



NATIONAL
SCIENCE
FOUNDATION

CHEMISTRY IN SRI LANKA



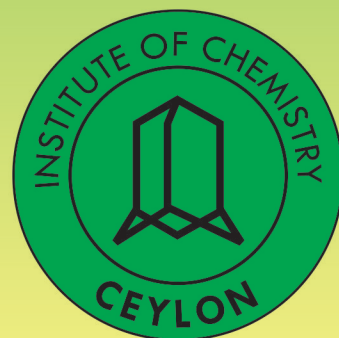
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Chemistry in Sri Lanka

ISSN 1012 - 8999

The Tri-Annual Publication of the Institute of Chemistry Ceylon

Founded in 1971, Incorporated by Act of Parliament No. 15 of 1972

Successor to the Chemical Society of Ceylon, founded on 25th January 1941

Vol. 30 No. 3

September 2013

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Theme for the year -

Curricula and Evaluation in Chemistry for a Sustainable Economy

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Outline of our Institute

The Institute of Chemistry Ceylon is a professional body and a learned society founded in 1971 and incorporated by act of Parliament No. 15 of 1972. It is the successor to the Chemical Society of Ceylon which was founded in 1941. Over 50 years of existence in Sri Lanka makes it the oldest scientific body in the country.

The Institute has been established for the general advancement of the science and practice of Chemistry and for the enhancement of the status of the profession of Chemistry in Sri Lanka. The Institute represents all branches of the profession and its membership is accepted by the government of Sri Lanka (by establishment circular 234 of 9-3-77) for purposes of recruitment and promotion of chemists.

Corporate Membership

Full membership is referred to as corporate membership and consists of two grades: **Fellow (F.I.Chem.C.)** and **Member (M.I.Chem.C.)**

Application for non-corporate membership is entertained for four grades: **Associate (former Graduate) (A.I.Chem.C.)**, **Licentiate (L.I.Chem.C.)**, **Technician (Tech.I.Chem.C.)** and **Affiliate Member**.

Revision of Membership Regulation

All Special Degree Chemists can now apply directly to obtain **Associate (Graduate) Membership**. Three year B. Sc. Graduates (with an acceptable standard of Chemistry) can

- directly become **Licentiate**
- obtain corporate membership in a lesser number of years.

Tech.I.Chem.C.

Those who have passed the DLTC examination or LTCC examination or have obtained equivalent qualification and are engaged in the practice of Chemistry (or chemical sciences) acceptable to the Council are entitled to the designation **Tech.I.Chem.C.**

Members/Fellows are entitled to the designation of **Chartered Chemist (C.Chem.)** on establishment of a high level of competence and professionalism in the practice of chemistry and showing their commitment to maintain their expertise.

All corporate members (Members / Fellows) are entitled to vote and become Council/ Committee members whether Chartered Chemists or not.

Membership Applications

Any application for admission to the appropriate class of membership or for transfer should be made on the prescribed form available from the Institute Office.

Current Subscription Rates

Fees should be paid on 1st of July every year and will be in respect of the year commencing from 1st July to 30th June

Fellow	Rs. 1200
Member	Rs. 1200
Associate	Rs. 900
Licentiate	Rs. 750
Technician	Rs. 500
Affiliate	Rs. 500
Membership for Life	Rs. 10000

Entrance Fee

All the grades	Rs. 500
Processing Fees*	Rs. 200
Processing Fee for Chartered Chemist designation	Rs. 1000
Institutional Members	Rs. 2500

*per application for admission/transfer to any grade

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CHEMISTRY IN SRI LANKA

Chemistry in Sri Lanka is a tri-annual publication of the Institute of Chemistry Ceylon and is published in January, May and September of each year. It is circulated among the members of the Institute of Chemistry and students of the Graduateship/DLTC course and libraries. The publication has a wide circulation and more than 1500 copies are published. Award winning lectures, abstracts of communications to be presented at the annual sessions, review papers, activities of the institute, membership news are some of the items included in the magazine.

The editor invites from the membership the following items for publication in the next issue of the Chemistry in Sri Lanka which is due to be released in January 2014.

- Personal news of the members
- Brief articles of topical interests
- Forthcoming conferences, seminars and workshops
- Latest text books and monographs of interest to chemists

All publications will be subjected to approval of the 'Editorial and Publicity Committee' and the Council of the Institute of Chemistry Ceylon.

Further, prospective career opportunities for chemists, could be advertised in Chemistry in Sri Lanka at a nominal payment. The editor welcomes from the members suggestions for improvement of the publication.

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Cover page

The cover page depicts plantation crops grown in Sri Lanka: tea, rubber, coconut, coffee, cocoa, cashew nut and spices. Refer pages 8 - 17 for more details. This issue of Chemistry in Sri Lanka is sponsored by National Science Foundation of Sri Lanka (NSF).

Message from the President



Economy of a Country is dependent on the 'Quality' of Education. What is quality? It is to meet the predetermined requirements to the satisfaction of the users for a particular substance or a

service. Education is a service. Users are the employers who employ the trained students. What are the predetermined requirements that an employer (mainly industry) expect from a student who has the training in the subject of Chemistry such that the trained student possesses the, (i) Ability to understand the organization process and the (ii) Ability to apply fundamental principles of Chemistry whenever a need arises in the industry. Economy is dependent on the availability of knowledge based industries which are responsible for the value addition to the resources of a country. The economy will progress if the employable human resources possess the above capabilities (Principles of chemistry → Technology → To fulfill the technological needs of a country → Development of Knowledge Economy). The application of the principles of science to technology becomes fruitful if there is a scientific culture in a country where Education in Science and Technology plays a vital role.

The concept of 'sustainability', implies meeting human needs while preserving the environment and natural resources needed by future generations. The Technology can be considered as the output of scientific theories giving the final product needed for economic growth. An industry utilizes a technology or several technologies in its manufacturing stages. Any form of technology cannot survive without science. Technology may flourish for sometimes but ultimately die off if it is not supported by the science. The survival of a particular technology is dependent on the applications of the associated sciences required to improve the existing technology(ies) such a way that

the manufactured product(s) will meet the present challenges in the market. i.e. 'Quality'. One could argue that ancient Sri Lanka had only the technology, which helped in the booming of the economy from time to time with the assistance of good governance. It is clear that the ancient technology was based on some form of unwritten science surely not the modern science. Due to historical reasons most of the ancient unwritten sciences died off leaving us to apply the 'modern science' to ancient as well as modern technology. Therefore, the application of modern science to technology is essential since the sustainable development of a country is based on the improvement of the technologies.

In order to achieve the National Goals the curriculum at G.C.E. (A/L) should cater for 90% of the students who do not gain admission to Universities in Sri Lanka. The fundamental principles in chemistry should be taught thoroughly with at least one application of each principle. The evaluation should be based on testing the ability of the student to apply the principle to different situation which has not been taught. The credit given at examination should be merit of the competency to use the knowledge and not the ability to memorize the learnt materials. This is a difficult task for the examiners. However, it helps in the development of the economy of the country.

Teaching of scientific principles as applied to day to day life, laboratory and environment and EVALUATION geared towards the testing of the ability to use the knowledge when the need arises will undoubtedly fulfill the above needs. Does the traditional Science Education in Sri Lanka provide the TRAINING to use the knowledge when the need arises? It mainly provides students to imagine the so called SCIENCE in TEXT BOOKS. There are several examples where the knowledge is confined to text books and not to the applications to lab or day to day life. As a professional body, it is very essential that the Institute of Chemistry Ceylon takes adequate measures to influence all educational institutions of Sri Lanka including its College of Chemical Sciences to produce students of QUALITY.

Professor H D Gunawardhana
President, Institute of Chemistry Ceylon

Role of Chemistry in Sustainable Agriculture

Dr S Mohanadas

Immediate Past President, Institute of Chemistry Ceylon

Sustainable agriculture means in short is a prerequisite for sustainable human inhabitation on this planet earth. Agriculture is not only essential for food, clothing and shelter but also for healthcare, recreation and education as well. Sustainable agriculture brings employment opportunities, economic growth, national development and prosperity to the country. Chemistry is closely connected with the sustainable agriculture and in turn to the prosperity of Sri Lanka.

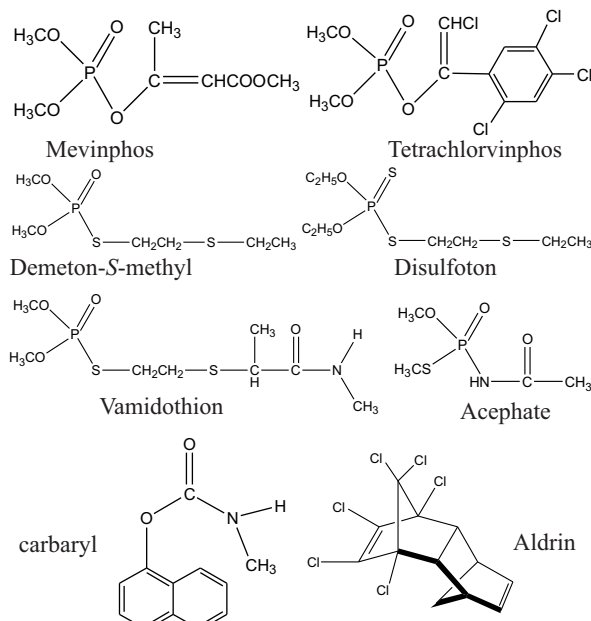
"The Role of Chemistry in Sustainable Agriculture" was the theme of the 42nd Annual Sessions of the Institute of Chemistry Ceylon and it was a common forum for all chemists, agronomists, food technologists, environmentalists and other scientists to discuss, update and share their knowledge and experiences on subject related to chemistry and agriculture. Chemistry plays a major role in sustainable agriculture in many ways such as chemistry on plantation crops, soil, agrochemicals, hazardous chemicals in agriculture and its impact on human health and agriculture for greater economic growth.

In Sri Lanka the chemistry education is starting from schools and continues to universities in both undergraduate and postgraduate levels at a very high standard. The Institute of Chemistry Ceylon has been imparting knowledge on chemical education in this country over three decades at various levels such as certificate, diploma in laboratory technician and graduate chemists. This high quality chemical education has led to good research output in many research institutes, government departments and universities in Sri Lanka. These research findings have been very useful to farmers, industrialists, entrepreneurs and policy planners.

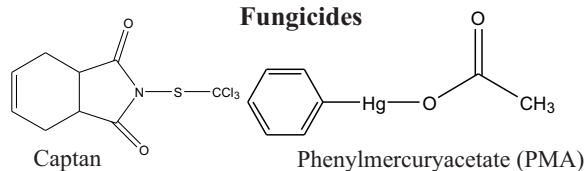
Chemistry is the central science which connects with physics and biology and geology. Chemistry deals with atoms and molecules. It explains the synthesis of compounds. Agrochemicals and fertilizers are mostly synthetic compounds and they are synthesized mostly from natural resources. In Sri Lanka we have a few natural resources that have opportunities to synthesis these compounds of agrochemicals and fertilizers. The Eppawalla rock phosphate is a raw material for the manufacture of phosphorous fertilizers such as Triple Super Phosphate (TSP) and Single Super Phosphate

(SSP). Limestone and corals are used as calcium nutrient as well as for soil reclamation. The defunct Paranthan Chemical factory produced hydrogen gas as a byproduct with other waste materials and this was used for the synthesis of ammonia which in turn is used for the manufacture of urea. The ammonia and urea are nitrogen fertilizers. Nitrogen, phosphorous and potassium (NPK) are the major nutrients of plants. The applications of agrochemicals are weedicides, fungicides, herbicides and insecticides etc. (figure 1) and use of these have increased the crop production significantly. The effect on the application of fertilizers on the crop yield is shown in table 1 and figure 2.

Insecticides



Fungicides



Herbicides

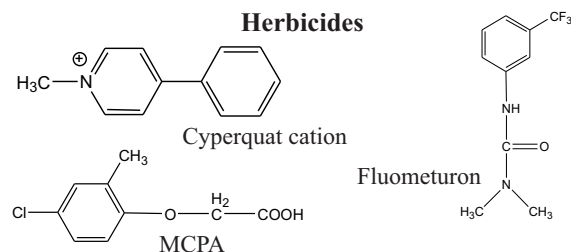


Figure 1: Commonly used agrochemicals such as insecticides, fungicides and herbicides.

Table 1: Fertilizer consumption and wheat yield. Source: FAO Production Year book, Vol. 37 (1983) and Fertilizer Year book, Vol. 33 (1983). FAO, Rome.

Country	Fertilizer Consumption (kg N+P ₂ O ₅ +K ₂ O per ha arable land and permanent crops)	Average grain yield (t/ha)
Germany	435	5.44
France	299	5.13
Italy	161	2.56
China	158	2.83
USA	87	2.65
USSR	87	1.61
Pakistan	62	1.68
Turkey	54	1.86
Canada	44	1.97
India	35	1.84
Australia	24	1.72

Table 2: Nutrient elements and chemical form in which they are taken up from soils.

Primary nutrients	Chemical form	Secondary nutrients	Chemical form	Micro-nutrients	Chemical form
Nitrogen	NH ₄ ⁺ , NO ₃ ⁻	Calcium	Ca ²⁺	Iron	Fe ²⁺ , Fe ³⁺
				Zinc	Zn ²⁺
Phosphorus	HPO ₄ ²⁻ , H ₂ PO ₄ ⁻	Magnesium	Mg ²⁺	Manganese	Mn ²⁺ , Mn ³⁺
				Copper	Cu ²⁺
Potassium	K ⁺	Sulphur	SO ₄ ²⁻	Boron	BO ₃ ²⁻
				Molybdenum	MoO ₄ ²⁻
				Chlorine	Cl ⁻

Commonly used fertilizers are based on NPK values in different proportions and it is based on the requirement by the particular crop.

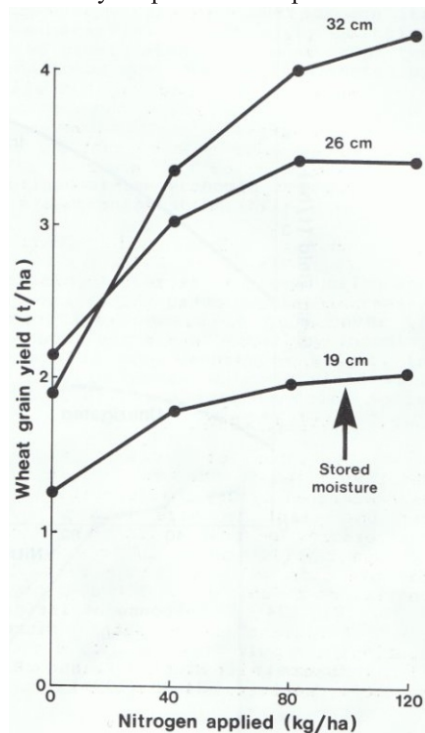


Figure 2: Response of rainfed wheat to nitrogen in soils with different stored moisture.

Soil pH and relative availability of nutrients are given in the figure 3.

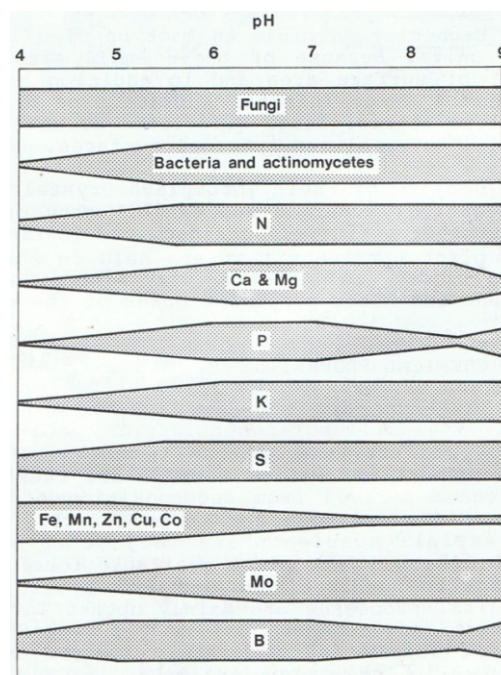


Figure 3: Scale of Soil pH values. Soil pH and relative availability of plant nutrients and activity of soil microflora (the wider the band, the greater the availability/activity).

Organic sources of plant nutrients such as farmyard manure, compost, green manuring contain NPK and considerable amount of sulphur and micronutrients. Inorganic micronutrients that are available on commercial scale as NPK fertilizers contain small amount of micronutrients such as copper, zinc, manganese, boron, molybdenum. These elements and their quantities depend on the source of the raw material and the process that has been used.

Agrochemicals and fertilizers are invaluable inputs to increase the agricultural production which needs to meet our large and ever increasing population. The government of Sri Lanka is providing a subsidy of Rs. 3000/= for every 50 kg bag of fertilizer sold in the market. The price of a 50 kg bag of urea is Rs 1200/= in the market whereas it cost to the government Rs. 4200/=. There is an urgent need to develop newer and safer chemicals and formulations for agrochemicals and fertilizers. Non-judicious use of these chemicals has created problems such as chemical contaminations in the environment by the presence of pesticide residues, on food and living beings. The current trend is to minimize the use of synthetic hazardous chemicals by replacing with non-chemical methods.

For the sustainable development of agriculture the technologies should be adopted to accentuate more efficient resource utilization of high productivity, better crop production and protection technologies. In the changing scenario more efforts are needed to modernize the existing technologies and develop new methodologies to produce more food for the people.

To achieve the leadership in agriculture sector the emerging areas that need consideration are;

- (i) Efficient soil and water resource management
- (ii) Integrated nutrient management
- (iii) Integrated pest management
- (iv) Increased use of biofertilizers
- (v) Use of biodegradable pest control chemicals
- (vi) Use of botanical and biopesticides
- (vii) Environmental engineering and pollution control
- (viii) Development of stress resistant crop varieties
- (ix) Raising new high yielding varieties and hybrid seeds through somatic cell fusion or protoplast fusion
- (x) Multiplication of genetically engineered transgenic plants.

Benevolent Fund Benefits for Members

- **Long life** Benefits: Rs. 10,000 (over 70)/Rs. 15,000 (over 75)/Rs. 20,000 (over 80)
- **Critical illness** benefits (upto Rs. 50,000)
- **International travel** for conferences (upto Rs. 50,000)
- **Balance** 50% of **Tuition fees** of any member's child following the Graduateship Programme (Since 50% concession is already by CCS, this will amount to a 100% waiver)

Any member who has paid membership fees for life (after 3 years of such payment) is entitled for these benefits. All members are advised to pay the membership fee for life and become beneficiaries.

Graduate Chemists Welfare Fund

This fund has been established with effect from 1-1-2012. The principal benefits towards CCS Graduate Chemists would be,

- a) To provide partial assistance towards international travel of those proceeding abroad for PG degrees (once a life time)
- b) To provide partial assistance towards registration fees in respect of IChemC/CCS events such as International Conferences (Preference for those presenting papers)
- c) To provide assistance towards registration fees for IChemC/CCS training seminars etc.
- d) To provide partial assistance towards activities of the Alumni Association.

Note: Depending on the demand, Graduate Chemists who maintain positive content and participate in IChemC/Alumni activities will get preference for the above mentioned benefits.

Forty Second Annual Sessions and Seventy Second Anniversary Celebrations 2013

Chief Guest's Address

The Role of Chemistry on Plantation Crops

Dr. P. Rethinam

Plantation crop specialist & Former Executive Director, Asian & Pacific Coconut Community

Chemistry is a branch of physical science, is the study of the composition, properties and behavior of matter. As it is a fundamental component of matter, the atom is the basic unit of chemistry. Chemistry is concerned with atoms and their interactions with other atoms, with particular focus on the properties of the chemical bonds formed between species. Chemistry is also concerned with the interactions between atoms or molecules and various forms of energy (e.g. photochemical reactions, oxidation-reduction reactions, changes in phases of matter, separation of mixtures, properties of polymers, etc.).

Chemistry is sometimes called "the central science" because it bridges other natural sciences like physics, geology and biology with each other. Chemistry is a branch of physical science but distinct from physics.

