INSTITUTE OF FUNDAMENTAL STUDIES

Annual Review 2011

Institute of Fundamental Studies
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Sri Lanka

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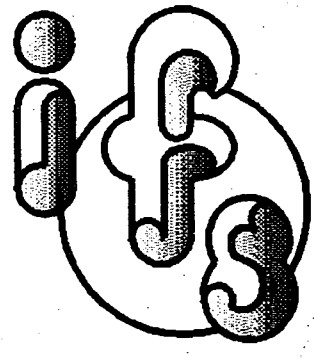

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Institute of Fundamental Studies

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Cover design by
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Printed by
Sanduni Offset Printers (Pvt) Ltd.
No. 4/1, Sarasavi Uyana Good Shed Road
Sarasavi Uyana
Peradeniya
081-2387777

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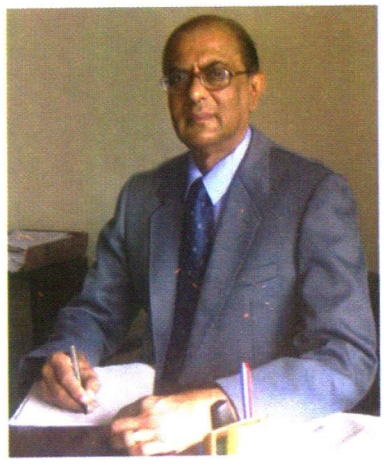
MESSAGE FROM THE DIRECTOR



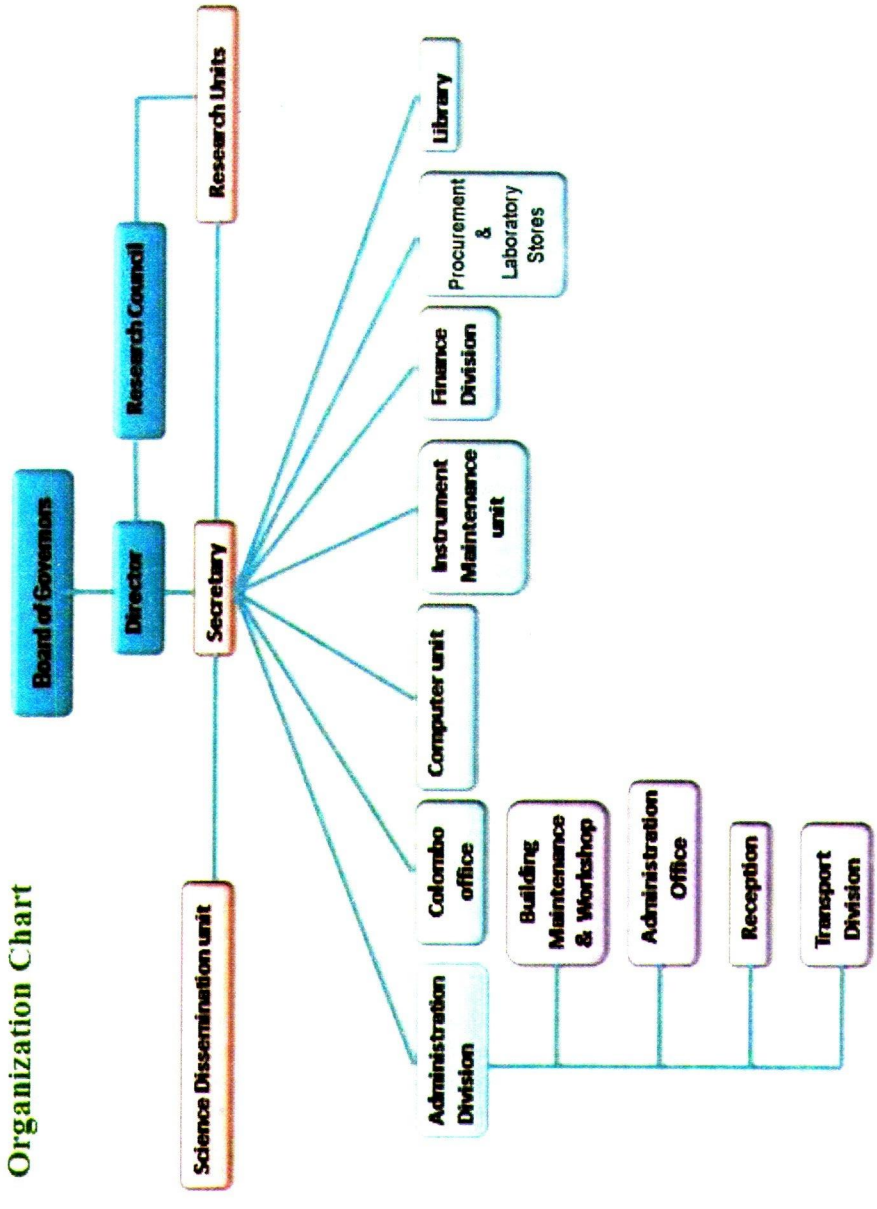
I am indeed pleased to write this message on the occasion of the 2011 Annual Review of the Institute of Fundamental Studies. In keeping with the national requirement, the IFS has focused on carrying out research that ultimately benefits the people. In the past, publications of papers merely for the extension of publication lists in personal CVs had been the main objective of some scientists. I am happy to note that we have taken a step further to derive benefits from these research projects funded by public money. The IFS has developed the Consultative and Collaborative Division (CCD) even further and it is indeed heartening to note the greater public and private sector interest shown towards the IFS research activities. IFS research work leading to technology transfer, particular in the water and sanitation sector, has received major recognition by the Ministry of Technology and Research. The beneficiaries are ultimately the rural folk of the dry zone of Sri Lanka. The collaborative research programmes with several international and national institutes have been strengthened further and the training of IFS scientific personnel abroad has also received a major boost. Our scientists have performed creditably well and this augurs very well for the future of the Institute of Fundamental Studies.

I wish the 2011 IFS Annual Review all success.

C. B. Dissanayake

Prof. C.B. Dissanayake
Director
Institute of Fundamental Studies

Organization chart



GENERAL INTRODUCTION

Prof. C.B. Dissanayake, Director, IFS

The year 2011 has been a significant one for the Institute of Fundamental Studies (IFS). As announced at the 2010 Annual Review, there has been an important policy change with basic research of national importance receiving special attention. Accordingly several projects with private and state sector participation got underway and are progressing well. Special mention should be made of the granting of Rs. 12 million to the IFS for the research and installation of 10 water purification units in the kidney disease prone areas of the North Central Province of Sri Lanka. This is a pioneering effort by the IFS in technology transfer in the water sector and the scientists involved deserve special appreciation.

The new green house and the microbial biotechnology laboratories have now been completed and inaugurated. It is envisaged that there will be greater private sector participation in IFS research on biofertilizers.

Projects pertaining to natural resource mapping have also shown good progress. The data obtained in Sri Lanka's first ever magneto-telluric survey for geothermal resources of Sri Lanka is now being processed and the early indications are that there are some promising geothermal reservoirs in Sri Lanka.

Another pioneering research project of the IFS which is receiving collaboration from the Atomic Energy Authority (AEA) is radon mapping. Equipment has already been received from Japan and with Japanese expertise, Sri Lanka's first radon maps will be produced.

The Nanotechnology Team (TNT) of the IFS which was established in 2011 has already received funding from the National Research Council of Sri Lanka and several IFS scientists are now busy working on the application of nanotechnology for national development.

It is with a great deal of happiness that I state here the successful holding of two international symposia. The first one *"Solar Asia – 2011"* was attended by over 100 participants from 15 countries and it was after a lapse of several long years that an international conference was held at the IFS. This was followed by another very successful international symposium on *"Application of Natural Products in Health and Agriculture"* also by participants from 15 countries. The response by the international participants was most encouraging and this augurs very well for the future.

The Science Dissemination Unit (SDU) has, during the past year, carried out outstanding programmes, mainly workshops and seminars, for a large number of teachers and students trained in the fields of geology and fast growing nanoscience and nanotechnology. In addition, to highlight the importance of Nanoscience and nanotechnology an all island competition in "නැනෝ ලොවෙන් නව ලොවට" was successfully completed. Teachers and students preformed exceptionally well at this event.

Laboratory visits were organized for school children, teachers, undergraduate and students from other institutions. Research meetings, research colloquia public lectures were also organized to promote the public understanding of science.

Finally I wish to record my sincere appreciation to the Minister of Technology and Research Hon. Pavithra Wanniarachchi, the Deputy Minister, Hon. Faiszer Musthahpa and the Secretary Mrs. Dhara Wijayatilake for their unstinted support to the IFS in all our activities.

From left to right

Mr. K.T. Waisundara, Dr. R. Liyanage, Dr. K.G.N. Nanayakkara, Prof. S.A. Kulasooriya, Dr. R.R. Ratnayake, Prof. P.R.G. Seneviratne, Prof. J.M.S. Bandara, Dr. N.D. Subasinghe, Prof. C.B. Dissanayake (Director), Dr. M.C.M. Iqbal, Mr. J. Padmasiri, Prof. M.A.K.L. Dissanayake, Prof. A. Nanayakkara, Dr. W.P.J. Dittus, Prof. N.S. Kumar, Dr. C.T. K. Tilakaratne, Dr. S.P. Benjamin, Prof. U.L.B. Jayasinghe, Dr. G.K.R. Senadeera, Dr. D.N. Magana-Arachchi, Dr. M.S. Vithanage

GENERAL REVIEW AND SUMMARIES

7.1 ALTERNATIVE AND RENEWABLE ENERGY

7.1.1 BIOFUEL RESEARCH PROJECT

Project leader: Dr. Renuka Ratnayake (*Research Fellow)*

Description of the project

The biofuel research project was initiated in October 2009 with the aim of developing effective methods to use biological resources for the production of biofuels. Chemical, enzymatic and microbial techniques have been developed to convert cellulosic biomass into simple carbohydrates that can be fermented into bio-fuels.

Large scale cellulosic biofuel production is not economically viable due to factors such as the recalcitrant nature of lignocellulosic material, high cost and lack of efficient cellulases. Large amounts of energy and chemicals are needed to make them amenable for enzymatic degradation, adding to the cost of the process. Our research studies are directed to improve the steps in lignocellulosic degradation for biofuel (ethanol) production, to make the process commercially viable. There are two ongoing projects under these studies.

Invasive weeds and biofilms to produce biofuels

It has been reported that biofilms are more active than their component microbial partners. Biofilms could therefore increase the rates of biodegradation processes. Our objective is to investigate the use of cellulose degrading fungi and bacteria to produce efficient cellulose degrading biofilm communities. Four terrestrial invasive weeds were selected as substrates for the degradation studies based on their abundance in Sri Lanka.

Improvement of microbial strains and biofilms for ethanol production from cellulosic substrates

In this project further improvement of efficient microbial strains through mutagenesis will be carried out for maximum cellulase production. Dual and tri-partite biofilm forming combinations will be developed. The efficiency of improved microbial strains and biofilms will be carried out on wider range of lignocellulosic material such as invasive aquatic weeds, saw dust, straw and other crop residues, kitchen waste, sugarcane bagasse, garbage and municipality waste etc. Substrates such as garbage and market wastes were included to assist the important environmental issue of waste management.

Soil carbon sequestration and management

Science has shown that the increase in atmospheric carbon-dioxide is responsible for global warming and climate change. This carbon should be removed and stored – sequestered- to reduce atmospheric carbondioxide. Carbon can be stored via sequestration for hundreds to thousands of years reducing the amount of carbon dioxide in the atmosphere. Of all the sinks of carbon, soil is the largest sequester (2500 Gt) that can be managed. Soils are considered as potentially important terrestrial carbon sinks to meet the CO_2 emission reduction targets set by the Kyoto Protocol. This project is looking at minimizing carbon loss and maximizing the retention of carbon in land. There are 3 sub projects under this.

Soil carbon sequestration in forest and tea plantations

Carbon sequestration potential of forest plantation, tea plantation and natural forest will be studied with an objective of improving C sequestration in forest and tea plantations. The factors affecting carbon sequestration and microbial contribution for C sequestration will also be monitored.

Home garden systems to optimize soil carbon sequestration

Home gardens are an unexplored potential source for carbon sequestration due to their different species composition. The project aimed at developing a feasible home garden system that ensures maximum C sequestration and high productivity.

Land use and carbon sequestration in north Sri Lanka

Enhancing carbon sequestration in agricultural soil would yield a win-win situation of reducing local productivity problems and reducing net emissions of greenhouse gases and mitigating the projected global climate change. There is a great potential of storing C in soils of agricultural lands in Sri Lanka, especially in the northern region, where a significant part of lands are available for agriculture. This research would compare and quantify the available carbon stocks in under different agricultural land-use systems and management practices in Jaffna with a long term objective of improving soil C sequestration by applying different management options.

Scientific Expertise: Prof. S.A. Kulasooriya (*Visiting Research Professor*)
Research Assistants: W.A.D.D. Wasalamuni, K. Mohanan,
M.M.S.N. Premathileka (*Vounteer),* K.M.D. Gunathileka (*Volunteer)*

Research work in progress

7.1.1.1 Biodegradation of cellulose for biofuel production using microbial biofilms

K.M.D. Gunathileke, R.R. Ratnayake, S.A. Kulasooriya

Biofuel Research Project, IFS, Kandy

Introduction

Producing biofuel from plants often consumes more energy than it produces and this is one of the major problems in biofuel industry. The crystalline structure of cellulose makes it difficult to hydrolyze into simple sugars. Development of microbial consortia or microbial enzymes which can be used for this purpose is a major concern. Biofilm is a community of microorganisms living together adhered to each other and/or to a solid surface. These organisms may deviate from the behavior of same organisms living in isolation. Hence biofilms may have a potential to improve efficiency of cellulose degradation.

Objectives

To develop and screen fungal - bacterial biofilms that could effectively degrade lingo-celluloses.

Results

The screening revealed that fungi are 2-3 times more efficient than bacteria in degrading lingo-celluloses. Seven different biofilms were produced. During the period of 5-6 weeks of incubation, the cultures in cellulose broth showed fluctuations in the sugar concentration (Fig. 1). Most of the cultures showed an elevated sugar concentration in the 2^{nd}-3^{rd} week of incubation followed by a decline in the following week (Fig. 1). The highest recorded simple sugar concentration was produced by the fungus F23. In all comparisons the harmonic mean of the sugar yield of F23 culture was significantly higher than the tested fungal-bacterial biofilms and other monocultures.

References

1. L.R Lynd, (1996). Overview and evaluation of fuel ethanol from cellulosic biomass: technology, economics, the environment, and policy. *Annu. Rev. Energy Environ. 21*.403–465.

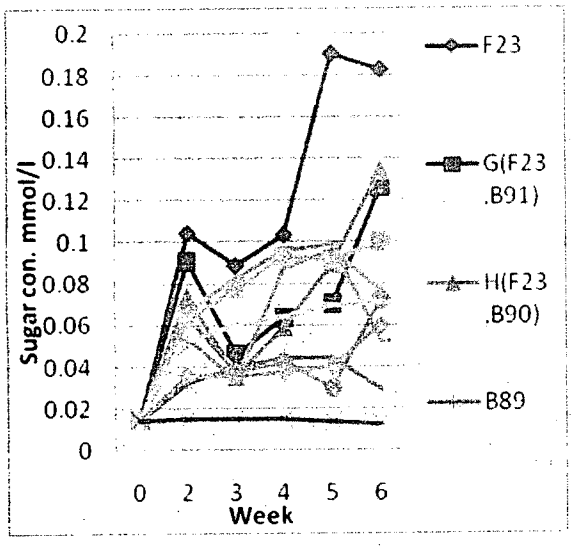


Fig. 1: Sugar production from commercial Cellulose by the most efficient cellulose degrading fungus (F23), bacteria (B89) and biofilms (G,H)

7.1.1.2 Development of biofilms and mutant strains for ethanol production from lignocellulosic materials

K.Mohanan, R.Ratnayake, S.A. Kulasooriya

Biofuel Research Project, IFS, Kandy

Introduction

Biofuels are promising candidates for renewable energy. Cellulose containing materials can be used as feedstock for ethanol production through enzymatic conversion. Elimination of expensive pre-treatment steps is needed to make the process commercially viable[1]. To this end, development of more efficient methods of enzymatic conversion will be essential.

Objectives

The goal of this project is to develop biofilms which can degrade cellulose and hemicelluloses efficiently and to mutate efficient cellulolytic anaerobes to disrupt fermentative pathways leading to products other than ethanol. To achieve this, our objectives were:

(1) Isolation of cellulolytic micro-organisms and screening them for activities of cellulases (exo/endo glucanases and β-glucosidases) and xylanases.
(2) Combining the most efficient micro-organisms to form biofilms and measuring the cellulolytic activities of the enzymes from the biofilms.
(3) Random mutation of *Clostridium thermocellum* and rumen bacteria to block fermentative pathways other than ethanol forming pathway to increase the yield of ethanol.

Results

So far, about 83 aerobic bacterial strains and 19 fungal strains have been isolated from soil, dung, compost and garbage samples from various sites. The growth rates of the bacterial isolates on cellulose agar were graded as very good (6), good (26), moderate (20) or scanty (31). Twenty cellulolytic bacterial strains, previously isolated from aquatic weeds were identified and five strains that were fast-growing on cellulose agar were studied for cellulase activity on filter paper. The best strain showed an activity of 0.004 IU/ml.

Reference

1. A. Margeot, B. Hahn-Hagerdal, M. Edlund, R. Slade, F. Monot, (2009). New improvements for ignocellulosic ethanol. *Curr. Opin. Biotech.*, *20*, 372 – 380.

7.1.1.3 Soil carbon sequestration in *eucalyptus grandis* forest plantations

M.M.S.N.Premetilake[1], R.R. Ratnayake[2], S.A. Kulasooriya[2]

[1]*Uva Wellassa University, Badulla,* [2]*Biofuel Research Project, IFS, Kandy*

Introduction

Forest plantations are one of the major carbon pools and the forest soil along with microorganisms play a major role in sequestering carbon. Various factors affect carbon sequestration in plantation forests. Since *Eucalyptus grandis* is one of the commonly grown species in plantation forests in Sri Lanka, we are studying the various effects on carbon sequestration in *Eucalyptus* forest plantations. In this study, we expect to determine these factors towards improving the carbon sequestration of soil. And also suggestions will be made on the best thinning stages of the forests. Simultaneously, we are

also comparing the forest plantation carbon sequestration with an adjacent tea estate, and a natural forest to find out the variation of carbon sequestration among these ecosystems.

Results

Microbial biomass carbon (MBC) varied significantly between two layers of four plantation forest sites. The youngest site, which is 5 years old had the lowest amount of MBC while the 11 years old site contained the highest amount of MBC in the 0-15 cm layer. Preliminary result indicates a decreasing trend of the MBC in the 15-30 cm layer with age of the plantation. However the MBC in 15-30 cm layer increase with the age of the plantation. The data showed that the MBC correlates well with soil pH. The 28 year old site showed the highest amount of microbial biomass in the 15-30 cm layer, probably due to the lowering of antagonistic effect by litter on the microbial biomass in deeper layers. The data obtained so far showed that 11 year old plantation had the highest amount of microbial biomass C which is the most important fraction of carbon in soil organic matter dynamics in tropical soils. The other fractions of C are yet to be analysed.

References

1. J.M. Anderson, J.S.I. Ingram, (1998). Tropical soil biology and fertility; A hand book of methods. CABI publishing, New York, 79-186 p.
2. D.Sarkar, A. Haldar, (2000). Physical and chemical methods in soil analysis. New age international publishers, New Delhi, *36*,41 p.

7.1.1.4 Home garden systems to optimize soil carbon sequestration

W.A.D.D. Wasalamuni, R.R. Ratnayake

Biofuel Research Project, IFS, Kandy

Introduction

Tree home gardens are recognized as one of the best agro- forestry systems in tropical Asia. With the decline of natural forest cover these home gardens would contribute substantially to capture CO_2 in the terrestrial environment. Although estimates of carbon storage exist for forests and forest plantations, such estimates are not available for home gardens in the tropics. The traditional tree home gardens in rural and semi-rural areas of Sri Lanka are known as the Kandyan Forest Gardens. These gardens represent a traditional system of perennial cropping which has been in practice for several centuries. Traditional home gardens in the dry zone of Sri Lanka are known to be self sustainable and different from the Kandyan forest gardens by structure and composition.

Objectives

The overall objective of this study is to assess the carbon sequestration potential of home gardens and developing a feasible home garden system in Sri Lanka that ensures maximum carbon sequestration and high productivity. In the first Phase of this project: Traditional home gardens with different species composition in the wet zone were studied in detail for the potential to sequester soil carbon.

Results

The alterations in soil properties due to the changes in vegetation were reflected in the differences in microbial biomass C (MB-C), microbial biomass N (MB-N) and above ground litter accumulation. The soil microbial properties varied in parallel to the introduction of spice crops. Microbial biomass C varied significantly between 0-15 and 15-30 cm soil layer in all sites having the highest content in top 0- 15 cm layer showing that microbial reactions are restricted to the top soil layer. However the MB-N content was not significantly different between the two layers. The data obtained so far showed that

the Traditional Kandyan home garden 2 has a higher potential for soil C sequestration when compared to the other sites.

Table 1: Variation in soil carbon fractions between home gardens

Name of the site	Soil pH		Soil % Moisture content		Soil Microbial Bio Mass Carbon (MBMC) (mg/Kg)		Soil Microbial Bio Mass Nitrogen (MBMN) (mg/Kg)		Soil % Total organic Carbon	
	A	B	A	B	A	B	A	B	A	B
KHG1	5.7^{a}	5.6^{ab}	22.2^{a}	20.7^{a}	196.4^{b}	161.7^{a}	27.2^{b}	29.4^{a}	1.8^{c}	1.7^{c}
KHG2	5.9^{a}	5.8^{a}	22.6^{a}	20.2^{a}	369.6^{a}	161.7^{a}	118.1^{a}	88.3^{a}	5.0^{a}	4.1^{a}
SHG	5.3^{b}	5.2^{b}	23.3^{a}	22.2^{a}	219.5^{b}	165.4^{a}	22.0^{b}	53.0^{a}	4.0^{b}	3.0^{b}

A = 0-15 cm soil depth ; B = 15-30 cm soil depth; KHG1/KHG 2 Traditional Kandyan home garden 1& 2; SHG home garden incorporated with Spice crops; Values in the same column followed by the same letter are not significantly different at $P < 0.05$.

7.1.1.5 Assessment of soil carbon stocks in different agricultural land uses in the Jaffna district

T. Kugendren[1], R.R. Ratnayake[2]

[1]Faculty of Agriculture, University of Jaffna, [2]Biofuel Research Project, IFS, Kandy

Introduction

Enhancing carbon sequestration in agricultural soil is increasingly important for improving soil productivity, reducing net emissions of greenhouse gases and mitigating the projected global climate change. There is a great potential of storing and improving C in tropical agricultural soils. There are no proper records available on C storage potential of different agricultural management practices in the Northern part of Sri Lanka. Data on carbon status of different agricultural land-use and management practices would give valuable information for sustainable land management for the farmers.

Objectives

This research would compare and quantify the available C stocks in different agricultural land uses and management practices in the northern part of Sri Lanka with the long term objective of improving soil C sequestration by applying different management options. In this study soil carbon sequestration in six land use patterns: Annual crop- organic fertilizer only, Annual crop- inorganic fertilizer only, Annual crop- organic/ inorganic both, maintained home gardens, abandoned home gardens and the agricultural fields of perennial crops will be quantified and compared.

Results

This study shows that within the agricultural land use patterns, application of organic fertilizer causes substantial differences in carbon content and the undisturbed abandoned home gardens also have high amount of soil organic content than other land use patterns. The top soil layers (0-15cm) have high organic carbon content and active carbon. Microbial biomass C and N data reflected that the

microbiological situation in agricultural fields with only organic fertilizer application is better compared to the fields with no intense soil management.

Land uses with only organic fertilizer application have the highest amount of organic carbon as well as microbial biomass carbon. The abandoned home gardens showed the next highest amount of organic carbon as well as microbial biomass carbon explaining the tillage effect on soil C.

References

1. J.M. Anderson and J.S.I.Ingram,(1993). Tropical soil biology and fertility. CABI publishing., UK.

Table 1: Carbon stocks estimates of different agricultural land uses studied

Land uses	Total Organic Carbon (Tons/ha)	$KMnO_4$ oxidizable carbon (Tons/ha)	Microbial biomass carbon (Tons/ha)	Water soluble carbon (Tons/ha)	Active carbon (Tons/ha)	Potential Stable carbon (Tons/ha)
Perennial crop	8.11	1.07	0.88	1.12	3.07	5.04
Abandoned home garden	19.74	1.41	1.35	1.58	4.34	15.40
Maintaining home garden	8.52	1.45	1.08	1.44	3.98	4.54
Only inorganic fertilizer	6.64	0.96	0.66	0.12	1.73	4.91
Only organic fertilizer	14.31	0.99	1.56	0.61	3.15	11.17
Inorganic+organic fertilizer	8.10	0.48	0.79	0.89	2.17	5.94

Human resource development

Research students (M.Sc., B.Sc.) & Trainees

Permila Roshani- M.Sc. Student, PGIS, Peradeniya
T. Kugendran- Undergraduate Student, Faculty of Agriculture, University of Jaffna
Anuradhi Ekanayake- Post graduate student, University of Florida, USA
S. Rajakaruna- Graduate student, Rajarata University of Sri Lanka
S. Galappaththi and N. Wadasinghe- Pre university students

7.1.2 CONDENSED MATTER PHYSICS AND SOLID STATE CHEMISTRY

Project leaders: Prof. M.A.K.L. Dissanayake *(Research Professor)*
Dr. G.K.R. Senadeera (*Visiting Associate Research Professor*)
Visiting scientist: Prof. M.A. Careem (*Visiting Research Professor*)

Description of the project

During 2011, the research activities of the Condensed Matter Physics and Solid State Chemistry Projects at IFS were largely focused on (i) efficiency enhancement of dye sensitized solar cells based on liquid, solid and gel type electrolytes and (ii) synthesis and characterization of nano-composite solid and gel polymer electrolytes for possible use in dye sensitized solar cells, lithium rechargeable batteries, fuel cells and supercapacitors.

Details of the research projects are given below:

1. Investigations of the efficiency enhancement in dye sensitized solar cells

Due to the rapidly depleting fossil fuel resources globally, there is an urgent need to develop alternative energy sources and hence the research focussed on low cost solar cells has become an important area of R&D, both nationally and internationally. Among various alternative energy resources, the solar energy is one of the most abundant and in exhuastable energy sources available to the mankind free of charge.

This research project is aimed at designing and fabricating, high efficiency, low cost and stable Dye Sensitized Solar Cells (DSSCs) for various applications by surface and structural modifications of semiconducting materials, employment of dye cocktails, ionic liquids and electronically conducting polymers. In this context, dye-sensitized solar cells (DSSCs) (see figure 1) are taken as the system which has an enormous advantage as an alternative energy provider.

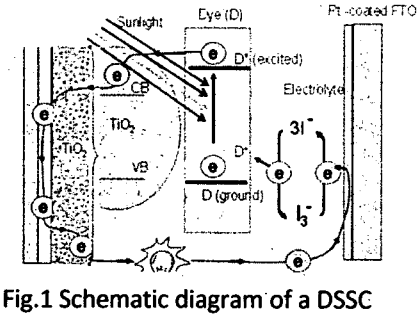


Fig.1 Schematic diagram of a DSSC

However, a typical dye sensitized solar cell generally consists of expensive sensitizers such as ruthenium (II) polypyridyl complexes and electrolytes with volatile solvents. Therefore, there is considerable interest in both the development of a solid state electrolyte for these devices and replacement of expensive dyes with inexpensive and readily available materials. On the other hand, in the context of the efficiency enhancement of these DSSCs, another important factor that needs to be considered is the semiconducting surface used to adsorb the dye molecules. Even though, TiO_2 has been used in these cells, numerous studies have been carried out by researchers including our group on the replacement of TiO_2 with other semiconductors like SnO_2 and structurally modified semiconducting surfaces.

2. Synthesis and characterization of nano-composite solid and gel polymer electrolytes for possible use in "Clean and Green energy sources" such as Dye sensitized solar cells , Lithium rechargeable batteries , Fuel cells and Supercapacitors:

Electrolytes are basically substances that contain free ions which make the substances electrically conductive. The most common electrolyte is an ionic solution, although molten and solid electrolytes are also found. However, for applications in the next generation of rechargeable lithium batteries, dye-sensitized solar cells and organic solar cells it is important to develop non-corrosive, low cost, solid or quasi solid, and efficient electrolytes. For applications in these devices, it is essential to have electrolytes with high ionic conductivity, chemical and electrochemical stability and high reliability

over a long period within a wide range of operating temperatures. For this goal, the optimization of the properties of electrolyte is very important. In this regard solid or gel polymer electrolytes may be the best option to be used as the eletrolytic medium in these devices.

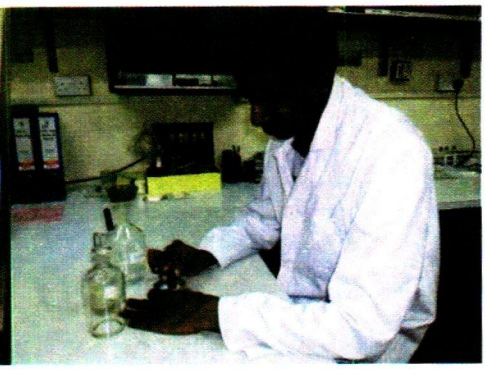
Poly(ethylene oxide) (PEO)-based solid polymer electrolytes (SPE) have many potential applications in solid-state lithium batteries, dye-sensitized solar cells and oganic solar cells. SPE systems typically possess the mechanical properties and structural integrity required for above applications, but have inherently lower conductivities due to the more restricted motion of the polymer molecules. Solid polymer electrolytes are non-volatile, non-corrosive materials, which can readily be processed into virtually any shape or size. In addition, their inherent lightness and flexibility enable the production of more robust energy storage devices having high energy densities.

Polyacrylonitrile (PAN)-based gel polymer electrolyte systems provide a balance between the high conductivity of organic liquid electrolytes and the dimensional stability of solid polymer electrolytes. The design of such gel systems depends on an understanding of the mechanism of ionic conduction in gels, and on the ability to tune the structure of the polymer component in the gel to optimize the overall physical properties. More research efforts are needed in order to develop polymer electrolytes that possess enhanced mechanical stability and enhanced ionic conductivity. Therefore, in this project nanocomposite polymer electrolytes based on PEO, PAN and other host polymers incorporating nano-fillers such as alumina, titania, silica (including high purity low cost nano silica synthesized from local rice husk ash) has been synthesized and characterized. Laboratory scale DSSCs, rechargeable lithium batteries, fuel cells and supercapacotors are being tested incorporating these electrolytes.

Collaborators: Dr. V.A. Seneviratne, Department of Physics, University of Peradeniya
Prof. B.-E. Mellander, Chalmers University of Technology, Gothenburg, Sweden
Prof. I.M. Dharmadasa, Sheffield Hallam University, UK
Prof. Piyasiri Ekanayake, Faculty of Science, University of Brunei, Darussalam, Brunei
Dr. T.M.W.J. Bandara, Department of Physical Science, Rajarata University

Research Assistants: Mr. C.A. Thotawathage, Ms. W.N.S. Rupasinghe, Ms. S.L. Jayaratne, Ms. H.K.D.W.M.N.R. Divarathne (NRC Research Student)

Condensed Matter Physics and Solid State Chemistry Research Group (2011)



Fabricating dye-sensitized solar cells

7.1.2.1 Investigations of the efficiency enhancement in dye sensitized solar cells

(i) Effects of Ni doping of the nanostructured photo anode on the performance of dye sensitized solar cells (DSSCs)

T.R.C.K. Wijayarathne[1], Y.P.Y.P. Ariyasinghe[1], C.A. Thotawatthage[1], V.P.S. Perera[2], G.K.R. Senadeera[1,2]

[1]Condensed Matter Physics and Solid State Chemistry Project, IFS, Kandy ,[2] Department of Physics, The Open University of Sri Lanka, Nawala

In the efficiency enhancement of the DSSCs, it is observed that metal ion doping (by both acceptor or donor type elements) can significantly modify the structure properties of the nanostructures used in these solar cells [1-2]. In this context, our research group has already attempted to improve the efficiencies of these DSSCs, by doping some metal nano-particles with TiO_2 [2]. As a continuation, in the present work, we investigated the effect of Ni doping in the semiconductor electrode on the performance of DSSCs which gives much insight into the mechanisms of band positions and trap levels. We suggests a mechanism of charge transport process of the DSSCs based on Ni doped nanocrystaline TiO_2 films with the evidences for trap-filling conditions, changes in the band positions and the band gaps. The reproducible results presented in this work clearly demonstrate that the performance of DSSCs based on TiO_2 thin film could be enhanced by doping Ni with TiO_2.

References

1. Gratzel, M. (2001). Photoelectrochemical cells, *Nature, 414*, 338-344.
2. Wijayarathna, T.R.C.K., Aponsu, G.M.L.P. Ariyasinghe, Y.P.Y.P,. Premalal, E.V.A Kumara, G.R.R. and Tennakone, K. (2008). A high efficiency indoline-sensitized solar cell based on a nanocrystalline TiO_2 surface doped with copper, *Nanotechnology, 19*, 485703.

(ii) Quantum dot sensitized solar cells (QDSSCs) with some gel type polymer electrolytes

K. Kumaraarachchi[1], M.A. Careem[1], G.K.R. Senadeera[2], T.M.J. Bandara[3], B.E. Mellander[4]

[1]Department of Physics, University of Peradeniya, [2]Condensed Matter Physics and Solid State Chemistry Project, IFS, Kandy and Department of Physics, Open University of Sri Lanka, Nawala, [3]Department of Physical Sciences, Rajarata University, Mihintale, [4]Applied Physics, Chalmers University of Technology, Gothenburg, Sweden.

Beside the aforementioned DSSCs, narrow band gap semiconducting quantum dot sensitized solar cells (QDSSCs) have attracted attention as promising third-generation photovoltaic devices (1). However, in order to overcome the problems associated with the use of liquid electrolytes in these cells, in this study we have explored the possibility of the use of several redox couples in a jellified electrolyte comprising either polyvinylidene fluoride (PVdF) or polyacrylonitrile (PAN) in TiO_2/CdS QDSSCs. CdS quantum dots are sequentially assembled on to a nanocrystalline TiO_2 films to prepare a TiO_2/CdS photo-electrode by chemical bath deposition technique and QDSSCs were fabricated with the above TiO_2/CdS electrodes and polymeric electrolytes based on either polyacrylonitrile (PAN), or poly(vinylidene fluoride) (PVdF) having sulfide (S^{2-}/S_x^{2-}), iodide (I^-/I_3^-) or ferric (Fe^{2+}/Fe^{3+}) redox couples. The best photovoltaic performance was obtained from the PVdF-sulfide polymeric electrolytic system yielding an overall power conversion efficiency of ~ 0.8 with a short circuit current density of 2.6 mA cm^{-2} under the illumination of one sun (AM 1.5, 100 mW cm^{-2}). The polymeric electrolytes based on iodide or ferric electrolytes were not as effective as polysulfide electrolytes for TiO_2/CdS based QDSSCs.

References

1. P.V. Kamat, (2008). Quantum Dot Solar Cells. Semiconductor Nanocrystals as Light Harvesters", *J. Phys. Chem. C112,* 18737–18753

7.1.2.2 Novel mixed iodide effect in enhancing the efficiency of dye sensitized solar cells based on polyacrylonitrile (PAN) and nano-porous TiO_2

C.A. Thotawatthage[1], M.A.K.L. Dissanayake[1] ,G.K.R. Senadeera[1,2],T.M.W.J. Bandara[3]

[1]Condensed Matter Physics and Solid State Chemistry Project, IFS, Kandy, [2]Department of Physics, Open University of Sri Lanka, Nawala [3], Department of Physical Sciences, Rajarata University, Mihintale

In the past decade, dye-sensitized solar cells based on nano-porous TiO_2 and quasi-solid polymer (or gel) electrolytes have drawn the interest of many research groups. These cells have become potential, low cost alternatives to conventional inorganic photovoltaic devices. However, a major drawback of these solar cells with gel electrolytes is their relatively low power conversion efficiencies compared to their liquid electrolyte counterparts.

