionnaire-based survey conducted on employees of hotels. Secondary data were collected from Municipal Council in Kandy, books and internet related to the hotel industry. The study found that the use of environmental technology reduces the risk of harm to the environment and society. Sewage Treatment Plant (STP), Solid Waste Treatment, Solar Energy Production and Biogas Production can be taken as the methods that hotel industry uses. They remove the contaminants through STP system before disposing waste water. The purified water is being used on hotel gardens. By using solar energy, they generate the energy needed for their hotels. Kitchen waste and sewage use to produce biogas for lighting purposes and generating heat. These systems have huge advantages such as attraction of tourists to revisit destinations, Eco-friendly certifications, increased stand of their hotels, cost reduction for waste disposal etc. However, hotels without environmental technological practices do not have the advantages mentioned above. The majority of hotels in Kandy use traditional methods to deliver waste to the urban council instead of using environmental technologies. This incur additional costs daily. This is mainly because of the lack of awareness about environmental technological practices, reluctance to get away from the traditionalism and there is no need to use such a methodology to protect environment. Therefore, the study recommended that technologies are a great value in preventing pollution.

(The support given by the chief engineers of the hotels, Municipal Council members in Kandy and Central Environmental Authority officers in Polgolla is greatly acknowledged.)

Keywords: Environmental technology, STP (Sewage Treatment Plant), Natural resources, Solar power, Abetment
An Assessment of Current Air Pollution Monitoring Processes in Sri Lanka

T.P. Weerakoan¹ and M.T.C. Perera²*

*mtcperera@yahoo.com

¹ University of Colombo, Sri Lanka
² University of Sri Jayewardenepura, Sri Lanka

Amidst increased emphasis on limiting air pollution around the world, in Sri Lanka many discussions have taken place, but implementation of practical measures of air pollution monitoring is rare. Thus, the objective of this study is to study the current air pollution monitoring and control procedures in Sri Lanka. This may contribute to adverse weather conditions and diseases. Even the medical researchers have pointed out that health impacts of air pollution in Sri Lanka have been underestimated. In order to achieve this objective, this study was carried out primarily as a critical literature review. Through this study researchers will learn that there are only a handful of places where air quality is measured in the country. There are numerous air pollution monitoring processes that were implemented recently, but the air quality level in major industrial cities have increased and it is on rise in rural areas as well. Currently Sri Lankan air pollution monitoring process is carried out mainly by means of human resources which has not been effective so far. Even with the current human-centric monitoring processes where the incurred cost is very high the air pollution levels are on the rise. On top of that, apart from vehicular emission other sources of air pollution are less monitored or not monitored at all. It is imperative to measure air pollution by factories, air travel, power generation, vehicular emissions as well as biomass burning using technology-based monitoring systems, which would reduce the cost of operations for relevant authorities. Researchers also recommend that, focusing on un-monitored air pollution activities such as biomass burning and waste burning as well. There should be alert systems in place to notify the authorities when the air pollution levels are breached from such activities.

Keywords: Air pollution, Emission, Monitoring processes, Sri Lanka
Construction Complications and Challenges in the Process of Installing Landfill Gas and Leachate Collection System to the Meethotamulla Solid Waste Dump Site Closure

W.K.N. Chandrasena* and H.D.S. Premasiri
*kasthurinalin@gmail.com
National Building Research Organisation, Sri Lanka

The Meethotamulla Municipal Solid Waste (MSW) dumpsite was one of the largest open dumping sites operated in Sri Lanka. As estimated in 2017, about one million ton of waste stock was collected at the site with an area of 78,000 m² up to the height of 45-50 m range. Because of the heavy load of waste dump on top of the thick peat layer, the waste dump collapsed in 2017 leading to the death of 32 people. As an immediate action taken by the Government of Sri Lanka, further dumping of MSW to the Meethotamulla dumpsite was terminated. Since the beginning of the dumpsite at Meethotamulla it has created a lot of environmental problems such as unmanaged gas emissions, odour problems and leachate contamination to surrounded water bodies. The Government of Sri Lanka decided to reclaim the site as an Urban Park. The Urban Development Authority (UDA) was assigned the responsibility of managing environmental and social hazards. The National Building Research Organization (NBRO) was designated as the consultant to the project. The reclamation and closure process considered all technical design works including slope stability, leachate management, landfill gas management, final cover material selection and the development of surrounding areas. The concepts used for the design and construction were based on results obtained by an experimental trial fill of 50x30m² compacted waste up to 5 m height. Recorded CH₄, CO, H₂S, VOC concentrations at gas wells were 10-30%, 19 ppm, 42 ppm, 16 ppm, respectively. The major challenges encountered during the implementation of the design were, installation of gas wells and leachate collection blankets without removing or replacing of waste from the site. As a systematic approach followed in the construction stage, site specific trench system and cut and fill methods with benching were practiced to install the gas wells and leachate blankets. Site specific testing methods have been developed for testing waste compaction, landfill gas content, efficiency of gas wells and leachate collection system. These smart approaches were facilitated to resolve construction complications and to cover the construction targets.