The importance of chemistry is that it is the study of you and the world around you. How do they work? Everyone can and should understand basic chemistry, but it may be important to take a course in chemistry or

even make a career out of it. Chemistry is important because there are endless possibilities; you can create a new medicine; you can create a cure for the diseases.

Plantation crops at a glance

Let us know something about Plantation crops before going into the subject proper. The plantation crops are high value commercial crops of greater economic importance and play a vital role in the global economy and more particular to the economy of India and Sri Lanka. The crops include tea, coffee, rubber, cocoa, coconut, arecanut, oil palm, cashew nut and spices. The main drawback within this sector of crops in whole of Asia-Pacific Region is that majority of the area is of small and marginal holding with resource poor farmers and hence with varying level of soil fertility gradient which hinders the adoption of intensive cultivation. While coffee, tea and rubber are under organized sector, the other crops like coconut, areca nut, oil palm, cocoa and cashew nut are not organized properly.

Table 1: Area, Production and Productivity of Plantation crops in India, Sri Lanka and World (2011).

Crops	Area (ha)			Production (tons)			Productivity (kg/ha)		
	India	Sri Lanka	World	India	Sri Lanka	World	India	Sri Lanka	World
Cashew Nuts	953200	23090	4707983	674600	6890	4201010	707.7	298.4	893.5
Areca nut	400100	15640	873060	478000	31600	1082549	1194.7	2020.5	1239.9
Cocoa beans	56500	2550	10003270	14400	1630	4395657	254.9	639.2	439.4
Coconuts	1960000	394840	11437523	11200000	1522560	59189887	5714.3	3856.1	5175.1
Coffee, green	360485	8690	10476355	302000	5320	8284135	837.8	612.2	790.7
Ginger	149100	2400	313989	702000	13660	2029680	4708.2	5691.7	6464.2
Tea	580000	221969	3256762	966733	327500	4668968	1666.8	1475.4	1433.6
Oil Palm	203000	n.a.	16265248			233810539			14374.9

The vast area and the varied agro-climatic conditions ranging from tropical to temperate make it possible to grow almost all different kinds of plantation crops in both the countries. Plantation crops

play an important role in our countries' economy by earning valuable foreign exchange, providing direct and indirect employment to many people and also by supporting a number of horticultural based industries.

Table 2: Area and production of important spices in the world. Source FAO database (2007).

Spice(s)	Area (thousand ha)	Production (thousand t)
Anise, badian, fennel, coriander	661.16	467.86
Chillies and pepper (dry)	2,004.81	2,662.73
Chillies ad peppers (green)	1,725.54	24,803.01
Cinnamon (canella)	176.98	134.8
Cloves	466.08	145.18
Ginger	338.9	1,119.74
Nutmeg, mace and cardamom	222.89	74.02
Pepper (<i>Piper sp.</i>)	473.55	407.41
Vanilla	76.44	10.36
Other spices	1,440.67	2,034.58
Total	7,587.02	31,859.69

The fact remains that though the area and production under different plantation crops had increased over years the productivity increase is not encouraging in spite of the fact that many high yielding varieties and hybrids as well as production technologies have been developed through research efforts. The spread of high yielding varieties hybrids have yet to make an impact. The input management such as optimum manures and fertilizers applications, irrigation, weed management etc are inadequate. So the yield gap between the potential and achievable yield is very wide.

Export of plantation crops: These crops are highly export oriented earning considerable foreign exchange to countries and help to increase GDP.

Coconut: The tree of life, tree of heaven, Nature's super market and Tree of abundance has unlimited scope for export through, many value added products like coconut water, coconut milk, milk powder, desiccated coconut, virgin coconut oil, activated carbon, bio fuel/ bio lubricants coir and coir products. Philippines and Indonesia are the highest export earners. India and Sri Lanka still need to go a long way on value addition except coir products.

Rubber: World production of natural rubber was 4.4 million tonnes in 1985, in which the share of Asia was as much as 91% at 4.0 million tonnes. The Asian production is mostly smallholder based, but relatively large, State-owned plantations dominate in China, Vietnam and Cambodia. Asia continues to be the largest supplier NR to the world. The world NR

production rose to 10.29 million tons in 2010 and the Asian share increased to 93% of this at 9.58 million tons.

Coffee: Coffee is the world's most widely traded tropical agricultural commodity, accounting for exports worth an estimated US\$ 15.4 billion in 2009/10, when some 93.4 million bags were shipped.

Some 70 countries produce coffee, of which the Exporting Members of the International Coffee Organization are responsible for over 97% of world output. In 2010 total coffee sector employment was estimated at about 26 million people in 52 producing countries.

For many countries, coffee exports are not only a vital contributor to foreign exchange earnings but also account for a significant proportion of tax income and gross domestic product. For seven countries the average share of coffee exports in total export earnings exceeded 10% in the period 2000–2010, although the importance of coffee for many countries is diminishing over time as their economies diversify. This can be demonstrated by the fact that during the period 1996 to 2000, there were 15 countries which fell into this category, i.e. the average share of coffee exports in their total export earnings exceeded 10%.

Consumption has increased on average by around 1.2% annually since the early 1980s, rising to more than 2% in recent years. Probably the most spectacular growth of a major market occurred in Japan, where it initially averaged some 3.5% a year until appearing to have reached a plateau over the last ten years. Japan is now the third largest importer of coffee in the world.

Over the last five years market growth in Europe

has been weak, with consumption showing signs of stagnation and possibly even decline. The situation is only slightly better in the United States, where overall consumption, despite the boom in the specialty sector, has grown at a low rate.

The figures for consumption in some producing countries and in non-member countries point to a surprisingly large upsurge since the turn of the century, growing on average by over 6% per annum, although the economic turmoil of recent years has been a brake on growth.

Tea: Sri Lanka is the largest exporter of tea followed by Kenya, China and India in descending order. The domestic and export demand continued to increase.

Table 3: Top tea exporting countries in the world.

Country	Exports in US \$' 000 (2008)
Sri Lanka	1,258,700
Kenya	934,921
China	713,011
India	590,226,
United Kingdom	324,694
Germany	207,227
Indonesia	158,959
Viet Nam	147,300
Rwanda	125,454
United Arab Emirates	11,480

Cocoa: Cocoa as a mixed crop in coconut, arecanut and oil palm in India. Switzerland, Liechtenstein, Luxemburg, UK and Belgium are in the order of one to five consumer countries in terms of chocolate confectionery consumer countries.

Oil Palm: As of today, Indonesia was the largest producer of palm oil, surpassing Malaysia in 2006, producing more than 24.1million tones as on 2011 and that of Malaysia is 18.912 million tons. Indonesia aspires to become the world's top producer of palm oil. But at the end of 2010, 60% of the output was exported still in the form of Crude Palm Oil. FAO data show production increase from 16.92 million tons in 1998 to 50.518 million tons in 2011.

Cashew: Posting an export turnover of \$1.14 billion in 2010 from shipping abroad 196, 000 tons of cashew nuts, Vietnam has been the world's leading cashew exporters for the fourth consecutive year. India, Nigeria and Cote d'Ivoire occupy second, third and fourth positions respectively. Naturally these

countries should be the top in export.

Spices: Today, Guatemala is the biggest producer and exporter of cardamom in the world, followed by India. Some other countries such as Sri Lanka have also begun to cultivate it. *Elettaria* pods are light green while *Amomum* pods are larger and dark brown.

It is the world's third most expensive spice by weight, outstripped in market value only by saffron and vanilla.

The Middle East, South Asia, South East Asia and Europe are the main markets for cardamom consumption. From 2006 to 2008, global demand for cardamom rose steadily from 31,448 MTs to 37,712 Mts.

Chemical Composition of crops is highly variable

1. Plants don't have a single fixed composition but vary greatly in composition depending on variety, place of planting, and year of cultivation
2. Commercial GM crops have the same composition as other varieties of the same crop
3. It is particularly important to understand that crop foods are biological materials and as such, they display biological variability.
4. Any discussion of changes in composition must take into account that crops exhibit a range of content for each constituent—no GM crop has ever been approved that has a biologically significant difference in any component.
5. Smith's discussion of “lower” isoflavone content of GM soybeans is a perfect example of a biased and flawed analysis.

Therefore, understanding the Chemistry of these crops is very important for increasing the production productivity as well as developing value added products and utilization of by products.

Chemistry of Plantation Crops

Chemistry of Coconut

Coconut water (coconut liquid endosperm), with its many applications, is one of the world's most versatile natural product. This refreshing beverage is consumed worldwide as it is nutritious and beneficial for health. There is increasing scientific evidence that supports the role of coconut water in health and medicinal applications. Coconut water is traditionally used as a growth supplement in plant tissue culture/micro propagation. The wide applications of coconut water can be justified by its unique chemical

composition of sugars, vitamins, minerals, amino acids and phytohormones.

Coconut water consists of 95 % water, holding in solution proteins, sugars, and salts. It is used as a diuretic. Fermenting the coconut milk for 36 hours, heating slowly and filtering produces clear oil that retains the scent of coconut.

Approximately 50% of the fatty acids in coconut fat are lauric acid. Lauric acid is a medium chain fatty acid. Lauric acid is known to the pharmaceutical industry for its good antimicrobial properties, and the monoglyceride derivative of lauric acid, monolaurin, is known to have even more potent antimicrobial properties, against lipid-coated RNA and DNA viruses, numerous pathogenic gram-positive bacteria, and various pathogenic protozoa.

The coconut milk, which is the product of the expressed juice of the grated endosperm (white meaty stuff), was popular during World War II and was used as a substitute for cow's milk. Research had shown that lauric acid is present, which is also present in human mother's milk. The milk is reported to be refrigerant, nutrient, aperient, diuretic, laxative, and anthelmintic.

It is also believed that coconut water could be used as an important alternative for oral rehydration and even so for intravenous hydration of patients in remote regions. Coconut water may also offer protection against myocardial infarction. Some of the most significant and useful components in coconut water are cytokinins, which are a Class of phytohormones.

Furthermore, micronutrients (nutrients needed in small quantities) such as inorganic ions and vitamins in coconut water play a vital role in aiding the human body antioxidant system. Hyper metabolism gives rise to an increased production of reactive oxygen species (or free radicals), as a result of increased oxidative metabolism.

Chemistry of Arecanut

The medicinal components are primarily associated with the nut and betel quid. The nuts contain at least 9 structurally related pyridine alkaloids including arecoline, arecaidine, arecaine, arecolidine, guvacine, isoguvacine, guvacoline, and coniine. However, the most common is the parasympathetic stimulant alkaloid arecoline. The total alkaloid content can reach 0.45%. The methyl esters of arecoline and guvacoline are hydrolyzed in the presence of alkali to the respective acids, arecaidine and guvacine. The hydrolysis is catalyzed by lime, which is added to the quid. Arecoline most likely is present in the nut as a salt

of tannic acid, and the lime facilitates the release of the base from the salt. Ten Components of the betel quid, most likely from *Piper betel* and not betel nuts, contain about 1% of a volatile oil, chalcetol, chavicol, cadinene, allylpyrocatechol, and saffrole.

Nearly all of the scientific data involve animal or *in vitro* studies. Arecoline is a parasympathetic stimulant and acts on muscarinic and nicotinic receptors. Glaucoma – The alkaloids of betel nut cause pupil dilation, vomiting, diarrhea, and in high doses, convulsions and death. These alkaloids have a cholinergic action, and it is believed that the central stimulating activity of arecoline is greater than that of pilocarpine. Consequently, extracts of the nut have been used for the management of glaucoma in traditional medicine. Betel nuts contain tannin (e.g., Areca II-5-C) with angiotensin- converting enzyme (ACE) inhibitor activity *in vitro*. The activity of this tannin was comparable with that of captopril. Spontaneously hypertensive rats received oral doses of 100 to 200 mg/kg of the tannin extracts and the antihypertensive effects were similar to 30 to 100 mg/kg of captopril. The IV dose of the tannin was equivalent to 5 times the effect of an equivalent amount of captopril. Research reveals that no clinical data are available regarding the use of betel nuts for hypertension.

Antibacterial activity is associated with the extracts of betel nuts. An ethanol extract inhibited *Staphylococcus aureus*, *Salmonella* sp., *Neisseria* sp., *Yersinia enterocolitica*, and *Listeria monocytogenes*. Research reveals no animal or clinical data regarding the use of betel nuts as an antibacterial.

Arecoline is a basic oily liquid that has been used in veterinary medicine as a cathartic for horses and a vermifuge. Betel nut chewing induces a number of physiologic changes, including an increase in salivation, gradual resorption of oral calcium induced by the lime, gingivitis, periodontitis, and chronic osteomyelitis. Arecoline is thought to be responsible for some of the claimed effects of betel quid chewing, such as alertness, increased stamina, a sense of well-being, euphoria, and salivation. An antidepressant effect of the betel nut may be associated with the hexane and aqueous extracts. The extracts inhibit monoamine oxidase type A isolated from the rat brain. The muscarinic cholinomimetic action of the alkaloids may also relieve symptoms associated with schizophrenia.

Chemistry of Oil palm

The palm fruit (*Elaies guineensis*) yields palm oil, a palmitic-oleic rich semi solid fat and the fat-soluble minor components, vitamin E (tocopherols, tocotrienols), carotenoids and phytosterols. A recent innovation has led to the recovery and concentration of water-soluble antioxidants from palm oil milling waste, characterized by its high content of phenolic acids and flavonoids. These natural ingredients pose both challenges and opportunities for the food and nutraceutical industries. Palm oil's rich content of saturated and monounsaturated fatty acids has actually been turned into an asset in view of current dietary recommendations aimed at zero trans content in solid fats such as margarine, shortenings and frying fats. Using palm oil in combination with other oils and fats facilitates the development of a new generation of fat products that can be tailored to meet most current dietary recommendations. The wide range of natural palm oil fractions, differing in their physico-chemical characteristics, the most notable of which is the carotenoid-rich red palm oil further assists this. Palm vitamin E (30% tocopherols, 70% tocotrienols) has been extensively researched for its nutritional and health properties, including antioxidant activities, cholesterol lowering, anti-cancer effects and protection against atherosclerosis. These are attributed largely to its tocotrienol content. A relatively new output from the oil palm fruit is the water-soluble phenolic-flavonoid-rich antioxidant complex. This has potent antioxidant properties coupled with beneficial effects against skin, breast and other cancers. Enabled by its water solubility, this is currently being tested for use as nutraceuticals and in cosmetics with potential benefits against skin aging. A further challenge would be to package all these palm ingredients into a single functional food for better nutrition and health.

The first group consists of fatty acid derivatives, such as partial glycerides (MGs, DGs), phosphatides, esters and sterols. The second group includes classes of compounds not related chemically to fatty acids. These are the hydrocarbons, aliphatic alcohols, free sterols, tocopherols, pigments and trace metals.

Most of the minor components found in the unsaponifiable fraction of palm oil are sterols, higher aliphatic alcohols, pigments and hydrocarbons. The other minor components, such as partial glycerides and phosphatides, are saponifiable by alkaline hydroxide. The partial glycerides do not occur naturally in significant amounts except in palm oil from damaged

fruits. Such oils would have undergone partial hydrolysis resulting in the production of free fatty acids, water and the partial glycerides. Different isomers of MGs and DGs are found in palm oil. α -MGs are more stable than their β -isomers. As in most vegetable oils, the α, α' -DGs (or 1,3 DGs) are the predominant DGs in palm oil.

Several minor nonglyceride compounds are found in palm oil. The nonglyceride fraction of palm oil consists of sterols, triterpene alcohols, tocopherols, phospholipids, chlorophylls, carotenoids and volatile flavor components, such as aldehydes and ketones. Sterols are tetracyclic compounds with generally 27, 28 or 29 carbon atoms. They make up a sizeable portion of the unsaponifiable matter in oil. The content of sterols in palm oil is about 0.03% of its total composition. Cholesterol (2.2- 6.7%), Δ^5 -avenasterol (0-2.8%) Δ^7 -stigmasterol (0- 2.8%) and Δ^7 -avenasterol (0-4%) was also found in the sterol fraction (326- 627 mg/kg) of palm oil. Most of the sterols are relatively inert and do not appear to contribute to any important property to palm oil. However, Δ^5 -avenasterol has been reported to show antioxidant activity in edible oils.

Crude palm oil has a rich orange-red colour due to its high content of carotene (700–800ppm). The major carotenoids in palm oil are α - and β -carotene, which account for 90% of the total carotenoids. There are about 11 different carotenoids in crude palm oil.

Chemistry of Cocoa

The physics and chemistry of cocoa beans and cocoa products is very complex, changing throughout the life of the bean, depending on the processing it receives. The following gives an indication of the changes in the bean through its life.

Cocoa beans are the seeds of the tree *Theobroma cacao*. Each seed consists of two cotyledons (the nib) and a small embryo plant, all enclosed in a skin (the shell). The cotyledons store the food for the developing plant and become the first two leaves of the plant when the seed germinates. The food store consists of fat, known as cocoa butter, which amounts to about half the weight of the dry seed. The quantity of fat and its properties such as melting point and hardness depend on the variety of cocoa and the environmental conditions.

The seeds are fermented, which causes many chemical changes in both the pulp surrounding the seeds and within the seeds themselves. These changes cause the chocolate flavour to develop and the seeds to

change colour. The seeds are then dried and despatched to processors as the raw material for the production of cocoa mass, cocoa powder and cocoa butter. The first stage of processing includes roasting the beans, to change the colour and flavour, and shell removal. After roasting and deshelling an alkalising process can take place, to alter flavour and colour.

The chemical composition of the bean; however, it must be remembered that this will vary depending on the type of bean, the quality of the fermentation and drying and the subsequent processing of the bean.

Cocoa mass is produced by grinding the nib of the cocoa bean. The quality of the cocoa liquor will depend on the beans used. Manufacturers often blend different types of beans to gain the required quality, flavour and taste. The cocoa liquor can undergo further roasting and alkalisation to alter the colour and flavour which will also alter its chemical composition.

The fat or cocoa butter can be extracted from the bean in a number of ways. Pure press butter is extracted from the cocoa mass by horizontal presses. Sub-standard cocoa beans can be pressed without deshelling by using continuous expeller presses. Pure press butter needs no cleaning but it is often deodorised. A solvent extraction process can be used to extract butter from the cake residue left after the expeller process; this type of butter must be refined. Cocoa butter obtained by pressing the cocoa nib exhibits the following properties: brittle fracture below 20 °C, a melting point about 35 °C with softening around 30-32 °C. Cocoa butter is composed of a number of glycerides.

Cocoa powder is formed from cocoa mass. Presses are used to remove some of the fat and leave a solid material called cocoa press cake. These cakes are then crushed to form cocoa powder. The processing can be altered to produce cocoa powders of different composition and with different levels of fat.

The composition of cocoa powder depends on the roasting, alkalisation and pressing processes undertaken

Chemistry of Cashew nut

Cashew, the king of dry fruits, is not merely the best topping for a delicious last course; it is also an aphrodisiac that can boast of many curative properties. The latent and benign medicinal properties of cashew, of which India is the largest producer worldwide, are enormous, according to research data published by the Cashew Export Promotion Council of India, at Kochi.

Laden with 21% protein and an equally high

percentage of poly unsaturated fatty acids. Cashew helps in reducing the blood cholesterol level considerably preventing possibilities of heart attacks. With an exceedingly low content of saturated fat and soluble sugar, cashew could slim down one's waistline. Besides, cashew kernels, rich in calcium, phosphorous and iron, can help prevent anagemia and nervous system ailments, the research found. In fact, the vegetable proteins contained in cashew kernels stand at par with milk, eggs and meat. Besides, it also contains a high concentration of much needed acids in right proportions, generally very rare in nuts.

A cashew kernel contains 47% fat, 82% of this fat is unsaturated fatty acids. This unsaturated fatty acid helps in lowering blood's cholesterol level. The most prominent vitamins in cashew are vitamin A, D and E. These vitamins help in assimilating the fats and increase the immunity level. Being a rich source of minerals like calcium, phosphorus and iron, consumption of cashew kernels can help protect the nervous system as well.

Cashew kernel is very low on carbohydrates-as low as one per cent of soluble sugar-which means that one is privileged to a sweet taste without worrying about excess calories. One big property of cashew is that it helps in controlling diabetes, says the journal. Cashew kernel oil is also considered a good mechanical and chemical antidote for irritant, poisons, and it is a vehicle for linaments and other external applications, experts point out. The kernel is also used as a substitute for almond mixture, and is a good food for patients suffering from incessant and chronic vomiting.