In this project for the first time in this field of reserch, we have identified and studied a novel effect of using a mixed iodide salt system with two cations to significantly enhance the power conversion efficiency of dye sensitized solar cells made with polyacrylonitrile (PAN) based gel electrolyte and nano-porous TiO_2 electrode. Instead of a single iodide salt, a mixture of two salts, namely MgI_2 and tetrapropylammonium iodide (Pr_4NI) were used to provide iodide ion conductivity. Solar cells of configuration Glass/FTO/TiO_2/Dye/electrolyte/Pt/FTO/glass were fabricated using nano-porous TiO_2 electrode sensitized with Ruthenium dye (N719). The composition of the gel electrolyte was: PAN(10.36 wt %), EC (41.43 wt%), PC (41.43 wt%), salt (6.21 wt%) and I_2 (0.57wt%).

With identical electrolyte compositions, the cell with MgI_2 alone gave an efficiency of 2.5 % and the cell with Pr_4NI alone gave an efficiency of 3.3 %. The cell with the mixed iodide system, MgI_2: Pr_4NI = 36:64(molar ratio) however, showed an enhanced efficiency of 3.7 % with a short circuit current density (J_{sc}) of 8.61 mA cm^{-2}, open circuit voltage (V_{oc}) of 743 mV and a fill factor of 58.2 %.

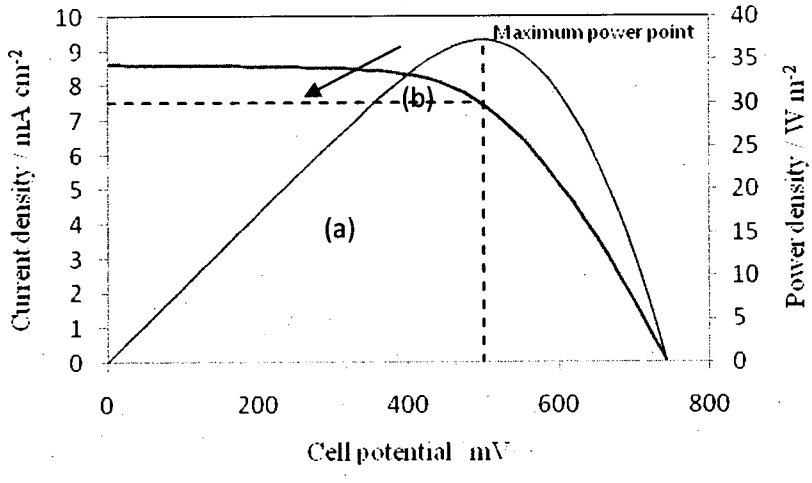


Fig. 1: curve (a) shows the I-V characteristics of the solar cell containing the best electrolyte with 36 mole % $MgI_2$and 64 mole % $Pr_4N^+I^-$. Curve (b) shows the power density of the same solar cell.

References

1. B. O'Regan and M. Gratzel, (1991). "A low-cost, high efficiency solar cell based on dye-sensitized colloidal TiO_2 films". *Nature 353* (353): 737–740.
2. T.M.W.J. Bandara, M.A.K.L. Dissanayake, B.-E. Mellander, (2010). "Dye sensitized solar cells with poly(acrylonitrile) based plasticized electrolyte containing MgI_2". *Electrochimica Acta 55,* 2044.
3. O.A. Ileperuma, M.A.K.L. Dissanayake, S. Somasunderam, L.R.A.K. Bandara, (2004). "Photoelectrochemical solar cells with polyacrylonitrile-based and polyethylene oxide-based polymer electrolytes". *Sol. Energy Mater. Sol. Cells 84,* 117.

Human resource development

Ph.D, M.Phil., M.Sc. students and undergraduate students trained during 2011 with their affiliations; (completed and passed out during 2011)

Postgraduate students trained/supervised

Ms. Ann Nugera (M.Sc in Physics of Materials-2011 completed) , PGIS, University of Peradeniya.

Ms. E.A.D.M. Athukorala (M.Sc. in Physics of Materials, Report under preparation) PGIS, University of Peradeniya

Mr. Dinidu Suranga Lanka (M.Sc in Physics of Materials-Report under preparation) PGIS, University of Peradeniya.

Mr. Nalinda Kulathunga (M.Sc in Physics of Materials-Report under preparation) ,PGIS, University of Peradeniya.

Mr. M.R. Nishantha (M.Phill- Thesis under review- Open University of Sri Lanka)

Ms. C.N. Nupearachchi (M.Phill- to be completed - Open University of Sri Lanka)

Mr. Y.P.Y.P. Ariyasinghe- M.Phill- Open University of Sri Lanka (Reserach Assitant - Institute of Fudamental Studies, Writing Thesis)

Mr. T.R.C.K. Wijayaratna- M.Phill – Open University of Sri Lanka (Reserach Assitant - Institute of Fudamental Studies, Thesis under review)

Cmdr. C.I.F. Attanayake- PhD to be completed - Moratuwa University of Sri Lanka

Undergraduate students trained during 2011

Ms. K.Janitha, Physics Special Final year student project - University of Jaffna
Ms. T. Shyamala- Physics Special Final year student project - University of Jaffna
Mr. L.R.G. Wickramasinghe- Final year student project- The Open University of Sri Lanka
P. Abeygunawardhana- Final year student project – The Open University of Sri Lanka
Ms. H. A. C. S. Perera- Physics Special Final year student project- University of Peradeniya
Ms. H. Iqbal- Physics Special Final year student project - University of Peradeniya
Mr. C.M.D. Hippola- Physics Special Final year student project - University of Peradeniya

7.1.3 GEOTHERMAL ENERGY

Project leader: Dr. N.D. Subasinghe (*Senior Research Fellow*)

Description of the Project

Currently Sri Lanka depends heavily on imported fossil fuel for its energy needs. Hydroelectricity can only satisfy a fraction of Sri Lanka's growing electricity demand, and almost all the possible hydroelectricity sources have already been exploited. These facts triggered the need for search of non-conventional energy sources, especially renewable sources. Geothermal energy comes up as one of the possible solutions to the above quest. IFS has taken the lead in investigating the potential of geothermal energy for the benefit of the country.

7.1.3.1 Geothermal resources mapping project

In Sri Lanka, known geothermal sources are distributed along a certain belt, as shown in the Fig. 1. This region closely follows the geological boundary between Highland and Vijayan lithological complexes, suggesting that there is a possible relationship between the geothermal resources and the boundary.

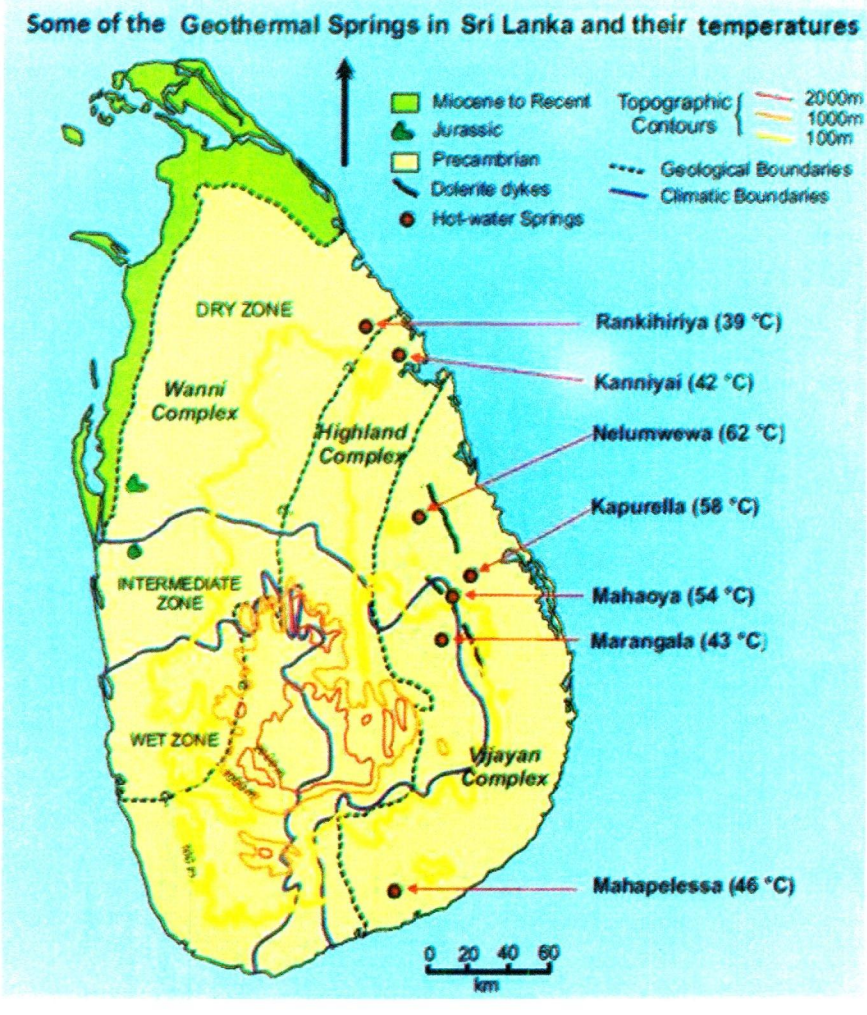


Fig. 1 Map of Sri Lanka showing the lithological boundaries and the distribution of geothermal springs with their surface temperatures.

Geothermal Resources Mapping Project at the IFS was started to evaluate the potential of geothermal resources in Sri Lanka with a view to exploit them for the development of the country. In addition, the relationship between Highland-Vijayan boundary and the origin of the hot water springs will also be investigated.

Geophysical Investigations: An extensive geophysical survey was conducted in an around the known geothermal areas using the state-of –the-art instruments. Magneto-telluric (MT) is a modern remote sensing geophysical technique capable of collecting data on structural features down to tens and hundreds of kilometres. Time domain electromagnetic (TDEM) is another technique employed to get detailed information on relatively lower depths. A group of British and Sri Lankan scientists jointly conducted this first ever MT survey in Sri Lanka with the support of an instrument grant from the UK. Data analysis is currently underway. Preliminary results indicate fracture zones and heat sources that are extending deeper into the earth.

Fig. 2. **Left**: A British scientist is checking the quality of MT data, collected at Kapurella geothermal spring area. **Right**: Collecting water samples from Mahapalassa thermal springs for chemical analyses.

Geochemical investigations: In addition to the geophysical surveys, geochemical methods are also employed to study the geothermal springs. Carbon, hydrogen and oxygen isotope ratios as well as dissolved ion contents help to characterise the origin and the original temperature of the geothermal waters. Some of the analyses are conducted at the institute while others are conducted in Germany, in collaboration with University of Peradeniya. Underground temperatures of the geothermal springs are calculated using standard geothermometry methods.

Other indirect methods: It is a known fact that radon gas is emitted from the opening of the earth and, consequently, most of the thermal waters in other countries are rich in radon. Radon, being the heaviest noble gas, is radioactive. It is emitted by radioactive elements such as uranium and thorium during radioactive decay. No radon mapping has ever been conducted in Sri Lanka. Therefore, recently, a radon mapping program was initiated in collaboration with the Atomic Energy Authority (AEA) of Sri Lanka and National Institute of Radiological Sciences (NIRS), Japan. This first ever radon monitoring programme may help to identify the areas with potentially hazardous radon levels (if any) as well as the hither to unknown radioactive mineral resources. In addition to that, any anomalous radon levels around the geothermal springs will be an indication that the geothermal springs are originating from deep down the earth.

Combining geophysical, geochemical and other relevant information on geothermal springs will provide a more complete picture of the geothermal resources for the benefit of the country.

Research Assistants: N.B. Suriyaarachchi, T.B. Nimalsiri
Senior Staff Technical Officer : S. Opatha

7.1.3.2 Geophysical and geochemical studies on geothermal resources in Sri Lanka

N.D. Subasinghe[1], N.B. Suriyaarachchi[1], T.B. Nimalsiri[1], C.B. Dissanayake[1], R. Chandrajith[2]

[1]Geothermal Energy Project, IFS, Kandy, [2]Department of Geology, University of Peradeniya

Introduction

World is facing the challenge of finding renewable and reliable energy sources to replace the fast-depleting fossil fuel to meet the fast increasing energy demand. Countries like Sri Lanka feels the pressure even more, since 100% of fossil fuels should be imported for our needs. Few renewable energy sources such as hydroelectricity, wind power and solar energy contribute towards our electricity needs, but they are all weather dependent and fast approaching their maximum capacity. Geothermal energy is a renewable energy source with the potential to contribute to Sri Lanka's electricity needs.

Aims

Study on geothermal resources in Sri Lanka was started with the following major aims:

1. To evaluate the source of heat and the geothermal gradient of the geothermal resources
2. To understand the nature of Highland-Vijayan lithological complexes where all the known geothermal springs are closely associated.

Methodology and Results

Geophysical investigations using magneto-telluric (MT) and other electromagnetic methods were conducted around the areas. Apparent resistivity profile for Mahapalassa geothermal field, the longest stretch of the geophysical survey conducted along the suspected Highland-Vijayan boundary, is shown in Fig. 1. Frequency data obtained were converted into depth values assuming the resistivity variations were directly proportional to the thermal properties of the rocks.

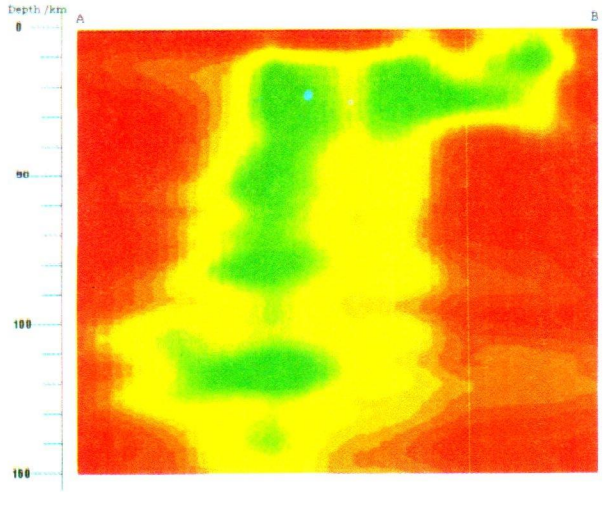


Fig. 1. Apparent resistivity profile of Mahapalassa traverse. Total length of the section (A-B) is 26kms.

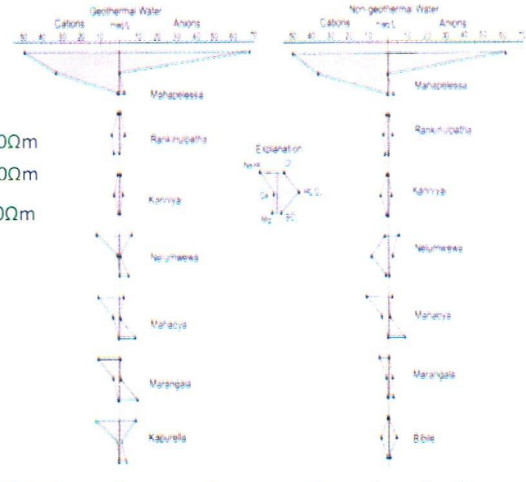


Fig.2. Comparison of chemical compositions of geothermal and non-geothermal waters.

Geochemical and isotope work has also been conducted on water from the geothermal areas. Comparison was made with the geothermal and non-geothermal waters from each area as presented in Fig. 2. Many locations display close similarities in chemistry indicating a related origin for two types.

Reference

1. R. Chandrajith, J.A.C. Barth, N.D. Subasinghe, D. Merten, C.B. Dissanayake (Under Review). Origin and low enthalpy characteristics of geothermal springs in Precambrian metamorphic terrains of Sri Lanka. *Journal of Hydrogeology.*

Human resource development

Research Assistants registered for M.Phil. Degrees

T.B. Nimalsiri registered for M.Phil. degree at University of Peradeniya with the title: Geothermal gradient of Sri Lanka with special reference to Highland-Vijayan boundary.

N.B. Suriyaarachchi registered for M.Phil. degree at University of Peradeniya with the title: Mapping geothermal resources in Sri Lanka using Magnetotelluric and other geophysical methods.

7.1.4 PHOTOCHEMISTRY

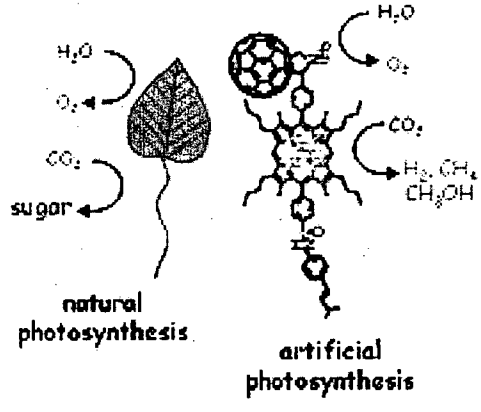
Solar energy as an alternative energy

Project leader: Prof. J.M.S. Bandara (*Research Professor*)

Description of the project

Fossil fuel is our main energy resource and 80 percent of our energy comes from it. However, fossil fuel resources are of finite extent and are distributed unevenly beneath the Earth's surface. It has been estimated that the present fossil fuel reservoirs are just enough for about 100 years. Apart from that, when fossil fuel is turned into useful energy through combustion, it often produces environmental pollutants that are harmful to human health and greenhouse gases that threaten the global climate[1]. Due to the so called energy crisis, scientists started looking for alternative energy resources such as nuclear, wind, geothermal and solar energy. All of these alternative energy resources have their own advantages and disadvantages. However, solar resources are widely available and have a benign effect on the environment and climate, making it an appealing alternative energy source. It is known that the sunlight is not only the most plentiful energy resource on earth, it is also one of the most versatile, converting readily to electricity, fuel and heat. The challenge is to raise its conversion efficiency by factors of five or ten which requires understanding the fundamental conversion phenomena at the nanoscale. The Photochemistry group at the IFS is actively involved in investigation of the conversion of solar energy into useful energy resources.

In natural photosynthesis, carbon dioxide is converted to sugar by green plants by a series of chemical reactions. The natural process involves two critical steps or half reactions. First is the oxidation of water molecules to produce oxygen and protons (hydrogen), and the second step involves the reaction of oxygen with carbon dioxide to form glucose. By mimicking the natural photosynthetic process, solar energy can be converted into electricity and chemical energy.



Schematic diagram of natural and artificial photosynthesis

The main long-term goal of the project is to find a feasible solution to the energy crisis. The objective of the project is to investigate and research on alternative energy resources. The Photochemistry project is involved mainly in the field of renewable energy research and the project focused its research on development of new materials for photoconversion of solar energy into chemical and electrical energies.

The Photochemistry project also involves investigation of low cost purification methods for abatement of industrial pollutants by using sunlight. In addition to the main goal described above, the Photochemistry project has also initiated an important research project in collaboration with the Veterinary Faculty of the University of Peradeniya on investigation of the cause of renal failure in families in the dry-zone of Sri Lanka.

The Photochemistry group at IFS conducts research on conversion of solar energy into electricity, fuel and removal of water pollutants.

Photochemistry group members

Research Assistants: J. Akilavasan, K.T. Wijeratne, S.M. Wasana, U.W. Pradeep (Volunteer) D. Darmawickrame (Volunteer)

Senior Staff Technical Officer: D. Aluthpatabendi

References

1. J.D. Figueroa, T. Fout, S.Plasynski, H.Mcilvried,(2008). Advance in CO_2 capture technology- The U.S. Department of Energie's Carbon Sequestration Program. *Inter.J. Greenhouse Gas Control.* 2, 9-20.

7.1.4.1 Fabrication of dye-sensitized solar cells, bulk hetero junction solar cells and hybrid solar cells for the conversion of solar energy into electrical energy

J. Akilavasan, D. Aluthpatabedi, D. Darmawickrame, U.W. Pradeep, S.M. Wasana, K.T. Wijeratne, J. Bandara

Photochemistry Project, IFS, Kandy

Objective

Conversion of solar energy into electrical energy

(a) Different solar cells are being fabricated to convert solar energy into electrical energy. Q-dot CdS was investigated as light harvesting units on TiO_2 naotube films.

(b) Donor-acceptor concept was employed to fabricate bulk heterojunction solar cells.

(c) SnO_2nanotube was synthesised to be used as electrode for solar cells.

Results

(1) Transparent TiO_2 nanotube arrays prepared on a FTO substrate are employed as 1D nanostructures providing elongated direct pathways for electron transport and collection in solid-state dye-sensitized solar cell (SDSC). Donor-antenna (D-A) dyes provide an exciting route for improving the light harvesting efficiency in dye sensitized solar cells owing to their high molar extinction coefficients and the effective spatial separation of charges in the charge-separated state. Hence in this study we fabricated SDSC devices with different thicknesses of transparent TiO_2 nanotube array electrodes sensitized with Ru-(II)-donor-antenna dye and spiro-OMeTAD as a hole conductor. At AM 1.5 G, 100 mW/cm^2 illumination intensity, a power conversion efficiency of 1.94% was achieved when the TiO_2 nanotubes are initially subjected to $TiCl_4$ treatment. Furthermore, a linear increase in the cellcurrent without loss in fill factor is observed for increasing length of TiO_2 nanotubes. The structural and morphological characteristics of the transparent TiO_2 nanotube arrays as well as the optimal conditions for the fabrication of SDSCs with transparent TiO_2 nanotubes on FTO glass are reported.

(2) We investigated an inverted organic photovoltaic device structure in which a densely packed ~100 nm thin TiO^2 layer on fluorine doped conducting glass serves as anode and poly(3,4-ethylenedioxythiophene): poly 26 (styrenesulfonate)/Au layer on top of the active layer serves as cathode. The active layer is comprised of a blend of poly(3-hexylthiopene) (P3HT) and [6,6]-phenyl-C61-butyric acid methyl ester (PCBM). The 28 rectification behaviour of such a device is improved significantly and injection losses are minimized compared to devices without any compact TiO_2 layer. Moreover, nanostructured P3HT active layer was achieved in-situ by spin coating concentrated pure P3HT and P3HT:PCBM blend. Solar cell performances on thickness of the active layer were also investigated. For the inverted solar cells constructed with different concentrations of 32 P3HT and PCBM keeping the P3HT:PCBM ratio 1:0.8 (wt.%), the highest short circuit current and efficiency was observed when the P3HT and PCBM concentration was equal to 1.5 (wt.%) and 1.2 (wt.%) respectively. This leads to highly stable and reproducible power conversion efficiency above 3.7% at 100 mW/cm^2 light 35 intensity under AM 1.5 conditions.

These findings were published (2011) in *Thin Solid Films*, *European Journal of Applied Physics and J. Natl. Sci. Foundation Sri Lanka.*

7.1.4.2 Development of a device with multiple band-gap tandem cells and thin-film photocatalyst that can be activated by UV, visible and IR photons for the economic production of hydrogen and oxygen through water splitting

J. Akilavasan, D. Aluthpatabendi, D. Darmawickrame, U.W. Pradeep, S.M. Wasana, K.T. Wijeratne, J. Bandara

Photochemistry Project, IFS, Kandy

Objective

Conversion of solar energy into electrical energy

Multiple bandgap solar cells are fabricated by a novel method and the new method can be used to fabricate tandem devices easily. Also thin-film photocatalysts (ie WO_3 and Cu_2O) were fabricated. These electrodes will be assembled in a tandem manner to fabricate a device for water splitting.

Results

A new technologically relevant method for multichromophore sensitizing of hybrid blend solar cells is presented. Two dyes having complementary absorption in the UV-visible regions are individually adsorbed on nanocrystalline TiO_2 powder. These dyed TiO_2 nanoparticles are blended with an organic hole-conductor (HC) Spiro-OMeTAD in desired compositions and applied on a conducting substrate by doctor-blading at room temperature to fabricate multichromophore-sensitized hybrid blend solar cells. The external quantum efficiency (EQE) of the single hybrid layer system fabricated with two dyes, that absorb mainly UV (TPD dye) and visible regions (Ru-TPA-NCS dye), exhibited a clear panchromatic response with the sum of the EQE characteristics of each single dye cell. The Jsc of the multichromophore cell is the sum of the individually dyed solar cells. The process described here is technically very innovative and very simple in procedure. It has potential to be adopted for panchromatic sensitization using more than two dyes in a single hybrid layer or layer-wise fabrication of a tandem structure at room temperature. This finding was published in *Physical Chemistry Chemical Physics* (2011).

7.1.4.3 Chemical, electrochemical and photochemical methods for the purification of water (special project on effect of Al and F on kidney disease)

J. Akilavasan, D. Aluthpatabedi, D. Darmawickrame, U.W. Pradeep, S.M. Wasana, K.T. Wijeratne, J. Bandara

Photochemistry Project, IFS, Kandy

Objective

1) To detect the fluoride and some selected metal ion concentration (Al^{+3}, Cd^{+2}, Pb^{+2}, Ca^{+2}, Mg^{+2}) of drinking water in the Anuradhapura district with reference to the Chronic Renal Failure.
2) To detect the effect of AlF_x compounds on Chronic Renal Failure (Rajarata Kidney Disease).
3) To develop an effective and economical method in order to reduce the Fluoride concentrations in drinking water to WHO standards.

Results

Water quality of the Rajarata area has been analyased and statistical is being carried out. Based on the findings of the statistical analysis, an animal trial was initiated. Results will be published once the animal trial is over.

Human resource development

J. Akilavasan, successfully completed M.Sc in Nanoscience and Nanotechnology.

7.1.5 THERMOELECTRIC POWER GENERATION

Project leader: Dr. N.D. Subasinghe *(Senior Research Fellow)*

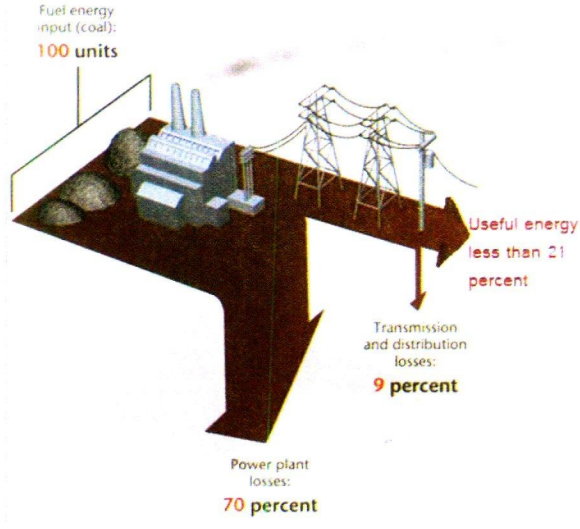
Description of the project

Scientists around the globe are working on energy related issues like never before. Researches in energy sector are focussing on either finding new energy sources, or developing new technologies to increase the efficiency of energy use.

As a basic rule in science, no energy transfer is 100% efficient and most of the energy is eventually lost as heat. In most of the energy transformations, more than 50% of energy is lost to the environment.

Electricity is the largest sector of energy in the world. Globally, over 87% of electricity is generated by thermal power plants using heat energy generated either by burning fossil or nuclear fuel. Next is the transport sector, which is almost 100% depends on burning fossil fuel. It is still a small fraction of energy that comes from renewable sources.

One of the biggest disadvantages in converting heat energy into electrical or mechanical energy using conventional methods is that essentially only a small fraction of heat generated can be used for the intended purpose (e.g. generating electricity or moving a machinery) while the majority of heat is released to the environment. This is because a steam engine or internal combustion engine can only be operated above a certain temperature. In addition, there are several energy transformations that take place in conventional processes. For example, in a coal-powered electricity generator, following energy transformations take place:



Chemical Energy of coal→ heat energy → kinetic energy of water molecules → mechanical energy of turbines → mechanical energy of generator → electricity

Eventually less than 25% of the original energy is used for useful purposes while most of the energy is lost as heat, as shown in the above diagram.

Considering the amount of energy we remove intentionally or unintentionally as heat, if there is a system that re-uses at least a fraction of this waste heat it would save large amount of energy that are otherwise lost. Co-generation is a hot topic in energy research, as it increases the overall efficiency of an existing system. Further, as a tropical country, we receive a large amount of solar heat, which can be harvested for our electrical needs if the heat can be converted to electricity directly.

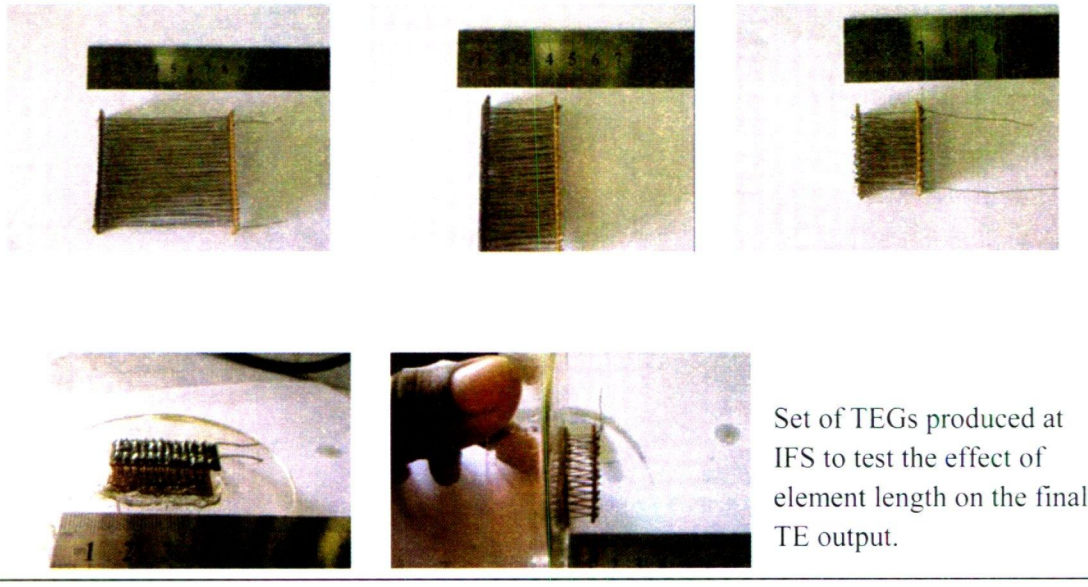
Thermoelectricity project will develop material and devices to generate electricity directly from heat, using the *thermoelectric effect*.

A thermoelectric device is an energy conversion system that converts thermal energy to electrical energy. A device of this type is commonly referred to as a thermoelectric generator (TEG). It has been known that when a conductor is subjected to a temperature gradient, there is a flow of electrons along the conductor. In order to get these electrons as a useful current through an external circuit, it is

necessary to make two junctions with dissimilar material and maintain a temperature difference between the junctions. The phenomenon that generates electricity this way is called ***Seebeck effect.***

Essentially, any TEG should have "hot" junctions and "cold" junctions, sometimes called "thermocouples". Since the voltage generated does not depend on the size of the thermocouples, size of the TEGs may only be limited by the available technology. Developing a suitable texture/fabric may increase the efficiency of any TE system regardless of the material used. It is expected that combining nano-technology and self-assembly techniques, more efficient arrays may be produced. IFS may lead the thermoelectric research work in Sri Lanka.

At present, preliminary work has been conducted using readily available material. Basic modules of TEGs were produced to test the effect of physical parameters on the TE output.



Set of TEGs produced at IFS to test the effect of element length on the final TE output.

Expected Outcomes

- Introducing and initiating one of the timely fields of research in Sri Lanka.
- Developing interest and awareness on thermoelectricity and its applications in Sri Lanka.
- Understanding the effect of different parameters and geometry of elements on the TE power output and developing more efficient TE modules using non-conventional assembly methods.
- Developing TE modules that are cheap, affordable, and practical, which can run on any locally available waste energy source (e.g. solar energy, waste heat from cooking or from factories, heat from burning straw, rice husk or dried weeds).
- Investigation of possibility of producing low-cost TEG units as a local/domestic industry.

7.1.5.1 Thermoelectric power generation

N.D. Subasinghe, N.B. Suriyaarachchi, T.B. Nimalsiri

Thermoelectric Power Generation Project, IFS, Kandy

Introduction

Developing energy efficient technologies and finding new ways of generating energy are of paramount important in energy hungry world. Thermoelectric generators (TEGs) can generate electricity, virtually from any available heat source, as long as a temperature difference can be maintained. TEGs can also improve the overall efficiency of an existing system using the principle of co-generation. We introduce this timely field of research that has not been properly developed in Sri Lanka.

It has been known that when a conductor is subjected to a temperature gradient, there is a flow of electrons along the conductor. In order to get these electrons as a useful current through an external circuit, it is necessary to make two junctions with dissimilar material and maintain a temperature difference between the junctions. The phenomenon that generates electricity this way is called ***Seebeck effect.*** A good thermoelectric material should have large Seebeck coefficient, low electrical resistivity and low thermal conductivity, in order to generate a higher voltage.

Aims

We attempt to introduce low-cost TEGs that produce electricity using solar heat or waste energy. Since such TEGs co-generate electricity by scavenging 'free' energy from any available heat source, efficiency is not the most important issue. Effect of the physical parameters, array design and modular construction on the output will be investigated at the first phase of this project.

Experiments and Results

We investigate the effect of the variation of certain physical parameters such as length and diameter of the wires used in junctions, number of serial connections per module, temperature range, active and passive cooling and so on. Optimum values for certain parameters are determined. As shown in Fig. 1& 2, effective output increases with junction separation.

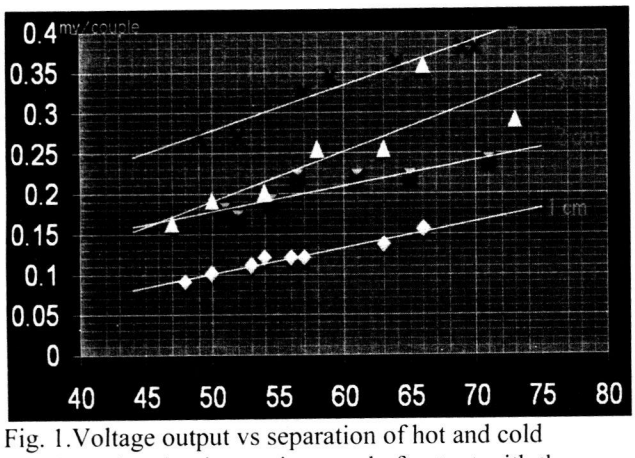


Fig. 1.Voltage output vs separation of hot and cold junctions showing increasing trend of output with the junction separation.

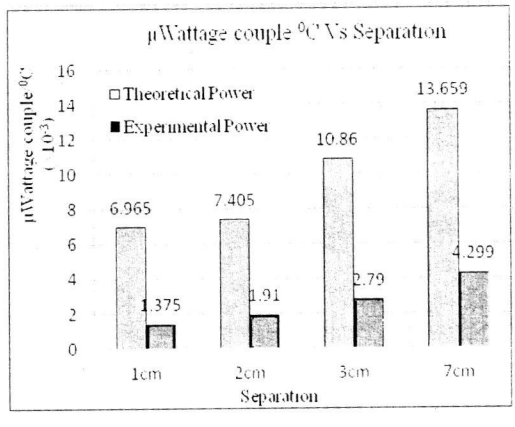


Fig.2. Comparison of theoretical vs practical outputs of the modules (Subasinghe *et al*, 2011).

References

1. N.D. Subasinghe, N.B. Suriyaarachchi, T.B. Nimalsiri (2011). Low-cost thermoelectric power generation using solar energy. *Proceedings of Solar Asia 2011*. Institute of Fundamental Studies, Kandy. 28-30 July 2011.