Keywords: Municipal solid waste, Construction complications, Landfill gas wells, Leachate collection blanket
Anaerobic Digestion of Municipal Solid Waste: A Review of Operational Issues

*thusharia@pdn.ac.lk
Department of Chemical and Process Engineering, Faculty of Engineering, University of Peradeniya, Sri Lanka

Anaerobic digestion of municipal solid waste (MSW) has two-fold advantages: a feasible solution for environmental pollution control and a source of low-cost energy. Nevertheless, it has not yet gained as much attention as aerobic digestion, mainly because of the high capital expenditure and difficulties in stabilizing the reactor operations. The aim of this study is to find out the operational issues especially behind solid waste anaerobic digestion. In comparison to liquid phase anaerobic digestion, solid waste anaerobic digestion requires a larger amount of inoculum and much longer retention time. Poor mixing of solid substrate in the bioreactor negatively impacts on mass and heat transfer, and thereby on reaction kinetics. The intermediate volatile fatty acid (VFA) accumulation is one of the major issues in solid waste digestion. The VFA accumulation occurs because of biochemical reactions of complex and heterogeneous molecules in the substrate. The substrate is a mixture of different molecules belonging to four main categories: carbohydrate, protein, lipids and cellulose. The VFA is formed at different rates as a result of the hydrolysis and acetogenesis of vastly different components in the substrate at different rates. The highly soluble substrate increases the VFA concentration rapidly, and as a result the pH is dropped suddenly to create an inhibitory environment for acetogenic and methanogenic reactions. Another serious problem with the substrate is the presence of organically bound nitrogen compounds. Inhibitory products such as ammonia, ammonium, nitrites and nitrate that enters the system during the metabolic activities of these compounds and make the process unstable. Particle size of the substrates too determines contact surface area of microbes and then the rate of reaction. Finally, it is concluded that though the municipal solid waste is a sound substrate for anaerobic digestion, there are several issues to be addressed further.

Keywords: Municipal Solid Waste, Biogas, Solubility
Theme 4 - Sustainable Resource Utilization
Detection of Landuse and Landcover Change: a Study of the Pottuvil DSD, Ampara

M.L.M. Hicmathullah* and A. Nanthakumaran
*Hicmathullah@gmail.com
Department of Biological Science, Faculty of Applied Science, Vavuniya Campus of the University of Jaffna, Vavuniya, Sri Lanka

Issues of landuse/landcover changes and the relationships of these changes have become much considered in recent years. Thus, the objectives of this research were to study the nature, extent, rate of changes and to analyze the spatiotemporal change patterns of landuse/landcover in the Pottuvil Divisional Secretariat Division (DSD) for sustainable management of land use. Multi-temporal Landsat TM1987, TM1996, ETM2003, TM2009 and OLI-TIRS2017 images were used for this study. Based on the extent of the study area to obtain the appropriate accuracy assessment 200 training samples were selected for the classification of the Landsat images using supervised maximum likelihood method in QGIS 3.10.1 and landuse maps were generated and change detection analysis was performed from 1987 to 2017. Agricultural land, forest cover, settlements, sandy land, scrubland and water bodies were identified for the landuse classification. Distinct changes have occurred in the landuse pattern. Results revealed that nearly 13.5% of agricultural land and 3.3% of settlements increased from 1987 and 13.4% of forest cover, 3.7% of water bodies and 0.3% of sandy land decreased from 1987 in the total area cover of the Pottuvil DSD. Conversions of land from forest cover (1775 ha) and scrubland (1786 ha) to agriculture represent the most significant land use change in the study area. The rate of change was as high as 3.36% for increasing settlements and agricultural lands were converted from other lands by 3.09% per year. The unutilized lands (13.93 ha) and abandoned settlements (3.38 ha) and abandoned agriculture lands (1.66 ha) were identified. Therefore, it is crucial that development plans be accompanied with a sustainable livelihood options for a better future of the country. Spatiotemporal landuse/landcover changes in GIS platform may be used to supplement the available tools for urban planning and sustainable environmental management in the region.