One of the most popular systems of Indian medicine, ayurveda also lists quite a few unique curative properties of Indian cashewnut and prescribes it as a good stimulant, rejuvenator, appetizer and excellent hair tonic aphrodisiac and restorative. Experts say raw cashew fruit was used as an anaesthetic in leprosy, and also for curing warts, corns and ulcers.

The juice of the nut is used as a substitute for iodine while the oil obtained from the shell is good for cracks in feet. The cashew apple contains 10.44 per cent of fermentable sugars and 261.5 mg per 100gm of vitamins C, giving both the fruit and the wine made of it very good antiscorbutic properties. The liquor is also valued as a diuretic with healthy effect on kidneys and advanced cases of cholera. Apart from its commercial importance as an intoxicant liquor, cashew feni, very popular in Goa, is said to have high medicinal value

and has for centuries been used by the Goans as a cure for ailments ranging from worm sickness in children to diarrhoea and even Cholera. Apart from its commercial importance as an intoxicant liquor, cashew feni is very popular in Goa. Cashew Nut Shell Liquid (CNSL) is a reddish brown viscous liquid, having the honey comb structure of the shell of cashew nut obtained from cashew tree. It contains Anacardic acid 80.9% and Cardol 10-15% and small amounts of other materials notably the methyl derivatives of cardiol under natural condition. CNSL extracted with low boiling petroleum contains Anacardic acid 90% and Cardol 10%.

Using cashew nut shell liquid, novel and cheaper liquid crystalline polyester has been synthesized that can substitute for polymer fibres and films in specialty applications. Liquid crystalline (lc) polymers have attracted much attention in recent years because of their potential use as high performance materials. CNSL is used in the manufacture of dark coloured paints and enamels. Paints and varnishes made from CNSL have superior properties than those of conventional oils or synthetic resins. Varnishes resistant to water and gasoline have been made by incorporating sulphur in CNSL. Lacquers developed from CNSL could be used for insulation, protective or decorative coatings for furniture, buildings, automobiles, etc. The films have toughness and elasticity, excellent gloss and superfine adhesive qualities. The dried films are superior to those of ordinary oil paints in respect of resistance to oils, grease moisture and chemicals. Cashew lacquers are cheaper than ordinary oil varnishes.

Electrical Insulating varnishes are obtained by treating CNSL with formaldehyde and compounding the resulting material with pure phenolic resin varnish or alkyd resin in suitable proportions. Films of those materials are water and chemical resistant and can be used as insulating varnished with high electrical resistance and as bobbin enamels and laboratory table tops. Cashew polymers react with formaldehyde to give a rubbery gel, which can be used as a cement hardening agent that would be immune to acids and alkali reaction. It can be used for cementing floors exposed to chemical attack.

CNSL modified by heating at 160 °C. in the presence of certain accelerators give stoning enamels that are resistant to alkali and acid solutions, mineral and fatty oils and various organic solvents. Coating compositions possessing insecticidal properties are obtained by adding DDT, Gammexane etc., to CNSL

or chlorinated CNSL after treatment with Formaldehyde gums and resins and drying or semi-drying oils. Apart from the polymeric products, CNSL forms the basic raw material for a vast number of industrially important chemicals and chemical intermediates. Chlorinated products of cardanol and hydrogenated cardanol are found to have pesticide action. The various components of cardanol can be suitably modified to obtain emulsifiers and surface active agents, dyestuffs, antioxidants, plasticizers, stabilizers, accelerators, curatives, reclaiming agents and ion-exchange resins.

Chemistry of Tea

Tea shoot, contains a full complement of enzymes, biochemical intermediates, carbohydrates, proteins and lipids. In addition, tea shoot is distinguished by its remarkable content of polyphenols and methyl xanthines (caffeine and other purines, such as theobromine and theophylline). Popularity of tea as a beverage may be due to the presence of these two groups of compounds which are mainly responsible for the unique taste of tea, in addition to various compounds associated with tea aroma. Chemical composition of tea shoot varies with agroclimatic condition, season, cultural practice and the type of material.

Flavanols, flavonol glycosides, polyphenolic acids and depsides put together are referred to as total polyphenols and make up about 30% of the dry weight in a tea shoot. Flavanols or catechins are the major compounds that are oxidisable in the tea leaf. (-) epigallo catechin (EGC) and (-) epigallocatechin gallate (EGCG) are the predominant catechins present in tea leaf. The catechins are located in the cytoplasmic vacuoles and play a significant role during fermentation.

The enzyme polyphenol oxidase plays a key role in tea fermentation; it is present in chloroplasts. Polyphenol oxidase (PPO) has remarkable specificity for the ortho-dihydroxy functional group of the tea catechins. In intact plant, the enzyme is not in contact with the substrates, flavanols. The idea behind fermentation is to bring the enzyme and substrate together in the presence of oxygen by rupturing the membrane so that polyphenols can diffuse into the cytoplasm. As a first step during fermentation, the catechins are oxidised to highly reactive, transient orthoquinones by PPO. The quinones, thus derived from a simple catechin and a galocatechin, dimerise to produce theaflavins which are orange-red substances

that contribute significantly to astringency, briskness, brightness and colour of tea beverage. Theaflavins comprise 0.3 to 2.0% of the dry weight of black tea. Theaflavins of black tea comprise a number of fractions namely theaflavin, theaflavin monogallate and digallate, epitheaflavic acid and isotheaflavin. As the gallation increases the astringency also increases and the proportions of theaflavin fractions present in black tea depend upon the method and conditions of manufacture.

Quality of tea is determined by the presence or absence of chemical compounds which impart colour, briskness, brightness, strength and flavour in the infusion. Majority of the chemicals imparting quality are produced during processing of the tea leaves. Biogenesis of such precursors is influenced, on one hand by the genetic and environmental factors which cannot be controlled and on the other by the cultural practices adopted in the field as well as by the conditions of processing, which can be controlled. Though biochemical changes start immediately after plucking (the crop shoots) the precise changes required for quality start from withering onwards.

Theaflavins are orange red substances that contribute significantly to the astringency, briskness, brightness and colour of the tea beverage. TF of black tea comprise a number of fractions namely, theaflavin, theaflavin monogallate and digallate, epitheaflavic acid and isotheaflavin. Thearubigins are complete condensation products of oxidised catechins with theaflavins. Together with HPS, TR contributes to the colour, mouth feel and body of the tea liquor. Caffeine is relatively a stable molecule and is a direct stimulant of the central nervous system. Together with TF imparts briskness to the tea liquor. High levels of caffeine indicate a good leaf standard. Caffeine decreases with the maturity of the crop shoots. Volatile flavour constituents, in addition to the biochemical constituents that give the tea its unique taste, black tea is also well known for its characteristic aroma. Terpenoids and amino acids degrade to produce linalool, phenyl acetaldehyde, phenyl ethanol and methyl salicylate which contribute to desirable aroma of tea.

Black tea also contains minerals such as calcium, phosphorus, iron, sodium potassium and vitamins (A, B1, B2, Niacin & C) besides the biochemical constituents such as amino acids and soluble sugars. Polyphenols work out to about 15-20% in the black tea and it comprises the catechin fractions. Compared to black tea, green tea has a higher content of

polyphenols, almost around 25-30% on dry weight basis. All the above constituents may vary in their content according to the type of tea plants, environment, agronomic practices, pest & disease incidence and manufacturing practices.

Tree leaf contains 25% dry weight of flavanils, 15% protein, 13% polysaccharides, 7% sucrose, 5% each of phenolic acids, 4% amino acids, 3% each of flavanols.

Table 4: Traditional Health Claims for Tea.

Traditional claims	Possible scientific basis
Improved blood flow	Vasodilatation and decrease platelet activity
Elimination of alcohol and toxins	Increased activity of phase I and phase II enzymes
Clear urine and improve flow	Diuretic affects
Relieves joint pain	Anti-inflammatory activity
Improved resistance to diseases	Prevention of cancer and coronary heart disease

Chemical reactions during the manufacture of green, oolong, and black teas are responsible for the development of their respective colours and flavours. During tea fermentation the colourless catechins of green tea are converted to a range of products of orange-yellow to red-brown colour through a series of oxidative condensation reactions and numerous volatile flavour constituents are formed. These changes are reflected in the red-amber colour, reduced astringency, and more complex flavour of black tea beverage.

Chemistry of Coffee

The composition of coffee varies with the species and with the step in the line. The following sections deal with the main components, caffeine, carbohydrates, chlorogenic acids, lipids, other nitrogenous compounds, volatiles, and melanoidins, and include the transformation processes.

The first compound covered here is caffeine, associated even by name to our subject, coffee. Caffeine is a nitrogenous compound that is not affected by the central process in coffee chemistry, roasting.

Caffeine biosynthesis takes place in the leaves and in the pericarp, the outer part of the fruit. In aged leaves the caffeine content is lower. Chemical Composition of crops is highly variable. Food and feed crops exhibit a range of chemical compositions.

Caffeine is a physiologically active compound, and the human exposure to it after a cup of coffee is of interest. Some general calculations can be made: an aqueous extraction at regular brewing conditions

transfers the caffeine almost completely into the beverage, a cup of 100 ml with a brew of 55 g/l of roast and ground coffee, has full compliment of its caffeine.

Chemistry of Spices

Spices are woven in to history of nations. Spices impart colour, Aroma, taste to food preparations and some times mask undesirable odours. The volatile oil from spices give the aroma and oleoresins impart the taste.

There is a growing interest in the theoretical and practical aspects of inner biosynthetic mechanisms of the active principles in spices as well as in relationship between biological activity and the chemical structure of these secondary metabolites. The antioxidants properties of herbs and spices are of particular interest in view of the impact of active modifications of low protein, lipoproteins, cholesterol in the development of atherosclerosis. A range of biochemical compounds in herbs and spices have been studied for the anticarcinogenic properties in animals. Some of the chemicals in the major spices are as follows.

Black pepper: Caryophyllene rich oils poses sweet floral odours where as oils with high pinene content gives turpentine like off odours. The major compounds in fresh pepper are *trans*-linalool oxide and α -terpineol, whereas dry black pepper oil contains α - and β -pinenes, d-limonene and β -caryophyllene as major components.

Cinnamon : Cinnamon possesses a delicate, spicy aroma, which is attributed to its volatile oil. Volatile components are present in all parts of cinnamon and cassia. They can be classified broadly into monoterpenes, sesquiterpenes and phenylpropenes. The oil from the stem bark contains 75% cinnamaldehyde and 5% cinnamyl acetate, which contribute to the flavor.

Cardamom : In cardamom, the oil has very little mono- or sesquiterpenic hydrocarbons and is dominated by oxygenated compounds, all of which are potential aroma compounds. While many of the identified compounds (alcohols, esters and aldehydes) are commonly found in many spice oils (or even volatiles of many different foods), the dominance of the ether, 1,8-cineole, and the esters, α -terpinyl and linalyl acetates in the composition make the cardamom volatiles a unique combination.

Clove: The minor constituents like methyl amyl ketone, methyl salicylate, etc., are responsible for the characteristic pleasant odour of cloves. The oil is dominated by eugenol (70–85%), eugenyl acetate (15%) and *b*-caryophyllene (5–12%), which together makes up 99% of the oil. *b*-Caryophyllene, which was earlier thought of as an artifact of distillation, was first reported as a constituent of the bud oil by Walter (1972).

Nutmeg: The volatile oil of nutmeg constitutes the compounds: monoterpene hydrocarbons, 61–88%; oxygenated monoterpenes, i.e. monoterpene alcohols, monoterpene esters; aromatic ethers; sesquiterpenes, aromatic monoterpenes, alkenes, organic acids and miscellaneous compounds. Depending on the type, its flavour can vary from a sweetly spicy to a heavier taste. The oil has a clove like, spicy, sweet, bitter taste with a terpeny, camphor-like aroma.

Star anise: In star anise, the presence of a prenyl moiety in the phenyl propanoids plays an important role in antitumour-promoting activity. Hence, the prenylated phenylpropanoids might be valuable as a potential cancer chemo preventive agent.

The spices have many health benefits namely carminative hypolipidemic, antidiabetic, antilithogenic, antiinflammatory, antioxidant antimutagenic and anticarcinogenic properties. Piperine (1-piperoyl piperidine) in black pepper is shown to possess bioavailability enhancing activity with various structurally and therapeutically diverse drugs. This property of piperine may be attributed to increased absorption, which may be due to alteration in membrane lipid dynamics and a change in the conformation of enzymes in the intestine.

The volatile oil from cardamom is a potential grain protectant by killing various life stages of the stored product insects attacking wheat, viz: *Tetropium castaneum* and *Sitophilus zeamais* Motschulsky, via contact and fumigant action. Cinnamaldehyde in cinnamon has strong insecticidal activity against *Acanthoscelides oblectus* and antifeedant activity against *Ceratitis capitata*, a pest causing damage to fruit crops.

Nutmeg oil also possesses strong antibacterial, antifungal and insecticidal properties. Myristicin, which imparts hallucinogenic properties, is also reported to be an effective insecticide, while the lignin

types of the constituents in the nut are anticarcinogenic Larvicidal properties, against second stage larvae of *Toxocara canis*, are also reported in mace.

Chemistry of Rubber

All rubber like materials are polymers, which are high molecular weight compounds consisting of long chains of one or more types of molecules, such as monomers. Vulcanization (or curing) produces chemical links between the loosely coiled polymeric chains; elasticity occurs because the chains can be stretched and the crosslinks cause them to spring back when the stress is released. Natural rubber is a polyterpene, i.e., it consists of isoprene molecules linked into loosely twisted chains. The monomer units along the backbone of the carbon chains are in a *cis* arrangement and it is this spatial configuration that gives rubber its highly elastic character. In gutta-percha, which is another natural polyterpene, the isoprene molecules are bonded in a *trans* configuration leading to a crystalline solid at room temperature. Unvulcanized rubber is soluble in a number of hydrocarbons, including benzene, toluene, gasoline, and lubricating oils.

Rubber is water repellent and resistant to alkalis and weak acids. Rubber's elasticity, toughness, impermeability, adhesiveness, and electrical resistance make it useful as an adhesive, a coating composition, a fiber, a molding compound, and an electrical insulator. In general, synthetic rubber has the following advantages over natural rubber: better aging and weathering, more resistance to oil, solvents, oxygen, ozone, and certain chemicals, and resilience over a wider temperature range. The advantages of natural rubber are less build up of heat from flexing and greater resistance to tearing when hot. Natural rubber is one of nature's unique materials. The Native Americans of tropical South America's Amazon basin knew of rubber and its uses long before Christopher Columbus's explorations brought it to the attention of Europeans. The Indians made balls of rubber by smoking the milky, white latex of trees of the genus *Hevea* that had been placed on a wooden paddle, to promote water evaporation and to cure the substance.

Crude rubber is primarily hydrocarbon in nature. In 1826 English chemist Michael Faraday (1791–1867) analyzed natural rubber and found it to have the empirical (simplest) formula C_5H_8 , along with 2 to 4 percent protein and 1 to 4 percent acetone-soluble materials (resins, fatty acids, and sterols). In 1860 English chemist Charles Hanson Greville Williams (1829–1910) confirmed Faraday's analysis and in 1862 distilled natural rubber to obtain the pure monomer, which he named **isoprene**. He determined isoprene's vapour density and molecular formula, and he showed that it polymerizes to a rubbery product—an observation that led to the notion that rubber is a linear polymer of isoprene, proposed in 1910 by English chemist Samuel Shrowder Pickles (1878–1962).

The molecular weights of rubber molecules range from 50,000 to 3,000,000. Sixty percent of the molecules have molecular weights of greater than 1,300,000. The repeating unit in natural rubber has the *cis* configuration (with chain extensions on the same side of the ethylene double bond), which is essential for elasticity. If the configuration is *trans* (with chain extensions on opposite sides of the ethylene double bond), the polymer is either a hard plastic (naturally occurring gutta-percha, obtained from the leaves of *Palaquium*, a species of sapotaceous Malaysian and East Indies trees) that was used for wire and cable coating during the nineteenth century; or a substance like gutta-percha (balata, obtained from *Mimusops globosa*, trees native to Panama and South America), used for modern golf ball covers.

Chemistry has a greater role to play in plantation crops. Understanding chemistry of plantation crops are very essential right from seed development and germination to end product and also to go for value addition, product diversification and by product utilization. The use of plant growth regulators, soil fertility management through organic and inorganic manures and fertilizers, bio fertilizers, effect of heavy metals on the yield and quality of crops and the chemical pollution caused through use of fertilizer, herbicide, pesticide particularly in tree crops need to be understood very clearly for a better crop production.

Sri Lankan Foods: Glycaemic indices and physico-chemical factors affecting the glycaemic indices

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Introduction

Increased intake of highly refined carbohydrates (sugars, starchy foods made using highly milled grains) is identified as one major factor for the increase in nutrition related non communicable diseases (NCDs) such as diabetes, cardiovascular diseases and some cancers which have become the major causes of mortality, morbidity and disability among Sri Lankans.

In this context glycaemic index (GI) which ranks starchy foods according to their potential to raise the blood glucose level is important as this reflects how the food carbohydrates affect the glycaemic response. GI concept is applied to foods providing 15g-20g or more of glycaemic carbohydrates (glucose, fructose, galactose) per portion and is determined by consuming food portions containing 50 g of digestible carbohydrates. Thus GI reflects the glycaemic response of different foods to the same amount of carbohydrate; thus the quality of the carbohydrates in that particular food. Depending on the blood glucose raising potential, carbohydrates rich foods are classified as low ($GI \leq 55$), medium ($56 \leq GI \leq 69$) or high ($GI \geq 70$) GI foods. GI values are also used to calculate the glycaemic load (quantity) of an edible portion of starchy food in a diet. GL is useful as sometimes the actual carbohydrate load from a normal portion is not similar to a 50g digestible carbohydrate containing portion. The actual blood glucose levels are determined by the GI of the carbohydrate (quality) and quantity (GL) of the carbohydrate in edible portion.

Low GI foods are digested slowly and release glucose gradually into blood which facilitate higher extraction of carbohydrates from liver and periphery and gives rise to low glucose peaks which in turn demands a low insulin dose compared to high GI foods thus decrease the incidence of insulin resistance and development of intermediate risk factors such as obesity, hypertension, the key factors responsible for development of above mentioned nutrition related NCDs. Consumption of low GI/GL diets has shown to decrease obesity, lower the risk of diabetes type 2, reduce insulin resistance and risk of coronary heart diseases and certain cancers.

As Sri Lankan staple is a carbohydrate rich source be it rice, bread or any food made with either flour providing the highest amount of energy in our diets (55- >70 %) their influence on postprandial glucose concentration (GI & GL) is a major factor that would help medical practitioners, dieticians and nutritionists as well as general public in manipulating and controlling the dietary carbohydrates and thus the glycaemic response following a meal and also selection of foods for frequent consumption.

Glycaemic indices of Sri Lankan foods

Proximate compositions (digestible carbohydrate, protein, soluble dietary fibre (SDF), insoluble dietary fibre (IDF), fat) *glycaemic index (GI) and glycaemic load (GL) of edible portions of more than 50 food items of Sri Lankan origin, of which some are given in Table 1 which are available to the public at <http://www.nrc.gov.lk/SAG/index.html> have been determined.*

When considering rice, parboiled Nadu had the lowest GI (40) indicating the suitability of parboiled rice in the dietary regime of individuals with chronic NCDs. Red raw rice with "kiri hodi" and white raw rice with 'pol sambol' had the highest GI. Red raw rice given as a mixed meal, keera samba and basmati (white and red) had GI in increasing order. GL for a normal portion size of red basmati was lower when compared to the white basmati variety we studied due to high fibre. Increased dietary fibre (DF) content had shown to reduce the GI of Sri Lankan rice mixed meal. Effect on lowering GI was by both the increased quantity and use of different sources of fibre (*kohila*) in rice meals. Rice mixed meal had the most desirable GL indicating the suitability of a mixed meal in controlling the glycaemic response. However, the quantity of rice (starchy base) has to be taken into account when consuming rice. Beneficial effect of the meal would not be seen if a large rice portion is consumed as part of the meal. When the GI and insulin index of red rice mixed meal were determined in diabetic individuals, higher values (64; medium GI) than obtained with healthy individuals were observed but indicating good glycaemic control.