7.2 ARTIFICIAL ENERGY AND APPLIED ELECTRONICS

Brain computer interface and sinhala language based artificial intelligence

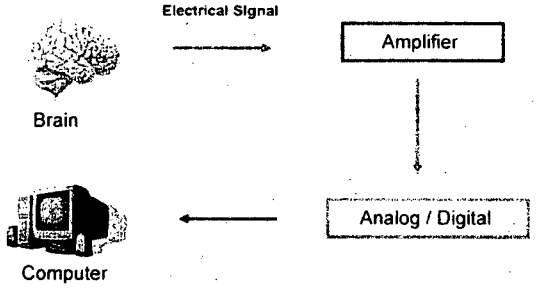
Project leader: Prof. Asiri Nanayakkara (*Research Professor*)

Description of the project

A Brain–Computer Interface (BCI), sometimes called a direct neural interface, is a direct technological interface between a brain and a computer. It is a system that uses electric, magnetic, or hemodynamic brain signals to control external devices such as switches, wheelchairs, computers, or neuroprosthesis. BCI systems are especially invaluable for patients who suffer from severe motor impairments (late stage of Amyothrophic Lateral Sclerosis (ALS), severe cerebral palsy, head trauma, and spinal injuries).

The Brain Computer Interface (BCI) project aims at building high performance hardware and software system, which provides a communication link between the human brain and the computer. Using such a system, a person can control any equipment or interact with the outside world using his or her thoughts alone without any physical involvement. This way, patients with severe physical disabilities can control equipments such as wheel chairs, televisions etc. and communicate with computer voice in his or her native language.

Certain actions in a normal human brain can generate various responses such as metabolic activities or electromagnetic signals which can be detected by appropriate sensors and hence can be used for controlling BCI systems. As an example, brain activity can produce magnetic fields that can be detected using Magneto encephalography (MEG). Certain brain activities may produce electrical signals that can be detectable on the scalp Electroencephalography (EEG) or cortical surface or within the brain Electrocorticography (ECoG). At present, EEG and ECoG are more popular as equipment needed for detection of other effects such as MEG is prohibitively expensive.



Although compared to MEG or functional Magnetic Resonance Imaging machines, EEG systems are much cheaper, still they are quite expensive for most of the people in Sri Lanka and hence they cannot afford to own EEG equipment. Therefore one of the aims of this project is to design and develop low cost software and hardware needed for BCI. Another aim is to develop a real time BCI system which could be used by severely physically disabled people in Sri Lanka. This includes development of new techniques to extract thoughts from EEG signals and carrying out activities according to thoughts.

Individuals with speech disabilities (non-vocal) need an effective way of communication with the general public. In this project we are developing a Sinhala speech synthesizer which can produce Sinhala speech, according to the input received from the disabled person. For disabled persons who can use their arms or hands, a keypad or an electronic glove is provided as input devises while for individuals who cannot speak and have lost muscle control in their hands and arms, a speech system can be used with electrical signals produced by working muscle Electromyography (EMG) in any part of their bodies. Finally we hope to improve the system to a Portable Sinhala speech synthesizer using Microcontrollers.

7.2.1 BRAIN COMPUTER INTERFACE

Introduction

The BCI research group is mainly interested in constructing a BCI system based on Electroencephalography (EEG) which can be used by paralyzed people. Since EEG equipment is usually expensive, one of the aims of the project is to design and develop low cost software and hardware needed for BCI. The other aim is to develop a real time BCI system which could be used by severely physically disabled people in Sri Lanka. This includes development of new techniques to extract thoughts from EEG signals and carrying out activities according to thoughts. Research and development work of BCI have been carried out during the last two years in two main avenues.

Aims and objectives

(1) Development of new methods and software system to recognize thoughts from individuals and control external devices according to recognized thoughts. This includes finding of new mental tasks which can be used with BCI systems more naturally and accurately.

(2) Design and construction of low cost BCI hardware including EEG amplifiers, recording electrodes, etc

Results

In the first phase of the project we concentrated on finding new mental tasks which can be used with our BCI system effectively. A new set of mental tasks were found which can be performed naturally and identified by a BCI system accurately. This new set of mental tasks is named ***imaginary arrow movements***. The performance of this new set of mental tasks was tested and found to be quite accurate.

In the second phase, we concentrate on constructing a Real Time Brain Computer system which can be used to control televisions, adjust room lighting, and communicate with Sinhala computer speech. First, the low cost 8 channel EEG/EOG (Electrooculogram), /EMG (Electromylogram) amplifier which was constructed last year in our laboratory was modified to be used with Real Time Brain Computer system. Then a complete software package for recording EEG, EMG and EOG signals from this amplifier was developed. Further, an EEG based Brain computer interface system (named **GENIE**) was constructed to accept and classify signals from subjects in real time. This system utilizes only four EEG channels. Since over 90% of the severely paralyzed patients could make eye movements, additional facilities have been incorporated into the BCI system to accept commands through EOG due to slight eye movements. In order to control televisions, lighting and other equipment from the computer, a new hardware (remote control) system was developed.

Research Assistants: D. Wijethunga, Z. Sakkaff

7.2.2 SINHALA LANGUAGE BASED ARTIFICIAL INTELLIGENCE

Description

Individuals with speech disabilities (non-vocal) need an effective way of communication with the general public who may or may not understand sign languages. Hence, it is useful for a person with speech disabilities (PSD) to have a portable electronic system which can produce Sinhala speech, according to input received from him or her. If the PSD can use a keypad or can control a glove type device, Sinhala speech system with a keypad or an electronic glove is suitable. For an individual who cannot speak and has lost muscle control in his or her hands or arms, EMG signals produced by working muscles in any part of his or her body can be used as input.

Aims and objectives

In this project we are developing a portable electronic speech system based on microcontrollers which can produce Sinhala speech, according to the input received from the disabled person. For disable persons who can use their arms or hands, a keypad or an electronic glove is provided as input devises while for individuals who cannot speak and have lost muscle control in their hands and arms, a speech system can be used with electrical signals produced by working muscles in any part of their body.

Results

Sinhala speech database using Sinhala phonemes was developed and computer software was developed for converting Sinhala text to Sinhala speech. An Electronic glove was designed and constructed which can be used not only with speech devises but also with any multimedia system. An EMG amplifier was designed and constructed for converting instructions given by slight movements of muscles.

In order to reduce the size of the Sinhala speech database consisting of diaphones, a detail investigation was carried out on techniques which can be employed for combining phonemes to produce quality Sinhala speech. Various methods have been explored. A large number of Sinhala words were recorded from two subjects by filming their muscle movements surrounding the mouth and neck areas for grouping Sinhala sounds according to the places where they are generated.

A new way of constructing hybrid phoneme and diaphone based speech system was found. By combining with Hidden Markov methods, this speech system will enable us to produce naturally sound computer generated Sinhala words using a smaller phone-diaphone database. The construction of the database was completed.

Human resource development

M.Sc. student: Mr. Prashath Karunasiri, PGIS, University of Peradeniya.

MPhil student: Mr. Dammika Wijetunga, Department of Electrical Engineering, University of Peradeniya.

7.3 ENVIRONMENTAL AND EARTH SCIENCES

7.3.1 CHEMICAL AND ENVIRONMENTAL SYSTEMS MODELING

Project leader : Dr. Meththika Vithanage *(Research Fellow)*

Description of the project

The research group of Chemical and Environmental Systems Modeling was established by Dr. Meththika Vithanage in the latter half of 2009. Although groundwater serves as a good source for increasing demand, particularly in view of natural, anthropogenic pollution, climate change and sea level rise, it may be unfit for consumption. Our research group works on understanding chemical processes in solid solution interface - assess, characterize groundwater pollution, salt water intrusion and model these systems in order to find solutions for human benefit.

Natural dissolution mechanisms of serpentine; Possible toxic element leaching to the environment

The aim of this research project is to understand the mechanisms of natural dissolution of heavy metal species such as Cr, Ni and Mn from serpentine soil. A model system was used to study Cr release based on different factors such as humic matter, Mn oxides etc. Synchroton based advance spectroscopic tools will be used in the future to understand the speciation of Ni and Cr in serpentine soils. Mechanistic modeling of Ni removal from various clay materials was also studied in relation to this project.

Three abstracts have been published in International and Local Conferences in 2011. Research Assistant, Ms. R.M.A.U. Rajapaksha is undertaking this research for her M.Phil Degree at the UoP. We received a research grant from the International Foundation for Science, Sweden to carry out the rest of this research.

Adsorption of arsenic on paddy soils in the presence of fertilizers

Arsenic fractionation can be different in different soil types based on pH and other physico-chemical parameters. Hence, a static incubation study was conducted to estimate fractionation of inorganic arsenicals and assess the lability with and without fertilizer based on different paddy soil types. Eight soil samples collected from dry and wet zones of Sri Lanka were applied with 1000 mg/kg representing the worst case scenarios.

Ms. R.M.A.U. Rajapaksha, Mr. S.S.R.M.D.H.R. Wijesekara, Ms. N. Weerarathna (Microbial Biotchnology Unit) and Prof. Y.S. Ok (KNU, Korea) worked in this project with the research group leader, Dr. M Vithanage.

Mechanistic modeling of fluoride adsorption on different materials

This research project (begun in 2010) was carried out to investigate characteristics of different materials suitable for fluoride removal using experiments, modeling and spectroscopic techniques.

Ms. R.M.A.U. Rajapaksha, Mr. S.S.R.M.D.H.R. Wijesekara, Mr. I.P.L. Jayarathna, Ms. A. Madhave (PGIS), Dr. K. Mahatantila, Mr. Bootharaju and Prof. T.Pradeep (IIT, Chennai) contributed to the research.

Fate and transport of landfill leachate and its treatment

This study for the characterization of landfill leachate and soils from Gohagoda and Gampola solid waste dumps was undertaken in 2010. Spatial and temporal variations are under consideration with the support of geophysical techniques. At the same time, we developed and tested different materials, including nano-materials, for leachate treatment.

Ms. B.G.N. Sewwandi, obtained her M.Phil. degree from the PGIA while Mr. SSRMDHR registered for M.Phil at PGIS. Several abstracts have been presented in several International and local conferences. Two undergraduate students from Sabaragamuwa University are conducting their undergraduate research projects.

Collaborative research projects:

- Soil incubation studies on metal contaminated soils using advanced spectroscopic techniques in collaboration with the Kangwon National University, Korea.
- SATREPS (Science and Technology Research Partnership for Sustainable Development): UoP, Saitama University, UoR – JICA – JST grant for 5 years on Waste Dumping Sites in Sri Lanka.
- Saitama University, Japan: Research work on Water repellency behavior of soils. University of Copenhagen, Denmark: Prof. Peter Engesgaard. Dr. Meththika Vithanage served on the advisory committee of Danish Master's student.
- Shimane University, Japan: A research collaboration on Adsorption.
- International Water Management Institute and University of Jaffna: A research study on N budgeting in the Jaffna aquifer system.

Research Assistants: I.P.L. Jayaratha, R.M.A.U. Rajapaksha, S.S.R.M.D.H.R. Wijesekara

Volunteers : A.M. Chandrasena (PGIS), Disna Eheliyagoda (Sabaragamuwa University of Sri Lanka), Sonia Mayakaduwa (Sabaragamuwa University of Sri Lanka), B.G.N Sewwandi (PGIA)

Collaborators : Prof. Y.S. Ok (Kangwon National University, Korea)
Prof. P. Engesgaard, Prof. K.H. Jensen, Dr. K. Dirdriksen (Uni. of Copenhagen, Denmark)
Prof. T. Pradeep (Indian Institute of Technology, Chennai)
Prof. R. Weerasooriya, Dr. A. Bandara, Dr. Pathmarajah (UOP)
Prof. K. Kawamoto (Saitama University, Japan)
Dr. Christopher Oze (University of Canterbury, New Zealand)
Dr. Herath Manthrithilake (IWMI, Sri Lanka)
Dr. T. Mikunthan (University of Jaffna, Sri Lanka)
Dr. Pathmarajah (University of Peradeniya, Sri Lanka)

7.3.1.1 Natural dissolution mechanisms of serpentine; possible toxic element leaching to the environment

A.U.Rajapaksha[1], M. Vithanage[1], C. Oze[2], W.M.A.T Bandara[3], R. Weerasooriya[3]

[1]Chemical and Environmental Systems Modeling Research Project, IFS, Kandy, [2]Department of Geological Sciences, University of Canterbury, New Zealand, [3]Department of Chemistry, University of Peradeniya

Ultramafic rocks such as serpentinite in Sri Lanka is known for high concentrations of trace metals such as Cr, Ni, Co and Fe in particular which may cause groundwater pollution leading to ecological

and health problems for the local population. This research was conducted to understand the mechanisms of natural dissolution of heavy metal species such as Cr, Ni and Mn from serpentine soil, to assess change in the metal dissolution behavior based on environmental factors such as pH, ligands and oxides etc. It was observed that some of the local wells surrounding serpentinite deposits in Sri Lanka are rich in Ni and Mn. Similarly, serpentine soil showed high release of Ni and Mn in bioavailable and exchangeable fraction indicating risk of contaminating groundwater and abosorption into plants (Table 1). Chromium release from serpentine soils was low. Hence, a model study was conducted with chromium bearing mineral, fuchsite, based on different factors as humic acid and MnO_2 to observe the possibility of toxic hexavalent chromium formation from fuchsite.

Table 1. Bioavailable and exchangeable Ni and Mn with water and ionic strength

Extractants	Amount released (mg kg^{-1})	
	Ni	Mn
Water and Ionic Strength		
Distilled H_2O (pH 6.5, 24 h)	56.0	4.8
0.1 M $NaNO_3$ (pH 7.0)	167.0	39.6
0.01 M $NaNO_3$ (pH 7.0)	47.0	16.0
0.001 M $NaNO_3$ (pH 7.0)	33.8	5.6

7.3.1.2 Adsorption of arsenic on paddy soils in the presence of fertilizers

M. Vithanage[1], A.U. Rajapaksha[1], S.S.R.M.D.H.R. Wijesekara[1], N. Weerarathna[2], Y.S. Ok[3]

[1]Chemical and Environmental Systems Modeling Research Project, IFS, Kandy, [2]Microbial Biotechnology Project, IFS, Kandy, [3]Department of Biological Environment, Kangwon National University, Korea

Inorganic arsenical pesticides are widely used in many countries. However, data is scarce on the fractionation of inorganic arsenicals in different paddy soils in particular for the tropical regions. An incubation study was conducted to estimate inorganic arsenicals with and without fertilizer based on 8 paddy soils collected from wet and dry zones of Sri Lanka. Soils were applied with 1000 mg/kg representing the worst case scenarios. Spectroscopic data suggested that the soils in wet region are rich in Fe/Al oxides. Soils with high arsenic lability were observed from the dry zone soil type, i.e. low humic gley with low Fe/Al oxyhydroxide amount and high pH. Results showed that arsenic lability was mainly influenced by soil physicochemical properties, i.e Fe/Al oxyhydroxide amount, pH, organic matter content and fertilizer application. Above all, fertilizer application was impacted in principal for lability of arsenic for the soils in wet regions.

7.3.1.3 Mechanistic modeling of fluoride adsorption on different materials

M. Vithanage[1], I.P.L. Jayarathna[1], A.U. Rajapaksha[1], S.S.R.M.D.H.R. Wijesekara[1], A.M. Chandrasena[2], M. Bootharaju[3], T. Pradeep[3]

[1]Chemical and Environmental Systems Modeling Research Group, IFS, Kandy, [2]Postgraduate Institute of Science, University of Peradeniya, [3]DST Unit of Nanoscience, Indian Institute of Technology, Chennai, India

The efficacy and the interface interactions of fluoride on laterite and gibbsite is under investigation using batch methods; under various ionic strength, pH, fluoride loading, surface complexation modeling and spectroscopic methods. Laterite used in this study was rich in iron (40 %) and aluminum (30%). Nano-gibbsite was synthesized. Proton binding sites were characterized by potentiometric titrations. Adsorption studies were conducted based on pH, adsorbent loading and the effect of

temperature. Adsorption of fluoride is strongly pH dependant showing a maximum adsorption at < pH 5, though not affected by the electrolyte concentration. Increase in temperature demonstrated an increase in adsorption on laterite (Figure 1). Surface complexation modeling and spectroscopic investigation are under investigation.

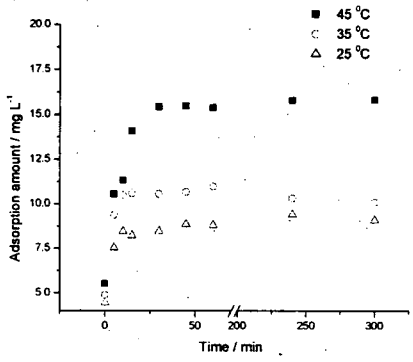


Figure 1. Fluoride (20 mg/L) adsorption on laterite (2 g/L) based on temperature

7.3.1.4 Fate and transport of landfill leachate and its treatment

S.S.R.M.D.H.R. Wijesekara[1], Meththika Vithanage[1], K. Mahatantila[1], B.G.N. Sewwandi[2], K. Dideriksen[3], N. de Silva[4], D.R.M.D.P. Eheliyagoda[5], S.S. Mayakaduwa[5], B.F.A. Basnayake[6]

[1]Chemical and Environmental Systems Modeling Research Project, IFS, Kandy, [2]PGIA, University of Peradeniya, [3]Nano-science Center, University of Copenhagen, Denmark, [4]Department of Natural Resources, Sabaragamuwa University of Sri Lanka, Belihul Oya, [5]Geological Survey and Mines Bureau, Dehiwala, [6]Department of Agricultural Engineering, University of Peradeniya

The landfill leachate characteristics, its transportation pathways and soil contamination are under investigation temporally and spatially from the Gohagoda soild watse dumpsite, based on chemical and geophysical methods. The efficacy of NZVI with different stabilizing agents, will then be compared with waste materials such as coir pith and saw dust for leachate treatment. Synthesized material was exclusively NZVI as observed by XRD and consisted of 10 nm particles (Figure 1). Coir pith showed high retention capacity for Cd and Pb than that of saw dust. High BOD, COD and nutrient content was observed in the leachate. Geophysical investigation showed few subsurface canals and perched water in the leachate transport pathway. Detaied geophyscial studies, leachate characterization and treatment are ongoing.

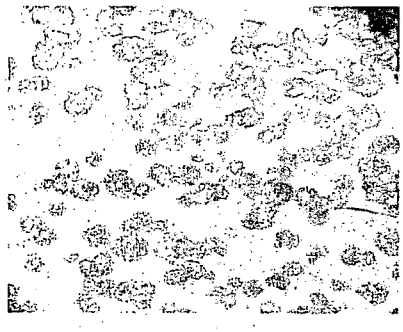
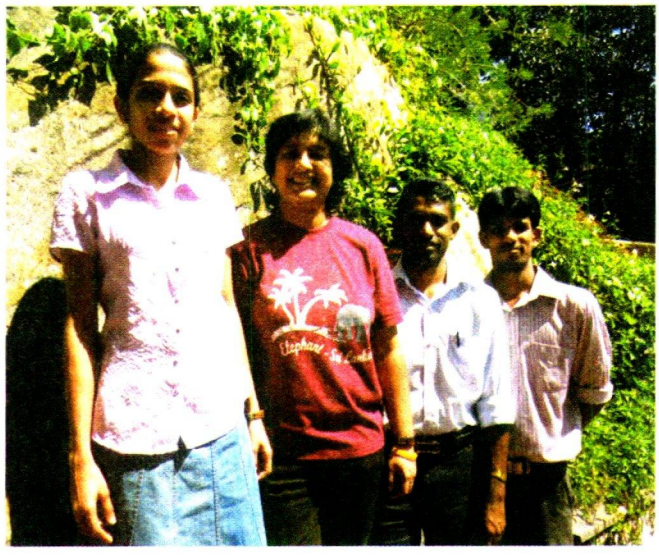


Figure 1. TEM of NZVI particles stabilized using starch

Resource personnel in workshops

Dr. M Vithanage conducted lectures for the Teacher training workshop on Earth Sciences organized by the SDU at IFS for the English medium school teachers in Kandy District, February, 2011



7.3.2 ECOLOGY AND ENVIRONMENTAL BIOLOGY

Project leader : Dr. Suresh P. Benjamin *(Senior Research Fellow)*

Description of the project

Biodiversity surveys of Sri Lanka

The loss of quality habitats due to anthropogenic causes like over population, habitat degradation and climate change demands the urgent attention of biologists. The focus of our project is thus the study of the mega diverse fauna and flora of Sri Lanka. The primary focus, however, is the largely uncharted fields of invertebrate and small plant biodiversity. The invertebrate fauna of our country remains largely unexplored, with most studies originating during the colonial period. Most studies on the flora of Sri Lanka are outdated. Arthropod diversity estimates can be useful as indirect assays of ecosystem function or productivity, or as direct estimators of ecosystem responses to human induced change. The groups of our focus are still pseduoscorpions, spiders and orchids, groups of high conservation necessity. However, this year we initiated a survey of the earwigs (Dermaptera) of Sri Lanka; they were last surveyed about 40 years ago.

Orchidaceae is one of the largest plant families in Sri Lanka, found in almost all terrestrial vegetation types and habitats. There are 188 orchid species belonging to 78 genera with one endemic genus and 55 endemic species in Sri Lanka. Forests of the lowland wet zone and the montane zone are rich in orchid diversity. Because of their beautiful flowers most orchids are ornamental plants of high economic value; sadly they are also threatened due to the same reason. Orchids are clearly an ideal target group for conservation. We are currently conducting a survey of the genera *Dendrobium* and *Bulbophyllum*. This is the first floral survey undertaken since the Smithsonian Institution initiated floral project of the 1960s. All research projects commenced in or around June 2009. Three research assistants and several volunteers from all over the island are being trained as part of these projects. Research collorborations have been established with local as well as international research institutes.

A first publication on pseudoscorpions of Sri Lanka is being prepared. Three papers have been published for 2011 on spiders. Over fifteen field visits were undertaken for the year 2011.

Research Assistants: Sudesh Batuwita, Buddhika Perera, Harshani Sandamali
Ziyard Jaleel (volunteer), Chathurika D. Kuruppuarachchi (volunteer)

Senior Technical Officer: Namal Atukorala

7.3.2.1 Biodiversity of soil arthropods

S. P. Benjamin and S. Batuwita

Ecology and Environmental Biology Project, IFS, Kandy

Sri Lanka possesses a highly diverse endemic fauna and flora and is a reservoir of unique evolutionary history. Unfortunately, Sri Lanka's diverse invertebrate fauna remains largely unexplored. Several taxonomic studies on both vertebrates and invertebrates were published during British rule of the island. The standard work on Sri Lanka's invertebrate fauna was published as a part of the monographic series "Fauna of British India, including Ceylon and Burma", during this time. However, it did not treat many smaller arachnid orders like pseudoscorpions. Spiders were only partially covered, with the smaller species being overlooked. We are currently carrying out an island-wide survey of pseudoscorpions and spiders using a range of collection methods to sample a set of diverse habitats around the island.

Our survey of pseudoscorpions produced 51 species belonging to 23 genera of which eight species might be new to science. The family Cheiridiidae was discovered in the island for the first time. Out of the 51 species, 20 species (40 %) are endemic to Sri Lanka. A checklist of Pseudoscorpions of Sri Lanka was submitted to the international peer-reviewed journal, Zootaxa on 02nd May, 2011. Two other publications are in preparation. The spider biodiversity project has resulted in the 3 publications for this year.

7.3.2.2 Comparative surveys of phytoplankton and zooplankton in Sri Lankan reservoirs

B. Perera[1], S.K. Yatigammana[2]

[1]*Ecology and Environmental Biology Project, IFS, Kandy,* [2]*Department of Zoology, University of Peradeniya*

Phytoplankton and zooplankton, tiny drifting plants and animals are vital components of the marine and freshwater aquatic food chains, and our water systems. As planktons are well known biological indicators the presence, abundance and diversity of these organisms provide important information of environmental conditions and also can be used to predict past and future scenarios of the environment. Since the beginning of this project, a total of 123 plankton genera were recorded. Among them sixty nine genera were phytoplanktons, while 29 genera were zooplankton. However, 27 species remained

unidentified. Out of 87 genera identified, 24 belong to the phylum Chlorophyceae, which can be considered as the dominant group. Of the rest three genera belong to the phylum Euglenophyceae, 03 genera belonging to Xanthophyceae, 19 genera belonging to Cyanophyceae, 17 genera belonging to Bacillariophyceae and 03 species belonging to Dinophyceae. Among the zooplanktons, Phylum Cladocera was the dominant group while Phylum Ostracoda rare. The number of genera identified belonging to different zooplankton groups were as follows: 07 genera of Rotifera, 12 genera of Cladocera, 02 genera of Ostracoda and 04 genera of Copepoda. Among the zooplankton, cladocerans were the dominant group. All the observed planktons were photo documented and will be used for the plankton guide. Almost all recorded Cyanobacteria species were observed in the dry zone (Anuradhapura district). Toxin producing Cyanobacteria species such as *Cylindrospermopsis raciborskii*, *Microcystis* sp. and *Peridinium* sp. were also recorded in dry zone reservoirs in relatively high abundance.

7.3.2.3 Taxonomic revision of the genera Dendrobium and Bulbophyllum (orchidaceae) of Sri Lanka

Harshani Sandamali, Suresh P. Benjamin

Ecology and Environmental Biology Project, IFS, Kandy

Orchidaceae is one of the largest plant families in Sri Lanka found in all terrestrial vegetation types. Seventeen field visits were undertaken to study the species of *Dendrobium* and *Bulbophylllum* this year. This year we were able to recorded *D.panduratum* and *D.macathiae*. We were able to cover 47% of the photo documentation (62% of *Dendrobium* and 36% of *Bulbophyllum*). We have found six species of *Dendrobium* out of eight and seven *Bulbophyllum* out of eleven species reported for Sri Lanka. A further objective of this survey is to determine host plant specificity of our study species.

Vegetative traits of all specimens were measured using a caliper and a measuring tape and dissected floral parts were drawn with the aid of a stereomicroscope equipped with a camera lucida. Vegetative and floral morphometric data will be analyzed using the delta software package. We also plan to characterize the species using facilities available at the modern molecular biology laboratory of the Ecology and Environmental Biology project at the Institute of Fundamental Studies. We have extracted DNA from our samples and are in the process of PCR amplification.

7.3.3 ENVIRONMENTAL ENGINEERING/ELECTROCHEMISTRY

Project leader: Dr. K.G.N. Nanayakkara (*Research Fellow*)

Description of the project

The major research area of the Environmental Engineering/ Electrochemistry research group is investigating the fundamentals of pollution removal processes and studying the possibilities of applying those processes in engineering applications. Electrochemistry is used as a process in treatment (e.g. through electrochemical pollution removal) as well as a tool in process development (e.g. investigating reactions and material properties).

While our main research projects are on electrochemical methods for water treatment, we have successfully modified and characterized adsorbents for water treatment as a secondary research project. In addition, some collaborative research projects were carried out with Prof. Rohan Weerasooriya on pyrite-carbofuran system.

Electrochemical methods for water treatment

Water pollution is a serious environmental problem which creates health, economical, and ecological impacts in Sri Lanka. Pollution occurs through many routes such as industrial effluents, usage of agro-chemicals, and domestic wastewater effluents. While minimizing such contaminations can be the ideal control measure, treating contaminated water prior to discharge is more practical in protecting humans and the environment.

Compared to other technologies, electrochemical technologies have certain advantages. For instance, anodic reactions produce a series of oxidants in-situ. Therefore, no chemical storage or handling is required. Besides, direct oxidation of contaminants at the anode also possible. Thus, the potential of organic contaminant removal at the anode is high. Cathodic reduction provides an excellent environment for pollutant removal (e.g. heavy metals). As such, we are working on developing novel materials and processes for electrochemical water treatment technologies.

There are three research projects under this theme. All three projects were initiated during September-November 2011. The first project is on "Anodic oxidation of phenol in contaminated water on dimensionally stable anode", which is funded by IFS. Other two projects on "Development of electrochemical technologies to remove organic and heavy metal pollutants present in pesticides" and "Development of an electrochemical technology to remove nitrate from contaminated groundwater" are funded by the National Research Council and the National Science Foundation, respectively.

Modification and characterization of adsorbents

Rice husk ash and commercial activated carbon were chemically modified in order to increase the surface functional groups. Such modification helps increasing the adsorption efficiency. In addition, modification creates opportunities to treat a wide variety of pollutants by changing the original surface chemistry of the material. Surface characterization was carried out using several different methodologies such as pHzpc, zeta potential analysis, determination of surface area and titration for quantification of surface functional groups. These investigations revealed that the materials were successfully modified and surface chemistry was changed.

Research Assistants: Ms. P. B. Jayathilake, Ms. C. Weerakkody (NRC funded), Ms. G.C. Pathiraja (NRC funded/ Final Year Project Student- Uva Wellassa University), Ms. P.W. Abeygunawardhana (Technical Assistant- NSF funded), Ms. D. Kumari (Final Year Project Student- Uva Wellassa University), Ms. K. Dhanasekara (Final Year Project

Student- Uva Wellassa University), Ms. D.M.K.C. Daundasekara (Pre-University Research Assistant- Volunteer)

Senior Staff Technical Officer: Mr. W.G. Jayasekara

Project photos:

7.3.3.1 Anodic oxidation of phenol in contaminated water on dimensionally stable anode

H.A.P.P.B.Jayathilake[1], W.M.A.T. Bandara[2], W.G. Jayasekara[1], K.G. N. Nanayakkara[1]

[1] *Environmental Engineering/Electrochemistry Project, IFS, Kandy,* [2]*Department of Chemistry, Faculty of Science, University of Peradeniya*

Introduction

Naturally occurring phenolic compounds can be found in some foods, human and animal wastes, and decomposing organic material while synthetically manufactured compounds are used in plywood, adhesive, construction, automotive, and appliance industries in large scale [1]. Therefore considerable amount of phenolic compounds are released with wastewater streams to the environment and can be found in drinking water. Phenol and substituted phenol compounds in water has been recognized as major organic pollutant which has potential to act as human carcinogen and considerable health concern, even at low concentration, due to its high toxicity, high oxygen demand and low bio degradability [2].

The anodic oxidation is more attractive than the other technologies due to factors such as high efficiency, in-situ chemical generation and ease in operation. However, limited studies have been reported in literature to investigate the mechanism of oxidation and towards the development and optimization of anode material for specific contaminant [3]. Therefore, this project addresses the above limitations by probing mechanisms of electrochemical degradation of phenol and by developing optimized anode material for the electrochemical degradation of phenol.

Objectives

- To provide insight into the mechanism of anodic oxidization
- To develop and optimize the anode material of the electrochemical reactor cell to oxidize phenol in contaminated water

Results

Research work under this project was initiated in September 2011. Preliminary experimental work on electrode substrate material preparation is completed. In addition, theoretical investigation on mechanisms of electrochemical degradation has been carried out using chemical modelling simulation techniques.

References

1. Toxicological review of phenol (CAS no. 108-95-2) in support of summary information on the integrated risk information system (IRIS), U.S. Environmental protection agency Washington D.C, 2002.
2. L.S. Andrade, C.A. Martínez-Huitle,(2011). Electrocatalysis in wastewater treatment: recent mechanism advances,*Quim. Nova 34*,850-858.
3. G.H. Chen, (2004). Electrochemical technologies in wastewater treatment, *Sep. Purif. Technol. 38*,11–41.

7.3.3.2 Development of electrochemical technologies to remove organic and heavy metal pollutants present in pesticides

C. Weerakkody[1], G.C. Pathiraja[1], D.G.G.P. Karunarathne[2], K.B.S.N. Jinadasa[3], A. Wijesinghe[4], K.G. N. Nanayakkara[1]

[1] Environmental Engineering/Electrochemistry Project, IFS, Kandy, [2]Department of Chemical Engineering, University of Peradeniya,[3]Department of Civil Engineering,, University of Peradeniya,[4]Department of Science and Technology, Uva Wellassa University

Introduction

Water pollution is a serious environmental problem which creates health, economical, and ecological impacts in Sri Lanka [1]. Usage of agro-chemicals, especially pesticides, is one such pollution route. Our water bodies get contaminated with pesticides either through agricultural run-offs or through industrial effluents where formulation and packaging of pesticides is carried out. These effluents carry organic and inorganic contaminants (e.g. heavy metals) to surface and groundwater sources [2]. On one hand, such contaminants may end up in the drinking water since the conventional water treatment process is not capable of removing persistent chemicals. On the other hand, these contaminants may create adverse impacts on the ecology of Sri Lanka. This research addresses the above mentioned problems by developing sustainable technologies based on electrochemical reactions to treat pesticide contaminated water streams. The possibilities of simultaneous removal of organics and heavy metal(s) in a single reactor will be investigated.

Objectives

- To develop and optimize the anode material of the electrochemical reactor cell to mineralize organic components of the pesticides of interest.
- To identify the mechanism(s) of mineralization of organics at developed anode.
- To develop and optimize the cathode material of the electrochemical reactor cell to reduce the heavy metals present in the pesticides of interest considering the properties of cathode material pertaining to the efficient heavy metal removal.
- To investigate the possibilities of simultaneous removal of organics and heavy metals in a single reactor and analyze safety issues to ensure the safety of the treated effluent.

Results

Research work under this project was initiated in October 2011. Preliminary work on electrode substrate material preparation is completed. Preliminary work on plating techniques has been investigated. In addition, theoretical investigation on mechanisms of electrochemical oxidation of chlorpyrifos (organic pesticide) has been carried out using chemical modelling simulation techniques.

References

1. O.A. Ileperuma, (2000). Environmental pollution in Sri Lanka: A review, *J. Natl. Sci. Found. Sri Lanka, 28*, 301-325.
2. J.M.R.S. Bandara, H.V.P. Wijewardena, J. Liyanage, M.A.Upul, J.M.U.A.Bandara, (2010). Chronic renal failure in Sri Lanka caused by elevated dietary cadmium: Trojan horse of the green revolution, *Toxicol. Lett.198*, 33-39.

7.3.3.3 Development of an electrochemical technology to remove nitrate from contaminated groundwater

P.W. Abeygunawardhana[1], J.P. Pathmasiri[1], M. Vithanage[1], K.B.S.N. Jinadasa[2], K.G.N. Nanayakkara[1]

[1] *Environmental Engineering/Electrochemistry Project, IFS, Kandy,* [2]*Department of Civil Engineering, University of Peradeniya*

Introduction

Electrochemical nitrate removal has been studied and reported in scientific literature [1,2]. However, most of the reported work is based on available electrode materials. Little attention is paid on development of novel electrode materials considering the factors pertaining to efficient nitrate removal. In this work, attention is paid on novel electrode material development, considering the electrode properties pertaining to a higher degree of nitrate removal. In addition, major challenge in electrochemical nitrate removal is the oxidation of by-products. Two main by-products, nitrite and ammonia are generated in the process of cathodic reduction of nitrate. These two by-products are toxic to humans and environment. In literature, electrochemically generated chlorine has been researched and reported to oxidize the above mentioned by-products. As such, application of electrochemical nitrate removal is limited by the chloride content of contaminated water [3]. In this research, enhancing the oxidation (electrochemical) of by-products in chloride-free electrolytes is investigated.

Objectives

- To develop and optimize the cathode material of the electrochemical reactor cell to reduce nitrate considering the electrode properties pertaining to effective nitrate removal.

- To develop and optimize the anode material of the electrochemical reactor cell to oxidize the nitrate reduction by-products considering electrode properties and mechanism(s) pertaining to effective by-product oxidation in different electrolyte environments (both chloride-rich and chloride-free).
- To develop an electrochemical reactor cell combining the developed electrodes and testing using actual groundwater samples.

Results

Research work under this project was initiated in October 2011. Preliminary work on electrode substrate material preparation is completed. Cathode material development work is initiated and trial experiments are in-progress.