Keywords: Landuse/landcover, Spatio-temporal, Environment, Pottuvil DSD
Determination of Lignocellulose Biodegradation Efficiency of Enriched Microbial Consortia from Compost, Cow Dung and Coir Retting Water

S.M.D.C. Bandara* and E.M.J.M. Rizvi
*chathurikabandarad@gmail.com
Department of Biological Sciences, Faculty of Applied Sciences,
South Eastern University of Sri Lanka

Various drawbacks of fossil fuels have demanded the need for alternative sources of energy such as biofuels and second-generation bioethanol from lignocelluloses is favoured because of the food insecurity caused by first-generation bioethanol production. Even though lignocellulose is the most abundant, sustainable and cost-effective renewable biomass on earth, degradation of lignocelluloses to produce bioethanol is difficult because of its complex and robust structure. This study investigated the capability of microbial consortia enriched from compost, cow dung and coir retting water to degrade three lignocellulosic materials i.e., rice straw, corn straw and sawdust. Alkaline pretreated lignocellulosic substrates and a mixture of the three substrates in equal ratios were inoculated separately with the three microbial sources and a mixture of the three microbial sources, which were enriched twice (4 days each) using the same pretreated lignocellulosic substrate or the substrate mixture as the only source of carbon in basal culture medium (5 g of peptone powder and 3 g of yeast extract powder in 1 L of distilled water of pH 7). Four replicates each per treatment and a non-inoculated control was maintained in a completely randomized design, with no aeration at room temperature. The lignocellulose biodegradation ratio was tested by acetic acid-nitric acid reagent after 5 days of incubation. Statistical significance of the results were analyzed using one-way ANOVA (p <0.05). Subsequent mean comparisons of treatments were done by Turkey’s test using Minitab 19.2 version. All the substrates had a significantly higher degradation ranged from 21.43% - 66.70% compared to their control. Highest degradations of 66.70% and 58.12% were found in rice straw by enriched lignocellulosic substrate or the substrate mixture as the only source of carbon in basal culture medium (5 g of peptone powder and 3 g of yeast extract powder in 1 L of distilled water of pH 7). Four replicates each per treatment and a non-inoculated control was maintained in a completely randomized design, with no aeration at room temperature. The lignocellulose biodegradation ratio was tested by acetic acid-nitric acid reagent after 5 days of incubation. Statistical significance of the results were analyzed using one-way ANOVA (p <0.05). Subsequent mean comparisons of treatments were done by Turkey’s test using Minitab 19.2 version. All the substrates had a significantly higher degradation ranged from 21.43% - 66.70% compared to their control. Highest degradations of 66.70% and 58.12% were found in rice straw by enriched consortia from microbial mixture and compost, respectively. The values are comparable to 60% and 75% of rice straw degradation in two different studies which were incubated for 4 and 7 days respectively at 50 °C utilizing microbial consortia developed from compost by several enrichment cultures. The use of mixtures compared to the individual components alone both in the case of lignocellulosic substrates and microbial sources showed a positive effect on lignocellulose biodegradation. Further studies will reveal the bioethanol production efficiency of these lignocellulosic substrates and microbial sources.