Table 1: GI, GL for 50g digestible carbohydrate portion, GL for normal edible portion and proximate compositions of some Sri Lankan foods

Food/meal	GI	GL for the portion given for GI determination	GL of a normal portion	Carbohydrate % FW	Protein % DM	Fat % FW	Total dietary fibre (IDF+SDF+UC#) % FW
RICE							
Red raw rice+kirihodi only	80	40	40	21.5	3.0	5.0	2.3
Red raw rice+gotukola+dhal+egg+kirihodi*	47	23	16	14.3 (24+12)	4.8 (3.3 + 8+12.4)	6.1 (0.7+11+11.7)	4.3 (4.6+5.3+7.5)
Red raw rice+gotukola+dhal+egg+kirihodi+kohila sambol *	43	21	21	14.2 (24+12+ 2.5)	4.8 (3.3+8+ 12.4)	6.1 (0.7+11+1.1+ 11.7)	4.3 (4.7+5.3+7.5+6.4)
Parboiled Nadu+pol sambol	40	20	20	25	3.0	1.0	4.0
Keera samba+pol sambol	66	33	33	22	3.0	1.0	1.6
Samurdhi basmati+ pol sambol	73	37	>37	33	4.0	1.0	1.7
Red basmathi+pol sambol	73	37	27	19.1	1.3	0.6	1.9
Sudu kekeulu+pol sambol	81	40	40	27.3	1.2	1.1	1.4
Sudu kekeulu mung milk rice	55	28	28	12.0	3.5	2.0	5.3
BREAD							
White sliced bread(Prima)	77	39	20 (4 slices)	44	7.2	2.8	3.4
Whole meal bread(brown)	76	38	16 (3 slices)	39	8.9	2.7	8.0
Whole meal bread/lentil curry*	61	30	19 (3 slices/ 100g curry)	22 (39+12)	8.3 (7.2+ 8)	6.8 (2.8+11)	6.7 (8+7.5)
CEREAL BASED FOODS							
Hoppers (rice)+lunumiris	90	45	> 45	41.8	6.6	8.4	3.5
Wheat roti (1:coco1)+ lunumiris	54	27	27	35.0	9.0	22.3	9.6
Kurakkan/wheat (3;2;1coco)	52	26	<26	33.2	12.2	21.8	18.4
Rice/wheat roti (1:1:coco2)+lunumiris	50	18	18	34.4	8.5	20.0	6.0
Attaflour roti (1:Coco1)+ lunumiris	51	25	25	33.4	15.2	16.6	11.3
Rice stringhoppers + egg +kirihodi+coconut sambol*	79	40	26	18.5 (31+0.4)	4.0 (3.5+3.9+ 12.4)	13.3 (1.2+39+ 11.7)	4.3 (3.4+14.2)
Wheat stringhoppers +egg+ kirihodi+coconut sambol*	72	36	24	18.5 (31+0.4)	6.2 (7+ 3.9+ 12.4)	13.3 (1+39+11.7)	4.3 (3.4+14.2)
Rice flour pittu (1:Coco 1)+ lunumiris	76	38.5	38.5	26.9	4.6	17.4	6.6
Wheat pittu (1:1Coco)+ lunumiris	75	37.5	37.5	32.0	8.2	15.1	6.7
Kurakkan pittu (1:coco1)	64	32	20	26.5	4.1	17.1	14.7
Godamba roti	81	41	<41	50.1	4.0	6.7	5.8
LEGUMES							
Chickpea	22	6	6	13.4	8.8	3.0	14.0
Cowpea	34	9	9	14.5	10.8	1.4	10.1
Mungbeans	47	11	11	14.4	10.0	0.9	9.7
TUBERS/STARCHY VEGETABLES							
Manioc + onion sambol	86	43	43	25.6	0.8	0.6	3 (1.7+0.7+0.6)
Jakfruit meal (boiled)* (Fruits & seeds)	55	28	13	10.5 (82+53)	1.4 (0.9+4.7)	2.4 (0.8+1.3)	4.2 (1.5+1.1+0.3)+ (7.9+3.2+8.0)

Breadfruit+coconut	47	12	<12	9.3	1.1	0.5	2.7
Rajaala (dioscorea) white /violet	52/48	26/24	19/18	12.5/12.5	5.9/9.2	0.2/0.3	1.9/2.5
BANANA							
<i>Kolikuttu</i>	46	23	6	26.5	-	2.1	9
<i>Embul</i>	46	23	4	23.2	-	1.4	8
<i>Anamalu</i>	50	25	7	17.9	-	2.4	7.2
<i>Seeni</i>	52	26	5	22.6	-	2.4	4.2
GREEN LEAFY PORRIDGES							
<i>Hathawariya</i>	37	9	9	4.9	0.5	2.2	0.6
<i>Heenbovitiya</i>	55	14	14	3.8	0.6	0.9	0.6
<i>Polpala</i>	32	8	8	4.3	0.4	1.7	0.6
<i>Wal koththamalli</i>	38	9	9	5.4	0.5	1.3	0.5

#UC-undigestible carbohydrate; SDF- soluble dietary fibre; IDF- insoluble dietary fibre; FW-fresh weight; DM-dry basis

*mixed meals: total carbohydrate / fat/ protein / fiber in the meal and in parenthesis % carbohydrate / protein / fat / fibre of different components of the meal

Bread (white, brown) consumed without any accompaniments had high GI and high GL. However, the actual portion size that a person could consume contained a less carbohydrate load (GL). Brown bread eaten alone elicited a high GI which when given with a dhal curry produced a medium GI causing the GI to decrease. Though the GL was high in all three varieties, the metabolic response (lower peak eliciting lower insulin response) to the same carbohydrate load was better in the mixed meal.

Above observations clearly indicated the importance of addition of other accompaniments to the carbohydrate staple as these would contribute to lowering of the GI by virtue of reducing the portion size of starchy staple and addition of other nutrients which helps in reducing GI.

GI and GL of hoppers was high and the portion size was considered not adequate by the participants. Thus the GL of hoppers would be much higher and is not a suitable food for daily consumption as this would induce a high insulin response. *Roti*, irrespective of the flour used in the preparation elicited low or medium GI. Among different *roti*, *kurakkan roti* elicited the lowest GL due to high DF which decreased the digestible carbohydrate in a portion and induced satiety. Irrespective of flour (red or white) used in preparation and when given with as many accompaniments as with red raw rice meal, string hoppers elicited a high GI and high GL which were similar to that of brown bread. Compared to string hoppers, rice mixed meal where the GL as well as the glucose peaking after the meal was lower produce a better metabolic response.

Pittu when prepared using wheat or rice flour elicited high GI and had a high GL even for a normal portion. When *kurakkna* was used in the preparation, GI and the GL both decreased due to the high DF which makes the normal edible portion smaller by inducing satiety and decreasing digestible carbohydrate. Ingestion of *kurakkan pittu* elicits a better glycaemic profile with a lower peaking. Addition of other accompaniments (curries) may lead to a further lower GL.

Among the many tubers studied, *raja ala* (Dioscorea), consumed as a traditional breakfast with coconut scrapings elicited low GI in contrast to manioc which gave high GI and contained more protein (9%) and polyphenols. In contrast to popular belief, jack fruit and breadfruit eaten with coconut as a meal elicited lower GI. Thus addition of starchy fruit vegetables as accompaniments in a meal will not contribute to a higher glycaemic response and is suitable in a diabetic meal.

Boiled legumes, chickpea, cowpea and *mung* beans when consumed as breakfast had low GI and constituted a low GL. Incremental increase in blood glucose was low leading to lower insulin demand. Incorporation of *mung* beans when making milk rice decreased the GI. Thus increased consumption of legumes should be encouraged as a healthy option among public. Porridge made with different green leaves elicited a low GI and low or medium GL and good satiety thus proving the health benefits of these in dietary management. Further studies carried out with diabetes induced rats have shown that *wal koththamalli* porridge to be superior in controlling diabetic

parameters and led to produce a marketable product.

Physico-chemical factors affecting the glycaemic indices

When considering only rice (not the meal) GI was not affected as the DF in whole grain is not adequate to cause an effect on GI and thus all rice varieties produced high GIs. Parboiled rice had high DF (14% DM) due to the processing (starch retrogradation) it is subjected and elicited low GI. Likewise when rice or bread is consumed as a meal or boiled legumes or *pittu* made with kurakkan had lower GI due to high DF. Dietary fiber delays gastric emptying and thus absorption of carbohydrates, increases satiety and contributes to decreasing GI. Our studies showed that DF content in Sri Lankan foods correlate negatively with GI indicating if the diet is properly formulated we might be able to add adequate fibre to have beneficial effects. Correlation was more significant with IDF than with SDF indicating that the SDF in our meals to be less. Studies also showed the benefits of both the increased quantity and different sources of fibre in rice meals. Impact of protein on GI was not apparent when food groups with low protein such as green leafy porridges were considered. Nevertheless foods such as legumes, mixed rice meal or *mung* milk rice whose protein content was high had a GI lowering effect.

Fat in a portion given to determine the GI had no correlation with GI clearly indicating that fat in our diets is moderate and thus major source of energy is carbohydrates and therefore to reduce the incidence of NCDs more attention needs to be paid to the carbohydrates in our diet.

Moisture in a food is a major factor that determines the portion size. Higher the moisture in food lower the edible portion size. This was seen with different rice varieties where the moisture increased in order of white *basmati* < *nadu* < *samba* and a 50g carbohydrate containing portion increased as 150g > 200g > 225g where the participants said that *basmati* portion was inadequate. Moisture therefore was seen to be a major factor in determining the GL.

We proved that wet processed foods such as *pittu*, rice, string hoppers, manioc tends to have a higher GI compared to dry processed food such as *roti*. This was due to increased disintegration of the starch granule and gelatinization of the starch which was apparent when the starch granules of raw wheat flour and *roti* and *pittu* were compared. A clear correlation between starch granule destruction and GI was observed. Thus excessively wet processed foods may lead to higher

glycaemic responses as starch is more available for enzymic attack. Legumes and *raja-ala* were exceptions where starch granules were inside a protein matrix which delayed digestion of starch. Effects due to wet processing of the starchy staple can be overcome to a certain extent by addition of foods rich DF and protein as seen with rice only and mixed rice. If the processing is excessive as in string-hoppers this may not be possible and it would be better to consume these foods less frequently.

Effect of particle size of flour on GI was illustrated when two flour samples of *kurakkan*, one made using the stone-grinder and other industrial mill were used to make *roti* and *pittu* whose compositions were same except for the flour. Significant reduction in GI was observed with food made with stone-ground flour and was due to the higher particle size distribution in stone ground flour compared to industrially milled flour. A similar observation was made when porridges were made industrially by extruding.

Since GI will be a reflection of all these factors when selecting food/preparing meals careful selection of foods and combination of high and medium or low GI foods can be used to control the energy intake and the glycaemic control. This knowledge would help nutritionists, dieticians or individuals to plan meals utilizing low or medium GI regularly or to mix high GI foods with low or medium GI foods so the glycaemic responses can be brought lower and help prevent/reduce the increasing incidence of NCDs.

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Applications invited for Graduateship (36th Intake) and Diploma in Laboratory Technology (DLTC) (41st intake) Programmes in Chemistry to be conducted on weekdays as well as weekends

Applications are invited from those having three GCE (A/L) passes in recognized scientific disciplines (including Chemistry) or approved equivalent such as Diploma in Chemistry, or awaiting results. Admissions to the programme is possible for those having **passes** in the **Diploma in Laboratory Technology (DLTC) programme** conducted by our Institute. Prospective BSc Graduates from recognized universities can also apply directly for admission to the last two years of the Graduateship programme from September 2013 (2013-2015) while they are in the third year of a BSc Programme of a recognized University.

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Application forms and further details are now available at the Institute office and on our website www.ichemc.edu.lk

ROLE OF CHEMISTRY IN SUSTAINABLE AGRICULTURE

Thursday, June 20, 2013

Venue: Sri Lanka Foundation Institute, Colombo 07

Keynote Address

Agriculture for Greater Economic Growth

Mr B R L Fernando

Chairman, CIC Group of Companies

The theme “*Agriculture for Greater Economic Growth*” reflects the following:

- a) 44% of Sri Lanka land mass of 6.5 million hectares is suitable for agricultural production
- b) 80% of Sri Lankan population is rural and 75% of this number is involved in agriculture
- c) Agriculture provides employment to around 30% of the workforce.
- d) The aquatic resource base includes a territorial sea of 21,500 km² and an exclusive economic zone of 517,000 km².

The above possibly creates the ambience that economic growth could be enhanced by these resources. Agriculture's share of GDP has been on a slide over a long period and currently stands at a mere 11%. The question then is can agriculture enhance its contribution and change its current trajectory. It is difficult to believe that this is possible but agriculture revenue and profits can certainly be increased substantially. Again agriculture would to a large extent depend on the area available for production and the efficient utilization of these resources.

Looking at the composition of agriculture it encompasses a wide range of crops, herbs and fruits that we harvest and in a wider sense includes forestry and fisheries, both fresh water and salt water. The fishing industry, the largest area available for utilization is really in the ocean and thus fisheries is the single largest source for enhancing economic growth. Sri Lankans are no doubt aware of the numerous conflicts that are going on within our economic zone, with poaching by fishing fleets from a number of countries. There was an old belief that fish around Sri Lanka died of old age. Is this really true? Have we enforced adequate safeguards to ensure that the spawning grounds of the fish around the island are safeguarded? The use of unauthorized net types and explosives - do they carry adequate penalties and strict enforcement? Are we conscious on the need to prevent pollution of the waters which would be a potential threat to the marine life? Thus in addition to providing boats, fishing gear and technology there

remains a large number of issues which needs resolution in terms of sustainability. If these are addressed and investments facilitated for an aquaculture industry perhaps we could see a substantial improvement in the fishing subsector and hence agriculture's contribution to GDP. The Maldives has focused on the need to safeguard their fish resources which are worth emulating. They have -

- Adopted ecologically sustainable fisheries management measures based on best scientific evidence available, to ensure the attainment of maximum economic and social benefit from the sector while conserving resources for future generations.
- Formulated and implemented a Code of Conduct for responsible fisheries to ensure effective conservation, management and development of fishery resources, with due respect for ecosystem and biodiversity.
- Also established an effective technology-based system for Monitoring, Control and Surveillance (MCS) to ensure that all fishing activities are carried out in a manner consistent with national legislation and in conformity with international laws.
- Management responsibilities too have been vested at community level with the aim of Government Institutions and communities working together to develop conservation and management of the fisheries sector.

The 2.7 million hectares of agricultural and marginal land

In a recent presentation by Dr. Indrajith Coomaraswamy at the discussion on Economic Policy and the need for Reforms organized by the Liberal Party of Sri Lanka. He stated – I Quote “a major area of concern is our overall productivity. Agricultural productivity is just about half of that of Thailand. The government has recognized the sector's importance as it absorbs one third of the labour force but government

must also register the fact that it only accounts for 11% of GDP. This means that the productivity in agriculture is only one third of the national average which is anyway very low” Unquote. This emphasizes the need to increase productivity.

When the government focuses on increasing production it is also need to focus on markets. It is a common theme in Sri Lanka where, for example, tomato farmers in the Matale area produce a surplus at a particular point of time which they are unable to sell. Will an increase in production exacerbate this situation? Similarly we have seen this has happened with vegetable farmers who have dumped large volumes of vegetables as they were unable to sell. In addressing this issue we need to take heed that globally food production needs to be increased by around 70% by the year 2030 and that the era of cheap food is said to be over. This is in the face of diminishing agricultural land as a result of conversion to urban utilization.

The above underscores the need for better planning and the availability of information to the farming community about market prices and projected market prices based on production after the collation of information of crops planted in different areas. This means that evaluation of the potential crops in different ecosystems be researched and farmers in each area kept abreast of what the farmers in other areas, both in the vicinity and in different Provinces are cultivating. Estimates of the time during which the produce would come to the market could be used to project the potential movement in prices. Some work in this area is being done by the University of Colombo in collaboration with Prof. Athula Ginige, Professor of Information Technology - School of Computing & Mathematics, University of Western Sydney, Australia. This kind of information will ultimately result in the most productive crop for an ecosystem being cultivated of course with the possibility that other areas may leverage early or late seasons where price advantages could be worked out. Information should be available to farmers on a commercial basis thus inculcating in their minds that these decisions are commercial and therefore, entirely theirs and no one is obliged to buy the entirety of their crop or guarantee prices. Certainly some safeguards would be useful but that should not be the reason why different crops are cultivated.

Looking back at agriculture up to the 19th century the cultivation process did not have constraints of land. Arable areas continued to be expanded to meet increasing demand for food. But with the population growth, increased trade in agricultural commodities and

availability of new land suspect, the need for improvement in productivity became apparent. With this, agriculture changed in the first half of the 20th century propelled by the development of cheap fertilizer, access to plenty of water and chemicals to control both weeds and insects. Mendels Genetic theory was fine-tuned and contributed to the development of improved seed which in turn propelled productivity. These inputs enhanced agricultural productivity four or five fold by the end of the 20th century. Sri Lanka was no exception. The challenges today are entirely different. The arable land area is diminishing, water which was plentifully available is now in short supply, cheap fertilizer is no longer an option as the base raw material for fertilizer which is petroleum has recorded substantial increases in price. Further pesticides are under intense scrutiny by authorities. A major factor which drives the need for improvement of productivity is however, the increased demand for food and food security. Global warming which threatens food production however, projects the scourge of malnutrition and famine which could once again rear its ugly head.

Numerous studies and allegations leveled at the supply chain in the agricultural sector, sometimes unfairly with poorly collected and analyzed data lacking remedial measures and to approach these issues has been a huge problem. For example, the recent incident of attribution of the chronic kidney disease which was due to arsenic the finger was pointed at the pesticide industry. Similarly last week it was reported that the Sri Lankan rice have the second highest level of cadmium in a study of most rice producing countries and Bangladesh is said to be ahead of us. Over the last year there was an impact of climatic change in the paddy sector where the large farms have been operated. The seasons have witnessed minor shifts but this has impacted the paddy sector as the window for harvesting, which is normally a dry period has had inordinate rain. Then again excess rain has fallen on the crop at the time of planting submerging large tracts of paddy and destroying vegetables. The impact of these climatic change issues in addition to higher temperatures has had an adverse impact on production. Taking paddy as an example, overall production which was over 4 million tons in 2011 has dropped by 10-15% and surpluses for which we did not have adequate storage facility has mercifully been reduced.

There are several macro issues which need to be addressed in order to improve agriculture's contribution to economic growth. The first issue is

land. The fragmentation of land has become a major problem. For example average landholding in the paddy sector is less than an acre. In an economy where per capita income is projected to be at US \$ 4,000/- within the next five years, how will the farmer with such a small landholding make up his income? The cost of cultivation of an acre currently is marginally around Rs. 55,000/- and the fertilizer subsidy reduces this to around Rs. 45,000/-. Gross revenue assuming 100 bushels per acre which works out at a little over 5 tons per hectare would be Rs. 67,000/- leaving a margin to the farmer of Rs. 22,000/-. Our national average of paddy production is around 4.2 tons which differential would impact on revenue by nearly Rs. 10,000/-. Therefore, farmers income could be anything between Rs. 10,000 – 15,000/- per season, i.e. Rs. 30,000/- per year which is a mere US \$ 240/- per annum. One needs to enhance this by a further US \$ 350/- taking cognizance of the fact that cultivation costs includes labour wages. In this scenario will farmers continue to cultivate their land? Perhaps they would if they have no other option.

The second issue is the availability of labour flowing from potential earnings by the farmer. The availability of labour is a major issue. The shortage of labour needs to be addressed with continuing mechanization of repetitive backbreaking work. Mechanization is not possible with the current landholdings. All of these issues point in favour of consolidation of land for very little thought has been given. In fact the converse is true as even the available larger blocks of land continue to be fragmented.