References

1. M. Dortsiou, G. Kyriacou, (2009). Electrochemical reduction of nitrate on bismuth cathodes, *J. Electroanal. Chem. 630,* 69-74.
2. D. Reyter, D. Belanger, L. Roue, (2010). Nitrate removal by a paired electrolysis on copper and Ti/IrO_2 coupled electrodes-Influence of the anode/cathode surface area ratio, *Water res. 44*, 1918-1926.
3. S. Xiao, J.Qu, X. Zhao, H. Liu, D. Wan, (2009). Electrochemical process combined with UV light irradiation for synergistic degradation of ammonia in chloride-containing solutions, *Water res 43*, 1432-1440.

7.3.3.4. Modification and characterization of adsorbents

G.C. Pathiraja[1,2], T.D.K. De Silva[2], K.G.N. Nanayakkara[1]

[1] *Environmental Engineering/Electrochemistry Project, IFS, Kandy,* [2]*Department of Science and Technology, Uva Wellassa University*

Introduction

Adsorption is a natural process by which molecules of a dissolved compound collect on and adhere to the surface of an adsorbent solid. Developing novel sorbent materials to remove a wide range of pollutants is of importance. In this research, activated carbon and rice husk ash are chemically modified. Modified and unmodified materials are characterized in order to investigate the changes in surface properties.

Objectives

- To modify the surface of commercial activated carbon and rice husk ash by introducing functional groups.
- To evaluate the surface properties of modified and unmodified materials.

Results

Chemical modification of the surfaces were done by introducing –COOH groups. Fourier Transform Infrared Spectrometry (FTIR), Zeta Potential, pH of zero point charge (pHzpc), surface area analysis and Boehm titration were used in confirming and evaluating the modified and unmodified materials. Characterization showed the surfaces of the parent materials were successfully modified (Figure 1). Our data are in good agreement with other published literature [1-2].

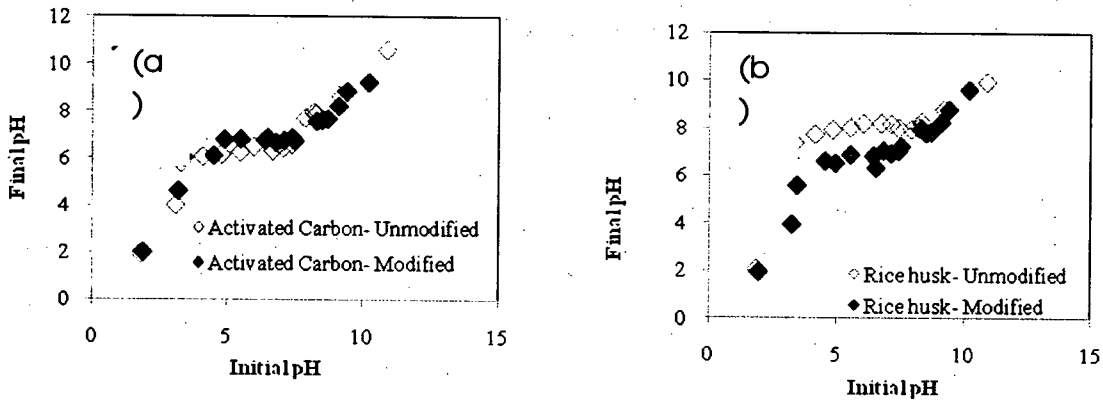


Figure 1: pHzpc of modified and unmodified materials. (a) Activated carbon (b) Rice husk ash

References

1. J.P.Chen, S. Wu, K.H. Chong, (2003). Surface modification of a granular activated carbon by citric acid for enhancement of copper adsorption.*Carbon 41*, 1979–1986.
2. F. Thielbeer, K. Donaldson, M. Bradley, (2011). Zeta Potential Mediated Reaction Monitoring on Nano and Microparticles. *Bioconjugate Chem.22*, 144-150.

Human resource development

H.A.P. Pavithra Bhakthi Jayathilake, IFS Research Assistant- Registered for M.Phil. at Postgraduate Institute of Science.

Chandima Weerakkody, NRC Research Assistant- Proposal submitted for starting M.Phil. at Postgraduate Institute of Science.

Gayani Chathurika Pathiraja, NRC Research Assistant- Preparing the proposal for M.Phil. application at Postgraduate Institute of Science. Worked as a Final Year Project Student- Uva Wellassa University (April 2011- June 2011). Project completed.

Pratheeksha Wimansi Abeygunawardhana, NSF Technical Assistant. M.Sc. Student at the Post Graduate Institute of Science.

T. Dilini Kumari De Silva, worked as a Final Year Project Student- UvaWellassa University (April 2011- June 2011). Project completed.

S.A. Kalani N. Dhanasekara, worked as a Final Year Project Student- Uva Wellassa University (April 2011- June 2011). Project completed.

D.M.K.C. Daundasekara, worked as a Pre-University Research Assistant (Aug 2011- Oct 2011, Volunteer).

7.3.4 NANOTECHNOLOGY

7.3.4.1 GREEN NANOTECHNOLOGY

Project leader: Prof. C.B. Dissanayake *(Director, IFS)*

Description of the project

It may seem contrary to everyday experience that by making a piece of material smaller one could affect changes in the materials properties However the reasons for these changes are bound up with the Quantum Mechanical rules that are obeyed as the world of molecular dimensions is approached. When the wave motion of a charge carrier is held in a smaller volume of space than it would occupy then it is said to be quantum confined. It is this confinement that results in many amazing properties. These dimensions are of the nanometre size range and as such materials which have one of their dimensions in this range are referred to as nanomaterials. A second aspect of materials on the nanoscale is that they possess large surface area to volume ratios and small radii of curvature. These astonishing physical and chemical properties of engineered nanomaterials in comparison with their bulk counterparts have provoked an exponential growth of nano-products on the free market. Along with research on the use and fabrication of nano-materials, there is the need to consider impacts of nano-materials on environment and human health. Nano-materials will have an increasing presence in consumer products and commercial applications that result environmental risks associated with the production, use and disposal of these materials.

The IFS Green Nanotechnology Research Program has been started to design environmentally safe nanomaterials in compliance with green chemistry principles. During the period of review, our research group has actively been involved in utilizing iron based material such as zero valent iron, iron oxides and pyrite for pollution control. Always we embarked into nanotechnology methods for chemical systems that have already been well characterized at micro scale. Therefore some of the results shown here were first carried out for materials at micro-scale to understand potent limitations and then the nanotechnology was used to engineer efficiency. Research will also include an examination of the transport and fate of nano-materials in aqueous environments examining the elements of nano-material surface chemistry and reactivity that affect toxicity and mobility, and performing life cycle assessments of environmental impact and risk associated with nano-materials production, use, and disposal.

The nano particles (NP) were synthesized in a variety of compositions with a high degree of particle size and shape control. However, they remained difficult to handle for various industrial applications due to their colloidal nature and the susceptibility to uncontrolled aggregation. Particular attention was paid to examine specific solution conditions under which cationic poly-electrolytes can induce negatively-charged particulates such as pyrite NPs to form micron-sized hollow spheres rather than the randomly structured precipitate that would ordinarily result from flocculation.

Research Staff : Prof. R Weerasooriya, Research Professor, IFS
Prof. A. Bandara, Senior Lecturer, University of Peradeniya, Peradeniya
M. Makehelwala, Chemist, National Water Supply & Drainage Board

Research Students: N. Walawewala, A. Siriwardhana, Research students, University of Peradeniya, Peradeniya
S.A.K.N. Dhanasekara, Research student, Uva Wellassa University, Badulla

7.3.4.2 Green remediation of nitrate in drinking water

R Weerasooriya[1], C.B. Dissanayake[1], A. Bandara[2], N. Walawewala[2], A. Siriwardhana[2]

[1] *Nanotechnology Project, IFS, Kandy* [2], *University of Peradeniya*

Highly soluble nitrate ion causes serious environmental issues; it causes methemoglobinemia (blue baby disease) and cancer. Nitrate pollution of Sri Lankan drinking water resource is a pressing issue which reports highest nitrate concentration (e.g. above 100 mg/L) in the Jaffna Peninsula. We proposed the utilization of nano zero valent iron (NZVI) in combination with chlorination step for complete destruction of the nitrate into nitrogen gas together with environmentally benign waste products. The ZVI serves as both a catalyst and an electron source. The overall rationale here is mediating the contaminants into the corrosion cycle of the iron. Besides its low cost, the secondary products such as Fe (II) and Fe (III) products are benign. We developed a methodology to remediate nitrate rich waters employing ZVI with near zero waste generation. The serious limitations of this technique were the generation of the excess waste, cementing the aquifers flow lines with iron rust, and uncontrolled oxidation of the material irrespective of the presence of contaminants. Most of these issues has resolved by fabricating the zero valent iron (ZVI) at nano scale (NZVI). When exposed to air in controlled fashion a ~5 nm coating of iron oxide is formed on the surface of the NZVI particles. Preliminary results showed that this layer did not thicken further for prolong periods which indicates minimal corrosion. In the micro-scale, we have already optimized the degraded products as ammonia over 95 % yields. Once these conditions are achieved at nano scale, the ammonia rich water will be subjected to chlorination. During this step, the system parameters required to be optimized to promote the reaction schemes that convert $NH_3 \rightarrow N_2$. In this way the nitrate free water will be produced with zero waste generation, and the method is designated as green nanotechnology. The utmost important step in the process is to fabricate NZVI to meet stringent current needs. (Limited experimental data were reported as advised by Patent Office).

7.3.4.3 Nano-pyrite to destruct organic pollutants in water

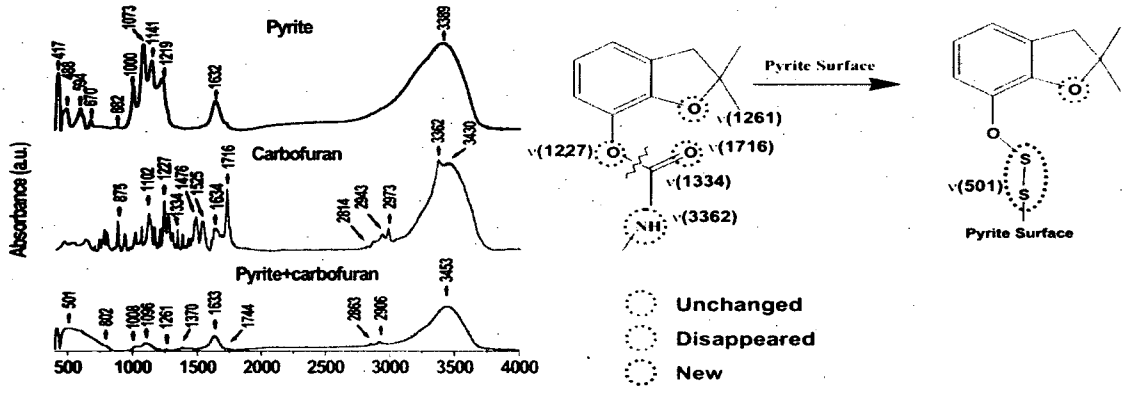
R Weerasooriya[1], C.B. Dissanayake[1], A. Bandara[2], S.A.K.N. Dhanasekara[3], M. Makehelwala[4]

[1] *Nanotechnology Project, IFS, Kandy* [2] *University of Peradeniya,* [3]*Uva Wellassa University, Badulla,* [4]*National Water Supply & Drainage Board*

The aim of this research is to provide an essential physico-chemical framework required for the development of mineral-induced decontamination technique for model carbamates (i.e. carbofuran). Pyrite and its nano analogs were selected due to following reasons. FeS_2 which is ubiquitous in nature is diamagnetic; the Fe (II) is a low spin inert metal ion (d^6, t^6_{2g}); in contrast, the S^{2-} has a series of molecular orbitals are key for electron transfer. The S^{2-} site can act as either electron donor or acceptor. Oxidation occurs by the electron transfer from a π^* orbital (HOMO) in S_2^{2-} to π orbital of oxidant (LUMO); the electron transfer should proceed from a σ^* orbital (HOMO) in the reductant to a σ^* orbital (LUMO) of S_2^{2-} in FeS_2 in the case of reduction. The degradation of carbofuran requires an electron switching mechanism which is envisaged at both Fe(II) and S^{2-} centers on pyrite surface. The approach envisaged here is in consonance with the national efforts for environmental conservation as identified in the National Environmental Action Plan of Sri Lanka.

The pyrite was synthesized in aqueous solutions at low temperatures and atmospheric pressure from the reaction between $FeCl_3$ and NaHS. The characterization of the synthesized pyrite for the presence/ absence of nano scale particles is currently under progress. During the period under review, the natural pyrite samples collected from the graphite veins in Sri Lanka was used. The partial degradation of carbofuran by pyrite was modeled mechanistically under well controlled laboratory environment. The

validity of surface structures of pyrite-organic compounds was assessed with molecular cluster modeling methods.



Thermodynamic parameters of carbofuran adsorption on pyrite were determined. The mean free energy of adsorption ranged from 12.0 to 28.8 kJ.mol^{-2}, which indicate the presence of chemical bonds in carbofuran – pyrite surface complexes. The interfacial properties of pyrite – water interface were characterized by ζ (zeta)-potential measurements. The pH_{IEP} of pyrite was around 1.70 when inert environmental conditions were maintained. In the presence of carbofuran, the pH_{IEP} shifted from 1.70 to ~3 indicating direct interactions with the surface which were subsequently validated by infra-red spectroscopy. As shown below, carbofuran seems to degrade via N-H bonding region upon prolonged contact with reactivity sites on pyrite.

Human resource development

Postgraduate Degrees completed

S.A.K.N. Dhanasekara - Science and Technology Degree Program 2011. Degradation of carbofuran by pyrite - Fenton like process, Uva Wellassa University (completed/undergraduate project)

N. Walalewala – B.Sc. Chemistry Special Degree, 2011. Probing the carbofuran and pyrite interface by zeta potential and spectroscopic measurements, Dept of Chemistry University of Peradeniya (completed/ undergraduate project)

M. Makehelwala - M.Phil. Degree, in progress. Project. Removal of organic pollutants by pyrite (tentative title) – PGIS, University of Peradeniya.

7.3.5 WATER QUALITY IMPROVEMENTS IN THE DRY ZONE AREAS IN SRI LANKA

Project leader : Mr. J.P.Padmasiri *(Visiting Research Fellow)*

Description of the project

Community based water supply schemes are available in the dry zone areas of Sri Lanka. Of these 30% are not used by the people for drinking purposes due to the hardness of water. Water of the said schemes have high hardness which can be detected easily by its taste while invisible poison, the excess fluoride can be known after chemical examination. On the other hand water from nearly 50 percent of the dug wells in these areas has high fluoride content in water thus contributing to dental fluorosis of the children and may have indirect effect on chronic renal failures. This water quality surveillance progaramme started in 2010 (9600 samples) continued in 2011 (7500 water samples) by visiting these areas. The public health inspectors of the health department and Vidatha Officers of the Ministry of Technology and Research were the coordinators in the surveillance programme.

Methodology

To reduce fluoride content in water in the dug wells, the Brick Chip Filter was introduced in these areas. The brick chip filter project was in the Kohombagaskada in Kahatagsdigiliya was sponsored by "Soroptimist International", Kandy while the Kekirawa project was sponsored by "Richard Pieris" (Pvt) Ltd. The Kekirawa project initation was done by Vidatha Officer, Kekirawa.

In the case of community based water supply schemes, the first Electorcoagulation water purification project (Rs 16 Lakhs) was established at Asokamalagama, Mihindu Praja Moola Sanvidhanaya in August 2010. This was sponsored by M/s Link Natural Products (Pvt)Ltd, Decentralization budget of Hon: W.B.Ekanayake. Member of Parliament of the Anurahdapura district and the private funds from Engineer W.M.Jayawardhane. This is being monitored monthly and on an average 10,000 liters of purified water distributed to the Asokamalagama.

The second water purification project with a softner (Rs 2.5 lakhs) was installed in the Sandamaleliya Praja Moola Sanvidhanaya in Thanthirimale in October 2011. The main water quality improvement is the reduction of hardness using a softner.

The third water purification using Electorcoagulation was installed in Suwasetha Praja Moola Sanvidhanaya in Nikawewa, Moragollagama in Kurunegala district in November 2011. Nikawewa has been identified as high prevalence of chronic kidney disease, and it is expected to reduce these diseases by providing purified water. Here again the building form purification plant was completed using a grant from Hon: Sarananth Basnayake, Member of Parliament of the Kurunegala district. The water purification plant was sponsored by "Link Natural Product" (Pvt)Ltd. Total cost is Rs.15 lakhs. All the fabrications and installations of the water purification units were done by Spectra Industries Lanka (Pvt) Ltd., Kurunegala.

Funds have been received from the Ministry of Technology and Research for 10 such units in these areas.

Project Staff: Engineer W.M. Jayawardhane (Volunteer)

Figure 1 : Electrocoagulation Unit

Figure 2 : Water Softner-

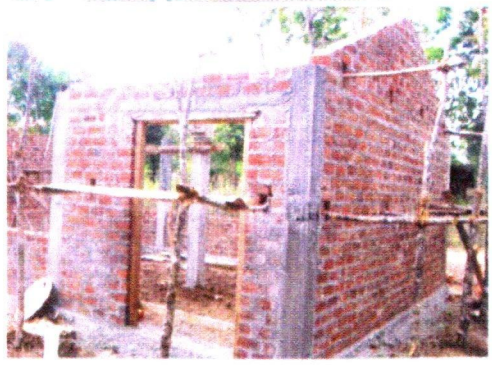


Figure 3: Building – Nikawewa

Figure 4: Awareness & Sample Testing

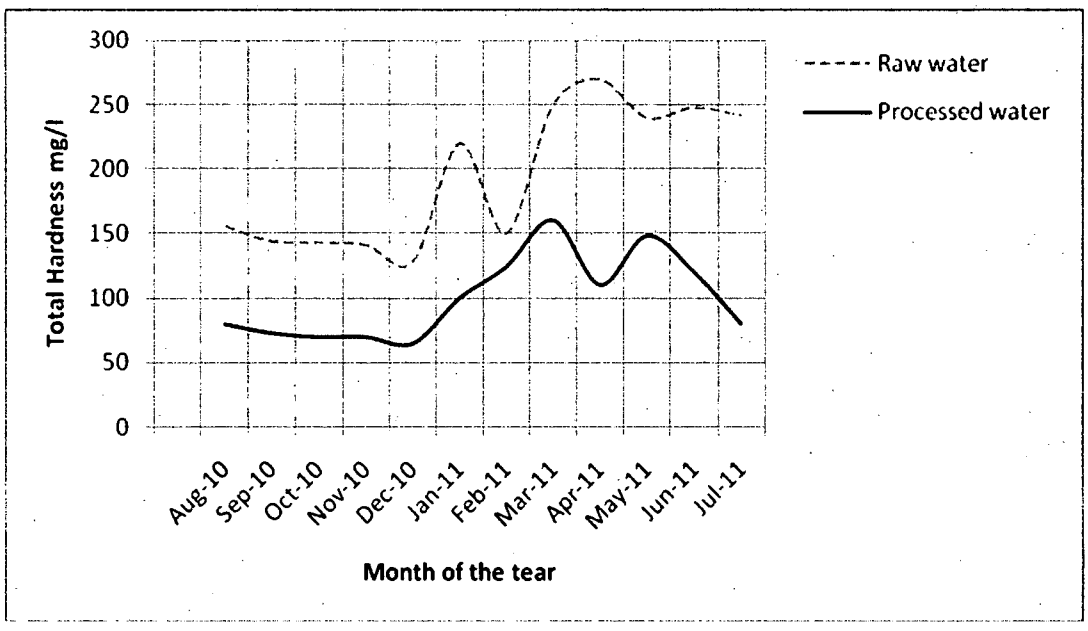


Figure 5 : Hardness content of water

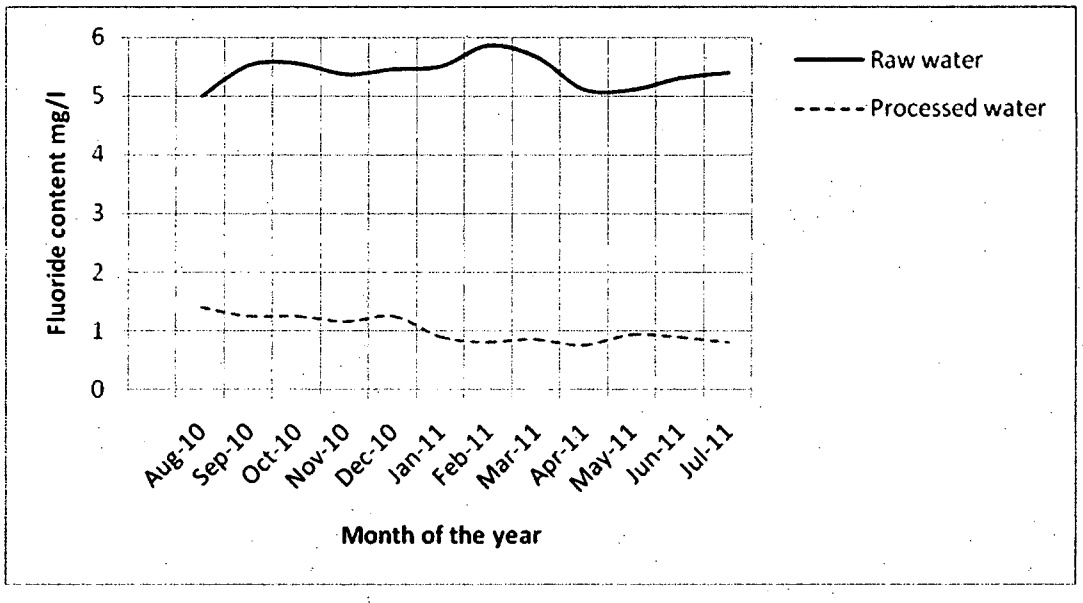


Figure 6 : Fluoride content of water

Figure 5 and 6 show the fluoride removal efficiency is in the range 80 – 90 % and that of hardness removal 50 – 70 % range, average for 12 months.

7.3.6 BIODIVERSITY AND CONSERVATION

7.3.6.1. Primate biology

Project leader: Dr. W.P.J. Dittus (*Honorary Senior Visiting Scientist)*

Description of the project

This project concerns observational studies of monkeys (primates) in their natural forest habitat at Polonnaruwa. We aim to establish new knowledge concerning the biological foundations for social behaviour in non-human primates (and by inference, in man). Behaviour is a multifaceted phenomenon and our aim has interdisciplinary ramifications. Hence, past research and publications have addressed the interrelationships among social organization, matrilineal kinship, ecology, genetic diversity and environmental change. In particular we are interested in measuring the effects of such variables on the Darwinian fitness of individuals and of demographic patterns. For example, our research was the first to establish an actuarial life-table for primates and showed that social behaviour influences individual differences in survival, breeding success, and morphological development. Such data are used to test current socio-biological and evolutionary hypotheses and have broad relevance in science and conservation.

In practice, to investigate the phenomenon of social evolution we have identified more than four thousand macaque individuals (living plus dead), distributed among 34 different social groups at our study site. For each macaque, we have traced its behavioural, genealogical, ecological and demographic history. In addition, we have recently completed the patrilineal identification of about 1,500 macaques. Our methods are similar to those of actuaries; linking variables of behaviour to those of survival. To this end, we require large samples over extended periods of time to assure statistical soundness.

Although we had established the link between behaviour and fitness it was not clear by which physiological and similar mechanisms behaviour affected death rates. Therefore, the research was expanded (with the aid of collaborators from a variety of institutions) to investigate the potential role of disease (parasitism) and genetic relatedness in relation to behaviour and vital statistics. Different aspects of disease and paternity exclusion analyses have been investigated in the primates at Polonnaruwa particularly in collaboration with of the Faculty of Veterinary Medicine, University of Peradeniya and overseas collaborators (University of Cologne, Germany).

Among others, one of our current investigations focused on establishing a reliable method for estimating the amount of body fat in wild primates. Knowledge of variation in body fat among primates aids in predictions of the effects of behaviour and environment on their vital statistics.

Our research has practical applications relevant to Sri Lanka's national development. For example, we have shown the important relation between human and primate diseases, such as dengue fever, toxoplasmosis, cryptosporidium and other infectious diseases. At another level we also are proactive in nature conservation and in outreach educational programs to local communities, and assist in mitigating the conflict between humans and monkeys. Finally, our research has been broadcast internationally through high quality documentary films. Our films have given Sri Lanka a positive image in the international political and economic arenas, and have attracted visitors to the country.

Collaborators:

- Prof. R. P. V. Jayanthe Rajapakse, Professor of Parasitology and Head of the Department of Pathobiology, Faculty of Medicine, University of Peradeniya.
- Dr. Asoka Dangolla, Faculty of Veterinary Medicine and Animal Health, University of Peradeniya.

- Professor Peter Nuernberg, Cologne Center for Genomics CCG, University of Cologne, Germany
- Kerstin Becker (Graduate student), Cologne Center for Genomics CCG, University of Cologne, Germany

Human resource development

(a) Five Students (University of Colombo) were trained in our research in 2011.

(b) Promotion of environmental awareness and nature education in collaboration with the Department of Education and delivered six programs to about 300 students in the Polonnaruwa District.

Conferences and lectures

4 April 2001. Conference: *International Association for Asian Heritage.* Sri Lanka's ancient culture of respect for its biological heritage.

24 June 2011. *Conference of District Secretaries (Ministry of Home Affairs and Public Administration).* Solutions to human-monkey conflicts.

30 June 2011. *National Trust –Sri Lanka*: Insights into social evolution from 40 years of monkey studies.

Conservation actions

In 2011 we executed 27 conservation action events.

7.4 FOOD SCIENCE AND NUTRITION

Project leader: Dr. Ruvini Liyanage (*Research Fellow)*

Description of the project

This project commenced in January 2011with the objective of studying the nutritional status of naturally available food resources in Sri Lanka. It involves studies on the quality of various food products as well as the effects of different types of diet on the body chemistry and exploring the links between food, nutrition and well being. At present, Sri Lanka is faced with the double burden of undernutrition and overweight. Under nutrition is mostly prevalent among pregnant mothers and children with low house hold incomes while obesity is increasing, especially among high income groups. For malnutrition among pregnant mothers and children a solution could be sought with available natural resources having the required nutritional properties. In this regard *Moringa oleifera* has been chosen as a potential local plant. To investigate the nutritional properties of *Moringa oleifera* leaves and their applications in the food industry, *Moringa* leaves from different areas of Sri Lanka were analyzed to determine the nutritional differences in plants from different localities of the island. It was observed that micronutrient contents vary with the district and material from the dry zone appears to be better compared to those of the wet zone where micronutrient contents of leaves are concerned. Further research is in progress to investigate whether there is an effect of fertilizer application on nutritional properties of *Moringa* leaves. Furthermore possibilities of incorporating *Moringa* leaves as nutritional supplements to food products in Sri Lanka will be investigated as a remedy for the problem of malnutrition.

Another study to investigate the health potential of commonly consumed cowpea varieties in Sri Lanka has commenced. Diet and obesity related non communicable diseases are on the increase in Sri Lanka at present and account for more than 20% of total deaths. Possible interventions are necessary to control these diseases by promoting suitable dietary sources. It has been shown that regular consumption of pulses can contribute to reduce the risks of heart diseases, obesity and diabetes. Although a considerable amount of data is available on health potential of legumes, only a few studies have been done to investigate the potential of cowpeas. In this study the anti-obesity effects of commonly consumed cowpeas in Sri Lanka will be investigated. Four cowpea types used in this study vary in their size, physical appearance and seed coat color and there could be a variation in functional properties as well. It has been shown that nutritional properties of cowpea vary with each other showing that there is a difference in antioxidant activity and phenol content in four cowpea varieties. The experiments will be a collaborative study with the department of Animal Science, Faculty of Agriculture, and University of Peradeniya using rats as experimental animals. Research is in progress to examine the functional properties of cowpeas *in vivo*.

Research expertise:	Prof. S.A. Kulasooriya
Research Assistants:	Ms. Oshini Perera, Mr. S.D.P.M.P. Chandika (undergraduate student)
Senior Staff Technical Officer:	Ms. Iranganie Thumpale

Human resource development

Ms. Oshini Perera, Research Assistant, IFS – to be registered for an M.Phil degree at the PGIA, University of Peradeniya.

Mr. S.D.P.M.P. Chandika, undergraduate student - Department of Animal Science, Faculty of Agriculture, University of Peradeniya.

Murunga leaf powder

Intensive cultivation of Murunga

7.4.1. Investigating the nutritional properties of *Moringa oleifera* leaves and their possible applications in the food industry in Sri Lanka

O. Perera, R. Liyanage, S.A. Kulasooriya

Food Science and Nutrition Project, IFS, Kandy

Moringa oleifera is an important multipurpose tree under-recognized for its nutritional and medicinal properties. The leaves of *M. oleifera* can be eaten fresh, cooked, or stored as a dried powder for months reportedly without any major loss of its nutritional value [1, 2]. *Moringa* trees have been used to combat malnutrition (especially among infants and breast feeding woman) in many developing countries, particularly in India, Pakistan, the Philippines, Hawaii and many parts of Africa [3]. *Moringa* leaves have been reported to be a valuable source of both macro and micro nutrients, being a significant source of Beta-carotene, Vitamin C (antioxidant), protein, calcium, iron and potassium. There are few or no experimental studies done regarding the potential nutritional value of this plant grown in Sri Lanka. In this study, nutritional properties of *Moringa* leaves will be analysed and their potential applications in food industry in Sri Lanka will be investigated.

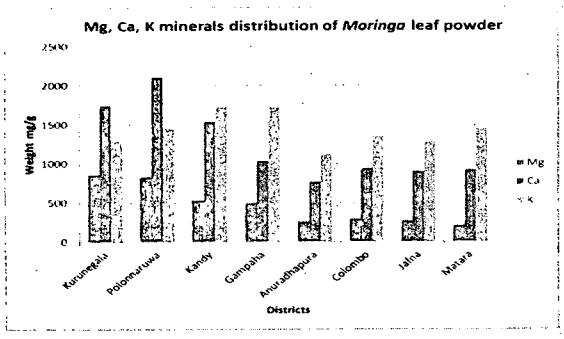
Objective

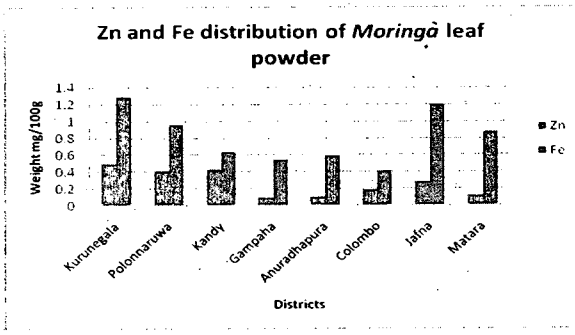
The main objective of the present study is to investigate the nutritional properties of *Moringa oleifera* leaves and their possible applications in the food industry in Sri Lanka.

Specific objectives

1. To determine the nutritional profile of the dried *Moringa* leaves representing all the districts of Sri Lanka.
2. To compare the difference in nutritional profile of dried *Moringa* leaves grown under fertilized and unfertilized condition.
3. To investigate the possible applications of *Moringa* leaf powder in the food industry in Sri Lanka.

The following figures show the initial results obtained in this study for some important minerals concentration in *Moringa* leaves collected from eight districts in Sri Lanka. There is considerable variation in micronutrients content in *Moringa* leaves among districts. Findings agree with data from other countries showing that *Moringa* leaves are a good source of micronutrients.





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7.4.2 Investigating the antiobesity effect of cowpea in rats

O. Perera, R. Liyanage

Food Science and Nutrition Project, IFS, Kandy

The growing prevalence of obesity in individuals is a worldwide public health problem with a considerable risk of chronic diseases. Increased body fat, mainly visceral fat, plays a major role in the complex disease state of metabolic syndrome such as the development of coronary heart disease, type II diabetes, and dyslipidemia[1, 2]. Metabolic syndrome may be strongly associated with reduced intake of plant fibers and plant antioxidants, and with increased consumption of carbohydrate/fat foods such as industrially produced refined sugars and dairy products [2]. Katulanda *et. al.*[3] have shown that there is a relatively high prevalence of overweight and obesity, particularly, abdominal obesity among adults in Sri Lanka . It has been shown that regular consumption of pulses can contribute to the reduced risk of heart diseases, obesity and diabetes. Cowpea (*Vigna unguiculata* L.walp) which is a grain legume, is a rich source of proteins, dietary fiber, micronutrients and bioactive phytochemicals. Antioxidant compounds in food play an important role as a health-protecting factor. Scientific evidence suggests that antioxidants reduce the risk of chronic diseases including heart diseases and cancers. In this study anti-obesity effect of commonly consumed cowpeas (Waruni, Bombay, Dawala and MI 35) will be investigated *in vivo* using experimental animals.

Objectives of this study

1. To investigate the effect of cowpea powder on high fat diet induced body weight gain and visceral fat in rats.
2. To investigate the effect of cowpea powder on serum biochemical parameters related to obesity and dyslipidemia
3. To investigate the effect of cowpea powder on liver lipids, glutathione levels, and liver antioxidant enzyme activities
4. To investigate the effect of cowpea powder on abundance of mRNA s related to lipogenesis and lipolysis

According to initial investigations it was found that antioxidant activity(IC_{50} values) of Waruni, Bombay, Dawala and MI 35 were 350, 560, 815 and 1200 μg/ml, respectively against the corresponding standard butylated hydroxyl toluene (BHT) (12.5μg/ml) and the phenol content of Waruni, Bombay, Dawala and MI 35 was 11.74, 9.9, 7.2, and 6.0 mg/g, respectively.

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7.5 MOLECULAR BIOLOGY AND GENETICS

7.5.1 CELL BIOLOGY

Project leader: Dr. D.N. Magana-Arachchi (*Research Fellow*)

Description of the project

The Plant Cell Biology project was initiated in 2004 December with research on cyanobacteria. In 2009 the project was renamed as Cell Biology. Currently research is being carried out in two main areas; cyanobacteria & tuberculosis with sub projects in each category in order to explore resources, improve human welfare and contribute to national development.

Molecular phylogenetics of cyanobacterial species in Sri Lanka

Cyanobacteria represent a major untapped reservoir of biodiversity for potential discovery of new biotechnological products. The present study provides information on the enormous diversity and wealth of cyanobacterial and archaeal species in Sri Lanka to explore their hidden wealth and potential for human welfare. In many eutrophic fresh water lakes, cyanobacteria frequently form toxic blooms which are a potential health risk. Determination of the toxigenicity of the cyanobacteria gives a warning of potential toxicity development and permits early intervention to avoid health problems. The monitoring of toxicity levels in water bodies similar as in other countries, is necessary to minimize potential health risks.

Cyanotoxins and Chronic Kidney Disease of unknown aetiology (CKDu)

Among the cyanotoxins, microcystin and cylindrospermopsin are the predominant toxins in freshwater lakes and have been implicated in several cases of animal and human intoxications by causing damage to the liver and the kidney. Further, more recently, an epidemic of Chronic Kidney Disease of unknown aetiology (CKDu) prevailing in the North Central Province and has increased concerns regarding the occurrence of cyanobacteria in Sri Lankan water bodies. However, the incidence, aetiology, and demography are largely unknown and only a few studies have been published. The reason might be due to the combined effect of chemical and biological compounds, probably cyanotoxins, present in water sources of such areas. Therefore, identification of such cyanobacteria in water sources would provide long term objective of providing new, rapid molecular monitoring capability for tracking cyanotoxin producing cyanobacteria. According to our findings, tanks in Anuradhapura (Nuwara wewa, Tissa wewa and Kala wewa), Girandurikotte, Unachchiya water purification centre and Parakrama Samudraya have a vast distribution of cyanobacterial species such as *Microcystis*, *Cylindrospermopsis*, *Phormidium*, *Lyngbya* with toxin generating ability and could be a major risk factor for the CKDu in the dry zone.