Keywords: Biofuels, Lignocellulose, Enriched microbial consortia, Biodegradation
Land-Use Land-Cover Change of the Unawatuna Beach Area in Galle: A Special Emphasis on the Human Impact

A.M.W. Kanchana
athanayaka.94@gmail.com
Department of Geography, Faculty of Humanities and Social Sciences, University of Ruhuna, Sri Lanka

Costal Eco systems are rich in natural resources and especially, tropical coastal zones in a developing country support economic development and social welfare of the country. As a result of that the coastal zone attracts people to utilize their resources. This unlimited human consumption of the resources makes a reason to rapid land-use land-cover change in the coastal area. The study area consisted of three Grama Niladari (GN) Divisions namely, Bonavista, Yaddehimulla, and Unawatuna Central located along the Unawatuna coast. The objective of the study was to identify the change of coastal land use land-cover of Unawatuna area during the period of 1956-2018. Primary and secondary data were collected for the study. Primary data were collected via five focus group discussions, aerial photographs, google earth images and questionnaire survey selecting 10% of sample from each GN division. Secondary data were collected through research papers, reports and internet. The qualitative and quantitative methods were used to analyze the collected data. Tables, maps, figures and photographs were used to present information. In 2018, more build up areas, strong road network and less coastal vegetation cover can be observed comparing with 1956 and 1994. Coastal land-use land-cover of the area had become more complex with the human activities. It was found that land-use land-cover of the area was dominated by the expansion of tourism infrastructure. Overcrowding, development activities and urbanization were identified as the main drivers that influenced land-use land-cover changes. As a result of land-use land-cover changes, negative impacts such as habitat loss for associated species, coastal erosion, and decrease of coastal vegetation cover including the reduction of aesthetic value of the area was evident. Removal of illegal constructions and introducing reservation areas will be effective to minimize the negative impact.

(Department of Geography, University of Ruhuna is gratefully acknowledged for awarding a research grant).

Keywords: Tropical, Vegetation, Urbanization, Habitat, Aesthetic
Productivity Thresholds in a Tank-Based Agriculture System: A Case Study

S. Sirimanna and D.V.P. Prasada*
*pp16252@gmail.com
Postgraduate Institute of Agriculture, University of Peradeniya, Sri Lanka

Tank cascades are human-made systems of water retention in water deficient agricultural systems. The logic of a cascade lies in maintaining an appropriate balance between the catchment area and the command area, and facilitating a continuous water flow in the downstream direction. This study investigates the current status, water use efficiency and production thresholds in 17 tanks of Mahakanumulla, a small village tank cascade system in the North Central province of Sri Lanka, using the cross-sectional survey methodology. In this cascade system, we estimate a total water holding capacity of 0.0026 km$^3$ and a release volume of 0.0018 km$^3$, supplied to a total command area of 494.56 hectares. Average yields of 2156 kg per acre and 252.6 kg per acre were calculated based on the survey responses for Maha and Yala seasons, respectively. The large difference in productivity across Maha and Yala is characteristic of solely rain-fed systems. The calculated average water productivity in the cascade is 124.55 kg per m$^3$ of tank water. We calculate tank production thresholds varying from 40 kg per m$^3$ to 268 kg per m$^3$. There are productivity losses in the midstream arising from land use changes. Analysis reveals that while the quality of physical tank structures is not correlated with water productivity, the land uses in the command area are correlated with water productivity. This finding highlights the need for socio-economic interventions in addition to physical improvement in the tank structure for the sustainable functioning of cascade systems.

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Keywords: Production threshold, Water productivity, Physical indicators, Agriculture, Village tank
Exploring the Impact of Green Operations Practices on the Organizational Environment and Financial Performance in Manufacturing Sector Organizations in the Anuradhapura District


*kaushiaravinda251@gmail.com
Rajarata University of Sri Lanka, Sri Lanka

Climate Change results in both pressure and drivers for Sri Lankan enterprises to improve their environmental performance. As a developing country, Sri Lanka has to balance economic and environmental performance. If the firms needed to get strong performance continuously, they re-establish their corporate strategy by introducing and implementing more integrated sustainable green operations practices. When reviewing literature regarding green operations practices, developed countries are prominent than developing countries. Hence in the Sri Lankan context, this concept must be identified for organizing the manufacturing sector. To achieve the aim of this study, an in-depth literature study and empirical research were undertaken. A self - 41 administered questionnaire was completed by 80 operational managers from 80 manufacturing firms in the Anuradhapura District using convenience sampling method. To investigate the relationship between the Green Operations Practices and Environmental and Financial Performance, 4 hypotheses were tested. A conceptual framework was developed by researchers for the current study based on the survey. According to the correlation analysis results revealed significant positive relationships between these variables. The ordinary linear regression analysis was used to examine the impacts of these variables and a regression model is formulated. Green Production significant positive impact on Organizational EF Performance (Beta = 0.737) and there is a significant influence because of significant value is less than 0.05 (0.05>0.000). Green policies and organizational EF performance have positive and significant influence. Because of the positive Beta, value (0.267) and significant value is (0.006). Green marketing has a positive impact on organizational performance. Because of Beta value is 0.065, but there is insignificant influence because of significant value (0.582) is greater than 0.05. This study will contribute to the all the society, decision makers and policy makers. The results also provide various implications for managers and present some suggestions for future researches.