In addressing each one of these concerns and in developing remedies the best option available would be to detail how we have addressed each of these issues in the farms that CIC manage. Firstly, look at the question of total revenue of the farm and also revenue per acre. Accordingly CIC have tried to optimize land utilization, by undertaking different activities in the highland area and focusing on seed paddy production in the lowlands which was our mandate. In the highland areas we applied rain water harvesting methodologies and converted the land mass in to different zones depending on soil condition as well as availability of water. CIC developed an integrated model of horticultural products, animal husbandry initiatives and also enhanced the growth of nitrogen fixing plants with sustainability in mind. With the optimization of land use we have different revenue streams from fruit, vegetables, milk, chicken, eggs, agro tourism and training.

In the paddy sector CIC undertook an accelerated programme for developing new hybrid rice varieties with export potential, keeping an eye on the high price realization by rice varieties such as basmati. We have developed a red basmati type rice which finds favour in export markets yielding a price of little over a dollar per kg. We have got a number of other rice varieties in the pipeline with improved fibre, mineral and glycemic indexes. We have also developed a 90 day variety with potential to yield over 10 tons per hectare. Currently we cultivate 1,500 acres of paddy per annum. Our average yields per hectare have varied but under good conditions we have produced 8.2 tons which is virtually double the national average and easily the highest yield in the region. As a seed producer we continue to grow varieties as required by the seed market and not necessarily the high yielding varieties. This has depressed overall yields. We have thus pursued both volume and price which has enhanced revenue.

The next issue is water management. In our highland crops we now focus on profit per litre of water. This methodology has helped us to improve water use. For example – CIC have cultivated around 50 acres of pineapple at Pelwehera, in the past. The crop was impacted by a drought as we were unable to put in adequate water. Consequently, fruit size dropped from 1300 gm to 700 gm which directly impacted on our sales and bottom line, as revenue from pineapple per acre is substantial in comparison to other crops. After numerous trials on water management we have now formalized the protocol wherein we could manage the pineapple with a little over 20% of the water that was required earlier. With this initiative we are once again ready to roll out a cultivation programme for pineapple in the dry zone. Dwelling into water management CIC group of companies were pioneers in the development of Sprinklers and Drip Irrigation methodologies having acquired knowhow from the success models operated by Israeli Farmers.

We have also been conscious that irrigated fields do not respond to water in the same way it responds to rainfall. If you are a gardener you will notice how plants rejuvenate themselves when a rain comes down. We have now developed an option to improve the absorbability of water by breaking down the lattice structure of delivered water to mimic natural spring water. The lattice structure in drip systems is said to have between 12-15 molecules whereas spring water would be 4-6 molecules. This perhaps explains the tea brewed in Nuwara Eliya would be different to the

chorine packed water used for brewing in Colombo. Current experiments are with simple methodologies to improve the absorbability of water by disrupting the lattice structure. The higher temperatures will have an impact on the carbon availability of water which needs to be addressed in a different way. Scientists need to look at this matter. The efforts in water management in paddy has yielded around a 25% saving in water which is substantial considering it takes nearly 6 tons of water to produce one kilo of rice. Consequently, we have been able to cultivate near 60% of the land in each Yala season, contributing to enhanced surpluses.

The plants are dependent on non-mineral nutrients and mineral nutrients. The fertilizer subsidy is geared to the macronutrient component of mineral nutrients. The impression has been created in minds of the farming community that feeding plants with these macronutrients is the tool for improving productivity. The fertilizer utilization efficiency in this country is less than 30%, thus of the 210 kg of fertilizer we apply in an acre of paddy, only 70 kg is said to be used by the plants using a utilization model. The balance 140 kg goes waste polluting our waterways and rivers virtually poisoning drinking water. The nitrate content of ground water in some areas is reported to have reached near toxic levels. The fertilizer subsidy amounts to nearly 1% of our GDP and the continuous misuse does have an adverse reaction on the environment. In the paddy sector we have addressed this to some measure and continue numerous trials to reduce application of fertilizer, as we did not receive the benefit of subsidized fertilizer.

When we took over the Hingurakgoda farm the organic content in the fields was less than 1%. This is to be expected considering that we are a medium intensity ultraviolet light country, coupled with heavy rainfall, both of which tend to destroy and wash away organic matter. In the farms under our control organic matter is now a little over 3%. We have reaped the rewards in that our production as stated earlier is over 8 tons per hectare. In order to enhance the organic content in the soils we have developed a dairy herd. Initially our focus was only the cow dung from which we generated around 2,000 tons of compost per annum. Looking at the revenue potential we have now focused on milk production as well. Our average yield per buffalo when we started was a mere 2-3 litres, today our average yield is around 8.5 litres. We continued with a vigorous artificial insemination programme and have consequently improved the genetic makeup of our herd. Some of the new animals now yield 14 litres per

day and we project that we would take our average milk yield to 12 litres per animal in the short term. We are focusing on a temperature management, nutrition management program and now to grow substantial areas of high quality feed material. The dairy will now be a major revenue stream for us in the future while contributing to better soil management.

Again in the rice area we have continued to carry out numerous trials to develop a different methodology for the delivery of fertilizer to the paddy. Here we have taken note of the Washington State University study where by increasing photosynthesis they were able to produce 35% more grain and the findings by the Michigan State University that foliar feed is 8-10 times more effective in terms of speed with which nutrients are utilized. The world has seen tremendous improvements in surfactant technology which has been applied to the Pesticide industry and unfortunately not the fertilizer industry because of the cost proposition. Scientists should look at the transfer of fertilizer via the leaves which improves fertilizer uptake.

Finally the very contentious area is the pesticides. The global pesticide industry has taken giant steps in the development of molecules which have very specific application focus, unlike the earlier generation of molecules which were wide spectrum, quantities applied too has seen dramatic reductions. Unrecommended use of pesticides by various individuals however, remains a huge problem. The industry continues to spend time and a lot of effort with education programmes on 'Dos and Don'ts and application methodologies. But these continue to be violated due to poor infrastructure such as monitoring services. Facilities for testing residual pesticides in food are either non-existent or ineffective. Consequently, some persons tend to spray Pesticides at inappropriate times violating recommendations even though harmful to the consumer. Sometimes diluted solutions, sometimes greater concentrations are used with adverse results. Modern agriculture is built on the management of pests as well. Therefore, pesticides are an important component. The improper use of pesticides needs greater inputs in addition to the excellent regulatory frame work now in place.

In our supervised fields and in the farmer outreach fields we continue to pursue minimum use of pesticides and consequently have developed a reputation as marketing vegetables and fruits of superior quality.

Another area that we have addressed is the export of rice. Coupled to this we are currently developing protocols for the cultivation of fruit. The development

that we have finalized with regards pineapple similarly another two key fruit varieties need to cover are mango and banana and a host of other indigenous fruits. In this area we have leveraged the skills available in the tissue culture laboratory in developing methodologies promoting quicker generation of planting material as an option to grafting. We are in the process of cultivating experimental one acre plots of mango, guava and sour sup where we could manage the soil in which the plants are grown, the water and fertilizer inputs. We are also conscious of the need to reduce plant size and are experimenting with a closer planting methodology which will not only enhance the ease of picking of fruit but also improve production per acre by a minimum of two times. Banana is a further crop in which we have mastered the current global technology and now look to implement our learning into indigenous varieties. All of these initiatives are targeted at improving the gross revenue of the lands under our control while taking note of enhanced labour charges and the needed productivity.

Floriculture is another area in which we have excelled currently. Our tissue culture laboratory generates plants of wild flowers of Australia which we export back to that country. This is in addition to foliage exports and a Joint Venture we are building in Dubai to access the Middle Eastern market using a wide range of plants available in this country. Basically we are contriving to leverage the potential of indigenous varieties which are less susceptible to pests and diseases. The indigenous plant population in this

country is really our 'green gold'. We have leveraged on these varieties by investing in Science & Technology giving the pride of place to Ayurveda.

Samahan which we manufacture is a classic example. There is really no product of its class globally. It is a mix of herbs used for thousands of years, refined using modern methodologies of extraction blending and standardization. Similarly we manufacture Sudantha, a herbal toothpaste which is well on its way to be the leader globally in its class of herbal toothpaste.

These two examples are value added component to agricultural produce, available in the country which could contribute substantial revenue to agriculture. It is unfortunate that we have not developed the production requirements of our agri industry other than rice.

The final stage that we have to look at is storage, food processing and value addition. In the rice processing area we have installed a state-of-the-art Satake Rice Processing Mill which has enabled us to reach out to export markets. We are looking at expanding this processing facility thus adding substantial value to the paddy farmers and also to the overall economy. With these initiatives we have not only increased production and our own revenue. By providing farmers with good quality seed paddy we have enhanced their yields. We have computed the value of the increased yields at around 20 bushels per acre which considering the volume of seed we have supplied, works out to the addition of over One Billion Rupees to the rural farming community.

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Hazardous Pesticides in Agriculture and its impact on Human Health

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Man in the struggle for supremacy over other living beings has used his skills to assist him in his fight against pests, such as insects, which have a 200 million year evolutionary edge over him. Some of these pests destroy his food and transmit deadly diseases which include malaria and plague.

The value of chemical substances in their fight against pests was realized quite early by man. A papyrus of 1500 B.C. has recorded formulae for preparation of insecticides against lice, fleas and wasps.

However, the recent chemical pesticide use was started during the industrial and scientific revolution of the nineteenth century. In 1867, the farmers in the

United States applied an arsenical poison "Paris Green" to protect potato farms from the Colorado beetle. In 1882, Millardet demonstrated the value of Bordeaux mixture as a fungicide. In 1897, the French vine-grower Bonnet applied copper sulphate to kill Charlock. The discovery of the insecticidal dichlorodiphenyltrichloroethane (DDT) by Paul Muller in 1939 has truly opened the chemical pesticide era.

In spite of using over 30 billion US dollars worth of pesticides, the Food and Agricultural Organization has estimated that one third of food supplies of the world is lost to pests and diseases. This amounts to as high as 35% for wheat, 24% for sugar beet and 40% for

potatoes. Effective control of pests is therefore essential to provide adequate food for the increasing population.

A pesticide is defined as any substance or a mixture of substances intended for preventing, destroying or controlling of any pest including vectors of human or animal disease, unwanted species of plant or animals causing harm during or otherwise interfering with the production, processing, storage, transport or marketing of food, agricultural commodities, wood and wood products or animal foodstuffs or which may be administered to animals for the control of insects, arachnids or other pests in or on their bodies.

The term includes substances intended for use as a plant growth regulator, defoliant, desiccant or agent for thinning food or preventing the premature fall of fruit, and substances applied to crops either before or after harvest to protect the commodity from deterioration during storage and transport.

Pesticide poisoning is a global problem. The exact number of victims of pesticide poisoning is difficult to assess. In 1973, the World Health Organization (WHO) expert committee on "Safe use of pesticides" estimated worldwide there were as many as 500,000 cases of pesticide poisoning and about 5,000 deaths. In 1986, the WHO estimated that the number of unintentional acute pesticide poisoning victims globally was around one million resulting in 20,000 deaths.

A few years ago the Economic and Social Commission of Asia and the Pacific (ESCAP) indicated that the incidence of pesticide poisoning could be as high as two million a year resulting in forty thousand deaths. Every minute someone in an economically underdeveloped country is poisoned by a pesticide. Nearly 85% of the world pesticide production is consumed in the industrialized countries. Yet, the incidence of pesticide poisoning is 13 times higher in developing countries.

Pesticides have five main areas of use in Sri Lanka. They are widely used in public health programmes to kill vectors of malaria and filariasis. Secondly, pesticides are used for domestic and personal purposes for application to kill, for example; insects like cockroaches, or on the skin, to control scabies or head lice. Thirdly, they are used for fumigation of houses, ships and buildings. Fourthly, pesticides are used for the protection of material by incorporating in paint, timber, glue and leather to prevent or retard attacks by insects or fungi. Finally, in agricultural production, on garden crops, livestock and agricultural produce pesticides are widely used.

The usefulness of pesticide to man is proven beyond doubt. Even in early seventies it was claimed that DDT used against anopheline mosquito had already saved 15 million people from death due to malaria. Sri Lanka almost eradicated malaria with the help of DDT in early 1960s.

Although Sri Lanka has not yet achieved the goal of self sufficiency in food, in the seventies and eighties the paddy production has almost doubled. For example, the average yield of paddy which was 1.7 metric tons per hectare in 1965 was increased to 3.5 in 1985. Improved crop varieties, fertilizer and pesticides have all helped in this increased yield of paddy.

At present the world consumption of pesticides is approximately 2.5 billion kilos and it is estimated that as many as 25 million agricultural workers worldwide experience unintentional pesticide poisoning each year in spite of various pesticide regulation schemes in different countries.

Until 1962 there had been no regulation of pesticides import or use in Sri Lanka. At the time most of the pesticides were imported for malaria control and for the use in tea plantations. In 1963, the controller of imports and exports has limited the foreign exchange allowed for import of agrochemicals to Rs. 5.23 million. This decision has met with protest from importers and the government in response appointed a committee to look into the issue resulting in the preparation of a list of "Drugs, Chemicals and Proprietary preparations required for the agriculture" to avoid any effect on local agriculture production.

The introduction of more liberal economic policies after 1977 has demonstrated the urgent need for pesticide control legislation. With the change in economic policies the import of pesticides to the country increased dramatically by 237%, from 2166 tons in 1976 to 5144 tons in 1979, far exceeding the actual requirement of the country. Although the pesticide imports fell over the next few years one can imagine the potential problems, including opening doors for unscrupulous traders, brought about by open market policies with no regulations.

The Sri Lanka government introduced the Control of Pesticide Act No. 33 in 1980, one of the best legislations in Asia.

This Act provided for the appointment of a Registrar of Pesticides (ROP) to regulate the importation, formulation, packing, labeling storage, transportation, sale and use of pesticides. The act provided for the appointing of a ten-member pesticide formulary committee to advise the ROP. Although the

pesticide control act was approved by the parliament in 1980, due to various logistical reasons it was only in 1983 the Registrar of Pesticides was appointed and pesticide regulation was initiated.

Since enactment of the Control of Pesticides act the Controller of Imports has referred import applications for pesticides to the Ministry of Agriculture.

The health effects of pesticides depend on the type of pesticide. Some, such as the organophosphates and carbamates, affect the nervous system. Others may irritate the skin or eyes. Others may affect the hormone or endocrine system in the body.

Acute exposure to pesticides can lead to death or serious illness. Chronic pesticide exposure is most often a problem in the occupational setting, particularly among poor rural populations where men, women, and children all work and live in close proximity to fields and orchards where chemicals are applied and stored.

Long-term exposure to pesticides can increase the risk of developmental and reproductive disorders, immune-system disruption, endocrine disruption, impaired nervous-system function, and development of certain cancers. Children are at higher risk from exposure than are adults.

Pesticides, when not judiciously used, may disrupt natural biological pest control mechanisms. More vigorous pest attacks may result, along with heavier chemical use, and increased health exposures. Pesticides, as well as fertilizers, can infiltrate water sources – contaminating drinking water and animal species, e.g. fish, upon which humans rely for nutrition. Such contamination can lead to a range of secondary public health impacts.

Pesticides may cause acute and delayed health effects in workers who are exposed. Pesticide exposure can cause a variety of adverse health effects, ranging from simple irritation of the skin and eyes to more severe effects such as affecting the nervous system, mimicking hormones causing reproductive problems, and also causing cancer.

A systematic review in 2007 found that "most studies on non-Hodgkin lymphoma and leukaemia showed positive associations with pesticide exposure" and thus concluded that cosmetic use of pesticides should be decreased. Strong evidence also exists for other negative outcomes from pesticide exposure including neurological, birth defects, fetal death and neurodevelopmental disorder.

The World Health Organization and the UN Environment Programme estimate that each year, 3

million workers in agriculture in the developing world experience severe poisoning from pesticides, about 18,000 of whom die. According to one study, as many as 25 million workers in developing countries may suffer mild pesticide poisoning yearly.

One study found pesticide self-poisoning the method of choice in one third of suicides worldwide, and recommended, among other things, more restrictions on the types of pesticides that are most harmful to humans.

A 2007 study by the California Department of Public Health found that women in the first eight weeks of pregnancy who live near farm fields sprayed with the organochlorine pesticides dicofol and endosulfan are several times more likely to give birth to children with autism.

Since chlorinated hydrocarbon pesticides dissolve in fats and are not excreted, organisms tend to retain them almost indefinitely. Biological magnification is the process whereby these chlorinated hydrocarbons (pesticides) are more concentrated at each level of the food chain. Among marine animals, pesticide concentrations are higher in carnivorous fishes, and even more so in the fish-eating birds and mammals at the top of the ecological pyramid.

Unintentional poisonings kill an estimated 355 000 people globally each year. In developing countries – where two thirds of these deaths occur – such poisonings are associated strongly with excessive exposure to, and inappropriate use of, toxic chemicals. In many such settings, toxic chemicals may be emitted directly into soil, air, and water – from industrial processes, pulp and paper plants, tanning operations, mining, and unsustainable forms of agriculture – at levels or rates well in excess of those tolerable to human health.

People are exposed to various potentially toxic agents and conditions in their natural and occupational environments. These agents may be physical or chemical, may enter the human body through oral, inhalational, or transdermal routes, and may exert effects on all organ systems. Several well-known as well as lesser known associations exist between chronic kidney disease (CKD) and both environmental agents and conditions, such as heavy metals, industrial chemicals, elevated ambient temperatures, and infections. The effects of these agents may be modulated by genetic susceptibility and other co-morbid conditions and may lead to the development of acute CKD.

Pesticide use raises a number of environmental

concerns. Over 98% of sprayed insecticides and 95% of herbicides reach a destination other than their target species, including non-target species, air, water and soil. Pesticide drift occurs when pesticides suspended in the air as particles are carried by wind to other areas, potentially contaminating them. Pesticides are one of the causes of water pollution, and some pesticides are persistent organic pollutants and contribute to soil contamination.

In 1956, an unusual clustering of chronic tubulointerstitial kidney disease was observed in villages, families, and households in northwest Bulgaria. The disease was so focal that within an affected town, there would be individual households experiencing the disease next to households that were not. In addition, there was no racial, ethnic, or religious predilection for the disease. Another feature of the disease is its long incubation period. Affected individuals must live in the area for 15 to 20 years.

Therefore, it has neither been identified in children nor in adults who leave the area before reaching the age of 20 years. Finally, those with the disease were at a markedly increased risk of developing upper urinary tract tumors.

This disease was initially called "endemic Vratza nephritis," and was subsequently identified in Yugoslavia and discrete regions of Romania. Reflecting this wider geographic distribution, although still confined to the plains of the Danube Rivers, it was later renamed Balkan endemic nephropathy.

Balkan endemic nephropathy is a tubulointerstitial nephropathy with a slow progression after an insidious presentation.

The cause of Balkan endemic nephropathy remains subject to debate. One early hypothesis was contamination of food in endemic areas by ochratoxin A, a toxin produced by molds that belong to the *Aspergillus* or *Penicilium* fungal genera.

I mentioned Balkan endemic nephropathy because today there is a major debate as to what is the aetiology of the dreaded Chronic Kidney Disease of unknown origin (CKDu) spreading in some parts of Sri Lanka.

The last WHO report dated June 2011 discusses the relationship between Pesticides and Chronic Kidney Disease. This report concluded that '*exposure to a combination of factors which are toxic to Kidney seems to cause this kidney disease. Toxic factors identified up to now include, nephrotoxic agrochemicals, arsenic and cadmium. It also recommends to control of the sale of agrochemicals*

which are known to be nephrotoxic e.g. Propanil, chlopyrifos and others'.

However, in 2013 the Ministry of Health through the Ministry of Agriculture has submitted a detail report of the studies carried out by WHO in Sri Lanka on an identified Kidney disease. According to this report the Ministry of Health has informed the Cabinet of Ministers that they cannot be certain of the causal agent of CKDu from the WHO report.

The final WHO report states "*Nephrotoxic pesticides may be aggravating the progression of the disease* (page 45).