Gene expression analysis: Identifying the missing link in Chronic Kidney Disease of unknown aetiology (CKDu) in Sri Lanka

Studies have not been conducted as yet, to determine the gene expression analysis of these CKDu patients. Therefore, by doing this pilot study we can determine the gene expression patterns for selected genes (drugs, xenobiotics, environmental factors, oxidative stress, heavy metals, flavonoids, hereditary, diabetics) using Real Time PCR arrays with RNA expressions on human control and diseased kidney samples. The identification of gene expression patterns (potential biomarker patterns) that are associated with progression of CKDu, will enable us to determine the possible risk factors.

Multidrug-resistant tuberculosis (MDR-TB)

MDR TB is an emerging problem of great importance to public health, with higher mortality rates than drug-sensitive TB. One of the most important challenges in the control of TB is a rapid diagnosis of cases and the optimization of anti tuberculous treatment, mainly to prevent the development of resistance and the dissemination of resistant strains. Only minimum data are available on the local patterns of drug susceptibility of *Mycobacterium* species of Sri Lanka. From our study we detected a high rate of rifampin resistance among the tuberculosis patients in Kandy, and this finding emphasizes the need for a rapid and reliable method of diagnosing drug resistance in this country.

A rapid method to detect nontuberculous mycobacteria (NTM)

Atypical mycobacterium is one of the common infections causing organism, which affect immuno suppressive patients and patients with pre-existing lung diseases. Presently these patients are categorized as sputum negative patients. From our studies a molecular assay was optimized to differentially detect slow growing and rapidly growing non tuberculous *mycobacteria* (NTM).

Culturing of *Spirulina* on a large scale

The major objective of the current project is to popularize culturing *Spirulina* on a large scale in the country by collaborating with the Mahatma Gandhi Centre. *Spirulina* is to be used as a low input self-supporting commercial venture. A pure culture of *Spirulina* was obtained and presently *Spirulina* cultures are maintained at laboratory conditions/ natural conditions. Currently different media are being tested for formulating a new medium using cost-effective alternative chemicals.

Research Assistants: Ms. R.P. Wanigatunge, Ms. H.M. Liyanage, Ms. D.K. Weerasekara, Ms. S. Maheswaran (Volunteer)
Research Expertise : Prof. S.A. Kulasooriya (Visiting Research Professor)
Technical Assistant: A. Tennakone (*Spirulina* project)
Collaborations: Dr. N.V. Chandrasekaran (University of Colombo), Dr. T. Abeysekara (General Hospital, Kandy), Prof. V. Thevanesam (University of Peradeniya), Dr. D. Medagedara (General Hospital, Kandy), Prof. S. Yasawardena (University of Sri Jayewardenepura)

7.5.1.1 Molecular phylogenetics of cyanobacterial species in Sri Lanka

D.N. Magana-Arachchi, R.P. Wanigatunge

Cell Biology Project, IFS, Kandy

Introduction

The cyanobacteria and archaea are of great interest due to their ability to grow at high temperatures and in other extreme environments. The development of techniques for the analysis of 16S rRNA sequences in natural samples has already enhanced detection and identification of cyanobacteria and archaea in nature. Denaturing Gradient Gel Electrophoresis (DGGE) analysis of PCR- amplified 16S rRNA gene segments has also been used to profile microbial populations inhabiting different temperature regions. A major incentive that has driven extensive and intensive research efforts on extremophiles during the last decades is the potential biotechnological applications associated with these organisms and their products. Some of the examples of extremozymes that are commercially used include DNA polymerase obtained from *Thermococcus littoralis, Thermus aquaticus* etc. for application in the polymerase chain reaction (PCR), and alkaline proteases in detergents from psychrophiles.

Objectives

The objective of the study is to understand the diversity of extremophilic cyanobacteria and archaea in Sri Lanka and to isolate and characterize the microorganisms from selected extreme environments that can be used in potential biotechnological applications which will be beneficial to the country.

Results

To characterize diversity of cyanobacteria and archaea in Sri Lanka, water samples were collected from five hot springs Rangiriulpotha, Kanniya, Nelumwewa, Mahaoya and Wahawa (Padiyathalawa) with water temperatures ranging from 39.1 to 62 °C. All DNA samples submitted to PCR reactions from the environmental water samples collected from different sites for the 16S rRNA gene, yielded the unique fragment of about 450 bp, using the cyanobacterial specific oligonucleotide primers of Cya 359F forward and Cya 781Ra and Rb reverse. The reverse primers 781Ra and 781Rb target filamentous/ heterocyst and unicellular/ non heterocyst forming cyanobacteria, respectively in a cyanobacterial community. Our results clearly demonstrated the presence of morphologically diverse cyanobacterial species in the hot springs. For the detection of archaea, archaeal specific primers, forward primer UA 751F and the reverse primer UA 1406R were used and the 750 bp PCR fragment was observed, confirming the presence of archaea, in hot springs.

DGGE conditions are being optimized using 16S rRNA PCR products of the standard cyanobacterial strain *Microcystis aeruginosa* PCC7941 and samples from hot springs. DGGE separation of bulk cyanobacterial 16S rRNA PCR products obtained from environmental water samples from five hot springs showed distinct banding pattern confirming the significant cyanobacterial diversity in hot springs.

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7.5.1.2 Cyanotoxins and Chronic Kidney Disease of unknown aetiology (CKDu)

D.N. Magana-Arachchi, H. M. Liyanage

Cell Biology Project, IFS, Kandy

Introduction

Cyanobacteria are aquatic and photoautotrophic prokaryotes which in their mass occurrence produce harmful algal blooms (HAB) under optimal environmental conditions. Massive occurrence of HAB affects the water quality by changing the pH, transparency and biodiversity, and produce hazardous toxins (cyanotoxins) as their secondary metabolites. Among the cyanotoxins, microcystin and cylindrospermopsin are the predominant toxins in freshwater lakes worldwide.

Objectives

Isolation and molecular characterization of *Cylindrospermopsis* strains and determination of whether cyanotoxins is a risk factor for the Chronic Kidney Disease of unknown aetiology in Sri Lanka.

Results

Water samples from reservoirs in Girandurukotte, Anuradhapura, Nikawewa, from patients' water sources, soil samples from patients' paddy fields and blood and urine samples from patients attending to renal clinic Girandurukotte and water samples from other areas as controls were collected and cultured in four cyanobacterial specific media. Morphological observations were made from 70 samples (both environmental and cultured) under the microscope and *M. aeruginosa*, *Cylindrospermopsis*, *Anabaena*, *Chroococcus*, *Phormidium*, *Microcystis spp.*, *Oscillatoria*, *Limnothrix*, *Lyngbia*, *Calothrix*, *Anabaenopsis*, *Chroococcidiopsis*, *Scynechocystis*, *Scynechococcus*, *Arthospira*, *Merismopedia etc.* species were tentatively identified as toxin producers.

Genomic DNA was isolated from water samples (environmental and cultured), blood samples and urine samples using Boom's method. PCR amplification was done for water samples, blood and urine samples for 16S rRNA gene; and reservoir samples for cpc gene to identify the presence of cyanobacteria. From sequencing two strains were identified as *Cylindrospermopsis raciborskii* and one as *Scynechococcus*. ELISA test was done for water samples collected from Girandurukotte, Anuradhapura and Kurunegala Districts to identify and quantify cylindrospermopsin toxin. Among reservoirs, highest toxicity was recorded in Henanigala tank while cylindrospermopsin toxin was also recorded from Nuwara wewa and Kurunegala tank.

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7.5.1.3 Detection of drug resistant *Mycobacterium tuberculosis* strains using PCR and DNA sequencing

D.N. Magana-Arachchi[1], M. Maheswaran[1], D.K. Weerasekara[1], D. Medagedara[2], V. Thevanesam[3]

[1]Cell Biology Project, IFS, Kandy, [2]Respiratory unit, Central Chest Clinic, Kandy, [3]Department of Microbiology, University of Peradeniya

Introduction

The emergence of drug resistant strains of *Mycobacterium tuberculosis* is an increasing problem in developed and developing countries. Drug resistant tuberculosis can be life-threatening and is a threat to tuberculosis control programmes in many countries. It substantially increases the cost and duration while decreasing the efficacy of treatment. Early detection is essential for the efficient treatment and control of drug resistant tuberculosis.

Objective

To determine the pattern of drug resistance of *M. tuberculosis* from tuberculosis patients attending the Central Chest Clinic, Kandy and to develop a simple and rapid assay based on PCR and DNA sequencing, targeting the mutations in *rpoB*, *inhA* and *katG* genes, in order to detect drug resistant *M. tuberculosis* strains.

Results

A total of 250 sputum specimens were obtained from first visit (n = 238) and recurrent tuberculosis patients (n = 12) who were positive for acid fast bacilli, were cultured. As a control population 25 sputum samples were also collected from patients attending the same clinic, who were negative for acid fast bacilli. Antibiotic susceptibility tests for isoniazid and rifampin were carried out on Lowenstein-Jensen / Middlebrook 7H10 medium, using the proportion method.

Of the 250 specimens, 174 (69.6%) grew within eight weeks of incubation. Of these 159 (63.6%) isolates were confirmed as *M. tuberculosis* / *M. tuberculosis* complex. Of the 25 specimens (from the control population) four grew within five days of incubation and the isolates were identified as non tuberculous mycobacteria. 3.2% of the *M. tuberculosis* /*M. tuberculosis* complex isolates showed isoniazid resistance and 16% were resistant to rifampin. 2.4% were multi-drug resistant. Thirty two *M. tuberculosis*/*M. tuberculosis* complex isolates were found to be rifampin resistant while being sensitive to isoniazid. PCR conditions were optimized for *inhA*, *katG*, and *rpoB* genes. Direct automated sequencing of the PCR products of *inhA*, *katG*, and *rpoB* genes from *M. tuberculosis* culture isolates are being carried out. During this period Gene sequencing was completed for 86 strains of *Mycobacterium tuberculosis*. Nucleotide sequences obtained from gene sequencing for *inhA* (n = 3), *katG* (n = 16) & *rpoB* (n = 35) genes were deposited in Gen Bank under accession numbers, GQ369430 - GQ369437; GQ 868653-GQ868655, GQ871909 - GQ 871920, HQ540563 - HQ540578 and HQ589040 to HQ589056. DNA sequence analysis of seven out of the 17 resistant *M. tuberculosis* strains revealed 15 different kinds of mutations.

Multiplex PCR (*inhA* + *rpo*B) and *katG* + *rpo*B) amplification was carried out using the already optimized PCR conditions. Amplified products are currently used to optimize the denaturing gradient gel electrophoresis (DGGE) conditions for rapid detection of drug resistance.

7.5.1.4 Detection of nontuberculous mycobacteria (NTM) in bronchoscopy and sputum samples

D.N. Magana-Arachchi[1], D.K. Weerasekara[1], U.Karunarathnne[1], N.Dissanayake[2], D. Medagedara[2]

[1]Cell Biology Project, IFS, Kandy, [2] Respiratory Unit, Central Chest Clinic, Kandy

Introduction

Nontuberculous mycobacteria (NTM), mycobacteria other than tuberculosis (MOTT), or simply atypical mycobacteria include those species not belonging to the *M. tuberculosis* complex [1]. Many species of these mycobacteria are recognized human pathogens. Chronic pulmonary disease resembling TB is the most common clinical presentation associated with NTM. In the US *M. avium* complex and *M. kansasii* are the most common NTM species affecting the lungs[2]. Other pathogens occasionally causing pulmonary disease include *M. chelonae, M. fortuitum, M. abscessus, M. xenopi* and *M. malmoense*[2]. Besides an overlap of disease spectrum with *M. tuberculosis,* infection with NTM may give rise to positive acid-fast bacilli (AFB) smears and histopathology findings similar to those found in TB.

Objectives

To isolate the causative organisms by culture and molecular techniques from patients in following categories, bronchiectasis, NTM co-existing with lung cancer, patients with negative pulmonary TB not improving with Std.TB treatment, etc.

Results

Study population consisted of patients attending the Central Chest Clinic, and General Hospital, Kandy, who had pulmonary symptoms, nodular or cavitary opacities on chest radiograph, or an HRCT scan that showed multifocal bronchiectasis with multiple small nodules. Clinical specimens of 202 bronchoscopy patients yielded positive colonies on culture media. 60 colonies were positive for acid fast staining (AFB rods), in which rapid growers were 52 and slow growers were 8. Two patients had *M. tuberculosis* in their bronchial washings. One of them had both *M. tuberculosis* and non-tuberculosis mycobacteria in his bronchoscopy. Treated sputum samples inoculated on LJ media yielded 27 patients with positive colonies on culture media. Out of 27 sputum samples, 17 were observed to be fast growers, out of which 14 were confirmed to be AFB (+ve) and 3 were AFB (-ve). DNA extractions were completed using standard protocols. PCR assay was optimized with sp1 and sp2 primers to differentiate rapid and slow growing mycobacteria from culture isolates.

Conclusion

According to our findings 28.8% of the study population is suffering from non tuberculosis mycobacterium diseases and it is alarmingly high. Similar to countries in Africa[3], only microscopic examination is usually available to confirm the diagnosis of tuberculosis in Sri Lanka, and the involvement of acid-fast NTM in tuberculosis like syndromes might result in the misdiagnosis of tuberculosis.

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7.5.1.5 Studies with *Spirulina*

S.A. Kulasooriya, R.P. Wanigatunge, D.N. Magana-Arachchi, A. Tennakoon

Cell Biology Project, IFS, Kandy

Introduction

Spirulina are multicellular and filamentous blue-green algae that have gained considerable popularity in the human health food industry. In many countries of Asia it is used as a protein supplement and as human health food. It has been also used as a complementary dietary ingredient of feed for poultry and increasingly as a protein and vitamin supplement (B-complex range B1, B12, B16, C, and E) to aquafeeds.

Objectives

The objective of the study is to collaborate with the Mahatma Gandhi Centre to popularize culturing *Spirulina* on a large scale in the country.

Results

Stock cultures of *Spirulina* samples brought from India were purified and maintained at the IFS both in liquid and solid media. One to two liter lab cultures raised from these stocks gave satisfactory growth and these were used as inoculants to commence outdoor semi-mass cultures in 20L plastic bottles at the Wattegedera Village Center managed by the MGC (Figure 1). However this attempt was unsuccessful because the cultures got contaminated by a unicellular green alga and were abandoned.

Figure 1: Semi-mass cultures in 20L bottles at Wattegedera

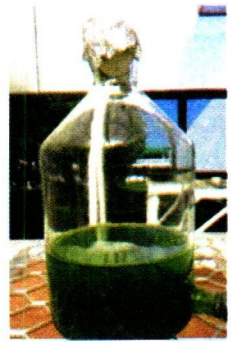

Figure 2: 20L bottle culture

Figure 3: Open tank culture

Figure 4: Microscopic view (x100)

A more systematic approach to increase the volume of the *Spirulina* cultures from laboratory stock cultures through a step by step system was tested at the IFS. This was successful and it has been

possible to semi-mass culture *Spirulina* in open tanks under green house conditions (Figures 2, 3 & 4). It is planned to transfer this technology to the MGC village at Wattegedera.

Human resource development

Dr. (Ms) V. Ambalavanar ; M.Phil; (University of Peradeniya); Completed in 2011.
Ms. R.P.Wanigatunge (University of Colombo); Registered for a PhD
Ms. H.M. Liyanage (University of Colombo); Registered for a M.Phil.
Ms. D. K.Weerasekara (Research Assistant-IFS)
Ms. D.M.D.P.K. Bandara (University of Peradeniya); Registered for a M.Sc.

Volunteer Research Assistants: Ms. U. Karunarathnne, Ms. C. Prematilake, Ms. S. Maheswaran

7.5.2 MICROBIAL BIOTECHNOLOGY

7.5.2.1 Development of biofilmed biofertilizers (BFBFs) for applications in agriculture

Project leader : Prof. G. Seneviratne (*Research Professor*)

Description of the project

Soil microbes are considered to be instrumental to fundamental processes that drive coexistence, stability, diversity and productivity in terrestrial ecosystems. However in domesticated crop cultivation (conventional agriculture), man has changed these naturally balanced ecosystems, very often to grow a single species (mono-crop) and manage it to obtain maximum commodity yields by applying biocidal chemical inputs, which collapse soil organisms. The loss of plant species diversity due to, for example mono-cropping in this manner threatens ecosystem functioning and sustainability (Tilman et al., 1996). Thus, basic concepts that are important to productivity and sustenance of the ecosystems have been largely ignored in conventional agriculture.

The overall objective of the project is to introduce microbes into the soil for compensating their collapse in conventional agriculture. This has been done by using microbial formulations called Biofilmed biofertilisers (BFBFs, Seneviratne et al., 2011), which reduce the use of chemical fertilizers and agrochemicals. Use of BFBFs in agriculture saves foreign exchange spent on fertilizer imports and helps to conserve the environment. It was found that BFBFs can biodegrade phytotoxins, and chelate cadmium and sediment in the soil solution. Thus, it is clear that the BFBFs can be used to rhizoremediate environmental pollutants.

Establishing rhizoremediation methods to reduce phytotoxins and heavy metals (cadmium) in agricultural soils: The objectives of this study were to, 1) biodegrade phytotoxins/allelopathic compounds, 2) bioremediate cadmium contaminated soil, by using BFBFs. Chemically fertilized maize soil and cadmium contaminated soil, respectively were used for the two studies. The maize and tomatoes respectively were planted with BFBF's on the two types of soils. Soils without BFBFs were used on controls. It was found that BFBFs can biodegrade phytotoxins, and chelate cadmium and sediment in the soil solution. Thus, it is clear that the BFBFs can be used to rhizoremediate environmental pollutants.

Evaluating soil carbon accumulation, when tea was applied with BFBFs: The objective of this study was to explain the increase in soil carbon, when tea was applied with BFBFs. A leaching tube experiment with tea plants was conducted under nursery conditions. It was found that when BFBFs were applied, leaching of carbon is reduced, thus increasing soil carbon accumulation.

Biochemical expression of exudates of fungal-bacterial biofilms during their growth and maturation: This study was carried out to evaluate time course change in the composition and activity of the biofilm exudates during the growth and maturation of a fungal-bacterial biofilm. This was done by analyzing functional groups of organic molecules using Fourier Transform Infrared (FTIR) spectroscopy. It was found that biochemical expression of exudates of the biofilms during their growth and maturation is very useful for breaking dormancy of seeds, their germination and growth, contributing to high plant productivity.

Effect of biodiversity on action of plant-soil system: In this study the effect of increasing soil microbial biodiversity by inoculating few microbes on biodiversity and action of the soil-plant system was examined. The BFBFs were used as the inocula, and pot experiments with a home garden soil and a maize-planted soil were conducted. In both soils, it was found that biodiversity of bacteria, fungi, algae, plants and micro fauna was increased, when BFBFs were applied. Soil mineral nitrogen release and plant drought tolerance also increased. This clearly indicates that the BFBFs application contributes to increased productivity and sustainability of agroecosystems.

Testing the BFBFs for organic rice under farmer's field conditions: This study was done at Duluwa, Gampola. Farmer's practice of organic fertilizer application was compared with application of BFBFs only in two consecutive, large field plots. A traditional rice variety called Ran thembili wee was grown. Average rice grain yields were 2.8 and 4.0 t/ha, respectively.

Improving drought tolerance in rice using BFBFs: Two drought tolerant varieties DSN 22, DSN 56 and two drought susceptible varieties BG352 and AT 307 were grown in soil pots (3 plants/pot) applied with the recommended fertilizer amount, so that there will not be any nutrition stress. Treatments were done in triplicate with or without BFBF for all 4 varieties. Drought was induced during vegetative and reproductive phases. Seedling growth and tillering were improved in one drought tolerant variety and both drought susceptible varieties, compared to no BFBFs application. Leaf drying was reduced in all four varieties with BFBFs. Further studies are required under field conditions to improve the drought tolerance of high yielding drought susceptible varieties such as AT 307.

Effect of BFBFs on maize crop: Effect of the developed BFBFs on maize growth under the application of different levels of chemical fertilizers was evaluated using two field trials at Anuradhapura and Mahiyanganaya. Nitrogen fixing activity (acetylene reduction assay, ARA) of roots of field grown maize and those grown in nutrient solutions, both inoculated with BFBFs was quantified. Seedling vigor was also evaluated. Then, plants grown in nutrient solutions with BFBFs or those grown with monocultures of bacteria that were used to develop the BFBFs were compared for above parameters. Nitrogen fixing activity and seedling vigor were significantly higher in BFBFs applied treatments than bacterial monocultures. Under field conditions in Anuradhapura, it was found that 50% of chemical fertilisers can be replaced, when the BFBFs were coupled.

Research Expertise: Prof. S.A. Kulasooriya (*Visiting Research Professor)*
Research Assistants: H.M.L.I. Herath, N. Weeraratne, U.V.A. Buddhika
Senior Staff Technical Officers: R.C.K. Karunaratne, A.K. Pathirana
Lab Attendant : M.A. Lal

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2. D. Tilman, D. Wedin, J. Knops, (1996). Productivity and sustainability influenced by biodiversity in grassland ecosystems. *Nature 379*, 718-720.

Human resource development

Ph.D.	K. A. J. M. Kuruppuarachchi (Open University of Sri Lanka, Nawala)
B. Sc. research projects:	M.D. Ariyarathne (Faculty of Science, University of Peradeniya)
	H.M.A.R. Senevirathne Banda and K.A.A.A.K. Athurugiriya (Faculty of Agriculture, Rajarata University of Sri Lanka)
	N. Senanayake, W. Athauda (Faculty of Agriculture, Sabaragamuwa University)
Volunteers trained:	S. P. Gunaratne, J. A. W. W. Jayasinghe
	M. T. K. Pushpitha, J. Gunatilake
	W. W. Jayasinghe, N. Jeyadharshan

7.5.2.2 Soil carbon accumulation with biofilmed biofertiliser application to a crop

G. Seneviratne, S. A. Kulasooriya

Microbial Biotechnology Project, IFS, Kandy

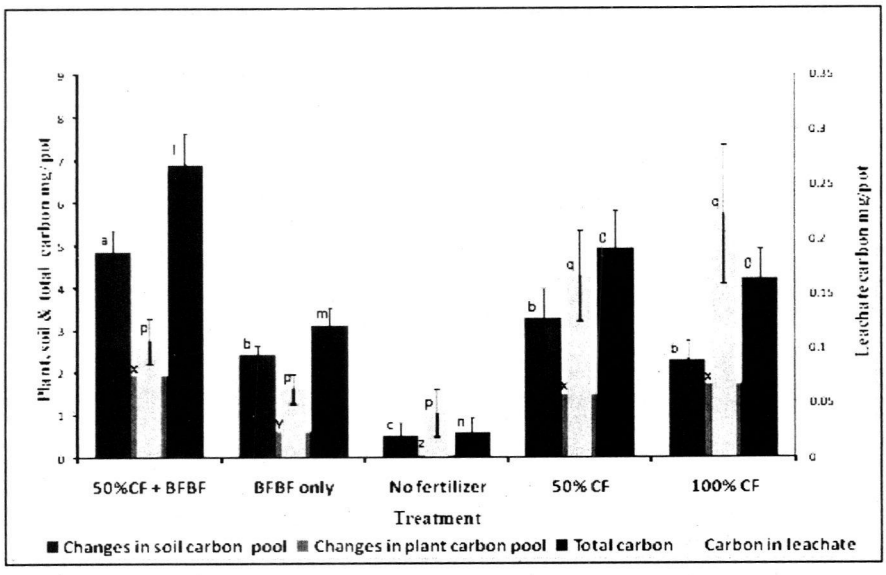
Introduction

When biofilmed biofertilisers (BFBFs) were applied to tea, it has been observed frequently that there would be a build up of soil carbon (C)[1]. It is speculated that this could be attributed to increased storage of root exudate C by the fungal components of the BFBFs, forming biofilms on the root surface and in the rhizosphere[2]. However, this has not been explained experimentally. Therefore, the objective of this study was to explain the increase in soil C.

Methods and results

A leaching tube experiment with tea plants was conducted under nursery conditions. There were five treatments; soil alone control, BFBFs alone, 50% of recommended chemical fertilizer (CF) for tea, 50% CF + BFBFs, and 100% CF. Leachate was collected fortnightly. Plants were harvested after four months. Soil and plant samples before and after the experiment, and leachate were analysed for organic C by wet oxidation method.

There was a significant increase of soil C pool in the 50% CF + BFBFs treatment. Increase in plant C were comparable in 50% CF, 50% CF + BFBFs, and 100% CF. There was a significant increase in C leached only in 50% CF and 100% CF. Thus, it was found that when BFBFs were applied, C leaching was reduced, while increasing soil C accumulation. This contributes to improved soil fertility and C sequestration on tea lands, which have economical and environmental implications (e.g. mitigating global warming).



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7.5.3 PLANT BIOLOGY

Project leader : Dr. M.C.M. Iqbal *(Senior Research Fellow)*

Description of the project

The Plant Biology project is conducting research related to climate change, environmental remediation and plant ecology. The climate change group is studying the storage of carbon in the biomass of the trees in the dry zone forests in Sri Lanka. Whereas the wet zone forests have been intensively studied, the forests in the dry zone were not accessible to research in the recent past due to the conflict situation in the Northern and Eastern regions where the dry zone is located.

Quantifying carbon stocks of tropical forests in developing countries face challenges of data availability and methods to estimate above ground biomass (AGB). Using forest inventory data, we estimated the AGB in eight dry (mixed) evergreen forests in Sri Lanka. The AGB ranged from 37.8 $Mgha^{-1}$ to 179.1 $Mgha^{-1}$. Few species, with wood densities equal to or greater than 0.9, contributed mostly to the AGB. These AGB estimates are consistent with other dry forests in the Asian region. A permanent two hectare plot was established in the Hurulu forest off Habarana in 2010 to monitor changes biomass in the future. Our preliminary calculations in this plot indicate an AGB of 109.3 ± 47 $Mgha^{-1}$. The total forest area in Sri Lanka in the latter 1950's (at the time of the forest inventory) was 2,899,455 ha (44% of the land area) of which 86% was in the dry zone. Sri Lanka now has a natural forest cover of 29 % of the land area of which 53 % occurs the dry zone. This is a decline of 33% over approximately 50 years. It is imperative that this natural forest cover be stabilized.

Changes in the climate are implicated in the sudden outbreak of dengue epidemics in Sri Lanka and elsewhere. The number of reported dengue patients has rapidly increased during the past few years, particularly due to socio-cultural and environmental factors. In this study, Geographical Information System (GIS) was used to integrate information on environment and climate parameters, hospital reports of dengue patients, and potential breeding locations in urban and semi-urban areas. Our objective is to prepare a Dengue Risk Map to identify areas of high, moderate and low risk and to identify the localities where special attention should be given for control measures. This would enable decision makers to strategize and take preventive action to control dengue transmission. The risk areas were determined by identifying the direct breeding locations and socio-economic variables contributing to breeding locations of the vector mosquito. Dengue incidence and socio-economic variables were merged with base maps of the study area using ArcGIS. The environmental factors showed a significant relationship. High temperature was associated with a number of dengue incidences and optimum pH for larvae breeding was the neutral pH. Among the socio-economic factors, correlations were found between dengue incidence and sanitation, types of roofing and level of education.

Discharge and disposal of industrial effluents contaminated with heavy metals have resulted in the pollution of valuable land and water resources. Since heavy metals are non biodegradable and toxic to biological systems, they are of concern to human and animal health. In developing countries, where enforcement of environmental regulations is less stringent, heavy metals enter the food chain through agricultural produce. Among many heavy metals used in industries, chromium and its compounds are widely used in leather tanning, chromium plating, wood preservation, alloy preparation, rust and corrosion inhibition and manufacture of dyes and pigments, owing to special characteristics of this heavy metal. Consequently chromium, which primarily exists as the soluble, highly toxic Cr(VI) and less soluble, less toxic Cr(III), is one of the most common heavy metals found in industrial waste.

Biosorption of heavy metals utilizes the ability of non-living biological materials to accumulate such metals from waste streams by either metabolically mediated or purely physico-chemical pathways of uptake. This study reports the potential of non-living biomass of *Cabomba caroliniana* (an aquatic

plant) for biosorption of Cr(III) and Cr(VI) from aqueous solutions. Effects of contact time and settling time, biosorbent dosage, pH of the medium and acidification of the biosorbent were found to positively influence the capacity for Cr biosorption.

Research Assistants: Mr. P.K.D. Chathuranga, Ms. M. Madannayake, Mr. G.D.A. Nalaka
Senior Staff Technical Officer: Ms. S. Jayasundera
Laboratory Attendant: Mr. R.B. Hapukotuwa

Experiments on metal uptake by plants

Collecting dengue vector mosquitoes for Identification

Field work in the Hurulu forest

7.5.3.1 Biosorption of environmental heavy metals

M. C. M. Iqbal[1], P. K. D. Chathuranga[1], N. Priyantha[2], S. S. Iqbal[3]

[1]Plant Biotechnology Project, IFS, Kandy, [2]Department of Chemistry, University of Peradeniya, [3]Department of Chemistry, The Open University of Sri Lanka, Nawala

Introduction

Discharge and disposal of waste products contaminated with heavy metals have resulted in the pollution of valuable land resources and groundwater. Since heavy metals do not degrade and are toxic to biological systems, they will continue to be an environmental concern for a long time unless they are removed from the ecosystem. Biosorption is a cost effective biological remediation technique which uses non-living biological materials to remove pollutants from the environment.

Aims and objectives

Our objective is to optimise the removal of Cr(III) & Cr(VI) from aquatic sources by non-living biomass of *Cabomba caroliniana* (a freshwater aquatic plant).

Results

The dried biomass of *Cabomba spp.* was thoroughly mixed separately in Cr(III) and Cr(VI) solutions and the residual concentration of each metal was analysed after pre-determined time intervals. Non-living biomass of *Cabomba* removed 46% of Cr(III) and 24% of Cr(VI) (Fig. 1). However, when the biosorbent was protonated, the removal of Cr(III) enhanced significantly up to 98% whereas Cr(VI) removal dropped to 3% (Fig. 1B). The extent of removal of both metal ions increased with the increase of biosorbent dosage. FTIR spectral analysis showed that –OH functional groups on the sorbent surface are responsible for the metal removal process. Surface titration experiments showed that the charge of the biosorbent surface depends on the pH of the surrounding media.

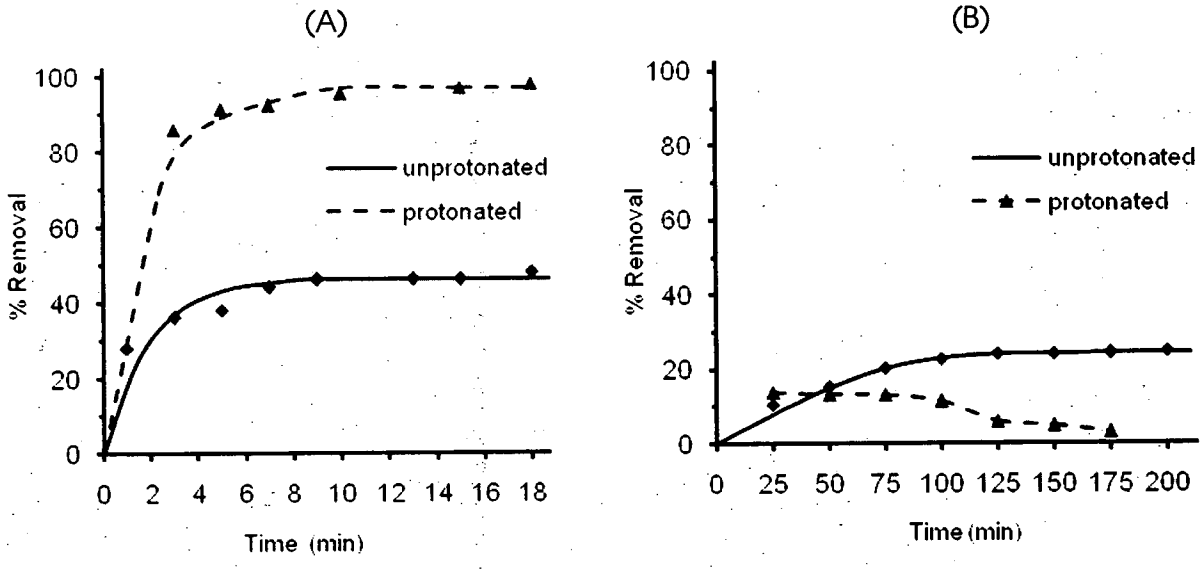

Figure 1.Percentage removal of (A) Cr(III) and (B) Cr(VI) by unprotonated and protonated dry *C. caroliniana* biosorbent at different shaking times (biosorbent dosage 2.0 g L^{-1}, initial metal ion concentration 5.0 mg L^{-1}, pH 5.0, temperature 25 °C, shaking speed 140 rpm).

7.5.3.2 Impact of climate and socio-economic factors on dengue epidemic and to generate risk maps using GIS technology

M.P. Madanayake, M.C.M. Iqbal

Plant Biotechnology Project, IFS, Kandy

Dengue is now the most severe mosquito borne disease in Sri Lanka. Various factors have been identified for the rapid increase of the incidence. According to the Epidemiology unit of the Ministry of Health the highest numbers of reported cases were identified in the years, 2009 and 2010, where the incidence rate per 100,000 population was 184 and 179 respectively. In addition to the entomological and medical aspects of the disease, it is necessary to focus on the socio-economical and climate factors that are contributing to vector breeding and spread of the virus. Geographical Information System (GIS) is a useful tool to integrate different contributing factors. Our objective in this study is to identify climate and socio-economic factors in the Gampola and Mawanella regions that are contributing to dengue incidence and use of GIS technology and statistics to identify them to prepare Dengue Risk Maps (DRM). As shown in Fig. 1 the distribution pattern of the patients in Mawanella area was identified as clusters in the years of 2004 to 2009 except in the year 2005 (Fig. 1, Madanayake et al. 2010). The data collection was done for Gampola area during the year 2011 and the generated database for the Gampola area being processed to prepare DRMs. The capability of DRM to identify the risk through environmental and socio-economic factors is essential in elimination of this vector borne disease from the study areas.

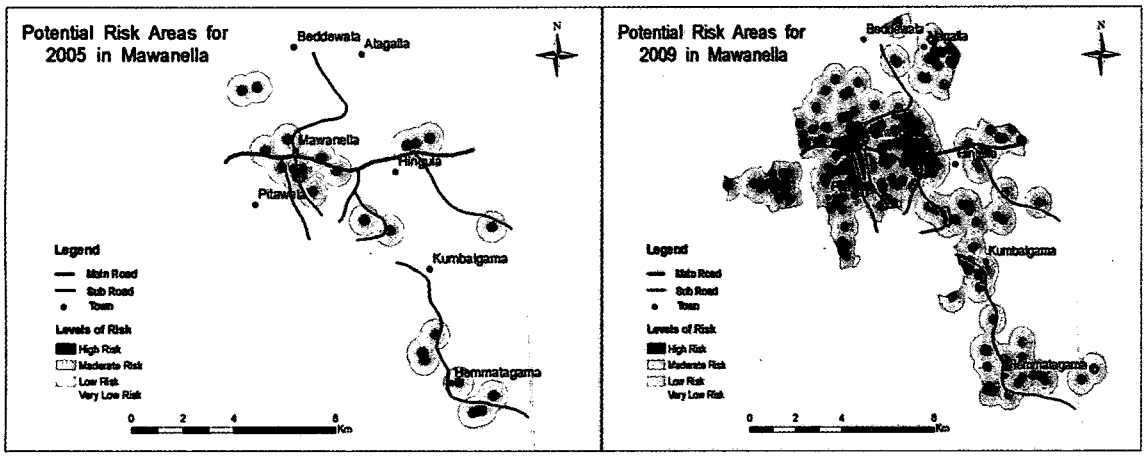

Figure 1. Potential risk areas for 2005 and 2009

Reference

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7.5.3.3 Carbon sequestration in dry forests of Sri Lanka

G.D.A. Nalaka and M.C.M.Iqbal

Plant Biology Project, IFS, Kandy

Introduction

Of the natural forests in Sri Lanka, 53% occur in the dry zone as dry mixed evergreen forests (Forest Department, 2008). The conflict situation in the Northern, North-Eastern and Eastern regions, where most of these forests are located, prevented extensive ecological studies. We have completed an analysis of forest inventory data in these forests to estimate the biomass and carbon sequestration potential.