(Rajarata University of Sri Lanka, Sri Lanka is gratefully acknowledged for awarding a research grant).

Keywords: Anuradhapura district, Green operations, Manufacturing sector organizations, Organizational performance
Recycling of Low-Quality Waste Aggregate with Plastic Coating for Asphalt Production

M.A.M.O. Manchanayake¹, K.P. Niroshani¹, H.M.C.M. Sumathipala¹, M.H.Y.K. Fernando¹, P.B.R. Dissanayake¹, K. Kawamoto² and R.M.L.D. Rathnayake¹*

¹ Department of Civil Engineering, Faculty of Engineering, University of Peradeniya, Sri Lanka
² Civil and Environmental Engineering, Saithama University, Japan

*lashithar@eng.pdn.ac.lk

The plastic waste has become a major threat to the environment. Finding a proper disposal method for plastic waste is the need of hour. Plastic shows some bituminous characteristics, so it can be used as a coating material on an aggregate surface. Concurrently, considerable amount of aggregate in the construction industry is discarded as waste because of its low quality. Such unacceptable properties of aggregate can be improved by coating aggregate surface with polythene. In this research, the mostly available aggregate type in Sri Lanka, namely Hornblende Biotite Gneiss with low mechanical properties, which is out of requested international standards were initially coated with polythene by changing the polythene content percentage wisely, 0%, 5%, 10% and 15% according to the weight of aggregate using dry method to prepare Plastic Coated Aggregate(PCA). Laboratory experiments revealed that, mechanical properties such as Los Angeles Abrasion Value, Aggregate Impact Value and Aggregate Crushing Value of PCA’s were achieved requested international standard values at 10% polythene content. Hence aggregate surface is covered with a polythene film, bonding ability of bitumen with polythene is relatively unknown. Therefore, above mentioned PCA’s were secondly coated with bitumen by changing the bitumen content percentage wisely, 4%, 5% and 6% according to the weight of aggregate to investigate the bonding and strength characteristics. Three laboratory tests, namely Marshal Stability test, Bitumen Extraction test, Stripping Value test were conducted. 7.5KN of maximum stability value was observed in the sample with 15% polythene and 6% bitumen contents by showing 49% increasement of stability compared with other samples. Only 85% of bitumen could be extracted in 15% PCA’s, predicting higher bonding ability is resulting at higher polythene contents. No stripping of bitumen was observed in 10%, 15% PCAs’. Therefore, this study revealed that waste aggregate can be recycled by preparing PCA to produce asphalt.

(University of Peradeniya Research grant ((URG/2018/24/E) is gratefully acknowledged).

Keywords: Waste plastic, Weak aggregate, Plastic Coated Aggregates (PCA), Dry process, Asphalt
Energy Recovery from the Gravity-fed Mawathagama Galagedara Integrated Water Supply Project

A.K.R.L. Rathnasekara1* and S.B. Weerakoon2

1 National Water Supply & Drainage Board, Kurunegala, Sri Lanka
2 Department of Civil Engineering, University of Peradeniya, Sri Lanka

rawendra222@yahoo.com

The water sector is committed to contributing towards “affordable and clean energy” Sustainable Development Goal by reducing carbon footprint of the water supply projects. Accordingly, the excessive pressure generated in pipelines in gravity-fed water supply systems that is usually dissipated by break pressure tanks is given attention as source for recovering energy using micro hydropower plants (MHPP). This study presents a Case Study of economic feasibility of integration of a MHPP to recover dissipating hydro energy in the gravity-fed Mawathagama Galagedara Integrated Water Supply Project (MGIWSP) by the deployment at different stages of the project. Economic analysis of following three cases were carried out considering revenue and cost streams; the cost anticipated for the MHPP installations, operation and maintenance, and revenue by selling electric energy to the Ceylon Electricity Board. NPV, IRR, payback period, benefit cost ratio and debt service coverage ratio are used to investigate the economic feasibility of three cases.

a. MHPP is integrated at the project design. Cost increase due to the pipe modification and MHPP is the capital cost. Here cross-saving is considered.

b. MHPP is integrated at the project design. But the cost of the pipe installation and MHPP is the capital cost. Cross-saving not considered.

c. Installation of MHPP as a later option after water supply project is done. Total modification cost included.