The report also states that pesticides contain minimum of 0.01 and maximum of 94.98 parts per billion (ppb) of Arsenic from 26 pesticide samples that they have analyzed from CKDu areas and 0.01-13.15 ppb of Arsenic from 26 samples analyzed from other areas. Since average or distribution of the data is not provided no inference can be made from these data. The amounts of arsenic found in pesticides are within the normal range found in other countries too.

WHO final report also indicate that pesticide residues have been found in people with CKDu as well as people from control areas. Some pesticide residues are found in urine of tested people but no link of pesticides with CKDu. In fact the presence of some residues of pesticides which are not even used in Sri Lanka make the validity of these data very doubtful in the context of kidney disease.

Following statement in the final report summarizes the findings of the WHO.

"These finding may support the contention that chronic exposure to low levels of Cd may be playing a role in causation of CKDu in Sri Lanka. Co-exposure to As is likely to aggravate the effect Cd on the kidney making the changes More pronounced than exposure to Cd alone".

Considering the above the Registrar of Pesticides in collaboration with the Pesticides Advisory Committee has decided that there is no conclusive scientific evidence linking CKDu and pesticides.

Arsenic in rice is a natural phenomenon. Arsenic is an abundant natural element found everywhere in the world. In Soil water, plant animals etc. Rice has a natural tendency to accumulate relative more arsenic as it grows in anaerobic conditions. Industrial Technology Institute and Kyoto University tested rice from all over the country and from CKDu endemic areas and found the arsenic levels in our rice is much lower than what is found in many other countries of the world.

Impurities of arsenic and other heavy metals are not

unusual phenomena in pesticides. Literature shows pesticides in other countries too have similar levels of heavy metals. Internationally ppb levels of impurities are not tested in pesticides.

The Ministry of Health has informed the cabinet of ministers that they cannot conclude the cause of CKDu from the WHO report and hence the cause of CKDu is still uncertain.

According to senior nephrologist in the Kandy General Hospital the cause of CKDu is multifactorial.

No group has established a link between CKDu and pesticides. They all have mentioned pesticides as a potential suspect in addition to many other factors.

Local evidence by geologist suggests there is no difference in levels of arsenic in agricultural and non agricultural soils.

Recent ban on importing four pesticides (Carbofuran, Carbaryl, Chlorpyrifos and Propanil) is not due to any link with CKDu but they are high volume pesticides and crop research stations have found out better and low volume pesticides for the control of same pests.

Undoubtedly pesticides are harmful to humans if improperly used.

What should happen in future? Integrated Pest Management (IPM) strategies can reduce the use of

agrochemicals, improve management, and optimize ecosystem mechanisms for pest control/soil enrichment – simultaneously protecting both farmers and the environment.

Future pesticide regulation scheme in Sri Lanka include more in house quality testing of pesticides, monitoring of pesticide residues in food and regulatory support for lowering of pesticide use in the country.

There should be policies to improve regulation and control of pesticide sale, distribution, and use. The health care systems should identify, treat, and monitor cases of pesticide poisonings. Educational/advocacy tools should be developed to inform the public as well as agriculture and health-care workers about health risks and best practice use of agrochemicals.

The global conventions on the management of highly toxic chemicals, including certain pesticides, from production to disposal stages should be implemented. These include: the Stockholm Convention on Persistent Organic Pollutants; the Rotterdam Convention on Prior Informed Consent Procedure for Certain Hazardous Chemicals in International Trade, and the Basel Convention on the Control of Transboundary Movements of Hazardous Waste and their Disposal.

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## Safe Use of Genetic Engineering for Agricultural Production

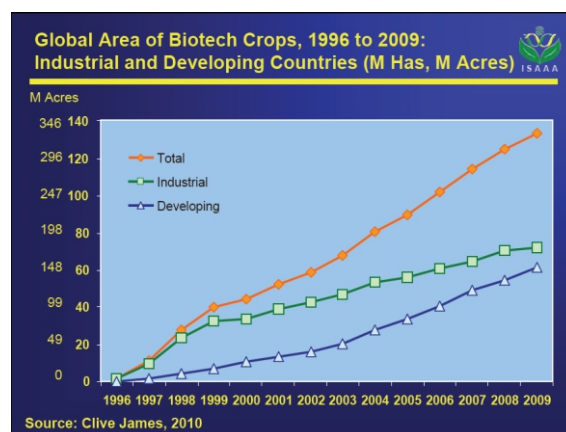
Professor Athula Perera

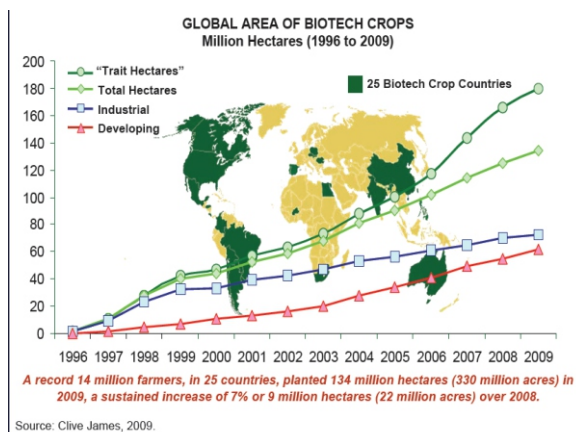
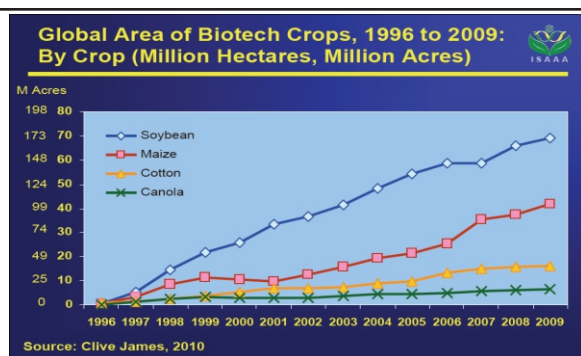
*Emeritus Professor, University of Peradeniya*

### Introduction

Genetic engineering or recombinant DNA technology (rDNA) constitutes one of the techniques comprising modern biotechnology. It creates novel organisms (Genetically Modified Organisms: GMOs; also known as transgenic organisms) by transferring genes across species and even kingdoms. GMOs can be used to produce food (genetically modified food), feed (genetically modified feed) and processed products that include genetically modified ingredients, together known as GMO/FFPs (genetically modified organisms, food, feed and processed products). Transgenic organisms include plants, animals and microbes carrying foreign genes providing resistance to pests, herbicides, increased growth, better quality products, pharmaceuticals etc. However, as with any other technology, risks and concerns arising from the use of this technology have been identified by the scientific community that can affect human health and

the environment in addition to other concerns such as gene theft, patents and socio-economic aspects. Notwithstanding these, the production of GMOs has expanded globally (see figures below) and the time has come for us to find out whether this technology can be used to contribute to agricultural production in Sri Lanka in a sustainable and safe manner.





### The global scenario

Today, the world population is around 7.2 billion for which about 25% of the habitable land and 90% of fresh water are used up for food production. Moreover, deforestation causes about 80% biodiversity loss and we experience around 30% greenhouse emissions. Confounding food production efforts is that there is about 1.3 billion tons of food wasted every year, with around 90 million tons wasted every year in Europe alone. In the developing world, >40% food losses are recorded; 1 in every 7 people goes to bed hungry and >20,000 children (< 5 years old) die every day due to hunger. The impact of food waste is both financial and environmental. In addition, there is wasteful use of chemicals and increase use of fuel. The emission of methane, the harmful greenhouse gas, is causing climate change, whilst the dumping of waste in landfills increase odour and attracts flies and vermin. Food is lost in the entire food chain from the farmer to the industry to retailers, caterers and consumers.

Going back in history, from the time of the Mayans to the Pharos and the Indus valley civilizations including our own 'granary of the east' period, to the present modern world, humans have gradually transformed their 'natural' world into a 'synthetic' world. Prior to the 1930s, synthetics were based on natural material such as alcohol, cellulose, corn, milk, starch etc. But thereafter, synthetics were produced from petroleum products, the excess hydrocarbons

from the oil and gas industries from which new molecules were created by chemists to produce material that can be easily manipulated. These included lightweight, shatter-proof, flexible plastics, stretchy, water-repellent fabrics, detergents that get rid of dirt and grease, non-stick cookware, grease-resistant food packages, lining of food cans, flame retardants, antibacterial soaps, artificial fragrances, sunscreens, pesticides, preservatives, cosmetics and toys. These are found in the products that we wear, sit on and sleep with and hence rub into our skins. Traces of these molecules have been found in the food we eat, water we drink, the air we breathe. These molecules flow in our blood. They are found in our urine, breast milk, in the soil and in marine life. More than 400 million tons of such chemicals are produced every year. Humans are thus exposed to multiple chemicals simultaneously, while some can persist in the environment for years. Some fat-soluble chemicals can accumulate in plant and animal tissue and thus interfere with the natural chemistry of living cells which can eventually affect vital body systems, disrupt the balance of hormones, affect fertility, metabolism and cause behavioural problems and even cancers, through several generations.

So what can we do about these risks to the environment and human health due to the use of modern technology, including rDNA technology? Can we turn the clock back? If not, how then can we use this technology, the rDNA technology, to solve our agricultural problems in a safe and sustainable manner whilst protecting our rich culture and values? For this, we need to know what our problems in agriculture are, what resources we have and then how rDNA technology can contribute to solve them.

### Our biological resources

Sri Lanka is a 'small' island nation situated next to a 'large' neighbor. Ours is a biodiversity 'hot spot' with a large amount of endemic species (Table 1).

Table 1. Some endemic species in Sri Lanka

|                     |                            |
|---------------------|----------------------------|
| Angiosperms –       | 3,154 species; 894 endemic |
| Pteridophytes –     | 336 species; 49 endemic    |
| Fresh water fish –  | 91 species; 50 endemic     |
| Fresh water crabs – | 51 species; 50 endemic     |
| Resident birds –    | 237 species; 33 endemic    |
| Mammals –           | 124 species; 21 endemic    |

(National Red List of threatened fauna & flora, 2012)

### National Biotechnology priorities

The National Biotechnology Policy of Sri Lanka

identifies the following 11 themes as priority areas for implementation.

Clean environment

Self reliance in food production

Well-being of the people through healthcare

Promotion of bioenergy

Sustainable use of biodiversity

Poverty reduction through bio-entrepreneurship

Bioprospecting of marine/ocean resources

Sustainable bioindustry

Positioning biotechnology in society

Human resource development to build capability in biotechnology

Government commitment for research and development and technology transfer (by establishing Centres of Excellence in the country and creating an Apex body to spearhead the development of Sri Lankan biotechnology sector).

### **Some 'burning' problems in agricultural production**

The 'burning' problems in agricultural production in our country include, high cost of production: labour, chemicals, seeds; heavy use of chemicals that are imported causing a hazard to human health & environment; lack of appropriate local seeds which are easily available and tested in our ecosystems for tolerance to drought, flooding, salinity etc.; decreasing land for cultivation and hence coming into conflict with animals – elephants, monkeys; change of food habits of urban populations; wastage of food; loss of traditional varieties/biodiversity in many crops such as mangoes, bananas, tomatoes, chilli and the loss of traditional knowledge.

### **The technology**

Recombinant DNA technology has been used to produce many novel GMO/FFPs including herbicide tolerant cotton, soybeans; Bt cotton, maize; TMV resistant tobacco; Flavr Savr tomato for improved quality; potatoes with high starch content; golden rice with increased vitamin A; improved canola oil; blue roses; carnations with increased vase life; drought, cold, salinity tolerant crops; plants producing pharmaceuticals; edible vaccines etc.

The technology involves the identification & isolation of a gene of interest, cloning it, transferring to a suitable vector such as *Agrobacterium* (or the use of a gene gun) for transforming cells of the crop of interest after which successfully transformed cells are developed into plants through the use of tissue culture

techniques.

### **Current news**

Currently, the apple genome has been mapped having 17 chromosomes, most of which are duplicates i.e. copies of parts of other chromosomes; the Christmas tree genome has been sequenced; the castor bean genome has been published; Wales want to remain GM free; France has enforced a national ban on MON 810 (Bt maize); China has slowed down GM research in order to investigate them more; the Philippines has enforced a court order to permanently stop all field trials of Bt egg plant; USA court has revoked the approval of GM sugarbeet - ~ 95% sugarbeets in US are Roundup Ready transgenic varieties – US court requires more stringent EIS report on how it will affect other plants; the Indian government has enforced a moratorium on Bt brinjal which took 8 years to produce; toxicological database on *B. thuringiensis* shows no mammalian health effects attributed to the delta-endotoxin (Cry proteins); studies on food & feed safety including toxicology & allergenicity tests carried out on rats, rabbits, fish, chicken, goats & cows; Austrian researchers proved Bt maize was harmful to mice; AquaAdvantage salmon, the 1<sup>st</sup> genetically engineered food animal has been produced - all are sterile females raised in land-based contained environments.

### **Risks to environment (agriculture)**

Many GMOs are being produced in laboratories across the world and more than 160 countries have signed the Cartagena Protocol on Biosafety which allows nations to establish safety measures with regard to production, transport and use of GMO/FFPs considering the risks to the environment and human health.

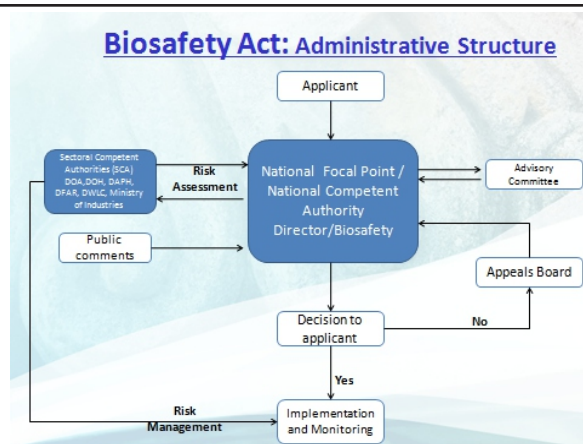
The risks to the environment include risks to Biodiversity due to the possible genetic erosion by aggressive/dominant GM crops e.g. traditional rice varieties; gene flow – contamination by GM pollen of traditional varieties, organic crops; transfer to weedy relatives; extinction of endangered varieties; marketability of non-GM products; effect on non-target organisms - butterflies, bees, moths, lady-bird beetles, lizards, frogs, crows, parrots & soil organisms; persistence of the transgene & its product.

Other risks include instability of the transgene through generations; evolution of resistance; weediness of GM crops; escape of salinity, drought, cold resistant crops; effect on soil ecology – functional

composition & biodiversity; socio-economic issues such as the livelihood of farmers who grow non-GM crops; ethical & moral issues including patents, biotheft & biopiracy; owning 'life'; vegetarians; genes & products in pigs, cattle etc.

### National regulations and the future

In order to regulate the GMO/FFPs (especially those imported), Sri Lanka as a signatory to the Cartagena Protocol has also ratified it. Progressing from there, Sri Lanka has established the National Biosafety Framework through which the National Biosafety Policy was also established. The Ministry of Health has included regulations regarding GM food in its Food Act with mandatory labeling. The Ministry of Environment, which is the National Focal Point for Biosafety, has now produced the final draft of the Biosafety Act of Sri Lanka which will be implemented as shown in figure below.



The stage is set for the decision makers to plan how to use this technology for improving agricultural production in Sri Lanka in a safe and sustainable manner, whilst remembering the words of wisdom of the Great Mahatma Gandhi:

*"The world has enough for its needs but not enough for its greed"*

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Managing Soils and Water in Sustainable Agriculture

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Reddish Brown Earth (RBE), Low Humic Gley (LHG), Non Calcic Brown (NCB), Immature Brown Loam (IBL), Red Latosol, Yellow Latosol, and Grumusols are major agricultural soils in the dry zone while Red Yellow Podzolic soils (Ultisols) being the modal soil in the wet zone. In the modern agriculture use of agrochemicals plays a significant role in achieving expected yield targets. Soils of Sri Lanka, in general, have low inherent fertility status, thus limiting crop growth and yields unless deficient nutrients are supplemented at adequate levels. Fertilizers and organic amendments contain many impurities leading to contaminate soils subsequently transferring to the humans through food chains. Out of the 17 plant nutrients, N and P reported of causing adverse effects to the ecosystems and environments when supplying more than necessary quantities. Trace metal pollution in soil is of a great concern because soil is a long-term sink for potentially toxic elements. Parent material and anthropogenic inputs such as fertilizers are found to be sources of heavy metals in soils. The solubility, mobility and bioavailability of trace metals in soils depend on the chemical species of trace metals which controlled by number of soil characteristics such as pH, organic matter, clay content and secondary minerals. Trace element studies, deals with trace amounts of

interesting metals since the occurrence in soils is as such. Hence following quality control quality assurance steps is very important in trace element studies. Site specific fertilizer recommendations, strategies to increase fertilizer use efficiency, use of slow release fertilizers, and discourage of over-application of fertilizers are some of the measures that can be taken for sustainable agriculture.

Variability of Soils of Sri Lanka

Spatial variability of soils is very high, which is also true for Sri Lankan soils. Twelve soil orders have been identified by the Soil Taxonomy classification at the highest hierarchical level, where Sri Lanka is having six out of them, namely, Alfisols, Ultisols, Inceptisols, Entisols, Vertisols and Histosols. Great Soil Groups put forward by the de Alwis and Panabokke in 1972 used as the base for the modern soil classification done for wet zone (Mapa et al., 1999), Intermediate Zone (Mapa et al., 2004) and Dry Zone (Mapa et al., 2010) according to the Soil Taxonomy. Reddish Brown Earth (RBE), Low Humic Gley (LHG), Solodized Solonetz, Non Calcic Brown (NCB), Immature Brown Loam (IBL), Red Latosol, Yellow Latosol, Calcic Red Latosols, Solonchaks, and Grumusols are the major agricultural soils in the dry zone. RBE and LHG soils on undulating

terrain covers the highest extent in the dry zone spreading from Anuradhapura, Monaragala, Vaunia, Polonnaruwa, Trincomalee, and Hambantota districts (de Alwis and Panabokke, 1972). Management of NCB is important in agriculture due to its sandy texture. NCB and LHG occur in undulating terrain covers districts of Ampara and Batticaloa. Red or Yellow Latosols occurring at flat to slightly undulating terrain covers the districts of Jaffna, Mannar, Puttalam and Vaunia. Latosols are deep soils and water holding capacity is very low requiring proper irrigation schemes for cultivation of crops. Grumusols occupies in flat terrain in the districts of Mannar and Jaffna where Gilgi micro-relief is the characteristic feature of the soils. Grumusols are highly productive soils with appropriate management practices to overcome poor soil physical properties. Alluvial soils and Regosols on Recent beach and dune sand are also use heavily on crop production with appropriate management practices. Sandy nature of the soil poses environmental threats, if fertilizer splitting and other management practices were not performed well.

Red Yellow Podzolic soils (Ultisols) are the modal soils of the wet zone of Sri Lanka both in the lowlands and in the central highlands. Low pH, low CEC and low base saturation are the main constraints in these soils. Addition of lime to correct pH and base saturation, addition of organic matter to increase CEC and application of fertilizers in several splits to reduce nutrient losses are the major management practices associated with this soil type. Reddish Brown Latosolic (RBL), Bog soils and Half-Bog soils are the other soil groups present in the wet zone. IBL (Inceptisols) soils occurs on steeply dissected, hilly and rolling terrain, are very susceptible for landslides and soil conservation measures need to apply when agriculture practices on this soil. Regosols and Alluvials are also agriculturally important soils found in the wet zone. Alluvials found in floodplains are relatively fertile soils. Poor water retention and fertility are some of the problems associated with Alluvials and Regosols on recent beach sands.

Soil Fertility and agricultural inputs

Soil fertility is the capacity of soil to supply plant nutrients in adequate amounts to facilitate optimum growth and obtain the yield potential of a crop. Fertilizers are applied to crop production to supply the essential plant nutrients. Of the 17 essential nutrients, C, H and O supplied naturally, through the air and

water. Nitrogen, Phosphorus and Potassium were the macro nutrients while S, Ca and Mg were secondary nutrients and Cu, Fe, Mn, Zn, Mo, Cl, B and Ni are the micro nutrients where the classification was done based on the required quantities by the crops. In the modern agriculture use of agrochemicals plays a significant role in achieving expected yield targets. Soils of Sri Lanka, in general, have low inherent fertility status, thus limiting crop growth and yields unless deficient nutrients are supplemented at adequate levels (Indraratne, 2012). Soil properties that influence the availability of the essential soil nutrients are organic matter, texture, structure, cation exchange capacity, base saturation, soil temperature, topography, soil management factors and soil depth. Fertilizer import also increased significantly in the recent past.