Aims and Objectives

Our objectives are to determine the Aboveground Biomass (AGB) from forest inventory data in eight forests in the dry zone, and the contribution of the species and trees size class to biomass. This would provide an estimate of the carbon sequestration status of our dry forests at the time of the inventory in the late 1950's.

Results

The eight forests (Hurulu, Kumbukkan, Pallekelle, Kantalai, Madhu, Panama, Terravil-Oddusuddan, Omunugala, Nuwaragala, Ratkarrawwa) were classified in to three yield categories: LY (Low Yield), MY (Medium Yield), and NP (Non Productive). AGB was estimated using a published allometric equation (Brown et al., 1989). The AGB ranged from 37.75 $Mgha^{-1}$ in NP category to 179.07 $Mgha^{-1}$ in MY category of Terravil-Oddusuddan forest. Few species, with wood densities equal to or greater than 0.9, contributed mostly to the AGB. The contribution of the diameter classes to the AGB was skewed to the 20-30 cm Diameter at Breast Height (DBH) class for all the forest types (Fig. 1). The medium and low-yield forests had a higher frequency of trees in the larger diameter classes of >50 cm than the non-productive forests. Overall, for all the three forest types, AGB was contributed mostly by the 10 – 50 cm DBH class of trees. The contribution of large tree size class (>80cm), was less than five percent to the AGB, indicating the potential "sink" capacity of the smaller trees for biomass accumulation at the time the inventory. These AGB estimates are consistent with other forests in the Asian region. The stand density (number of trees/ha) was an important determinant for AGB in dry forests in addition to the moisture availability.

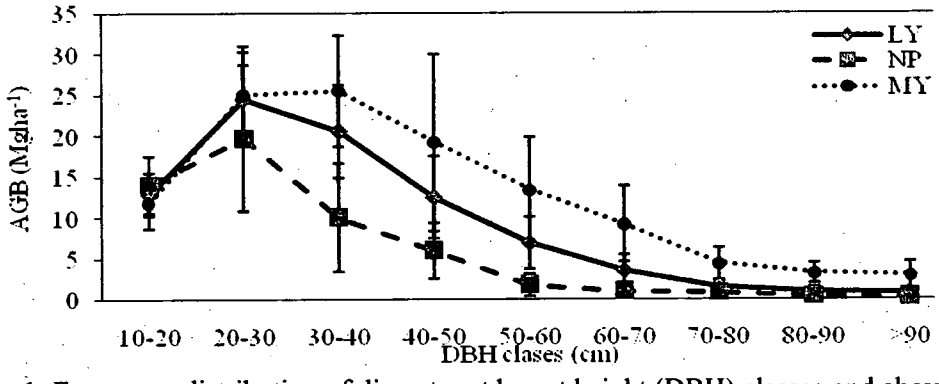

Fig. 1: Frequency distribution of diameter at breast height (DBH) classes and above ground biomass in the yield categoriesLY (Low Yield), MY (Medium Yield), and NP (Non Productive).

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7.6 NATURAL PRODUCTS

Project leaders: Prof. N.S. Kumar *(Research Professor)*
Prof. U.L.B. Jayasinghe *(Research Professor)*

Description of the project

Natural products are organic compounds produced by plants, fungi, other microorganisms, marine organisms and lichens. The research project on Natural Products has now widened the scope to include six different areas of research - Plant secondary metabolites, fungal toxins and metabolites, microbial transformations, polyphenols from tea and fruits, chemistry and bioactivity of edible fruits of Sri Lanka and value added products from under- utilized fruits of Sri Lanka. The overall objective of these projects is the search for bioactive compounds from natural sources as potential resources for control of human and plant diseases.

Bioassays were used to assess the bioactivity of extracts and compounds isolated. These included the DPPH (2,2'-diphenyl-1-picrylhydrazyl) assay to detect the presence of natural antioxidants, the brine shrimp (*Artemia salina*) lethality assay to detect cytotoxicity, the lettuce (*Lactuca sativa*) seed germination assay to detect the presence of phytotoxic compounds and the TLC bioautography method to detect the presence of antifungal compounds in extracts. In addition, enzyme inhibition bioassays were introduced to the natural products research at the IFS in year 2011. Specific enzyme inhibitors interact with enzymes and block their activity towards their corresponding natural substrate and are biochemical tools that have potential utility in the treatment of diseases. Examples are α-amylase, β-glucosidase and lipase inhibitors that are drug targets for the treatment of diabetes, obesity and hyperlipaemia.

Fungal metabolites from fungal species were isolated from healthy and diseased fruits found in Sri Lanka. Pure cultures were isolated from fruits of *Musa* sp (Ambul), *Persea americana* (avocado), *Flacourtia indica* (ugurassa), and *Limonia acidissima* (wood apple). Each pure fungal species was cultured in different media (rice, potato dextrose agar and potato dextrose broth). The fungal mycelia and media that were used for culturing were extracted with ethyl acetate and methanol and subjected to the in-house bioassaays. Active extracts were chromatographed to isolate fungal metabolites. Some of the compounds were identified as polyketides. Bioactivity studies of isolates are in progress.

As a part of a training program on microbial transformation of organic compounds, preliminary studies on the behaviour of simple organic compounds cinnamic acid, phenanthroquinone, methyl umbeliferone, *m*-anisic acid, caffeine, 3-hydroxybenzaldehyde in cultures of the fungi *Cunninghamella blackesleana, Macrophomina phseolina, Fusarium lini, Beuvaria bassiane* were carried out at the International Center for Chemical and Biological Sciences, University of Karachi, Pakistan. Some changes were observed in the media of *Beuvaria bassiane* and *Cunninghamella blackesleana* with cinnamic acid, caffeine and phenanthroquinone.

Liquid Chromatography – Mass Spectroscopy (LC-MS) is a powerful technique to analyze chemical constituents present in a mixture. Structures of the chemical constituents are generally identified on the basis of their retention times and mass fragmentation patterns by the LC-MS studies. Analysis of the phenolic profile obtained by LC-MS studies of green and black tea leaves and popular fruits *Phyllanthus acidus* (Rata Nelli), *Phyllanthus ambelicum* (Nelli), *Garcinia cambogia* (Goraka), *Pouteria campechiana* (Lavulu), *Camella sinensis* (Tea), *Flacourtia indica* (Uguresa), *Flacourtia inermis* (Lovi), *Persea americana* (Alipera), *Hylocereus undatus* (Dragonfruit), *Elaeocarpus serratus* (Veralu) have been recorded.

Edible fruits are a potential source of environmentally friendly bioactive compounds. Chemistry and bioactivity studies of popular edible fruits *Pouteria campechiana* (lavulu), *Garcinia cambogia*

(goraka) and *Musa* (banana) sp. were carried out. This work has led to the isolation of various classes of compounds including some novel natural products with biological activity.

Garcinia cambogia (goraka) found in the lowland tropical rain forests of Sri Lanka and in many home gardens, has been used in Sri Lanka for culinary and medicinal purposes for centuries. Various parts of the tree are used in Ayurveda medicine because of its therapeutic and antiseptic properties. Goraka is in high demand in the current world market as a nutraceutical because of its potential as a dietary supplement used for weight and appetite control. Studies are in progress to identify its economic potential as a food additive and a nutraceutical.

Research Assistants: Ms. A.G.A.W. Alakolanga, Ms. A.M.D.A. Siriwardena, Ms. H.M.S.K.H. Bandara, Ms. K.G.E. Padmathilake, Ms. G.G.E.H. De Silva

Senior Staff Technical Officer: Mr. D.S. Jayaweera

Natural Products Research Group – 2011

7.6.1 Polyketides from the endophytic fungus *Aspergillus* sp. associated with *Limonia acidissima*

A.M.D.A. Siriwardane, U.L.B. Jayasinghe, N.S. Kumar

Natural Products Project, IFS, Kandy

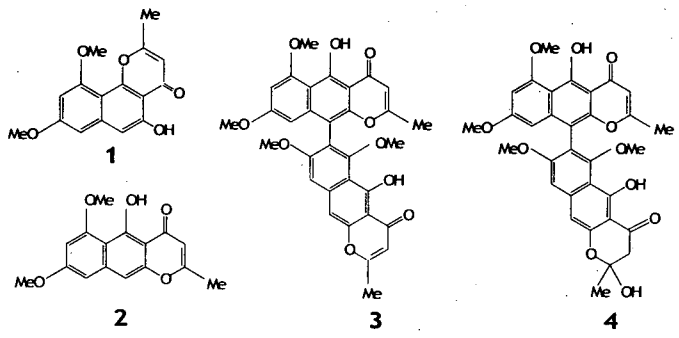
Introduction

Endophytic fungi have been recognized as a potential source of structurally novel and biologically potent metabolites which are a valuable source for pharmaceutical and eco-friendly agrochemical industries applications [1]. The objective of this study is to isolate cytotoxic, phytotoxic and antioxidant compounds which may lead to the discovery of anti cancer drugs and compounds of importance in agriculture.

Methods and Results

The endophytic fungus *Aspergillus* sp. was isolated from the seeds of *Limonia acidissima* (L.) on potato dextrose agar (PDA) medium and cultured in different media such as PDA and PDB on a large scale. EtOAc and MeOH extracts were subjected to bioassays for antioxidant activity on thin layer autobiographic (TLC) plates against DPPH (2,2'-diphenyl-1-picrylhydrazyl), cytotoxicity against brine shrimp *Artemia salina* lethality assay and phytotoxicity in the lettuce (*Lactuca sativa*) seed germination assay.

All extracts obtained from both PDA and PDB media exhibited the presence of antioxidant compounds. EtOAc and MeOH extracts obtained from PDB media showed significant cytotoxic activity with LD_{50} values, 180 ppm (EtOAc extract of mycelia) and 218 ppm (MeOH extract of mycelia). The two extracts from PDA showed LD_{50} - 80 ppm (EtOAc extract) and 140 ppm (MeOH extract). EtOAc extracts of both PDA and PDB showed significant phytotoxic activity. Chromatographic separation of EtOAc and MeOH extracts from both PDA and PDB media furnished nine compounds. Four were identified as polyketides flavasperone (**1**), rubrofusarin B (**2**), auresperone A (**3**) and foncesinone D (**4**) respectively[2] .



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7.6.2 Bioactive extracts from some fungi of importance in agriculture

W.C. De Silva, A.M.D.A. Siriwardane, H.M.S.K.H. Bandara, G.G.E.H. De Silva, N. S. Kumar, U.L.B. Jayasinghe

Natural Products Project, IFS, Kandy

Introduction

Fungi are a rich source of secondary metabolites. The discovery of penicillin by Sir Alexander Fleming (1928) produced by the fungus, *Penicillium notatum*, is one of the important discoveries of the 20th century. The study of secondary metabolites originating from fungi is now a rapidly expanding field of research in the search for novel bioactive compounds [1].

Objectives

The current study was directed to the isolation of environmental friendly bioactive compounds originating from fungi of importance in agriculture.

Methods and Results

Fusarium oxysporum, Trichoderma viride, Cercospora canescens, Macrophomina phaseolina, Fusarium solani and *Colletotrichum* sp., were isolated from diseased banana stems, onion bulbs, sesame stems, guava fruits and potato tubers respectively. Fungi were identified by detailed analysis of morphological characters. Pure cultures of each fungus were cultured in different solid media inoculated in to different types of solid media, then sequentially extracted with *n*-hexane, EtOAc and MeOH and subjected to the cytotoxicity bioassay – against brine shrimp (*Artemia salina*) lethality, phytotoxicity bioassay against lettuce seeds (*Lactuca sativa*) and antifungal activity bioassay - against *Cladosporium cladosporioides.*

EtOAc extracts from rice and potato media of *C. canescens*, *T. viride* and *F. oxysporum* showed significant cytotoxic activity. Both *n*-hexane and EtOAc extracts of *F. solani* and *Colletotrichum sp.* from potato medium showed cytotoxic activity in the brine shrimp lethality assay. EtOAc extracts of both *C. canescens* and *T. viride* from the rice medium showed root and shoot inhibition while *n*-hexane extracts of *Colletotrichum sp.* obtained from the potato medium showed significant root inhibition. Extracts of *C. canescens* and *M. phaseolina* and *T. viride* showed antifungal activity against *C. cladosporioides.* Results from these bioassays indicate that these fungal extracts may be sources of environmental friendly bioactive compounds.

References

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7.6.3 Bioactive secondary metabolites from a fungus *Aspergillus* sp. associated with *Musa sp.*

H.M.S.K.H. Bandara, N.S. Kumar, U.L.B. Jayasinghe

Natural Products Project, IFS, Kandy.

Introduction

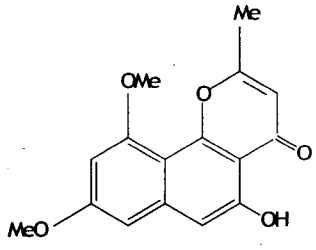
Fungi produce structurally diverse biologically active secondary metabolites. Several important bioactive compounds such as penicillin (antibiotic), cryptocandin (fungicide), and helvic acid (herbicide) have been isolated from the fungi *Penicillium notatum*, *Cryptosporiopsis* cf. *querina*, *Aspergillus fumigatus* [1] respectively. Hence there is an increasing trend to search the fungal world for new bioactive metabolites. The objective of this study is to search for new drugs, antibiotics, fungicides, herbicides, antioxidants etc. which have pharmaceutical potential and agricultural applications.

Methods and results

Black colored densely sporulated epiphytic fungus with septate hyaline was isolated from diseased *Musa sp.* Based on the morphological characters, it was identified as *Aspergillus sp.* Pure cultures of the fungus were extracted with n-hexane, ethyl acetate (EtOAc) and methanol and subjected to bioassays for antifungal activity against *C. cladosporioides* by the TLC bioautography method; antioxidant activity against DPPH radical using the TLC bioautography method; cytotoxic and

phytotoxic activities were determined using the brine shrimp (*Artemia salina*) lethality assay and *Lactuca sativa* Petri-dish bioassay respectively.

Only the EtOAc extract obtained from the rice medium showed antifungal activity against *C. cladosporioides* displaying a zone of inhibition on the TLC plates. All extracts showed antioxidant activity while some extracts displayed cytotoxic activity, and also inhibited in growth of shoots and roots in the lettuce seedling assay. Eight compounds were isolated, using chromatographic separation methods, from the extract which displayed cytotoxicity and phytotoxicity. One of the compound was identified as flavasperone (2) [2].



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7.6.4 Chemistry and bioactivity of the seeds of *Punica granatum* (pomegranate)

A.G.A.W. Alakolanga, U.L.B. Jayasinghe, N. S. Kumar

Natural Products Project, IFS, Kandy

Introduction

Punica granatum of the family Punicaceae is a popular fruit bearing shrub growing in Mediterranean, North American and Asian regions. All parts of this shrub including fruits, roots, leaves and flowers have been used for various medicinal purposes from ancient times [3]. Chemistry of this plant has been carried out extensively. Several fatty acids, monoacylglycerols, triglycerides, phytosterols, pectins and sugars have been reported from the seeds [2, 3].

Objectives

Isolation and identification of novel chemical compounds which act as antioxidants, fungicides, weedicides, and cytotoxins from dried seeds of *Punica granatum.*

Methodology and results

Dried seeds of *P. granatum* were extracted using 80% aq. acetone from which aqueous and ethyl acetate (EtOAc) extracts were obtained after work-up. The two extracts were subjected to bioassays for phytotoxicty, antifungal activity, cytotoxicity, antioxidant activity and hemolytic activity. Both extracts showed significant inhibition at 500 ppm on both roots and shoots of *L. sativa*. Cytotoxic activity against 2nd instar nauplii stage of *A. salina* was not observed even at 1000 ppm. Saturated solution of EtOAc extract in 70% methanol did not show any hemolytic activity with blood agar; however the aqueous extract showed a significant hemolytic activity. The crude EtOAc extract

showed antifungal activity against *C. cladosporioides* and antioxidant activity. Chromatographic separation of the EtOAc extract furnished eight compounds. NMR and MS spectral data indicated the presence of acyl glycerols and derivatives in the extract. [1]

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7.6.5 Chemistry and bioactivity of the seeds of *Pouteria campechiana*

K.G.E. Padmathilake, N.S. Kumar, U.L.B. Jayasinghe

Natural Products Project, IFS, Kandy

Introduction

Pouteria campechiana (local name - *Lavulu*) is a golden yellow coloured popular edible fruit of the family Sapotaceae growing in tropical countries. Several phenolic compounds and carotenoids have been reported from the edible part of the fruits of *P. campechiana*[1,2]. A preparation from seeds is used as a remedy for ulcers and a decoction from bark is used for skin eruptions in Cuba.

Objectives

Chemical or biological investigations of the seeds of *P. campechiana* have not been reported on previously. The chemistry and bioactivities of the seeds were studied in the search for bioactive compounds.

Methods and Results

Dried and powdered seeds of *P. campechiana* were sequentially extracted with EtOAc and MeOH. The EtOAc and MeOH extracts, and the *n*-BuOH extract from the MeOH extract were subjected to bioassays for antifungal activity against *C. cladosporioides* using the TLC bioautography method; antioxidant activity against DPPH radicals by the TLC bioautoghaphy method; cytotoxicity against *Artemia salina* using the micro-well bioassay and phytotoxicity against *Lactuca sativa* seeds germination bioassay. The EtOAc extract was significantly active for all the bioassays tested and the *n*-BuOH extract showed significant activity in all the above bioassays except in the assay for phytotoxicity.

Chromatographic separation of the EtOAc extract and *n*-BuOH extract furnished eight compounds. Five were identified as taxifolin, quercetin, gallocatechin, 4-hydroxyacetophenone and a glycerol ester of an unsaturated fatty acid (MW 356)[3].

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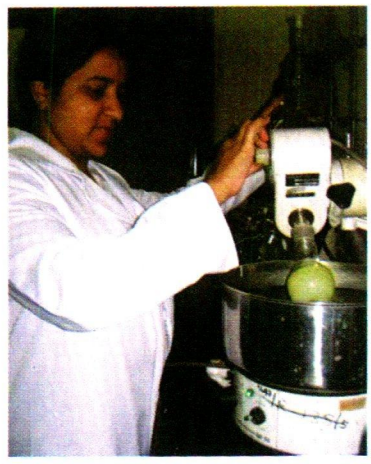
Natural Products Research Group at work






Human Resource Development

Research Assistants currently registered for M. Phil. Degrees

Ms. A.G.A.W. Alakolanga, Ms. A.M.D.A. Siriwardena, Ms. H.M.S.K.H. Bandara, Ms. K.G.E. Padmathilake, Ms. G.G.E.H. De Silva, Mr. D.S. Jayaweera (Senior Staff Technical Officer).

Ms. S.S.K. Marasinghe, Sabaragamuwa University of Sri Lanka and Mr. P.P.D. Chaturanga, Faculty of Allied Health Sciences, University of Peradeniya completed their final year research project at the IFS Natural Product Laboratory.

Many postgraduate students from the Sri Lankan National Universities had the opportunity to participate in the International Symposium on Natural Products and their Applications in Health and Agriculture (NPAHA2011) organized by the Natural Products Research Division was held at the IFS during October 3-8, 2011 and to interact with other researchers (both local and international) in their fields of interest. Resource persons/participants from overseas (27), 71 Sri Lankan Resource persons/participants (71) were present.

7.7 THEORETICAL AND COMPUTATIONAL SCIENCE

7.7.1 SONOLUMINESCENCE

Project leader: Prof. Asiri Nanayakkara (*Research Professor)*

Description of the project

Single-Bubble Sonoluminescence (SBSL) is observed when a single gas bubble, which is acoustically levitated in a liquid, undergoes nonlinear oscillations in synchrony with the applied sound field and emits subnanosecond flashes of light at the point of maximum implosion. As the bubble collapses, vibrational energy gets concentrated by at least a factor of $4x10^{11}$ to produce flashes of light in the UV range. These flashes of ultraviolet light have durations much shorter than a Nanosecond. At the latter stages of the collapse, both the temperature and the pressure inside the bubble reach extreme values such as 20,000K and 3,500 atm respectively. Also the bubble wall reaches acceleration over 10^{11} g near the maximum implosion. SBSL is observed by only with the bubbles having ambient radii between 1 μm to 10 μm and during the collapse radii of these bubbles come down to 0.1 μm to 1μm [1].

The spectrum of SBSL is fairly broad, extending from above 700 nm to below 190 nm. The intensity of emitted light increases with decreasing wavelength up to the ultraviolet cutoff of water (about 200 nm, though anything below 250 nm is attenuated). In water, the spectrum of SBSL fits blackbody radiation with surface temperatures in the range 6000K–20 000 K [2] for sound frequencies between 10 and 50 kHz. On the other hand spectrum of SBSL of an isolated bubble driven at 1 MHz sound frequency agrees well with thermal bremsstrahlung from a 10^6 K plasma[3].

There has been large number of theoretical and experimental investigations carried out to explore, understand and predict the above mentioned exotic physical conditions which take place inside the SBSL bubbles at the time of light emission [4] . Most theoretical / computational models have been based on continuum fluid mechanics (e.g. Euler equations or Navier- Stokes equations) [4] and they were able to simulate some of the experimental results successfully. Since the majority of the models are based on fluid equations and during the last stages of the collapse, the speed of the bubble wall exceeds the speed of sound in water (or the liquid) and other extreme physical conditions can be observed inside the bubble, the validity of these models is questionable [5] . Further, all these fluid approaches are limited in their predictive power by the need to represent transport processes and the equation of state.

SBSL has been, and continues to be, the subject of considerable experimental and theoretical research since light emission mechanism has not been fully understood yet. Also SBSL has attracted many scientists' attention due to its potential in producing unlimited clean energy via cold fusion. The light emitting mechanism in SBSL is one of the unsolved problems in Physics at the moment.

Research Assistants: Prabhath Herath, Gihan Panapitiya (until August 2011)

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7.7.1.1 Computational investigation of single bubble sonoluminescence

Asiri Nanayakkara, Sanjeewa Karunawansha

Single Bubble Sonoluminescence Project, IFS, Kandy

Introduction

Most theoretical / computational models of Single Bubble Sonoluminescence (SBSL) have been based on continuum fluid mechanics (e.g. Euler equations or Navier- Stokes equations) and they were able to simulate some of the experimental results successfully. Especially, the computational models developed by Yasui were able to simulate some sonochemical reactions correctly.

Aims and objectives

Aim of this project to understand the mechanism which produces light in SBSL. In order to understand what is going on inside the bubble when it emits light, we use computers to simulate physical situation inside the bubble when it emits light. Also using computational chemistry software, we study sonochemical reactions which may take place inside the bubble and investigate how they may affect the overall behavior of the bubble.

Results

Since construction of the workstation cluster could not be completed due to delay in delivery of computers for the cluster, the development of software for Molecular dynamics and Monte Carlo simulations of the bubble collapse was not continued in 2011. Instead, less CPU intensive simulation software based on hydro-dynamical model was developed for simulating collapse stage of the bubble. It is in the testing stage. Two undergraduates who were following special degree in Chemistry at University of Colombo carried out their final year research project. One of them involved in developing software to simulate bubble creation in liquid Ar, The other student carried out electronic structure calculations on radical reactions which may take place inside the bubble involving SO, NO, and OH.

7.7.1.2 Experimental investigation of single bubble sonoluminescence

Asiri Nanayakkara, Prabhath Herath

Single Bubble Sonoluminescence Project, IFS, Kandy

Introduction

Single-bubble sonoluminescence (SBSL) spectra in H_2O show featureless continuum emission. Recently, it was observed that SBSL from H_2SO_4 is over 10^3 times brighter than SBSL from water and provides atomic, ionic, and molecular emission lines. In the year 2010, from an acoustically driven, moving bubble in phosphoric acid (H_3PO_4), a very strong molecular emission was observed from excited OH radicals. The investigators were able to accurately estimate the temperature of the bubble at the last stages of the bubble collapse. These new findings showed the complexity of SBSL and the importance of further experimental studies of SBSL in liquids other than water.

Aims and Objectives

In this project we will find out experimentally whether the SBSL in acids such as Selenic (H_2SeO_4) and Selenious acids (H_2SeO_3) would produce spectral lines similar (or different) to what was observed in Sulfuric and Phosphoric acids. Further, we investigate how the intensity and spectral lines of SBSL in above two acids vary compared to Sulfuric and Phosphoric acids when physical parameters and the

initial conditions of the bubble collapse change. As the first step we will carry out detail investigations on SBSL in Sulfuric and Phosphoric acids. This will help us to compare the results we acquire from Selenic and Selenious acids with Sulfuric and Phosphoric acids.

Results

Construction of the SBSL laboratory was completed in October 2011. SBSL was generated for H_2O and H_2SO_4 in our laboratory. The behavior of the bubbles was monitored with various concentrations of air and Ar in H_2O. However, in order to carry out detail and accurate spectroscopic studies and to monitor size of the bubble during the collapse, some additional accessories such as quartz wires, C mount lenses and picture grabber cards are needed. Due to limited consumable budget, we were unable to purchase them during 2011. We expect to purchase them in 2012.

7.7.2 QUANTUM MECHANICS AND QUANTUM CHAOS

Project leader: Prof. Asiri Nanayakkara (*Research Professor*)

Introduction

In recent years, the manifestation of chaos in quantum mechanics has been of great interest. In particular, quantum systems which are classically chaotic have been investigated intensively. In order to study signature of chaos in quantum mechanics, we have been developing various theoretical and computational methods for multidimensional systems which bridge classical mechanics with quantum mechanics in a transparent manner. Also we have been investigating quantum mechanical quantities which contain information on chaos in the corresponding classical system.

Aims and objectives

In this project our aim is to understand the behavior of multidimensional systems in the semiclassical limit. (i.e. limit between quantum mechanics and classical mechanics) and classical, semiclassical and quantum mechanical behavior of both Hermitian and non-Hermitian Hamiltonian systems.

Results

This project has produced 26 research papers and 3 research communications since its inception.

A new powerful asymptotic energy expansion method was developed for 1-D systems. This method is based on power series expansion of the quantum action variable J in energy and can be applied to a wide range of potentials. Contour integrals involved in the method are much simpler than that in WKB methods. In 2011 this Asymptotic Energy Expansion method was extended for non-polynomial potential of the type $V(x) = x^{2N} + x^{m1} / (1+gx^{m2})$ and polynomial potentials with rational powers $(V(x) = x^{2n/m} + a_1 x^{n_1/m_1} + a_2 x^{n_2/m_2} + a_3 x^{n_3/m_3} + \ldots..)$

In 2011, three manuscripts based on above work have been submitted for publications.

M.Phil. Student: Thilakaraja Mathanarajan, (Since November 2011), University of Jaffna

Human resource development

M.Phil. students (Research)

(1) Prabhath Herath	Postgraduate Institute of Sciences, University of Peradeniya
(2) Mr. T. Mathanarajan	Postgraduate Institute of Sciences, University of Peradeniya

B.Sc. (Special) Final year Students (Research)

(1) Hasara Samarasinghe	Department of Chemistry, University of Colombo
(2) Shashika Wijesinghe	Department of Chemistry, University of Colombo

8. COLLABORATIVE AND CONSULTATIVE DIVISION (CCD)

Co-ordinator: Prof. S.A. Kulasooriya, Visiting Research Professor

The CCD established in December 2009 enabled the IFS to interact effectively with outside organizations and transfer technology and innovations developed at the IFS to the society at large. It collaborates with government and non-governmental organizations to engage in problem oriented and applied research and to take up commissioned research from outside organizations including the private sector. Through these activities the CCD expects to have a significant impact on National Development.

Progress of collaborative activities under the CCD has been quite satisfactory during the year under review. While ongoing activities initiated during the previous years continued, a number of new collaborations commenced during 2011. What is included in this section will be confined to the interactions with outside organizations. Results of the studies under the different projects will be presented by the respective units conducting them.

Projects continuing from previous years

1. Collaboration with Nature's Beauty Creations PLC (NBC) on Biofilm-Biofertilizers (BFBFs)

   IFS scientists: Prof. Gamini Seneviratne and Prof. S. A. Kulasooriya

   An agreement was signed between the Chairman NBC and Prof. Gamini Seneviratne and Prof. S.A. Kulasooriya (inventors) attested by the Director, IFS, awarding exclusive rights to NBC for large scale production, commercialization and marketing of BFBFs. Meanwhile Prof. Gamini Seneviratne and Mr. Nishan Wickremasinghe, General Manager, NBC, visited India and placed orders for large capacity fermenters and other equipment necessary to set up a pilot plant initially and eventually to construct a factory estimated to cost Rs.50 million.
   Research results are given under the Microbial Biotechnology Unit

2. Detection of Non-tuberculosis Mycobacteria (NTM) with microbiological and molecular typing methods

   IFS scientist: Dr. D. N. Magana-Arachchi
   Collaborating scientist: Dr. R. M. D. Madagedera, Physician, Respiratory Unit, Teaching Hospital, Kandy.

   Progress during 2011 has been satisfactory and the IFS has received a tranche of funding from the Health Department. Research results are given under the Cell Biology Unit.

Projects commenced in 2011

3. Water quality and algal toxins in reservoirs and other sources in Sri Lanka used for water supply schemes by the National Water Supply & Drainage Board (NWSDB)

   A MoU was signed between the Director, IFS and Chairman and Vice-Chairman of the NWSDB to conduct the following studies:

   Projects under this MoU.
   - Assessment of quality, occurrence of algae and measurement of algal toxins in water bodies used as sources for water supply schemes by the NWSDB.
   - Removal of algae in drinking water by electro-coagulation.

- Monitoring of water quality of the Community Based Organization operated water supply scheme for fluoride and hardness in drinking water.

IFS scientists: Mr. J. P. Padmasiri, Dr. D. N. Magana-Arachchi and Prof. S. A. Kulasooriya
Collaborators: Dr. S. Yatigammana, Department of Zoology, University of Peradeniya and Dr. S. K. Weragoda, NWSDB. Research Assistant: Ms. Buddhika Perera

Detailed research results are presented under the Water Quality Unit.

4. Development of measures to eliminate Chronic Kidney Diseases of unknown etiology (CKDu) in the North Western Province

IFS scientists: Mr. J.P. Padmasiri, Prof. S.A. Kulasooriya and Dr. D.N. Magana-Arachchi. Collaborators: Dr. R.M.S.K. Ratnayake, Provincial Director of Health Services and other Provincial Medical Officers , Director and scientists of the ITI, Academic Staff members of the Wayamba University. IFS scientists contributed to the preparation of project proposals which covered diverse aspects of the population susceptible for CKDu including their socio-economic status. A certain portion of funds received has been apportioned for research work at the IFS on water quality and algal toxins in water resources used by the targeted population.

5. Effective use of microbial bio-fertilizers for an improved economy and environment in Sri Lanka

IFS scientists: Prof. Gamini Seneviratne and Prof. S. A. Kulasooriya
Collaborator: Prof. Ivan Kennedy, University of Sydney ABN 15 211 513 464, Sydney, NSW 2006, Australia.

- A joint application submitted for a 3-year project to be funded by AUSAID has been successful. This proposal has provision for exchange visits by staff and students from the participating institutes. A preliminary workshop was held with the participation of Prof. Kennedy. An awareness workshop on the quality control and use of biofilm-biofertilizers was held at the IFS on 19th December 2011 for 30 selected participants from government departments, NGOs and universities.

6. Application of biofilm-biofertilizers to traditional and aged varieties of rice of Sri Lanka grown under organic farming practices

IFS scientists: Prof. Gamini Seneviratne and Prof. S. A. Kulasooriya
Collaborator: Mr. S. W. R. Daulagala, Chairman, RG Lanka (Private) Limited

MoU signed on September 29th and work commenced in paddy fields owned by the company at Kekirawa under the guidance and participation of Research Assistants Ms. Nirodha Weeraratne and Mr. Lasantha Herath of the Microbial Biotechnology Unit.

7. Application of biofilm-bioferilizers for organic farming of cold tolerant, traditional rice varieties under terrace cultivation in Hunnasgiriya

IFS scientists: Prof. Gamini Seneviratne and Prof. S. A. Kulasooriya. Collaborator: Mr. Asoka Manamperi, '*Hela Govi Vyaparaya*'.

Having planned and designed the experiments field studies commenced in November with participation of IFS research assistants Ms. Nirodha Weeraratne and Mr. Lasantha Herath.

8. Popularizing the large scale culture of *Spirulina* for use as a low input, self supporting venture in backward villages of Sri Lanka in collaboration with the Mahatma Gandhi Center (MGC), Colombo

IFS scientists: Prof. S. A. Kulasooriya, Dr. D. M. Magana-Arachchi and Dr. Ruvini Liyanage
Collaborators: Mr. Arjuna Hulugalle and Major General (retired) Kamal Fernando, Mahatma Gandhi Center (MGC), Colombo. A MoU was signed on July 6th 2011. Purified stock cultures of samples brought from India are maintained at the IFS. They are multiplied in flask cultures, 10 liter bottles and open trays in the green house. Detailed results are presented under the Cell Biology Unit.

9. Collaboration between the Alternative and Renewable Energy Unit of the IFS and the Mahidol University, Bangkok, Thailand

IFS scientist: Dr. Deepal Subasinghe
Collaborator: Prof. Weerachai Siripunvaraporn, Program leader, MU.

A MoU was signed on November 30th to enable the conduct of joint research on processing, inversion and interpretation of magnetotelluric and other geophysical data. Provisions have been made for the exchange and training of staff and students between Sri Lanka and Thailand. The participating research students from IFS are: Mr. N. B. Suriyaarachchi and Mr. T. B. Nimalsiri.

10. Rhizobium Inoculant Production

The IFS took over the project to produce and supply inoculants for pulse crop legumes grown in Sri Lanka as the PGIS, University of Peradeniya did not have a mandate to continue the project. Currently this project supplies 250g inoculant packets for soybean at the rate of Rs. 300/- per packet that can be used for one acre of soybean. Treatment of soybean seeds with this inoculant prior to planting can completely replace the application of urea for a soybean crop. Inoculation not only reduces cost but also minimizes environmental pollution. Results from the use of inoculants are shown below.

Nodulation after inoculation

Packets of inoculants ready for dispatch

An inoculated field of soybean at Madatugama

9. AWARDS, RECOGNITIONS AND PATENTS 2011

1. **Prof. U.L.B. Jayasinghe** - Research Fellowship (April – June 2011) - awarded by the Alexander von Humboldt Foundation to Jacobs University Bremen, Germany.

2. **Dr. M. Vithanage** presented an invited lecture at the Annual Meeting of the Korean Society of Soil Science and Fertilizer, October, 2011.

   Three abstracts have been published in international and local conferences in 2011. Research Assistant, Ms. R.M.A.U. Rajapaksha undertaking this research for her M.Phil Degree at the UoP. We received a research grant from the International Foundation for Science, Sweden to carry out the rest of this research.

3. **Prof. M.A.K. L. Dissanayake**, was awarded the "Emeritus Professorship" by University of Peradeniya. Prof. Dissanayake had served the University of Peradeniya for nearly 40 years and he was the Senior Professor of Physics at Peradeniya prior to his retirement.

4. **Dr. S.P. Benjamin** - Humboldt Research Fellowship for Experienced Researchers to SP. Benjamin NRC competitive research grant to SP. Benjamin

10. SCIENCE DISSEMINATION UNIT (SDU)

Our main objectives are:

- To bring together leading experts in different areas of science for advanced reviews, discussions and analyses of fundamental problems.
- To foster the exchange of technical and scientific information, by providing for a scientific community.
- To promote the public understanding of Science.