In Case (a) NPV is Rs. 42 MN, IRR of 34%. Case (b) was not economically feasible and Case (c) was only marginally feasible. According, MHPP should have been added at the planning stage and it is not economically feasible to install a MHPP to MGIWSP now.

Keywords: Micro hydropower, Water supply, Energy recovery, Economic feasibility
Effect of Solubility of Carbohydrate and Protein in Biogas Generation with Solid Waste

S.M.W.T.P.K. Ariyarathna* and M.A.V. Wathsala
*thusharia@pdn.ac.lk
University of Peradeniya, Sri Lanka

Municipal Solid Waste (MSW) management is a hot topic in most of the countries and it is a burning issue in Sri Lanka too. The MSW typically consists of high percentage of organic matter, about 65% by weight. The organic fraction of MSW is a sound substrate for biogas generation. These substrates can be divided into three main categories according to their molecular structure: i.e., carbohydrate, protein and lipid. It was suggested that the different solubility rates of these molecules effect on accumulation of volatile fatty acids (VFAs) in the digester and then biogas generation, especially in solid waste digestion. This study is to observe the effect of solubility via VFA accumulation with carbohydrate and protein in biogas generation. The experiments were performed in the laboratory scale in the batch mode. Imitating the food waste found in MSW, white nadu rice and chick-pea were used as carbohydrate and protein rich substrate, respectively. Triplicates were experimented for three mixing ratios of rice to chick-pea with inoculums grown by cow-dung. The VFA accumulation was monitored in terms of the pH. The daily biogas production and pH variations were observed for 50 days. The cumulative biogas generation was found as 8.59 ml/gVS, 8.96 ml/gVS and 35.95 ml/gVS for digesters with carbohydrate-rich, equal carbohydrate and protein and protein-rich, respectively. The average pH values in the digesters were observed as 3.94, 4.72 and 5.28 with respect to the above order. Solubility of carbohydrate molecule is higher than protein and therefore carbohydrate-rich digester had gained more VFA than in the protein-rich digester. It can be concluded that the molecular solubility effects the VFAs accumulation in digesters and then in biogas generation.

Keywords: Solid waste, Biogas, Volatile fatty acids, Carbohydrate, Protein, pH
Construction and Demolition Waste Generation and its Management in Sri Lankan Building Construction Projects

W.A.P.C.P. Gunawardhana¹, R.M.L. Madushantha¹, P.B.R. Dissanayake¹, K. Kawamoto² and R.M.L.D. Rathnayake¹*

¹lashithar@eng.pdn.ac.lk
¹Department of Civil Engineering, Faculty of Engineering, University of Peradeniya, Sri Lanka
²Civil and Environmental Engineering, Saitama University, Japan

Construction and demolition activities in the construction industry is a significant contributor to the waste generated globally. Disposal of the generated waste is a major environmental issue. In the construction industry, building construction takes a considerable portion of the construction activities. Construction and demolition waste generation has been an emerging problem in Sri Lanka with the huge boost in the construction industry in the recent past. Unfortunately, in Sri Lanka the data on the waste generation in construction industry has not been investigated. Therefore, it is necessary to investigate the construction and demolition waste generation in Sri Lankan construction industry. In this study, construction and demolition waste generation and its management of building construction projects in the Colombo and Kandy districts were investigated using a questionnaire survey. The total waste generated in observed building construction projects was estimated as 2.6 ± 1.0 % of total building materials used. Further, estimation revealed that out of its’ total composition steel (4.7 ± 3.2%), cement (3.3 ± 0.6%), timber (3.3 ± 1.5%), sand (3.3 ± 0.57 %), concrete (3.0 ± 1.7 %) and bricks (3.0 ± 1.0 %), are the highest wasted material in constructions sites. Furthermore, when the contractor grade decreases the construction waste percentages increase simultaneously. The wastages were 2.7 ± 0.9% in C1 grade and 4.3 ± 3.9% in C2 grade. Demolition waste mainly consisted of cement plaster (41.0 ± 8.0%), concrete (21.8 ± 13.8%), steel (13.5 ± 7.2%), brick (13.6 ± 7.2%) and other materials (12.1 ± 6.7%) such as aluminum, glass, asbestos and other materials. The changes to the original design and bad weather were identified as the main reasons for waste generation in the building construction projects. Moreover, study revealed that steel, timber, sand and cement are the most wasted materials in the building construction industry while cement plaster and concrete are the major components of demolished waste.