Soil properties responsible for fate of inorganic pollutants added to the soils

Fertilizers and organic amendments contain many impurities leading to contaminate soils subsequently transferring to the humans through food chains. In Sri Lanka use of fertilizers and organic manures in more than recommended doses is a common practice in intensively cultivated vegetable growing soils. Out of the 17 plant nutrients, N and P reported of causing adverse effects to the ecosystems and environments when supplying more than necessary quantities. Further fertilizers are known of having potentially toxic heavy metals in small amounts. Long term fertilizer application could cause elevated heavy metal concentrations in soils. Hence, nitrates, phosphates and heavy metals could consider as inorganic pollutants receiving to the soils due to agricultural practices.

Inorganic as well as organic colloids present in soils are predominantly negatively charged creating an environment where the cationic substances are held tightly through electrostatic processes. Anions present in the soil environment retained with the colloid through non-specific adsorption and specific adsorption processes. Non-specific adsorption is similar to the cation adsorption, which is bound to the colloids through electrostatic attraction. Specific adsorption takes place between colloidal surface and ions present in the soil solution irrespective of the charge of the ion. Nitrates and phosphates are negatively charged anionic groups in soils with different retention mechanisms. Phosphate is held strongly through specific adsorption while nitrate is

loosely held in soils by non-specific adsorption. Therefore, nitrates move freely through soil profile contaminating groundwater while phosphates adsorbed tightly with soil colloids. Phosphates could pollute surface waters through erosion and runoff. Nitrogen from fertilizers also can move directly into surface waters from runoff and erosion.

Cation exchange capacity of a soil determines by the factors such as clay % (texture), Clay mineralogy, OM content and pH. Electrostatic attraction for cations by negatively charged particles can be expressed using the Coulombs Law; $F = K q_1 q_2 / d^2$, where **F** is the attraction, **K** is the constant, **q1** and **q2** represent the charges of oppositely charged ions and **d** represent the distance between the two ions. When q1 increases, attraction between the ions increases indicating the affinity in the order of trivalent > divalent > monovalent. Similarly when ionic radius of the cation increases, d increases decreasing the attraction of the cation to the negatively charged soil surface. Accordingly high cation selectivity shows for trivalent cations and cations with smallest hydrated ionic radius by the soil surface. Hence multivalent trace elements added to the soils as impurities of agrochemicals could selectively bind to the soil surfaces.

The persistence and mobility of metals are determined by the sorption ability of solid phases. Adsorption of heavy metals by soil colloids is highly dependent on soil pH. Low pH results low adsorption of metals to the soil colloids. At low pH levels more heavy metals are present in the soil solution increasing the bioavailable fraction. Redox potential (Eh) is another important property that determines solubility of trace elements. Generally, trace elements solubility increases upon decreasing Eh. Outer sphere complexes and inner-sphere complexes are two main mechanisms responsible for adsorption of cationic metals. Electrostatic outer sphere complexes are weaker in its nature and exhibits cation exchange property. Trace elements are adsorbed to the colloids by inner-sphere or chemisorption process of which metals are adsorbed through covalent and hydrogen bonding. Precipitation and co-precipitation mechanisms are also responsible for retention of metals with soil colloids. Precipitation of trace elements is unlikely since a new solid phase will require some degree of supersaturation. Co-precipitation is more likely than precipitation in retention of trace element with soil colloids. A study on soil chemical properties on Cd and Pb sorption conducted by Appel and Ma, (2002) observed all soils sorbed more Pb than Cd, sorption depend on soil

mineralogy, Cd sorption is more pH dependence than Pb, Cd was sorbed via electrostatic surface reactions and/or possible inner-sphere complexation at pH > 3.7 and Pb participates in inner-sphere surface reactions and sorbed more strongly than Cd.

Characterization of physicochemical properties of a soil enables predicting the behavior of nutrients and pollutants added to the soil. A study was conducted to characterize environmentally important physicochemical properties and processes of an Alfisol (RBE) collected from the dry zone of Sri Lanka (Sanjeevani et al., 2013a). Point of zero charge of the soil was recorded as 4.0 indicating net negative charges at the existing soil pH of 6.37. At the near neutral pH of the soil, the cation retention enhanced, subsequently reducing the mobility of metals.

Fate of inorganic pollutants added to the soil environment

When nutrients are applied to the soils as fertilizers it could be undergone many processes in the soil environment. Other than the plant uptake, the possible pathways are volatilization to air, runoff to surface water bodies, percolation to aquifers and bio-cycling. If the application rates do not match with the plant uptake rates, then the environmental pollution is unavoidable. Though there are 17 elements essential and supplied through fertilizers, so far the environmental pollution and or health hazards were reported by only two nutrients, i.e., N and P.

Most freshwaters biological productivity is limited by P. Agricultural activities are one of the major sources of P in surface waters. Eutrophic threshold for P is much lower than N and the value is 20 to 100 µg P/L (Essington, 2004). Ratio of N:P in water body is known as Redfield ratio and it is the indicator use to identify of which nutrient is limiting the eutrophication process. For an example if the Redfield ratio is > 16: 1; P is limiting and lower the ratio N is limiting the eutrophic conditions in a water body.

Soils that contain high levels of P from excessive fertilization increase the potential of P loss through runoff. The degree of phosphorus saturation (DPS) has been used in evaluating the risk of P loss from soil through runoff (Ige et al., 2005). The DPS is the percent ratio of P retained by soil to the total capacity of soil to retain P. It is based on the fact that although soils have capacity to retain applied P, this P retention capacity is finite; and as more P is added to the soil, the soil's capacity to retain P decreases and the risk of P loss increases. Thus, two soils with the same extractable P

may not necessarily pose the same risk to the environment. Phosphorus adsorption capacities vary widely between 588 mg kg⁻¹ to 5000 mg kg⁻¹ in major soils of Sri Lanka (Indraratne et al., 2009). The degree of P saturation has been shown to be closely correlated with dissolved runoff P (Sharpley et al., 1996). Amarawansa and Indraratne, (2010) calculated DPS in intensively cultivated soils of Sri Lanka (Fig. 1) and identified that most of the intensively cultivating soils pose P loss to the adjoining water bodies.

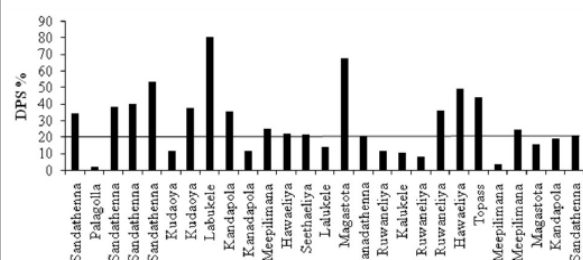


Fig. 1. Degree of Phosphorous Saturation in Intensively Cultivated Soils in Sri Lanka (Soils with more than 20% DPS are highly susceptible for run off P losses, Source: Amarawansa and Indraratne, 2010)

Many researchers paid special attention to intensive vegetable cultivation in Sri Lanka recently due to its possible negative environmental impacts (Rajapaksa and Raufa, 1999; Premarathne et al., 2011). Some features of intensive vegetable farming in Nuwara Eliya area are, continuous cultivation throughout the year cultivating 2-3 crops per year, use soil amendments (lime or dolomite), application of 3-4 times higher than recommended doses of fertilizers (Wijewardane, 1993), and use of higher doses of organic manures, foliar fertilizers and pesticides. More than 30% of Mid Country vegetable growing soils showed very high available P concentrations, i.e., >120 mg/kg (Fig. 2). This indicates very high risk of P losses from these fields to the adjacent water bodies.

Trace metal pollution in soil is of a great concern because soil is a long-term sink for potentially toxic elements. Parent material and anthropogenic inputs are found to be the main sources of heavy metals in soils. Common metal species found in soil are water soluble, exchangeable, organically bound, occluded in Fe and Mn oxides, definite compounds and structurally bound in silicates. Water soluble and exchangeable fractions are bioavailable of which would enter to the food chain, easily. A research carried out in the vegetable fields in some production areas of California showed that the concentrations of As, Cd, Pb and Zn had been shifted upward due to agricultural inputs (Chen et al., 2008).

Reactions of heavy metals with soil are important in determining metal fates in the environment. The solubility, mobility and bioavailability of trace metals in soils depend on the chemical species of trace metals which controlled by number of soil characteristics such as pH, organic matter, clay content and secondary minerals. Trace elements adsorbed to the soil colloids differently than the simple cation exchange mechanism. The mobility of the pollutant into the food chain is one of the issues of most concern. Mobile fractions of ions occur at a lower range of pH and at a lower redox potential. Hence, the concentration of trace elements is lower in soil solutions of alkaline and neutral soils found in the dry zone than in those of acidic soils in the wet zone. Therefore, type of soils play a major role in the accumulation, persistence and bioavailability of trace metals in soils. An experiment was conducted to study trace element concentrations in soils after using phosphate fertilizer at rates of 26, 39, and 52 kg P ha⁻¹ over a 40-yr period (Cakmac et al., 2010). Significant Cd increase was observed in phosphate application rates of 39, and 52 kg P ha⁻¹ while phosphate rate at 26 kg P ha⁻¹ (recommended P rate) showing no difference with control.

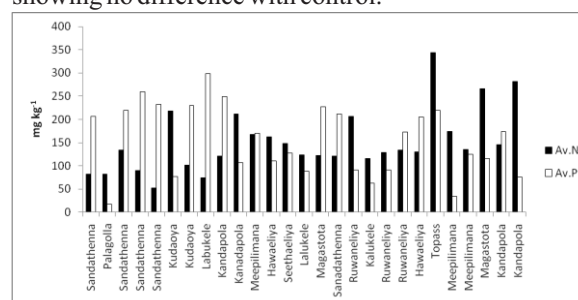


Fig. 2. High-input agricultural practices on available nutrients (Av. N.= available nitrogen, Av. P= available P; Source: Pitumpe Arachchige and Indraratne, 2011)

Surface horizons of 40 agricultural soils from low country and up country wet zone of Sri Lanka under vegetable crops were sampled to determine concentrations of Cd, Cu, Ni, Pb and Zn (Premarathne et al., 2011). Elevated levels of Cd, Cu, Ni, Pb and Zn than the uncultivated soils were observed in both up country and low country wet zone of Sri Lanka (Fig. 3). Measured mean values of Cd in few soils exceeded the maximum allowable limits imposed by the European standard; however, Cd concentrations in the vegetable crops were still below the standard levels. Authors observed the Cd to Zn ratio in studied soils indicated safer limits for Cd in more than 95% of the soils studied.

Establishment of baseline concentrations has been done in many parts of the world (Dudka, 1993).

Information on trace element baseline concentrations is not available in Sri Lanka. Therefore, Sanjeevani et al., (2013b) conducted a study to establish baseline concentrations of trace elements of surface soils in a selected soil map unit in dry zone of Sri Lanka (Table 1). This shows current background concentrations of the metals studied and will be helpful in future monitoring purposes.

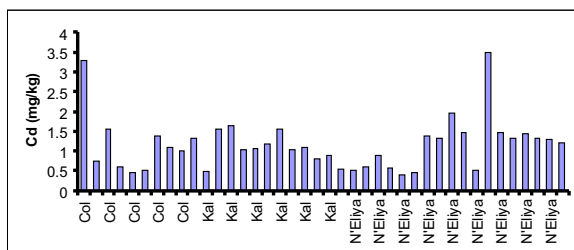


Fig. 3. Total Cd from intensively cultivated vegetable fields of Colombo (Col), Kalutara (Kal) and Nuwara Eliya (N'eliya) districts (Source: Premarathne et al, 2011)

Table 1. Trace metal and Baseline concentrations (mg/kg) for Cu, Pb, Ni, Zn and Cd in a soil map unit of the dry zone of Sri Lanka (Sanjeevani et al., 2013b).

| Trace metal | N* | Observed concentration s | Skewness | Baseline concentration s | GM | AM | Median |
|-------------|----|--------------------------|----------|--------------------------|-------|-------|--------|
| Cu | 86 | 1.56 - 33.51 | 1.503 | 2.98-26.51 | 8.89 | 10.23 | 9.3 |
| Pb | 85 | 0.96 - 19.22 | 0.709 | 2.44-19.53 | 6.9 | 7.77 | 6.78 |
| Ni | 82 | 0.35 - 32.17 | 0.876 | 2.02-38.8 | 8.85 | 10.86 | 10.65 |
| Zn | 86 | 7.44 - 71.32 | 2.008 | 8.24-51.25 | 20.55 | 22.94 | 19.58 |
| Cd | 74 | 0.13 - 1.22 | 0.753 | 0.13-1.39 | 0.42 | 0.5 | 0.43 |

* Number of samples

Validity of generated soil pollution data

Sampling procedures should be strong enough to predict the spatial distribution. Soil analysis always included a dilution factor in soil analysis unless the whole sample is feeding to the machine. Choosing of extracting solution will depend on the purpose of the analysis. Available fractions are more important than totals for nutrients and heavy metals, if the objective is to know the sufficiency for plant or food chain transfers. Trace element studies, deals with trace amounts of interesting metals since the occurrence in soils is as such. Hence following quality control quality assurance steps are a necessity. Running known and unknown blanks and check with Standard Reference Materials (SRM) are some of them.

Management strategies to minimize pollution by fertilizers

Recovery of applied N to paddy soils in Sri Lanka is around 30% (Sirisena et al., 2003). Some of the improved N management techniques are split

application, subsurface placement, use of slow release and coated urea fertilizers. Further N efficiency could be enhanced by the application of granular urea rather than prilled urea (Sirisena et al., 2003). Experiments conducted on adoption of leaf colour-based nitrogen application indicated 121 – 142 kg/ha can be saved when N is added based on leaf colour chart guidelines (Sirisena and Wanninayake, 2010).

Current researches on OM studies are trying to add high C: N ratio recalcitrant materials to the soils expecting to improve many soil conditions for crop growth (Mariaselvam et al., 2013). Biochar, produced by pyrolysis is one such recalcitrant organic material that can be used for soil improvements.

Site specific fertilizer recommendations reduce environment pollution and enhance the nutrient use efficiency by the crops. Many researchers reported that the new approach of fertilizer recommendation based on soil analysis, sorption studies, green house nutrient survey and field trials was successful (Amarasekara et al., 2007; Bandara et al., 2008; Kumaragamage and Indraratne, 2011).

Application of N fertilizers at the right time at correct doses is necessary to limit the buildup of nitrates during the periods at high leaching risks. This can be accomplished by applying nitrogen at the stage that crop can utilize it, using smaller and more frequent doses, and not applying excess amounts. Use of slow-release nitrogen fertilizers is another management practice that can prevent buildups of nitrates in soils. The rate of nitrogen release from fertilizers can be controlled by coatings or use of reduced solubility compounds.

Surface losses of nitrogen and phosphates can be minimized through application of soil conservation and water control practices. These practices include contour cropping, maintenance of adequate plant cover, returning crop residues to the soil, and use of forages and other close-growing crops on steeper lands. In the Sri Lankan context it is a must to discourage / prevention of over-application of fertilizers /manures in intensively cultivated areas, which has contributed significantly for the environment pollution in the recent past.

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Nanotechnology for greater agricultural productivity

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Currently, the major challenges encountered by world agriculture include urbanization, changing climate, sustainable use of natural resources and environmental issues like runoff and accumulation of pesticides and fertilizers. These problems are further intensified by an alarming increase in food demand that will be needed to feed an estimated world population of 9 billion by 2050. In addition to that decreasing of world petroleum resources and new arable soil exaggerate the world food crisis.

This above-mentioned scenario is intensively revealed in developing countries as the agriculture is the backbone of the national economy in these countries. They face many critical issues such as lack of new arable soil, reduction of the current agricultural land due to competing economic development activities, commodity dependence, poverty and malnutrition. Several structural changes in the agricultural sector have arisen due to the fast development of technological innovations. For developing countries, advancement in science and technology can offer potential solutions for discovering value addition in their current production systems. Many technologies have been developed that have the potential to increase agricultural productivity and also reduce the environmental and resource costs related with agricultural production. These technologies have the ability to conserve land and water by increasing yields through the application of the same or fewer inputs, ultimately conserving the environment.

Among the many advancements in science, nanotechnology is being visualized as a rapidly evolving field that has potential to revolutionize agriculture and food systems. Nanotechnology involves the characterization, fabrication and manipulation of structures, devices or materials that have at least one dimension that is approximately 1 – 100 nm in length. It deals with the physical, chemical and biological properties of matter considered at nanoscale and their implications for the welfare of human beings. When particle size is reduced below this threshold, the resulting material exhibits physical and chemical properties that are significantly different from the properties of macroscale materials composed of the same substance.

There are a number of nanotechnological applications in agriculture, but these are mostly at the

bench-top exploration stage. However, it is very likely that in the near future, agriculture and the food sector will see large-scale applications. Nanotechnology has the potential to revolutionize the agricultural and food industry with new tools for the molecular treatment of diseases, rapid disease detection, enhancing the ability of plants to absorb nutrients etc. Smart sensors and smart delivery systems help the agricultural industry combat viruses and other crop pathogens. Nanostructured catalysts are available at experimental level which increases the efficiency of pesticides and herbicides, allowing lower doses to be used. Nanotechnology also protects the environment indirectly through the use of alternative energy supplies, and filters or catalysts to reduce pollution and clean-up existing pollutants. In the agricultural sector, nanotechnology research and development is likely to facilitate and frame the next stage of development of genetically modified crops, animal production inputs, chemical pesticides and precision farming techniques.

Precision farming

In general, precision agriculture is a new attitude in farm management. Precision agriculture means that there is a system controller for each growth factor such as nutrition, light, temperature, etc. Available information for planting and harvest time are collected and controlled by satellite systems. This system allows the farmer to know, when is the best time for planting and harvesting to avoid of encountering bad weather conditions. Best time to achieve the highest yield, best use of fertilizers, irrigation, lighting and temperature are all controlled by these systems. An important nanotechnology role is the use of sensitive nuclear links in GPS systems controller. While nano-chemical pesticides are already in use, other applications are still in their early stages, and it may be many years before they are commercialized. These applications are largely intended to address some of the limitations and challenges facing large-scale, chemical and capital intensive farming systems. This includes the fine-tuning and more precise micro-management of soils; the more efficient and targeted use of inputs; new toxin formulations for pest control; new crop and animal traits; and the diversification and differentiation of farming practices and products within the context of large-scale and highly uniform systems of production.

Applications of nanotechnology in pests and plant diseases management

Currently, the use of chemicals such as pesticides, fungicides and herbicides is the fastest and cheapest way to control pests and diseases. Also biological control methods are comparatively expensive. Uncontrolled use of pesticides has caused many problems such as: adverse effects on human health, adverse effects on pollinating insects and domestic animals, and entering this material into the soil and water and its direct and indirect effect on ecosystems. Intelligent use of chemicals on the nano scale can be a suitable solution for this problem. These materials are used into the part of plant that was attacked by disease or pest. Also these carriers in nano scale has self-regulation, this means that the medication on the required amount only be delivered into plant tissue.