The following strategies were used to fulfill the above objectives

1. Science & Technology Promotions: - Workshops & Conferences; Exhibitions; Public Lectures; Special Lectures; Research meetings
2. Awareness & Educational Programmes for Students:- School Science Programme (SSP); Educational Lectures
3. Educational Visits; Lab visits for postgraduate students, undergraduate students, teachers and school children

Workshops & Conferences

- **Geology workshop for O/L teachers** (two day workshop – 21 February, 2011)
- Workshop on **"Proposal Writing"** (03 March 2011)
- Workshop on **"Use of Drama for Effective Teaching of Science"** (17 June, 2011)
- Workshop on **Scientific Method** – St. Gabriel Balika Vidyalaya, Hatton (15 March, 2011)
- Workshop on **"Transfer of Low Cost Water Treatment Technologies"** (15 July, 2011)
- Workshop on **"Nanoscience for Gampola Zone School Teachers"** (11 July, 2011)
- **SOLAR ASIA 2011.**
  International Conference on **"Solar Energy Materials, Solar Cells and Solar Energy Applications"** (28th – 30th July 2011)
- **International Symposium on "Natural Product and their Applications in Health & Agriculture"** (3rd to 8th October, 2011)
- Workshop on Geology for central province tamil school teachers (15 November, 2011)
- Workshop for science students (A/L) in Gampola Zone (23 November, 2011)
- Workshop on effective use of microbial biofertilisers for an improved economy and environment in Sri Lanka. (19 December, 2011)

Geology Workshop participants – G.C.E. (O/L) Teachers

Solar Asia 2011 International Research Conference (28-30 July 2011)

Prof. M.A.K.L. Dissanayake, Condensed Matter Physics and Solid State Chemistry Project, IFS, Kandy

A major event that took place during 2011 was the **Solar Asia 2011** International Research Conference which was held at the IFS from 28th to 30th July 2011. This conference was organized by the Condensed Matter Physics Group of the IFS in collaboration with the National Science Foundation (NSF). Prof. Lakshman Dissanayake and Prof. Rohan Weerasooriya were the Co-Chairs of the Organizing Committee and Dr. Rohan Senadeera was the Secretary/Treasurer. The other members of the Organizing Committee were: Prof. I.M. Dharmadasa (UK), Prof. Lalith Jayasinghe (IFS), Dr.Sarath Abayawardana (NSF), Dr. Rohan Senadeera (IFS/OUSL) and Dr.Kumari Thilakeratne (IFS). All arrangements were made under the guidance of the IFS Director, Prof. C.B. Dissanayake. All our research assistants participated actively in the organization of this event.

The inauguration of the conference was held on 28th July 2011 with Mrs.Dhara Wijayathilake, the Secretary to the Ministry of Technology and Research as the Chief Guest. At the inaugural session Prof. I.M. Dharmadasa from Sheffield Halam University, UK made a special presentation on "Poverty Alleviation through Solar Energy Utilization".

A total of 90 research scientists, representing 11 countries (Japan, UAE, Malaysia, India, UK, USA, Sweden, Turkey, S. Korea, Brunei, Sri Lanka) participated in the three day conference. Out of these, 26 were from overseas. Conference Proceedings were printed and published as a bound volume of 343 pages and was given free of charge to all the registered participants on the first day of the conference. Research areas covered included: Thin film solar cells (CdTe, CIS, other III-V thin films, GaAs, Quantum Dot, Cu_2O), Dye sensitized and other PEC solar cells; Silicon solar cells, solar panels, and solar energy applications.

A short Award Ceremony was also held on the third day to give away prizes to school children, who won the island wide essay competition on "Renewable Energy for Sustainable Development" conducted by the APSL (Association of Professional Sri Lankans in the UK) in 2010/2011.

SOLAR ASIA-2011

INTERNATIONAL CONFERENCE ON SOLAR ENERGY MATERIALS, SOLAR CELLS & SOLAR ENERGY APPLICATIONS

HELD ON 28-30 JULY 2011

STUDIO LAXMAN

1st Row (Seated L to R) - Prof. P. Ravirajan, Prof. R.M.G. Rajapakse, Prof. J.K.D.S. Jyanetti, Prof. W. Siripala, Prof. M.A. Careem,Dr. P.S. Wijewarnasuriya, Prof. H. Reehal, Prof. V.Dutta, .Dr. R. Dhere, Prof. C.D. Lokhande, Prof. H.N. Ghosh, Dr. G.K.R Senadeera, Prof. B-E Mellander, Prof. C.B.Dissanayake, Prof. M.A.K.L.Dissanayake, Prof. I.M. Dharmadasa, Prof. A. Konno, Prof. A.K. Pal, Dr. A. Bhattacharjee, A. Bangera, Dr. K.R. Justin Thomas, V. Viswanath, Dr. D.S.M. De Silva, Dr. K. Thilakarathne, Prof. K.A.S. Pathiratne, Prof. R.Weerasooriya, J. Akilawasan, Won Tae Kim.

2nd Row (Standing L to R) - S.L. Jayaratne, W.N.S. Rupasinghe, Dr.K.S. Perera, D.M.B.P. Ariyasinghe, A.R. Weerasinghe, E.V.A. Premalal, Wong Teck Sion, Dr.G.R.A. Kumara, Dr. K.P. Vidanapathirana, C.I.F. Attanayake, Prof. Y.UkJeong, Dr. T. Taskopru, V. Jathushan, T. Jaseetharan, K.M.D.C. Jayathilaka, Dr. R.P. Wijesundara, J.G. ShanthaSiri, S.M.A.W. Anuruddha, C.N. Nupearachchi, P.W. Abeygunawardhana, B.Kajitha, G.C. Pathiraja, T.D.K. De Silva, H.A.C.S. Perera, L.A.P. Sudassanie, W.A.S. Wickramasinghe, U.W.N.M. Ariyasingah.

3rd Row (Standing L. to R.) - W.M.K.T. Wijeratne, M.L. Karunarathne, Dr. T.M.W.J. Bandara, N.B. Suriyaarachchi, C. Bandara, Dr. D. Subasinghe, K. Balashangar, Park Dong Gyu, I. R.G. Wickramasinghe, V. Akileshan, S.H.D.P. Wijethunga, H.M.P.S. Herath, C.A. Thotawatthage,

studiolaxman@gmail.com

International Symposium on Natural Products and their Applications in Health and Agriculture (NPAHA2011)

Prof. N. S Kumar and Prof. U.L.B. Jayasinghe, Natural Products Project, IFS, Kandy

NPAHA2011 was held during October 3-8 2011, at the Institute of Fundamental Studies (IFS), Hantana Road, Kandy. The Symposium was funded by the Organization for the Prohibition of Chemical Weapons (OPCW) and UNESCO, through funds given to AFASSA (Africa, Asia, South America). There were 27 Resource persons/participants from overseas with five accompanying persons and 71 Sri Lankan Resource persons/participants at the Symposium.

The Chief Guest at the Inaugural Session (Oct. 3rd 2011), Hon. Dr. Sarath Amunugama, Senior Minister for International Monetary Cooperation, stressed the importance of research for national development. The Keynote address "Some Adventures in Natural Product Chemistry and Higher Education" was delivered by Prof. Atta-Ur-Rahman, (Coordinator General of COMSTECH, Patron, International Center for Chemical and Biological Sciences and Professor Emeritus, University of Karachi) highlighted the importance of higher education and research in achieving national developmental goals, with specific reference to Pakistan and other developing countries. Dr. A.M. Mubarak (Sri Lanka), Prof. A.A. L. Gunatilaka (USA), Dr. J. M. Rao (India), Prof. M. Iqbal (Pakistan) Prof. Y. Fujimoto (Japan), Prof. Sarath Gunasekara (USA), Prof. N. Kuhnert (Germany), Prof. Sabrina Dallavale (Italy), Prof. A. Bekhit (Egypt), Prof. V. Kumar (Sri Lanka,) Prof. L. Merlini (Italy), delivered the plenary lectures. Plenary lectures, invited lectures, contributed papers and posters were of an extremely high standard. A Welcome Reception was hosted by the Director/IFS, at the IFS premises on October 3rd evening. A technical session devoted to the chemistry of tea constituents was arranged as part of the field trip to the Tea Research Institute (TRI) on October 5th 2011. Participants and special invitees spent an enjoyable evening at the *Chaaya Citadel Hotel* in Kandy where the Symposium Dinner was held on October 6th. Recommendations of a Panel Discussion held on October 7th at the end of the technical sessions were prepared for submission to the main Sponsors (OPCW & UNESCO). On October 8th a Symposium tour to Polonnaruwa was organized for the participants. The Symposium had been a highly interactive event during which some collaborative links were established between research groups and useful knowledge had been gained in all areas covered by the Symposium.

First Workshop on Effective use of Microbial Biofertilisers for an improved Economy and Environment in Sri Lanka (19 December 2011, IFS, Kandy)

Prof. G. Seneviratne, Microbial Biotechnology Project, IFS, Kandy

This is a project carried out by the Microbial Biotechnology Unit (MBU) of the Institute of Fundamental Studies (IFS), in collaboration with the University of Sydney, Australia, funded by Public Sector Linkage Program (PSLP) of AusAID, Canberra. Duration of the project is from July 2011-April 2014. The objective of this project is to popularize the use of novel microbial biofertilisers like biofilmed biofertilisers (BFBFs) in agriculture and plantation sectors of Sri Lanka through a participatory approach of researchers and farmers via workshops. It is expected that this effort will lead to broader availability of this new technology resulting in a reduction in input costs for farmers and potentially producing increases in crop yields and cash income, while improving the environmental quality. To achieve this, it is important to make available of effective biofertilisers which will diminish the need for applying chemical fertilisers such as urea, phosphate and even potash. The effectiveness of the biofertilisers should be maintained by evaluating their quality. The major task of this project is to implement training programs of technical and extension personnel in quality control procedures of, particularly BFBFs for Sri Lanka. At the end of the workshops by 2014, it is hoped that there will be profuse availability of advanced, but easy-to-use microbial biotechnological methods of quality control that are currently lacking in Sri Lanka.

A limited set of participants representing universities and research institutes of Sri Lanka has already been selected for this first workshop.

Concluding note of the workshop

The workshop was concluded successfully, with a participation of 60 participants representing the entire country. They were very keen about the ecosystem principle and the role of biofilmed biofertilisers (BFBFs) in sustaining

IFS – AFASSA International Symposium on Natural Products and their Applications in Health and Agriculture
Institute of Fundamental Studies, Kandy, Sri Lanka 3 – 8 October, 2011

STUDIO LAXMAN

1st Row (L. to R.) M.C. Rajapakse, S. Tasleem (Pakistan), D. Arbain (Indonesia), J.O. Midiwo (Kenya), Y. Fujimoto (Japan), M. Mosihuzzaman (Bangladesh), L. Mirossay (Slovak Republic), S. Dallavalle (Italy), S. Sotheeswaran, L. Jayasinghe, N.S. Kumar, C.B. Dissanayake, Atta-ur-Rahman (Pakistan), A.A. Bekhit (Egypt), N. Kuhnert (Germany), M.I. Choudhary (Pakistan), V. Kumar, J.M. Rao (India), S.P. Gunasekera (USA), A. Wickramasinghe, A.A.L. Gunatilaka (USA), R. Weerasooriya, M.A.K.L. Dissanayake, C.T.K. Tilakaratne, G. Mojzisova (Slovak Republic)

2nd Row (L. to R.) S. Sotheeswaran, M.K. Mugisha (Uganda), B. Ali (Pakistan), H. Rashid (Pakistan), L.O. Kerubo (Kenya), P.S. Warakagoda, R. Samarasekara, U.G. Chandrika, N. Salim, M.A. Hettiarachchi, H.P.D.S. Jinasena, P.A. Paranagama, H.N.B. Mendis, P. Senanayake, C.G. Rajapakse, S. Derese (Kenya), R. Sivakanesan, S. Devarajan, V.M. Thadhani, H.K.I. Perera, P.A.S. Wickramarachchi, H.M.D.K. Kanatiwela, W.I.T. Fernando, G.G.E.H. De Silva, A.M.D.A. Siriwardane, H.M.S.K.H. Bandara, K.G.E. Padmathilake, A.G.A.W. Alakolanga, P.S.S. Samarakkody, D.N. Magana-Arachchi, L.C.P.T. Liyanaarachchie

3rd Row (L. to R.) M. Gunasekera, I. Sajid (Pakistan), O.S. Perera, N.H.N. Priyanwada, A.M. Abeysekara, R.P. Wanigathunge, H.M.L.I. Herath, H.M. Liyanage, D. Bopitiya, N. Syafni (Indonesia), K.M.D. Gunathilake, A.A.K. Karunathilake, K.A.N. Rajan, B. Choudhary (Pakistan), D. Nanayakkara, T. Sothyrupan, R.M.C.J. Bandara, D.A.S. Siriwardhana, N.V.A. Kumar (India), T.M.S.G. Tennakoon, D.S. Jayaweera, N. Govindappa (india), J. Wijayabandara, M.A. Siriwardhene, D.B.M. Wickramaratne, K.M.S. Wimalasiri, R.R. Ratnayake, D. Niyangoda, R. Liyanage, T. Thileepan, J. Mojzis (Slovak Republic)

studiolaxman@gmail.com

the ecosystems, which were introduced at the workshop. The participants were trained in basic microbiological methods that can be used for quality control of BFBFs and other biofertilisers. The participants were also interested in establishing collaborations with the IFS for research in the future.

The next workshop of this project will be held in August-September 2012, and the focus will be on molecular microbiological methods that can be used for quality control of BFBFs and other biofertilisers. Meantime, extension workshops on the field will be held time to time for different crops for demonstrating the beneficial effects of BFBFs, thus popularizing it. Farmers and extensionists will be invited depending on the region of the extension workshops.

First Workshop on Effective use of Microbial Biofertilisers for an improved Economy and Environment in Sri Lanka
Institute of Fundamental Studies, Kandy -19 December 2011

- **Public Lectures**

  Three public lectures were held during this year.

  08 June, 2011 **"Ethics in Scientific Research"**
  Prof. M.A.K.L. Dissanayake (Research Professor / IFS)

  30 March, 2011 **"Science Logic & Reality"**
  Prof. Asiri Nanayakkara (Research Professor / IFS)

  14 September, 2011 **"Theory of Everything! Einstein's Dream!"**
  Dr. N. D. Subasinghe (Research Fellow / IFS)

- **Special Lectures**

  Three special lectures were held during this year.

  05 January, 2011 **"Confronting Emerging Infectious Diseases"**
  Prof. Sriyal Malik Peiris (Professor of Microbiology & Tam Wah-ching Professor in Medical Sciences University of Hong Kong)

07 February, 2011 **"Forest Disturbance and Recovery"**
Francis Q. Brearley (Senior lecturer in Ecology/Manchester Metropolitan University, UK)

10 August, 2011 **"African Endemism and Pantropical Dispersal in Polystachya (Orchidaceae)"**
Dr. Rose Samuel (Department of Systematic and Evolutionary Botany, University of Vienna, Austria)

- **Research Meetings**

03 May, 2011 **"Impact of Climate and Socioeconomic Factors on Dengue Epidemic in Sri Lanka"**
M.Madanayake (Research Assistant/IFS)

25 May, 2011 **"Biofilmed Biofertilizer for Rice"**
N. Weerarathne (Research Assistant/IFS)

01 June, 2011 **"On the General Dendrobium and Bulbophyllum (Orchidaceae) in Sri Lanka"**
H. Sandamali (Research Assistant/IFS)

06 July, 2011 **"Visualization of Arrow Movement in Brain Computer Interface: The Past, The Present and The Future"**
Zahmeeth Sakkaff (Research Assistant/IFS)

07 September, 2011 **"Bio-filmed Biofertilizer for Maize (Zea mays)"**
U.V.A. Buddhika (Research Assistant/IFS)

17 August, 2011 **"Mapping Geothermal Resources in Sri Lanka using Magnetotellurics and other Techniques"**
N. Sooriyaarachchi (Research Assistant/IFS)

16 November, 2011 **"Molecular Characterization of Cyan Bacterial diversity in Sri Lanka and their toxin producing ability"**
R.P. Wanigatunga (Research Assistant/IFS)

30 November, 2011 **"Identification and Molecular characterization of cylindrospermopsis species in Sri Lankan water bodies "**
H.M. Liyanage (Research Assistant/IFS)

- **Educational Lectures**

1. Science Day at Vijaya College – Mathale (04 November, 2011)
   Dr. Kumari Tilakaratna delivered a lecture about nano technology

2. Science Day at Rahula College – Kandy (09 November, 2011)
   Prof. Lalith Jayasinghe delivered a lecture on chemistry of natural products

3 A special lecture on "Nanoscience" was done by Dr. Kumari Tilakaratne (Coordinator/Science Dissemination Unit, IFS). Demonstrations were done by Mr. S. Opatha (Senior Technical Office/IFS), Mr. T.B. Nimalasiri (Research Assistant/IFS), Mr. N.B. Suriyaarachchi (Research Assistant/IFS). (15 November, 2011)

- **Laboratory Visits**

Faculty of Agriculture, Rajarata University of Sri Lanka (11 March, 2011)
A special lecture on soil microbiology was conducted by Prof. Gamini Seneviratne.

Laboratory visits were arranged for the following schools

1. Minuwangoda Nalanda Boys College, Minuwangoda (04 May, 2011)
2. Two day laboratory visit was arranged for Trinity College students, Kandy (22 & 29 June, 2011)
3. Badrawathi Maha Vidyalaya, Galaha (12 July, 2011)
   Weera Parackrama Central College, Yatawatta (18 July, 2011)

Two day Training Programme on analytical techniques in natural science for the undergraduates of Faculty of Applied Sciences – Rajarata University of Sri Lanka

- **Exhibitions**

Dayata Kirula Exhibition

Participated in the "DAYATA KIRULA 2011" exhibition which was held on 4 – 10 February, 2011 at Buttala.

- **School Science Programme (SSP)**
  12 – 15 December, 2011

The school science programme (SSP) is the one of the most important annually conducted programme for the dissemination of science among the younger generation. The aim of this activity is to expose young students to frontiers of science and give them an indication as to how science is actually practised. This programme enables students to meet and mix with students from different ethnic, economic and cultural backgrounds in an informal atmosphere which is an added advantage.

The SSP has been conducted as a continuous series from 1987 and a total of 2607 students have participated up to now. This year we had hundred and eighty students for the School Science Programme (SSP-2011) from all over the country. Those who had excellent results at the GCE (Ordinary Level) examination have participated in this activity and this year we included an educational visit to the Nillambe Hydro Power plant & Kotmale Dam.

- "නැනෝ ලොවෙන් නව ලොවට" All island Nano science competition for teachers and students

The awarding ceremony of the above competition was held on 31st October, 2011. There are 40 winners from all over the country. Teachers and students in both Sinhala and Tamil medium performed well at this event.

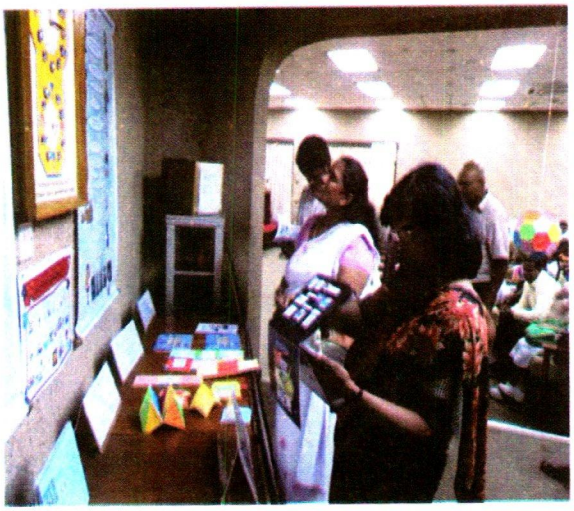
Other events

- The Institute of Fundamental Studies, organized a felicitation ceremony for Prof. S.A. Kulasooriya along with the inauguration of the IFS Green House Laboratory
  (11 November, 2011).

- The Primate Biology group has used their scientific discoveries at Polonnaruwa to educate and inspire people world-wide towards nature conservation by way of documentary film productions (based on Sri Lankan primates) broadcast on high profile television channels (Discovery, BBC Natural World). In 2011, negotiations for new productions were ongoing.

Science Dissemination Unit - some activities

School Science Programme participants



Observing the science kits developed by SDU

Manu lowin nano lowata drama at the "Nano Lowin nawa lowata" all island competition awarding ceremony

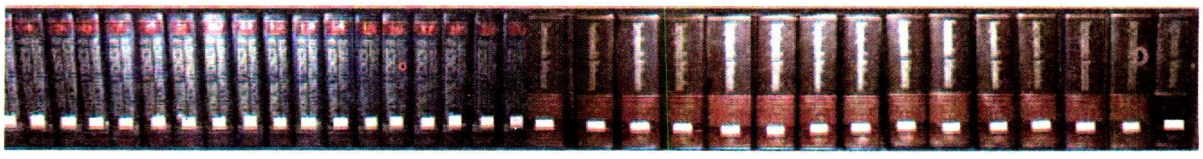
11. LIBRARY

The IFS library was established in 1985 with a small collection of books and journals donated by Prof. Cyril Ponnamperuma, well-wishers and the Asia Foundation. Since then it now has a modest collection of over 6160 books covering the life, physical and mathematical sciences as well as the philosophy and history of science Fundamental text books, monographs and edited volumes in the library serve as sources of references to the research staff, postgraduate students and visitors to the Institute. Among our oldest collection are two volumes on Leonardo Da Vinchi published in 1898.

Books are now continually added to the library from recommendations of the research staff. This year also saw the adding of over 132 valuable books donated by Professor Tissa R.Hevat and Prof. S. A. Kulasooriya.

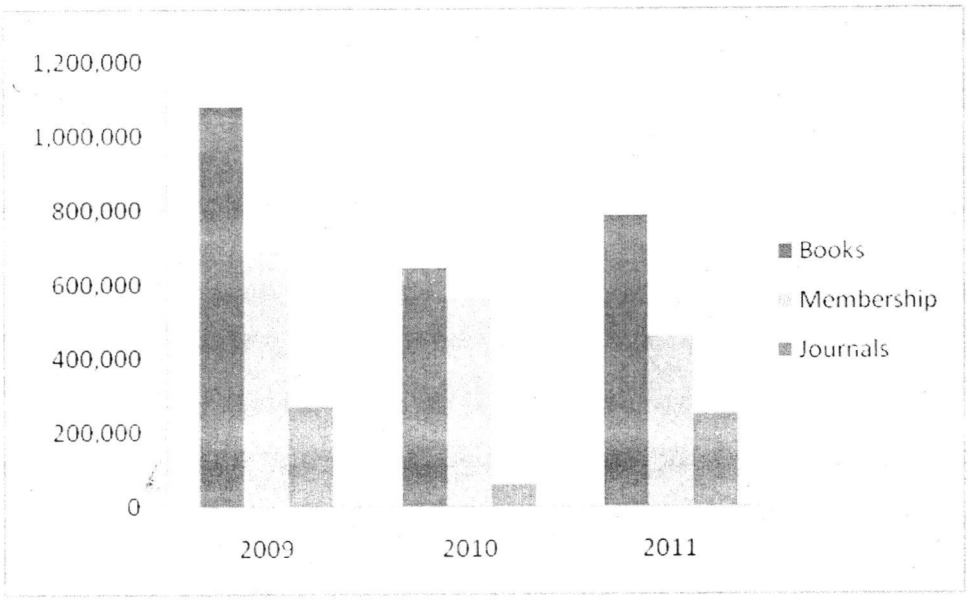
Present collection of the IFS library

Collection	Added during 2011 January-December	Total as on 31st December 2011
Books	315	6218
Theses	1	95
CDs	61	354
Reports	28	484
Subscription to journals	12	-
Exchange base journal Reprints	14	-
	15	702

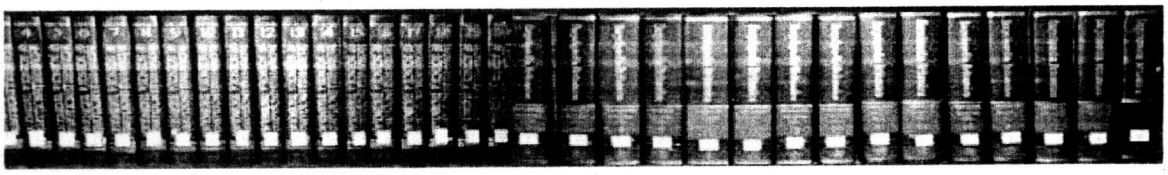


The mission of the IFS library is to assist research staff and students to acquire the relevant literature for their research. Services provided by the IFS Library include inquiry, reference and lending services, acquisition of materials, organization of the existing books and journals, document delivery, resource sharing, inter-library loan facility, photocopying facility, information alert services and sourcing web based electronic journals and articles. Researchers from other institutes and school students are regular visitors to the library who are assisted to locate information through the data base.

All the books and journals are maintained in a WINISIS data base which are easily searched and accessed using keywords. The classification system used by the library is the Dewey Decimal Classification 2nd Edition. The library also assists project staff to acquire subscription and membership in professional societies, thereby providing online access to journals for staff members. Leading multidisciplinary journals are available such as *Nature, Science, New Scientist etc.,* providing the latest information on a variety of disciplines. Besides printed text, the library also has a collection of CD's, Videos', maps and electronic materials. Among the library's special collections are the Prof A. Kovoor's collection, Prof. Stuiver's collection, Mr Lionel Liyanage's collection,Mr V.Manoharan's collection, Professor Tissa R. Hewat's collection, Prof. S. A. Kulasooriya collections and the Sri Lanka Collection.



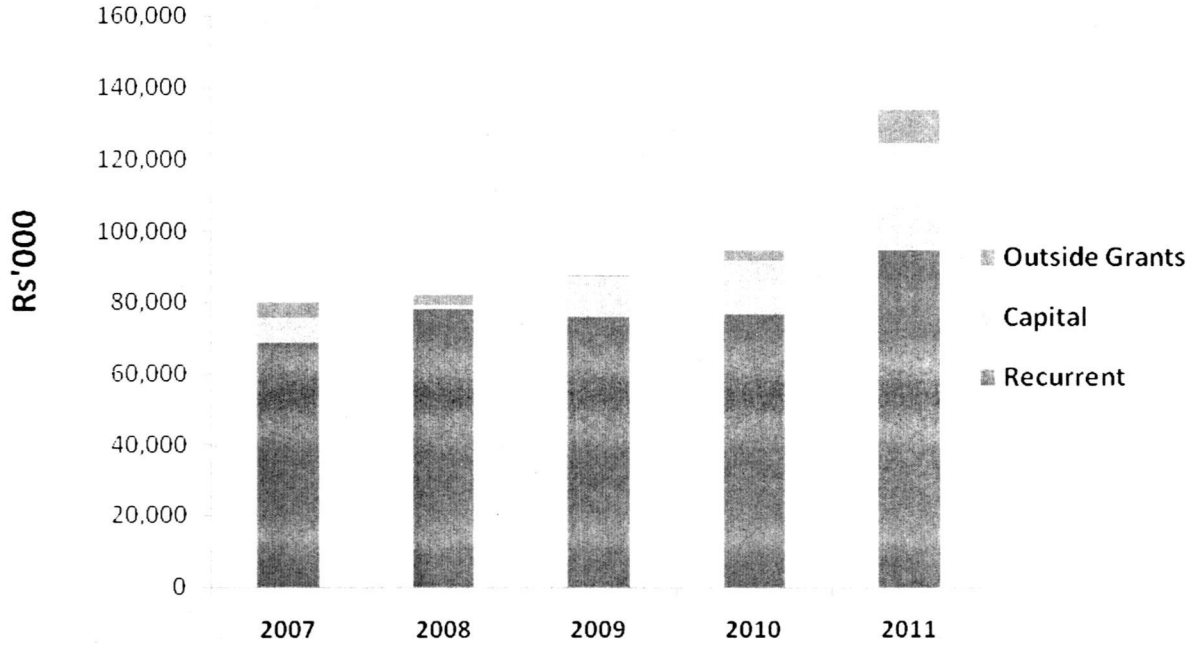
Budget allocation Rs for the past few years



12. BUDGET

Total Annual Expenditure (Rs'000)

	Item	2007	2008	2009	2010	2011
Recurrent	Personnel Emoluments	49,441	56,107	48,826	51,945	64,723
	Traveling Expenses	244	591	338	570	531
	Supplies	5,247	5,355	7,822	6,763	7,484
	Maintenance Expenditure	3,617	4,165	6,035	5,063	5,454
	Contractual Services	7,727	11,618	6,043	9,817	12,488
	Other Expenses	2,434	237	6,992	2,509	4,042
Capital	Capital Expenditure	7,058	1,344	11,216	15,123	29,731
Outside Grants	Outside Grants	4,328	2,893	536	2,996	9,752
Total		**80,096**	**82,310**	**87,808**	**94,786**	**134,205**



Total Annual Expenditure (Rs.) for the past five years

13. IFS STAFF NEWS - 2011

13.1 Recruitments

The following staff were recruited to the IFS during 2011

1.	Prof. Dissanayake M.A.K.L.	-	Research Professor
2.	Dr. Liyanage R.	-	Research Fellow
3.	Dr. Nanayakkara K.G.N.	-	Research Fellow
4.	Prof. Weerasooriya S.V.R.	-	Research Professor
5.	Prof. Careem M.A	-	Visiting Research Professor
6.	Jayaratne S.L.	-	Research Assistant- Grade II
7.	Jayathilake H.A.P.P.B.	-	Research Assistant -Grade II
8.	Kathirgamanathan M.	-	Research Assistant- Grade II
9.	Nalaka G.D.A.	-	Research Assistant -Grade II
10.	Rupasinghe W.N.S.	-	Research Assistant- Grade II
11.	Perera O.S.	-	Research Assistant -Grade II
12.	Weerasekara D.K.	-	Research Assistant -Grade II
13.	Dayaratne E.C.B.	-	Management Assistant Grade III
14.	Vithanage M.P.	-	Accounts Officer

13.2 International/National Committees

Prof. M.A.K.L. Dissanayake served as a member of the Board of Governors of the Institute of Fundamental Studies (IFS).

Prof. M.A.K.L. Dissanayake served as a member of the Board of Management of the Postgraduate Institute of Science (PGIS), University of Peradeniya.

Prof. M.A.K.L. Dissanayake served as the Chairman of the Research Panel on Basic Sciences of the National Science Foundation.

Prof. M.A.K.L. Dissanayake served as the Chairman of the International Partnership Committee of the National Science Foundation.

Prof. M.A.K.L. Dissanayake served as a Member of the Global Forum of Expatriate Scientists of the National Science Foundation and also as the Chairman of the session on Green Energy Technologies (13-15 December 2011).

Prof. M.A.K.L. Dissanayake served as a member of the UGC Advisory Panel on the proposed Postgraduate Institute of Humanities, University of Peradeniya.

Prof. M.A.K.L. Dissanayake served as a member of the National Task Force appointed by the Ministry of Technology & Research to prepare the "Science and Technology Innovation Strategy for 2011-2015" which has now been approved by the cabinet.

Prof. U.L.B. Jayasinghe, Member, Faculty Research Committee, Faculty of Science, University of Peradeniya.

Prof. N.S. Kumar, Member. Technical Advisory Committee on Good Laboratory Practices, Sri Lanka Accreditation Board (SLAB) for Conformity Assessment.

Prof. N.S. Kumar, Reviewer, for the Quality and Innovation Grant (QIG); Window 3:Postgraduate Research Programs of the Higher Education for the Twenty First Century (HETC) Project of the Ministry of Higher Education, Sri Lanka.

Dr. D.N. Magana-Arachchi
Member of the Board of Study in biochemistry & Molecular Biology , Post Graduate Institute of Science (PGIS), University of Peradeniya, Sri Lanka

Dr. N.D. Subasinghe
Executive Committee Member - Geological Society of Sri Lanka
Guest Editor – Journal of the Geological Society of Sri Lanka

Dr. C.T.K. Tilakaratne - Member, *National Committee on* Science Popularization NSF

Dr. M. Vithanage served the Committee on International Participation of the American Geophysical Union during the AGU Fall Meeting at San Francisco, USA, Dec, 2011.

Dr. M. Vithanage invited to serve as a committee member at the 1st International Biochar symposium at Kangwon National University, Korea, December, 2011.

Prof. R. Weerasooriya
Core Member of National Mirror Committee on Nanotechnology Colombo
Member Board of Governors Asian Energy Institute India
Visiting FacultY University of Moratuwa, University of Peradeniya, Rajarata University, Sabaragamuwa University, Uva Wellasssa University

13.3 Participation in International/National Workshops/Training Programs/Seminars by Research staff

1. J. Akilavasan and W.M.K.T. Wijeratne participated at Solar Asia-2011, International conference on Solar Energy matarials , solar cells and solar energy application, IFS, Kandy, Sri Lanka.

2. J. Akilavasan and W.M.K.T. Wijeratne Participated on a workshop on Electrochemistry, PGIS, University of Peradeniya.

3. J. Akilavasan visited Bangladesh for participating on the International training workshop on science education for sustainable development Dhaka, Bangladesh-2011, as a speaker.

4. Ms. A.G.A.W. Alakolanga and Ms. A.M.D.A. Siriwardene (Research Assistants) participated in the workshop entitled, "*Modern Techniques on Combinatorial Chemistry*", June 14th–16th, 2011 at COMSTECH Headquarter, Islamabad, Pakistan.

5. Prof. M.A.K.L. Dissanayake participated and presented a research paper in the International Conference on Materials for Advanced Technologies (ICMAT-2011), June 25th to July 1st , Singpaore.

6. Prof. M.A.K.L. Dissanayake visited Chalmers University of Technology, Gothenburg, Sweden, 13th - 26th November 2011 to complete joint research publications and participate in discussions on future research collaboration.

7. K.M.D. Gunathileke, R.R. Ratnayake, S.A. Kulasooriya, D.N. Karunaratne (2011). Biodegradation of Cellulose for Biofuel Production Using Microbial Biofilms. *International symposium on Natural Products and their Applications in Health and Agriculture*, Institute of Fundamental Studies, Kandy, 3rd – 8th October 2011.

8. H.A.P.P.B. Jayathilake participated in the Water professionals' day symposium 2011 at Faculty of Agriculture, University of Peradeniya, Oct. 2011.

9. H.A.P.P.B. Jayathilake, C. Weerakkody, G.C. Pathiraja and P.W. Abeygunawardhana participated in the Workshop on "*Electrochemistry*" at Postgraduate Institute of Science, University of Peradeniya, Nov. 2011.

10. Mr. D.S. Jayaweera (Senior Staff Technical Officer) underwent a three months training program (01.06.2011 to 31.08.2011) on "*Microbial transformations of organic compounds and Laboratory*

Management" under the supervision of Prof. M. Iqbal Choudhary, International Center for Chemical and Biological Sciences, University of Karachi, Pakistan.

11. T. Kugendran, R.R. Ratnayake, N. Gnanavelrajah (2011). Assessment of soil Carbon stocks in different land uses in Jafna district. *International Conference of the East and Southeast Asia Federation of Soil Science Societies,* Cinnamon Lakeside Hotel, Colombo, Sri Lanka, 10th to 13th October 2011. (Accepted)

12. T. D. Kumari De Silva and S.A.K.N. Dhanasekara participated the Research Symposium 2011 at Uva Wellassa University, 15-16 Dec., 2011.

13. D.N. Magana-Arachchi - Workshop on 'Interlectual Property Rights (IPRs) for Growth & Prosperity' - 07-09th February 2011. Organized by The Sri Lanka Alumini Association of the International Development Law Organization (IDLO) and the Industrial Technology Institute (ITI) Sri Lanka.

14. Dr. D.N. Magana-Arachchi, H.M. Liyanage and R.P. Wanigatunge; IFS-AFASSA International Symposium on Natural Products and their Applications in Health and Agriculture. 3rd-8th October, 2011 at the IFS, Kandy, Sri Lanka.