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Keywords: Construction waste, Demolition waste, Building construction, Waste compositions
Potential of Agrivoltaic Systems to Optimize Agricultural Land Use for Energy Production in Sri Lanka

R.M.S.R. Chamara\textsuperscript{1}\textsuperscript{*} and C.K. Beneragama\textsuperscript{2}
\*ruwanchamara034@gmail.com
\textsuperscript{1}Postgraduate Institute of Agriculture, University of Peradeniya, Peradeniya, Sri Lanka
\textsuperscript{2}Department of Crop Science, Faculty of Agriculture, University of Peradeniya, Peradeniya, Sri Lanka

The shift to renewable energy has currently grown in the world than ever before as a result of the economic and environmental challenges created by conventional fossil fuel-based electricity generation that is in line with the Paris agreement. Photovoltaic (PV)-based electricity generation shares a major portion of renewable energy in the world and also has a high potential in Sri Lanka because it receives an ample amount of solar radiation. Nevertheless, it needs to expand up to a considerable area of land of photovoltaic panels other than the available infrastructures like rooftops to cater to the increasing energy demand which are available to feed the ever-increasing population and could become problematic for a long period of time. In view of the future requirement of energy and food production, Agri-voltaic systems (AVS) has been proposed as a mixed system, combining photovoltaic with agriculture at the same time on the same land for both energy generation and food production while maximizing the solar efficiency on the land. The main eco-physiological constraint for crop production in the AVS is the reduction of solar radiation. However, the lessening of plant productivity can be compensated through energy harvesting from the PV panels combining to the land equivalent ratio (LER). Crop yield variation with panel shading and more crop-specific research to determine the optimum number of panels and their arrangement that do not reduce agricultural production need to be studied extensively. Since the impacts of most of the crops under the shade conditions were not studied before it is extremely difficult to recommend some crop species for their ability to shade tolerance in the system particularly below the panel area. This paper reviews the potential of the Agri-voltaic system identifying the research gaps in selecting suitable crops under the PV panels and practicalities to maximize the system.

\textit{Keywords}: Agrivoltaic, Photovoltaic, Food, Energy, Shade, Tolerance
The Energy Saving Potential in the SMEs: Selected Case Studies from the Industrial Sector in Sri Lanka

P.U.N.A. Dilhani, D.M. Jayasena* and A. Pallegedara

*jayasena@wyb.ac.lk
Faculty of Applied Sciences, Wayamba University of Sri Lanka, Sri Lanka

Energy efficiency in Sri Lankan SMEs in the industrial sector is typically low with a large untapped potential for energy saving. In order to enhance the effort of achieving Sustainable Development Goals 07: “clean and affordable energy” and Goal 12: “sustainable production and consumption”, it is important to study energy consumption behaviour of the SMEs sector in Sri Lanka. Thus, this study focused on identification, evaluation and analysing the energy saving potential of the selected SMEs in Sri Lanka. Five industrial sectors: printing and packaging, apparel, metal, chemical, and food and beverage which consume more than 50% of energy consumption of SMEs were selected. Two SMEs of each sector were selected to represent the sector and conducted comprehensive energy audits for a period of three weeks. Results showed that incorrect power factor adjustments, poor practice of switch off policy on lights and fans, inadequate modifications on lighting system, compressed air systems, boilers, and machineries were the most significant factors led to energy inefficiencies in the sector. Further, if prompt actions were to be taken for the above issue, the study estimated that the total energy saving potential for the selected firms would be about 20% to 30% of the total energy consumption. Moreover, it was about 10% to 15% of energy costs of the selected firms. The study concludes that SMEs in the industrial sector should focus on rectifying inefficient usage of energy.

Keywords: Energy efficiency, Energy cost, Energy saving potential, SMEs
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