15. Dr. D.N. Magana-Arachchi; Technology Market organized by Ministry of Technology & Research, 24-25th October 2011. BMICH.

16. M. Makehelwala, R.M.H.C. Amarasekara, Rohan Weerasooriya, V.N. Seneviratne, Athula Bandara (2011) Probing Reactivity Sites on Pyrite – Oxidative Interactions with 4-Chlorophenol and Carbofuran, Ab Initio Modelling in Solid State Chemistry University, Imperial College London, 14th 18th Sept., (poster presentation: Presenter: M. Makehelwala).

17. Mr.T.B. Nimalsiri (RA) and Mr. N.B. Suriyaarachchi (RA) attended Workshop on Scientific Writing, organised by the Postgraduate Institute of Science, University of Peradeniya on 27th May 2011.

18. Mr. T.B. Nimalsiri (RA) and Mr. N.B. Suriyaarachchi (RA) attended training on geophysical instruments, organised by Analytical Instrument Pvt. Ltd. on 17th December 2011.

19. G. C. Pathiraja participated the Research Symposium 2011 at Uva Wellassa University, 15-16 Dec., 2011.

20. R.R. Ratnayake, D. Wasalamuni, T. Gunaratne,(2011). Development of a sustainable home garden system in Sri Lanka to optimize soil C sequestration. In Proceedings of the *International Symposium on Soil Organic Matter: Organic matter dynamics – from soils to oceans*, Leuven, Belgium, 11-14 July 2011.

21. Dr. G.K.R. Senadeera participated and presented novel research findings in POLYCHAR 19, World Forum on Advanced Materials, March 20-24, 2011, (p 270) Kathmandu, Nepal.

22. Dr. N.D. Subasinghe presented a research paper on proposed radon and thoron mapping initiative in Sri Lanka and received training in all aspects of passive radon and thoron monitoring at National Institute of Radiological Studies, Japan. 01-03 November 2011.

23. Dr N.D. Subasinghe (SRF) and Mr. N.B. Suriyaarachchi (RA) attended Solar Asia 2011 International Research Conference, jointly organised by Institute of Fundamental Studies (IFS) and National Science Foundation (NSF) 28th to 30th July 2011.

24. Dr. N.D. Subasinghe presented a research paper at International Conference on Materials for Environmental Protection and Energy Application (MEPEA2011) Kuala Lumpur, Malaysia 26-28 September 2011.

25. Mr. N.B. Suriyaarachchi attended the Workshop on Geothermal Exploration, organised by International Centre for Theoretical Physics and International School on Geothermal Exploration in Trieste, Italy from 28th November to 5th December 2011.

26. Dr. C.T.K. Tilakaratne, Resource personal at the *International workshop on Science Education for sustainable development* (26th June-30th June 2011), Dhaka, Bangladesh.

27. Dr. C.T.K. Tilakaratne participated in the Workshop on new trends for Science Dissemination (26th September-28 September 2011) at International Center for Theoretical Physics. Italy.

28. Dr. M. Vithanage participated 1st Workshop on the water safety from source to tap – stratergies and implementations – Asia Pacific Network for global change research 20-22nd September, 2011.

29. Mr. S.S.R.M.D.H.R. Wijesekara and Ms. B.G.N. Sewwandi participated The 12th Annual Conference of Thai Society of Agricultural Engineering. Chonburi, Thailand; 31 March-1 April 2011.

30. D. Wijetunga and P. Herath participated in the Conference on Solar Asia 2011, Institute of Fundamental Studies, Kandy

13.4 Visits by IFS scientists

Prof. J.M.S. Bandara – As a visiting scientist, from June 2010 – May 2011, Advanced Functional Polymer Department, University of Bayreuth, Germany.

Dr. D.N. Magana-Arachchi, Sixth IWA Specialist Conference on Efficient Use and Management of Water Demand Management: Challenges & Opportunities. Sydney, Australia- 11th -13th July 2011.

Dr. R. Ratnayake visited research laboratory of Earth and Environmental Sciences Division, Katholieke University, Belgium – 10th-14th July 2011.

Dr. N.D. Subasinghe visited Mahidol University, Thailand to finalise a collaborative programme to train two postgraduate students in geophysics. An MOU was prepared and signed between IFS and Mahidol University, October 2011.

Dr. N.D. Subasinghe visited National Institute of Radiological Studies (NIRS) and Tokyo University, Japan on invitation. A collaborative research project on radon monitoring in Sri Lanka was initiated among IFS, Atomic Energy Authority of Sri Lanka, NIRS and Tokyo University, November 2011.

Prof. G. Seneviratne- Exploratory workshop on 'Biofilms: Friend or Foe? Berlin, Germany, 22 - 23 June 2011.

Dr. M. Vithanage and Ms. R.M.A.U. Rajapaksha participated a collaborative research program at the Department of Biological Environment at Kangwon National University, Korea from 3rd October to December 31st, 2011.

Mr. S.S.R.M.D.H.R. Wijesekara and R.M.A.U Rajapaksha (Research Assistants) and Dr. M Vithanage (group leader) visited the DST Nanoscience Unit at IIT, Chennai.

13.5 Research grants received during 2011

Prof. C.B. Dissanayake, **Prof. Lakshman Dissanayake** and **Prof. R. Weerasooriya** received a NRC Grant of Rs. Rs. 4.9 Mn to develop a low cost, anti microbial, nanofibre water filter and polymer nano fibre solar cells.

Dr. R. Liyanage

National Science Foundation Research grant(RG/2011/AG/09) - Investigate the effect of cowpea on the accumulation of visceral fat mass and oxidative status using animal experimental model.

Dr. D.N. Magana-Arachchi

NRC/11/059- Rs. 5,323,000.00 - National Research Council (NRC). The Presidential Secretariat, Sri Lanka - TB Campaign: Rs. 4,50,000.00.

Dr. K.G.N. Nanayakkara

National Research Council (Sri Lanka) Grant number 11-054: Development of electrochemical technologies to remove organic and heavy metal pollutants present in pesticides.

National Science Foundation (Sri Lanka) Grant number RG/2011/BS/01: Development of an electrochemical technology to remove nitrate from contaminated groundwater.

Prof. G. Seneviratne

Research Grants received during 2011: NRC grant no. 11-56.

Dr. N.D. Subasinghe

A travel grant from National Science Foundation was received towards the travelling expenses to visit Mahidol University, Thailand.

NIRS, Japan, provided first batch of 50 radon/thoron monitoring kits and intensive training on the relevant subject area, at NIRS premises. Travel and subsistance were covered by NIRS. A total of 200 radon monitoring kits and help in data analysis will also be provided by NIRS, Japan.

Dr. M. Vithanage

Grant from the International Foundation for Science, Sweden (Grant number W/5068-1) for the Serpentine Project (2 years) – 10250USD.

JICA-JST grant was officially signed and the project was started in the beginning of 2011 which will end up in 2016.

Prof. R. Weerasooriya

Co-Investigator Investigation of background concentrations and spatial distribution of heavy metals in surface soils and crops in agricultural fields in Sri Lanka NRC -2011 Research Grant.

14. PUBLICATIONS OF IFS MEMBERS - 2011

14.1 Publications in refereed journals

1. **J. Bandara**, K. Shankar, C.A. Grimes, M.Thelakkat, (2011). Efficient and stable, structurally inverted poly(3-hexylthiopen):[6,6]-phenyl-C61-butyric acid methyl ester heterojunction solar cell with fibrous like poly(30hexylthiopen). ***Thin Solid Film***, *520(1),* 582-590.

2. **J. Bandara**, K.Willinger, M. Thelakkat, (2011).Multichromophore light harvesting in hybride solar cells. ***Physical Chemistry Chemical Physics***, *13(28),* 12906-12911.

3. **J. Bandara**, M. Thelakkat, (2011). Thickness dependant of device parameters in solid state dye sensitized solar cells. ***J. Natl. Sci. Foundation Sri Lanka***, *39(1),* 35-42.

4. **J. Bandara**, K.Shankar, J.Basham, H. Wietasch, M.Paulose, O.K. Varghese, C.A. Grimes, M. Thelakkat, (2011). Integration of TiO_2 nanotube arrays into solid-state dye-sensitized solar cells. ***EPJ Applied Physics***, *53(2),* 20601.

5. **S.P. Benjamin**, (2011). Advancing the science of taxonomy in the Western Ghats-Sri Lanka Biodiversity Hotspot: need for collaborative studies. ***Current Science***, *100*, 280.

6. **S.P. Benjamin**, (2011). Phylogenetics and comparative morphology of crab spiders (Araneae: Dionycha, Thomisidae). ***Zootaxa***, *3080*, 1-108.

7. F. Alvarez-Padilla, **S.P. Benjamin**, (2011). Phylogenetic placement and redescription of the spider genus Atelidea Simon, 1895 (Araneae, Tetragnathidae). ***Zootaxa***, *2761*, 51-63.

8. J.A. Sumith, K.R. Munkittrick, N. Athukorale, (2011). Fish Assemblage Structure of two contrasting stream catchments of the Mahaweli River Basin in Sri Lanka: Hallmarks Exploitation and implication for Conservation. ***The Open Conservation Biology Journal***, *5*, 36-55.

9. S.K. Yatigammana, O.A. Illeperuma, M.B.U. Perera, (2011). Water pollution due to a harmful algal bloom: a preliminary study from two drinking water reservoirs in Kandy, Sri Lanka. ***Journal of the National Science Foundation of Sri Lanka***, *39*, 91-95.

10. T.M.W.J. Bandara, **M.A.K.L. Dissanayake,** I. Albinsson, B.-E. Mellander, (2011) Mobile charge carrier concentration and mobility of a polymer electrolyte containing PEO and $Pr_4N^+ I^-$ using electrical and dielectric measurements. ***Solid State Ionics***, *189(1)*, 63-68.

11. **L. Jayasinghe**, M. Lakdusinghe, N. Hara, Y. Fujimoto, (2011). Phenolic constituents from the fruit juice of *Flacourtia inermis*, ***Natural Products Research***, DOI: 10.1080/14786419.2011.586638; Available online: 10 Oct 2011.

12. **L. Jayasinghe**, N.R. Amarasinghe, B.G.S. Arundathie, G.K. Rupasinghe, N.H.A.N. Jayatilake, Y.Fujimoto, (2011). Antioxidant flavonol glycosides from *Elaeocarpus serratus* and *Filicium decipiens,* ***Natural Products Research***, DOI: 10.1080/14786419.2010.551514; Available online: 19 Sep 2011.

13. **S.A. Kulasooriya,** (2011). Cyanobacteria: Pioneers of Planet Earth. ***Ceylon Journal of Science (Bio.Sci),****40(2):* 71-88.

14. **D.N. Magana-Arachchi**[a,]*, D. Medagedara and V. Thevanesam (2011) Molecular characterization of *Mycobacterium tuberculosis* isolates from Kandy, Sri Lanka. ***Asian Pacific Journal of Tropical Disease.*** *1 (3);* 181-186

15. **D.N. Magana-Arachchi***, R. Wanigatunge and M. Liyanage, (2011) Molecular characterization of cyanobacterial diversity in Lake Gregory, Sri Lanka. ***Chinese Journal of Oceanology and Limnology.*** *29 (4):* 898-904.

16. **D.N. Magana-Arachchi*** and R.P. Wanigatunge, (2011). A simple and rapid DNA extraction method for cyanobacteria and monocots. ***Ceylon Journal of Science: Biological Sciences*** *40(1):* 59-63.

17. **A. Nanayakkara** (2011). Application of Lie transform perturbation method for multidimensional non-Hermitian systems, ***Pramana Journal of Physics,*** *76,* 37.

18. M.S. Senevirathne, **A. Nanayakkara**, **G.K.R. Senadeera,** (2011). A theoretical investigation of band gaps of conducting polymers with heterocycles, **J.** ***Nat. Sci. Foundation Sri Lanka*** *39 (2)*: 183-185.

19. **K.G.N. Nanayakkara**, Yu-Ming Zheng, J. Paul Chen. A low energy intensive electrochemical system for disinfection of *E. coli* in ballast water: process development, disinfection chemistry, and kinetics modeling. ***Marine pollution bulletin*** *(Accepted).*

20. **R.R. Ratnayake, G. Seneviratne**, **S.A. Kulasooriya**, (2010). Effect of land use and management practices on quantitative changes of soil carbohydrates. ***J. Natn. Sci. Foundation Sri Lanka,*** *39: 337-345.*

21. **R. R. Ratnayake**, **G. Seneviratne**, and **S. A Kulasooriya**, (2011). The effect of cultivation on organic carbon content in the clay mineral fraction of soils. ***International Journal of Soil Science,*** *6:* 217-223.

22. Y.P.Y.P. Ariyasinghe, T.R.C.K. Wijayarathna, I.G.C.K. Kumara, I.P.L. Jayarathna, C.A. Thotawatthage, W.S.S. Gunathilake, **G.K.R. Senadeera,** V.P.S. Perera (2011). Efficient passivation of SnO_2 nano crystallites by Indoline D-149 via dual chelation ***Journal of Photochemistry and Photobiology A: Chemistry***, *217(1),* 249-252.

23. **G. Seneviratne**, A.P.D.A. Jayasekara, M.S.D.L .De Silva and U. P. Abeysekera, (2011). Developed microbial biofilms can restore deteriorated conventional agricultural soils. ***Soil Biology and Biochemistry*** *43*: 1059-1062.

24. **N.D. Subasinghe,** Electron microscopic studies on phosphate binding processes in the presence of iron. ***Advanced Materials Research***, Vols. *343-344*, p. 307-311 (In press).

25. **M. Vithanage,** K. Villholth, P. Engesgaard, K. Jensen, (2011). Effect of December 2004 tsunami on saltwater intrusion in a coastal aquifer in Eastern Sri Lanka; Field observations and numerical modelling (Accepted in ***Groundwater Journal***, 2011).

26. S. Subedi, K. Kawamoto, L. Jayarathna, **M. Vithanage,** P. Moldrup, L. Wollesen de Jonge, T. Komatsu (2011). Characterizing time dependant contact angles for sands hydrophobized with oleic and stearic acids (Accepted in ***Vadose Zone Journal***, 2011).

27. K. Mahatantila, **M. Vithanage,** Y.Seike, M. Okumura (2011). Adsorptive removal of Cd by natural red earth; Equilibrium and kinetic studies. ***Journal of Environmental Technology***, 10.1080/09593330.2011.586059.

28. **R. Weerasooriya**, S.P. Indrarathna, N. Nanayakkara, L. Jayarathne, C.B. Dissanayake, N. Walelawala, A. Bandara, (2011). Probing pyrite – carbofuran interactions with ζ potential and IR spectroscopic measurements, ***Colloids and Surfaces A: Physicochemical and Engineering Aspects*** (In press).

29. **R. Weerasooriya**, M. Makehelwala, A. Bandara (2010). Probing reactivity sites on pyrite- oxidative interactions with 4-chlorophenol, ***Colloids Surfaces*** (In press).

30. C.P. Kumara, W.Ng, A. Bandara, **R. Weerasooriya**, (2010). Nano gibbsite: synthesis and characterization. ***J. Colloids Interface Science***, *352*, 252-258.

31. M. Makehelwala, K.B.S.N. Jinadasa, N.Tanaka, **R. Weerasooriya** , (2010). Reductive adsorption of Cr (iV) by coir pith, ***Bioremediation Journal*** (In press).

14.1 Other Publications

Five news paper articles were published by Dr. M. Vithanage in Vidusara and Lankadeepa national newspapers.

14.2 Book Publications (Sinhala)

1. M. Vithanage, The Hydrosphere. A book for the O/L school children. Institute of Fundamental Studies, Kandy, Sri Lanka. 2011

2. M. Vithanage, The Lithosphere. A book for the O/L school children. Institute of Fundamental Studies, Kandy, Sri Lanka. 2011

3. M. Vithanage, The Atmosphere. A book for the O/L school children. Institute of Fundamental Studies, Kandy, Sri Lanka. 2011

14.3 Chapters in Books

1. G. Seneviratne, K. P. K. Jayakody, M. L. M.A.W.Weerasekara, T. Someya, and N.Ryuda, (2011). Microbial biofertilizer application versus compost use in agriculture: soil health implications. In. Miransari, M. (ed.) Soil Microbes and Environmental Health. Nova Science Publishers Inc., USA (In press). Invited.

2. G. Seneviratne, M.L.M.A.W. Weerasekara, and K.P.K. Jayakody, (2011). Soil tillage effects on N_2 fixing bacteria and their communities. In. Miransari, M. (ed.) Soil Tillage and Microbial Activities. Research Signpost, India, pp. 1-18. Invited.

3. D. Magana-Arachchi. "Pattern of circulating *Mycobacterium tuberculosis* strains in Sri Lanka". In Mycobacterium tuberculosis /Book 1 (ISBN 979-953-307-078-9) (In press).

14.4 M.Phil. Theses

Ms. B.G.N. Sewwandi
Pollution mitigation in landfill sites: removal of heavy metals using locally available filter materials
Supervisors: Dr. M.I.M. Mowjood, Dr. Meththika Vithanage and Dr. S. Jinadasa

Dr. (Mrs). Valarmathy Ambalavanar
Identification of Drug Resistant *Mycobacterium tuberculosis* strains using PCR & DNA sequencing
Supervisors: Dr. D.N. Magana-Arachchi and Prof. V.Thevanesam

Ph.D Thesis
Mr. K.A.J.M. Kuruppuarachchi
Carbon sequestration as influenced by climatic, plant and soil parameters, their dynamics and control of selected Sri Lankan forests (2010).
Supervisors: Prof. G. Seneviratne and Dr. R. Ratnayake, Dr. T.K. Weerasinghe

14.5 Conference Abstracts/Papers (P - 22 + full Papers - 10 = 32) Abstract 49

1. **J. Akilavasan, J. Bandara**, (2011). Fabrication of solar cells by hydrothermally synthesized titania nanotubes and CdS quantum dots. International conference on solar energy materials, solar cells and solar energy applications, Solar Asia-2011, Kandy, Sri Lanka.

2. **M.A. Careem**, K. Kumaraarachchi, **G.K.R. Senadeera,** A.J.W. Bandara, B.E. Mellander, (2011). Quantum dot sensitized solar cells with some gel type polymer electrolytes. Presented at the International Conference on Advanced Materials and applications (ICAMA-2011), Kalasalingam University, Krishnankoil, Tamil Nadu, **India**, 4-5 March 2011.

3. **R. Senadeera**, S. Gunathilake, P. Ekanayake, **L. Dissanayake,** (2011). Synthesis and characterization of blended PVdF:PEO nanocomposite polymer electrolyte and its application in dye sensitized solar cells. POLYCHAR 19 – World Forum on Advanced Materials March 20-24, 2011, (p 270) Kathmandu, **Nepal**.

4. **M.A. K. L. Dissanayake, W.N.S., Rupasinghe** , J.M.N.I. Jayasundara, P. Ekanayake, T.M.W.J. Bandara. S. N. Thalawala, and V.A. Seneviratne, (2011). Ionic Conductivity Enhancement in the Solid Polymer Electrolyte PEO_9LiTf with Nanosilica Filler from Rice Husk Ash. *Proc. International Conference on Materials for Advanced Technologies (ICMAT 2011), 26th June to 1st July, 2011, Singapore.* (P)

5. **L. Jayasinghe**, (2011): Chemistry and bioactivity of some edible fruits, *Special Molecular Life Science Seminar,* 14th June 2011, Jacobs University Bremen, Germany.

6. **L. Jayasinghe**, (2011): Chemistry and bioactivity of some popular edible fruits of Sri Lank, *International Symposium on Natural Products and their Applications in Health and Agriculture –NPAHA 2011* Kandy, Sri Lanka, 51.

7. **L. Jayasinghe**, (2011): Search for environmental friendly bioactive compounds – Keynote Address: Annual Research Symposium - 2011, Technical Session - Science and Technology, Uva- Wellassa University, December, 15th, 2011.

8. G.G.E.H. De Silva, **L. Jayasinghe**, (2011). Antioxidant, antifungal, cytotoxic and phytotoxic activity of seven varieties of ripe fruits of banana (*Musa* sp.), *NPAHA 2011,* Kandy, Sri Lanka, 76.

9. R.P. Wanigatunge, **D.N. Magana-Arachchi**, **L. Jayasinghe**, (2011). Detection of hepatotoxic Mmicrocystin in *Chroococcidiopsis* Species, *NPAHA 2011* Kandy, Sri Lanka, 98.

10. D. Niyangoda, **N.S. Kumar**, **L. Jayasinghe**, (2011). Bioactivity studies of some plants used in traditional medicine to treat inflammations, *NPAHA 2011* Kandy, Sri Lanka, 102.

11. W.I.T. Fernando, H.K.I. Perera, S.B.P. Athauda, **N.S. Kumar**, **U.L.B. Jayasinghe**, R. Sivakanesan, (2011): Heat stability of the amylase and lipase inhibitors in methanol extracts of spices, *Annual Sessions, Sri Lanka Association for the Advancement of Science*, December.

12. D.S. Jayaweera, **N.S. Kumar**, G.J. Panagoda, B.M.R. Bandara, **L. Jayasinghe**, (2011). Bioactivity studies of some edible grains of Sri Lanka, *NPAHA 2011* Kandy, Sri Lanka, 99.

13. **N.S. Kumar**. (2011): Separation of some oligomeric proanthocyanidns from fresh tea leaves, *International Symposium on Natural Products and their Applications in Health and Agriculture – (NPAHA 2011)* , Kandy, Sri Lanka, 43-44.

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32
49

14. W.W. Kumbukgolla, A.A.K. Karunathilake, V. Thevenesam, G.J. Panagoda, **N.S. Kumar**, B.M.R. Bandara, Antimicrobial activity of tea polyphenols against some Clinically Important Pathogens. International Symposium on Natural Products and their Applications in Health and Agriculture – NPAHA 2011 Kandy, Sri Lanka, 61.

15. A.M.D.A. Siriwardane, **L. Jayasinghe**, **N.S. Kumar**, Y. Fujimoto, (2011): Polyketides from endophytic fungi *Aspergillus* sp. associated with *Limonita acidissima, NPAHA 2011* Kandy, Sri Lanka, 64.

16. W.I.T. Fernando, H.K.I. Perera, S.B.P. Athauda, **N.S. Kumar**, **L. Jayasinghe** , R.Sivakanesan (2011): Lipase and amylase inhibitory activity of spices, *NPAHA 2011,* Kandy, Sri Lanka, 69.

17. K.G.E. Padmathilake, **N.S. Kumar**, **L. Jayasinghe**,(2011): Chemistry and bioactivity of seeds of *Pouteria campechiana*, *NPAHA 2011* Kandy, Sri Lanka, 70.

18. W.C. de Silva, A.M.D.A. Siriwardane, H.M.S.K.H. Bandara, G.G.E.H. de Silva, **N.S. Kumar**, **L. Jayasinghe**, (2011). Bioactive extracts from some fungi of importance in agriculture, *International NPAHA 2011*, Kandy, Sri Lanka, 84.

19. H.M.S.K.H. Bandara, **N.S. Kumar**, **L. Jayasinghe**, (2011). Bioactive secondary metabolites from a fungus *Aspergillus* sp. associated with *Musa* sp, *NPAHA 2011,* Kandy, Sri Lanka, 86.

20. A.G.A.W. Alakolanga, **L. Jayasinghe**, **N.S. Kumar**, (2011). Chemistry and bioactivity of seeds of *Punica granatum*, *NPAHA 2011,* Kandy, Sri Lanka, 97.

21. **N.S. Kumar**, (2011): Research in Chemistry – Some Perspectives. Address as the Chief Guest. International Year of Chemistry 2011 National Symposium "Chemistry Comes to Life". Faculty of Applied Sciences, Rajarata University of Sri Lanka.

22. **M.B.U. Perera**, S.K. Yatigammana, **S.A. Kulasooriya**, **N. Athukorale**, (2011). Limnology and Cyanobacterial Species Composition of the Padawiya Tank During the Dry Season. Proceedings Peradeniya University Research Sessions, 149. (P)

23. **M.B.U. Perera**, S.K. Yatigammana, **S.A. Kulasooriya**, (2011). Diversity of plankton in Some Selected Reservoirs of Sri Lanka. International Symposium on "Sustainable Use of Water : Challenges Ahead". Symposium proceedings, 36-37. (P)

24. O. Perera, **R. Liyanage**, (2011). Antioxidant activity and phenol content of commonly consumed cowpea varieties in Sri Lanka, In Proceedings of the International Symposium on Natural Products and their Applications in Health and Agriculture, Institute of Fundamental Studies, Sri Lanka, 3-8 October,2011. (P)

25. S.D.P.M.P. Chandika, B.C. Jayawardana, J.K. Vidanaarchchi and **R. Liyanage** (2011). Antioxidant effect of onion on lipid oxidation and sensory qualities of cooked pork sausages, In Proceedings of the twenty first annual research session, Department of Animal Science, Faculty of Agriculture, University of Peradeniya,Sri Lanka.12th November, 2011. (P)

26. S.D.P.M.P. Chandika, B.C. Jayawardana, **R. Liyanage**, and J.K Vidanaarchchi, (2011) Anti-oxidative effect of onion (Allium cepa) on lipid oxidation, In Proceedings of the National Symposium on Agricultural Biotechnology, Council for Agricultural Research Policy, Rice Reaserach& Development Institute, Batalagoda, Ibbagamuwa. Sri Lanka. 16th December,2011. (P)

27. **D.N. Magana-Arachchi**, H.M. Liyanage and R.P. Wanigatunge. Molecular detection of cyanotoxins in water reservoirs in Anuradhapura District, Sri Lanka. Sixth IWA Specialist Conference on Efficient Use and Management of Water Demand Management: Challenges & Opportunities. (Manuscript number: IWA-5553).

28. H.M. Liyanage and **D.N. Magana–Arachchi** (2011). Detection and Quantification of Cyanotoxin; Cylindrospermopsin from Anuradhapura Water Reservoirs using a Biochemical Method. IFS-AFASSA International Symposium on Natural Products and their Applications in Health and Agriculture. 3rd-8th October, 2011 at the IFS, Kandy, Sri Lanka.

29. R.P. Wanigatunge, **D.N. Magana-Arachchi**, U.L.B. Jayasinghe (2011). Detection of Hepatotoxic Microcystin in *Chroococcidiopsis* Species. IFS- AFASSA International Conference on Natural Products and their Applications in Health and Agriculture. 3rd – 8th October, 2011. PO- 16; P. 98.

30. **D.N Magana-Arachchi**, B.A.C de Silva, D. Medagedara, V. Thevanesam. Spoligotyping of *Mycobacterium tuberculosis* strains isolated from patients attending the Central Chest Clinic Kandy. *Proceedings of the Kandy Society of Medicine, 33rd Annual sessions,* 10-12th February 2011. p68. (P)

31. **D.N Magana-Arachchi**, B.A.C de Silva, D. Medagedara, V. Thevanesam. Restriction Fragment Length Polymorphism (RFLP) on *Mycobacterium tuberculosis* strains isolated from patients attending the Central Chest Clinic Kandy. *Proceedings of the Kandy Society of Medicine, 33rd Annual sessions,* 10-12th February 2011. p67. (P)

32. N. Dissanayake, D. Medagedara, U. Karunarathnne, C. Prematilake, **D.N. Magana-Arachchi**. Detection of Non-tuberculosis Mycobacteria (NTM) in Bronchoscopy samples. *Proceedings of the Kandy Society of Medicine, 33rd Annual sessions,* 10-12th February 2011. p 61-62. (P)

33. N. Dissanayake, D. Madegedara, **D. Magana-Arachchi**, U. Karunarathna, D. Yasaratne, C. De Silva, C. Kulathunga, S. Nakandala, P. Wijerathne, C. Wirasinghe (2011). High burden of rapidly growing non-tuberculosis mycobacteria in patients with respiratory disease undergoing elective bronchoscopy. Proceedings of the European Respiratory Society. Amesterdam 2011. September 24-28. No; 3395. (P)

34. R.P. Wanigatunge and **D.N. Magana-Arachchi*** (2011). Application of molecular techniques for the detection of potentially microcystin-producing cyanobacteria in Kondawatuwana reservoir in Ampara. Proceedings of the Sri Lanka Association for the Advancement of Science. 67th Annual Session. P.51. (P)

35. H.M. Liyanage, **D.N. Magana–Arachchi** and S.A. Kulasooriya (2011). Detection and quantification of Cyanotoxin; Cylindrospermopsin from Girandurukotte water reservoirs and water sources using a biochemical method. Proceedings of the Sri Lanka Association for the Advancement of Science (SLAAS). 67th Annual Session, p.50. (P)

36. **N. Nanayakkara**, Yu-Ming Zheng, J. Paul Chen. Agricultural wastewater: A treatment perspective, Water Professionals' Day Symposium- 2011, Faculty of Agriculture, University of Peradeniya, Sri Lanka, October 2011

37. N. Walelawala, **R. Weerasooriya**, **N. Nanayakkara**, L. Jayarathne, S.P. Indrarathna, A. Bandara. The zeta potential and IR spectroscopic measurements of Pyrite-Carbofuran interactions, 10th International conference of the east and southeast Asia federation of soil science societies- Soil, a precious natural resource: Agricultural ecosystems, environmental health & climate change, Colombo- Sri Lanka, October 2011.

38. G.C. Pathiraja, **K.G.N. Nanayakkara** (2011). Surface modification of activated carbon to treat polluted water streams, UvaWellassa University Research Symposium 2011- Towards a knowledge economy, UvaWellassa University, Sri Lanka, December 2011.

39. S.A.K.M. Dhanasekara, **R. Weerasooriya**, **K.G.N. Nanayakkara**, L. Jayarathne, N. Walelawela, (2011). Kinetic modeling of partial degradation of carbofuran by pyrite, UvaWellassa University Research Symposium 2011- Towards a knowledge economy, Uva Wellassa University, Sri Lanka, December 2011

40. T.D.K. De Silva, **K.G.N. Nanayakkara**, (2011). Investigating properties of rice husk for contaminated removal from polluted water streams, UvaWellassa University Research Symposium 2011- Towards a knowledge economy, UvaWellassa University, Sri Lanka, December 2011.

41. **R.R. Ratnayake,** D. Wasalamuni, T. Gunaratne, (2011). Development of a sustainable home garden system in Sri Lanka to optimize soil C sequestration. In Proceedings of the *International Symposium on Soil Organic Matter: Organic matter dynamics – from soils to oceans*, Leuven, Belgium, 11-14 July 2011. (P)

42. T. Kugendran, **R.R. Ratnayake,** N. Gnanavelrajah, (2011). Assessment of soil Carbon stocks in different land uses in Jafna district. *International Conference of the East and Southeast Asia Federation of Soil Science Societies*, Cinnamon Lakeside Hotel, Colombo, Sri Lanka, 10th to 13th October 2011.

43. K.M.D. Gunathileke, **R.R. Ratnayake, S.A. Kulasooriya**, D.N. Karunaratne, (2011). Biodegradation of Cellulose for Biofuel Production Using Microbial Biofilms. *International symposium on Natural Products and their Applications in Health and Agriculture*, Institute of Fundamental Studies, Kandy, 3rd – 8th October 2011

44. M.M.S.N. Premetilake, **R.R. Rathnayake, S.A. Kulasoorya**, Perera, G.A.D. (2011) Variation of microbial biomass in plantation forests with age. *Research Symposium 2011*, Uwa Wellassa University of Sri Lanka.

45. **C. Thotawattage** and **R. Senadeera,** (2011). Quasi solid natural rubber polymer electrolytes for dye sensitized solar cells. POLYCHAR 19 – World Forum on Advanced Materials March 20-24, 2011, (p 250) Kathmandu, **Nepal.**

46. **C.I.F. Attanayake,** B.A.J.K.. Premachandra, A.A.P. De Alwis, and **G.K.R. Senadeera,** (2011) Conversion of solar energy to electricity by natural dye sensitization. Solar Asia 2011, July 28-29, IFS, Kandy, Sri Lanka.

47. T.R.C.K. Wijayarathne, Y.P.Y.P. Ariyasinghe, **C.A., Thotawatthage,** V.P.S. Perera, and **G.K.R. Senadeera,** (2011). Effects of Ni doping of the nanostructured photo anode on the performance of dye sensitized solar cells. *Annual Academic Sessions 2011, The Open University of Sri Lanka, 14-15 September, 2011*, p 311-314

48. **G. Seneviratne**, H.M.L.I. Herath, A.P.D.A. Jayasekara, and I.R. Kennedy, (2011). Developed microbial biofilms for sustainable agriculture. Exploratory workshop on 'Biofilms: Friend or Foe? Berlin, Germany, 22 - 23 June 2011.

49. **G., Seneviratne**, Herath, H.M.L.I., Ariyawansa, H.A., Jayasekara, A.P.D.A. and Kennedy, I.R. (2011) Developed microbial biofilms: A novel rhizoremediation tool to heal soil sickness. Exploratory workshop on 'Biofilms: Friend or Foe? Berlin, Germany, 22 - 23 June 2011.

50. **G. Seneviratne**, H.M.L.I. Herath, (2011). Biofilm-based bioremediation method to reduce cadmium levels in agricultural soil. In. Proceedings of International Symposium on Natural Products and their Applications in Health and Agriculture, 3-8 October 2011. Institute of Fundamental Studies (IFS), Kandy. p. 95.

51. **G. Seneviratne**, H.M.L.I. Herath, A.D. Igalavithana, (2011). Enhancement of glyphosate biodegradation via developed microbial biofilms. In. Proceedings of International Symposium on Natural Products and their Applications in Health and Agriculture. Institute of Fundamental Studies (IFS), Kandy. p. 96.

52. **G. Seneviratne**, H.M.L.I. Herath, M.C. Peris, (2011). Developed microbial biofilms: novel biofertilizer technique for common bean (*Phaseolus vulgaris* L.). In. Proceedings of International Symposium on Agriculture and Environment 2011. Faculty of Agriculture, University of Ruhuna, p. 25.

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Conference proceedings full papers

The following papers were presented at the *Solar Asia 2011*, 28-30 July 2011, IFS, Kandy, Sri Lanka conference and published as full papers in the conference proceedings:

1. P.D.N. Gunasekara, Y.P.Y.P. Ariyasinghe, T.R.C.K. Wijayarathna, **C.A. Thotawatthage, M.A.K.L. Dissanayake** and **G.K.R. Senadeera.** Poly (acrylonitrile) (PAN) based polymeric electrolyte for dye sensitized solar cells and its characteristics. Proc. Solar Asia(2011), 180-185.

2. P. Ekanayake, R. Zain, M. Iskandar, K. Tennakoon, S. Yoshikawa and **R. Senadeera.** Evaluation of dyes from *melastroma malabathricum*: a native plant of borneo, as potential natural colour for dye-sensitized solar cells. Proc. Solar Asia(2011), 246-251.

3. P. Abeygunawardhana, S. Palamakubura , **C. Thottawattage , L. Dissanayake** and **R. Senadeera.** Nanocrystalline TiO_2 photo-sensitized with natural dyes. Proc. Solar Asia(2011), 229-235.

4. H. Iqbal, K. Perera, V.A. Seneviratne, W.N.S. Rupasinghe, **C.A. Thotawattage, G.K.R. Senadeera** and **M.A.K.L. Dissanayake.** Quasi-solid state dye sensitized solar cells with polymethylmethacrylate (PMMA) based gel polymer electrolyte and nano-porous TiO_2 electrode. Proc. Solar Asia(2011), 163-168.

5. H.A.C.S. Perera, K. Perera, V.A. Seneviratne, W.N.S. Rupasinghe, **C.A. Thotawattage, G.K.R. Senadeera** and **M.A.K.L. Dissanayake.** Quasi-solid state dye sensitized solar cells with poly (vinylidene-fluoride) (pvdf) based gel polymer electrolyte and nano-porous TiO_2 electrode. Proc. Solar Asia(2011), 186-192.

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15. IFS STAFF 2011

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