Nanotechnology helps agricultural sciences and reduce environmental pollution by production of pesticides and chemical fertilizers by using the nano particles and nano capsules with the ability to control or delayed delivery, absorption and more effective and environmentally friendly; and production of nano-crystals to increase the efficiency of pesticides for application of pesticides with lower dose. Nano particles for delivery of active ingredients or drug molecules will be at its helm in near future for therapy of all pathological sufferings of plants. There are myriad of nano materials including polymeric nano particles, iron oxide nano particles and gold nanoparticles which can be easily synthesized and exploited as pesticide or drug delivery sponges. The pharmacokinetic parameters of these nano particles may be altered according to size, shape, and surface functionalization. They can also be used to alter the kinetic profiles of drug release, leading to more sustained release of drugs with a reduced requirement for frequent dosing. Diseases are one of the major factors limiting crop productivity. The problem with the disease management lies with the detection of the exact stage of prevention. Most of the times pesticides are applied as a precautionary manner leading to the residual toxicity and environmental hazards and on the other hand application of pesticides after the appearance of disease leads to some amount of crop losses. Among the different diseases, the viral diseases are the most difficult to control, as one has to stop the spread of the disease by the vectors. But, once it starts showing its symptoms, pesticide application would not be of much use. Therefore, detection of exact stage such as stage of viral DNA replication or the

production of initial viral protein is the key to the success of control of diseases particularly viral diseases. Nano-based viral diagnostics, including multiplexed diagnostic kit development, have taken momentum in order to detect the exact strain of virus and stage of application of some therapeutic to stop the disease. Detection and utilization of bio-markers that accurately indicate disease stages is also a new area of research. Measuring differential protein production in both healthy and diseased states leads to the identification of the development of several proteins during the infection cycle. These nano-based diagnostic kits not only increase the speed of detection but also increase the power of the detection. In the future, nano scale devices with novel properties could be used to make agricultural systems “smart”. For example, devices could be used to identify plant health issues before these become visible to the farmer. Such devices may be capable of responding to different situations by taking appropriate remedial action. If not, they will alert the farmer to the problem. In this way, smart devices will act as both a preventive and an early warning system. Such devices could be used to deliver chemicals in a controlled and targeted manner in the same way as nano medicine has implications for drug delivery in humans.

Applications of nanotechnology in food industry

Oxygen is a problematic factor in food packaging, because it can cause food spoilage and discoloration. One of the applications of nanotechnology in the food industry is developing new plastic for food packaging industry. The nano particles are used in the production of these plastics. Nano particles have been found to zigzag in the new plastic, and preventing the penetration of oxygen as a barrier. In other words, the oxygen for entry into package should during longer route, and hence with the long route for oxygen molecules, food can be spoiled later. Recently, nano-coatings are produced for fruit that covering the fruits completely, and prevent of fruit weight loss and shrinkage. Developing smart packaging to optimize product shelf-life has been the goal of many companies. Such packaging systems would be able to repair small holes/tears, respond to environmental conditions (e.g. temperature and moisture changes), and alert the customer if the food is contaminated. Nanotechnology can provide solutions for these, for example modifying the permeation behavior of foils, increasing barrier properties (mechanical, thermal, chemical, and microbial), improving mechanical and heat-resistance

properties, developing active antimicrobial and antifungal surfaces, and sensing as well as signaling microbiological and biochemical changes. With the coated enzymes by nanotechnology, we can keep them away of environment and prevent of working them. Thus, the nutrients corruption will be postponed and their longevity increases. Ethylene absorbent is the most important material that is produced by nanotechnology.

Absorbent ethylene nano materials, absorbs ethylene gas that is produced by fruits (fruit decay increases by ethylene gas) and increases persistence of fruit for long periods. Nano bar-codes and nano processing could also be used to monitor the quality of agricultural produce. Scientists at Cornell University used the concept of grocery bar-codes for cheap, efficient, rapid and easy decoding and detection of diseases. They produced microscopic probes or nano bar-codes that could tag multiple pathogens in a farm which can easily be detected using any fluorescent-based equipment. This on-going project generally aims to develop a portable on-site detector which can be used by non-trained individuals. With the advent of nanotechnology, nano-based bar codes are also available which can do the same function as that of conventional bar codes, thereby helping in tracking and controlling the quality of food product and give all relevant details in a minute. Biosensor is composed of a biological component, such as a cell, enzyme or antibody, linked to a tiny transducer, a device powered by one system that then supplies power (usually in another form) to a second system. The biosensors detect changes in cells and molecules that are then used to measure and identify the test substance, even if there is a very low concentration of the tested material. When the substance binds with the biological component, the transducer produces a signal proportional to the quantity of the substance. So if there is a large concentration of bacteria in a particular food, the biosensor will produce a strong signal indicating that the food is unsafe to eat. With this technology, mass amounts of food can be readily checked for their safety of consumption.

Nanotechnology in fertilizers

Nitrogen, which is a key nutrient source for food, biomass, and fibre production in agriculture, is by far the most important element in fertilizers when judged in terms of the energy required for its synthesis, tonnage used and monetary value. However, compared with amounts of nitrogen applied to soil, the nitrogen use

efficiency (NUE) by crops is very low. Between 50 to 70% of the nitrogen applied using conventional fertilizers — plant nutrient formulations with dimensions greater than 100 nm — is lost owing to leaching in the form of water soluble nitrates, emission of gaseous ammonia and nitrogen oxides, and long-term incorporation of mineral nitrogen into soil organic matter by soil microorganisms. Numerous attempts to increase the NUE have so far met with little success, and the time may have come to apply nanotechnology to solve some of these problems.

Carbon nanotubes were recently shown to penetrate tomato seeds, and zinc oxide nanoparticles were shown to enter the root tissue of ryegrass. This suggests that new nutrient delivery systems that exploit the nanoscale porous domains on plant surfaces can be developed. A nanofertilizer refers to a product that delivers nutrients to crops in one of three ways. The nutrient can be encapsulated inside nanomaterials such as nanotubes or nanoporous materials, coated with a thin protective polymer film, or delivered as particles or emulsions of nanoscale dimensions. Owing to a high surface area to volume ratio, the effectiveness of nanofertilizers may surpass the most innovative polymer-coated conventional fertilizers, which have seen little improvement in the past ten years. Ideally, nanotechnology could provide devices and mechanisms to synchronize the release of nitrogen from fertilizers with its uptake by crops; the nanofertilizers should release the nutrients on-demand while preventing them from prematurely converting into chemical/gaseous forms that cannot be absorbed by plants. This can be achieved by preventing nutrients from interacting with soil, water and microorganisms, and releasing nutrients only when they can be directly internalized by the plant. Examples of these nanostrategies are beginning to emerge. Zinc-aluminium layered double-hydroxide nanocomposites have been used for the controlled release of chemical compounds that regulate plant growth. Improved yields have been claimed for fertilizers that are incorporated into cochleate nanotubes (rolled-up lipid bilayer sheets). The release of nitrogen by urea hydrolysis has been controlled through the insertion of urease enzymes into nanoporous silica. Although these approaches are promising, they lack mechanisms that can recognize and respond to the needs of the plant and changes in nitrogen levels in the soil. The development of functional nanoscale films and devices has the potential to produce significant gains in the NUE and crop

production. In addition to increasing the NUE, nanotechnology might be able to improve the performance of fertilizers in other ways. For example, owing to its photocatalytic property, nano TiO₂ has been incorporated into fertilizers as a bactericidal additive. Moreover, TiO₂ may also lead to improved crop yield through the photo-reduction of nitrogen gas. Furthermore, nanosilica particles absorbed by roots have been shown to form films at the cell walls, which can enhance the plant's resistance to stress and lead to improved yields. Clearly, there is an opportunity for nanotechnology to have a profound impact on energy, the economy and the environment, by improving fertilizer products.

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## Global Environmental Impacts of Agriculture: Requirement for sustainable agricultural practices to save the world

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### Introduction

World population is predicted to reach about nine billion in 2050 indicating an increase demand for agricultural produce and will continue to grow in the future. Increased population exerts further pressure on increased production of food, fiber, biofuel and other essential needs. Therefore, agriculture is an important sector that is directly related to the economic growth of a country. Although food, fiber, biofuel, drugs are produced in large quantities to sustain and enhance quality of human life, many environmental problems faced today are due to the activities of the agriculture which have been directly associated with the intensification of food production. If the agricultural practices which have been introduced in past two decades are continued without a change, the agriculture related environmental problems will remain as serious issues during the next decade. Although development of sustainable agriculture with increased food production of an ever-changing planet is a challenge, there is an urgent need for major changes of the global agriculture systems. It is evident that sustainability of agriculture depends on generation of environmentally friendly, economically viable and socially acceptable products and the balance of these three major factors is extremely important in order to maintain sustainability of the agriculture. It is similar to a 3-legged stool while sustainable agriculture is on the top of the stool. If one leg of the stool is broken, the stool is not stable and will

fall over indicating priority should be given to these three key factors which directly affect on the sustainable agriculture and it is clearly shown that agriculture today is largely a struggle against nature.

This paper reviews the presentation I made at the theme seminar of the annual sessions of the Institute of Chemistry Ceylon and discussed the effects of key activities related to the global agriculture that have contributed significantly to global environmental impacts.

### Negative impacts of Green revolution

In this section I am highlighting the causes and effects of modern agriculture that was introduced after the green revolution. In 1960's the green revolution has been introduced by Nobel laureate, Norman Borlaug, who was called "Father of the Green Revolution". It was initiated with the intention to address the issues of malnutrition in the developing world, mainly targeted to increase the agricultural productivity. The technology of the Green Revolution involved generation of High Yielding Varieties (HYV) using selectively breed or genetically-engineered crops that work in combination with the use of chemical fertilizers, synthetic pesticides and high inputs of water to increase crop yields. The technology of green revolution was readily initiated in developed countries and later the developing countries (eg. Sri Lanka) were also following a similar trend to increase the food production. It was reported that fast growing dwarf

varieties of rice and wheat were developed for tropics and subtropics in 1967 to increase the yield of these crops and seeds were distributed among the farmers (Hedden, 2003). Since growth of the new HYV heavily needs fertilizers, pesticides and high inputs of water, there were many poor farmers who could not afford to participate in the Green Revolution. Hence the gaps between social classes were widen as wealthy farmers got comfortable and poor farmers lagged behind. Consequently, subsistence agriculture in which the farmers focus on growing enough food to feed themselves and their families was transformed to commercial agriculture which is performed using monocultures of HYV. The techniques used for monocultures involved the development of high-yielding varieties of cereal grains, vegetables etc., expansion of irrigation infrastructure, modernization of management techniques, distribution of hybridized seeds, encourage the use of synthetic fertilizers and pesticides to farmers and high inputs of water. The only target of commercial agriculture was to increase agricultural productivity and the yield in order to make a higher income. The use of HYV was novel to traditional farmers and most of them did not have sufficient cash to purchase new machineries introduced via green revolution. The farmers were not adequately educated to understand the environmental impacts that cause due to change of the agriculture systems. The research and development programmes were diverted only towards to create HYV and increase the productivity of crops. Only few researches concentrate their research on the environmental impacts although that was not strong enough to convince the relative authorities. To encourage the farmers on use of HYV and high input monoculture, a loan scheme was created to provide farmers to purchase new seeds, fertilizers, pesticides etc. and marketing systems were also introduced to sell their crops. Facilities were provided to farmers through them farmers can purchase fertilizers, pesticides or machineries. Thus, local farmers tend to produce cash crops for export rather than food crops or subsistence crops for local consumption. Consequences of introduction of commercial agriculture are given below (Mahaliyanaarachchi, *et al.*, 2006).

- The agricultural productions are aimed mainly for sales.
- Productions are targeted for profit maximization.
- The satisfaction of different needs of consumers and interests of consumers are aimed.
- Less attention for nutritional quality and food

security

- Implies the concepts of agri-business management

### **Criticisms of the Green Revolution**

It was found that agriculture developed through the green revolution has greater harmful environmental impacts than any human activity as cash crops tend to develop adverse, long term environmental problems. Therefore it has been highly criticized among the scientists and traditional farmers who are concerned on the negative effects of the green revolution due to the reasons given below (Kang, D.S., 1982).

- Gap between rich and poor farmers is widen because rich farmers have the resources for fertilizer, pesticides, irrigation water, machinery, storage and transportation
- Colour, texture and tastes of new crop varieties not well received.
- Production of HYV's are not cost effective and therefore high costs for small farmers
- Many HYVs require more labour than the traditional counterparts (irrigation and fertilization)
- Require heavy use of synthetic fertilizers and pesticides; salt build-up and contamination of watersheds by nitrates, phosphates and pesticide residues
- Farmers rely on a few strains of a plant and adapted to monocultures, a new disease can wipe out a large portion of the harvest
- Use of machinery causes sound pollution and air pollution
- More benefits only for larger landholders

### **Negative impacts of current mass production style of farming**

- Large-scale commercial farming is practically no different from large industrial enterprises as the main objective of commercial agriculture is achieving higher profits through maximization of crop yields per hectare. The Green Revolution changed the evolutionary history of crops by changing the fundamental nature of seeds and causes extinction of species because of destruction of natural habitat. The increase of global food production has led the serious environment damages in a variety of ways and some are given below.
- Reduced biodiversity
- Habitat destruction
- Deforestation
- Water, air and soil pollution
- Salinization, desertification

- Decline in water resources

It has been reported that nearly 30% of the world's cropland has been degraded to some degree by deforestation (Barrow, C.J. 1991). Deforestation is the permanent destruction of forests on a massive scale in order to make the land available for other uses. As a result of deforestation, ecosystems of the rainforest are converted into less bio-diverse ecosystems such as pasture, cropland or plantations (Kricher, 1997) and these lands were used for cultivation of monoculture crops. The environmental impacts cause due to monoculture crops are an enhancement of greenhouse gas emission (approximately 20% of the world greenhouse gas emission is accounted for deforestation), increase in pest population (as monoculture enables pests to have continual supply of food), increase in application of synthetic fertilizer (increase salt built up and toxic elements in soil), exhaustion of particular type of minerals (the same type of plants draws particular types of mineral from the soil for a long time), cause extinction of species because of destruction of natural habitat (It has been estimated that we are losing 135-140 plant, animal and insect species every single day due to rainforest deforestation) and soil erosion (soil erosion is also caused by heavy rains or strong winds after the deforestation).

The burning of biomasses after the deforestation, releases greenhouse gases such as CO<sub>2</sub>, CO, N<sub>2</sub>O, CH<sub>4</sub>, various CFCs and other trace gases into the atmosphere. Various forms of agricultural production may lead to significant trace gas emissions. Tilling of soils permits oxidation of organic matter and atmospheric CO<sub>2</sub> concentration increases. Use of nitrogenous fertilizer, however, increases nitrous oxide emissions from soil and water through nitrification and denitrification processes. Application of fertilizers increases the N<sub>2</sub>O release by plants, although emission rates vary greatly with soil condition (Follett, 2005).

Since, the above factors affect on human health, human wealth and nature's health, for the past several years research has looked at sustainable agriculture as a potential solution to correct and prevent these problems. In my opinion, the above problems can be minimized by practicing sustainability and by understanding the balances between ecological and social systems. However it is reported that the green revolution has brought disasters to most of the people and the ecological system (Shiva, Vandana, 1991) and however, people with different environmental world views often disagree about the seriousness of

environmental problems and major harmful environmental effects caused due to agricultural practices introduced through the green revolution.

Another concern of the modern agriculture is loss of genetic diversity of food plant after introduction of global genetically modified food (GM). In Sri Lanka, about 97% of the food plant varieties available in 1940 no longer exist in large quantities now. Possible environmental and health risks of GM foods are increasingly well documented. However, peer-reviewed scientific evidences to indicate environmental and health impacts of GM crops are given below.

- Toxic to harmless non-target species (Long-term exposure to pollen from GM insect-resistant maize causes adverse effects on the behavior and survival of the monarch butterfly, America's most famous butterfly (Dively, et al. 2004).
- Toxic to beneficial insects. GM Bt crops adversely affect beneficial insects important to controlling pests, such as green lacewings (Obrist, et al., 2006).
- Since many GM crops secrete their toxin from the roots into the soil, the active GM residues may be toxic and long term cumulative effects of the GM toxin are of concern (Icoz, & Stotzky, 2008).
- Plant parts of GM crops can enter the aquatic systems and the toxins can accumulate in aquatic plant and exert toxic effect demonstrating complexity of interactions in the natural environment (Cambers, et al., 2010).
- Since plant insect interactions are complex, several scientific studies show that new pests are filling the void left by the absence of rivals initially controlled by GM crops (Cloutier, et al., 2008).
- Herbicide-tolerant crops can cross-pollinate with weeds, resulting in "superweeds". Therefore increasing amounts of glyphosate or additional herbicides are needed to control these 'superweeds' (Duke, 2005).

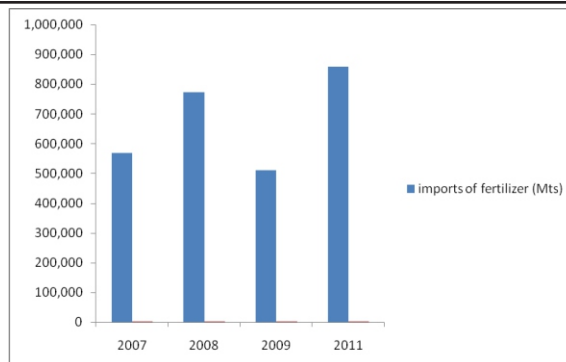
#### **Excessive use of fertilizers, pesticides and impact on public health**

The long-term use of fertilizers and pesticides has been shown to have detrimental effects on human health and overall soil health that leads to erosion. Leaching of nutrients and eutrophication of waters are key negative impacts of environment causes due to excessive use of fertilizer. Eutrophication is a condition in an aquatic ecosystem where high nutrient concentrations stimulate growth of algae. This leads to

intense growth of aquatic plants, increased oxygen consumption and production of excess organic matter. Non-organic fertilizers mainly contain phosphate, nitrate, ammonium and potassium salts are considered to be potential source of natural radionuclides and heavy metals (Chandrajith, et al., 2009). It has been reported that fertilizer contains a large majority of the heavy metals like Hg, Cd, As, Pb, Ni, and Cu; natural radionuclide like  $^{238}\text{U}$ ,  $^{232}\text{Th}$ , and  $^{210}\text{Po}$  (FAO, 1999). However, in recent years, fertilizer consumption increased exponentially throughout the world, causes serious environmental problems. In addition to the eutrophication, fertilization may affect the accumulation of heavy metals in soil and plant system. Plants absorb the toxic elements in fertilizers through the soil and they can enter the food chain. Thus, fertilization leads to water, soil and air pollution.

Sri Lanka is currently one of the world leaders in chemical fertilizer consumption, and imports. Table 1 shows the description of chemical fertilizers imported to Sri Lanka in 2010, and it shows urea, triple super phosphate (TSP) and Muriate of potash (MOP) are imported to Sri Lanka in high quantity for cultivation of rice, tea, rubber and coconut to use in the agriculture (Sri Lanka National Fertilizer Secretariat). Since Sri Lanka is an agricultural country, spending on fertilizer imports rose sharply and the expenditure on fertilizer imports increased by 119.4 % in 2011. Among them nitrogen and phosphorus are the major nutrients of concern that are frequently applied in our crop field in Sri Lanka. The average fertilizer imports per annum in Sri Lanka had been around 550,000 - 650,000 metric tonnes. Figure 1 shows the fertilizer imports in Sri Lanka from 2007 to 2011. In 2007, apart from the outflow of foreign exchange, the fertilizer subsidy import bill stands at over Rs 65.5 billion in Sri Lanka (Source: Daily News May 12, 2011). The farmers were convinced that chemical fertilizers are the most important contributor to increase the world agricultural productivity over the past 30 years and the largest user of chemical fertilizer in South Asian Region was Sri Lanka in the year 2008 (Table 2). This amount was approximately 56 % higher than the amount of chemical fertilizer used in Bangladesh, a country where a large number of the population suffers from chronic arsenic toxicity (Allen, *et al.*, 2000).

In Sri Lanka, excessive use of chemical fertilizers in agriculture, resulting in a large number of environmental problems because some fertilizers contain toxic elements (eg. cadmium and arsenic) and high concentrations of radionuclides (Jayasumana, et al., 2011 & Fernando, et al., 2012).



**Figure 1:** Fertilizer imports in Sri Lanka from 2007 to 2011

Source - FAO Fertilizer Report, 2010

**Table 1.** Fertilizer consumption in Sri Lanka (2010)

Description of the fertilizer imported to Sri Lanka	Urea*	TPS <sup>1</sup> *	MOP <sup>2</sup> *	Total*
Paddy	308,000	100,000	93,000	501,000
Tea	100,000	37	26,000	126,037
Rubber	3,050	20	2,057	5,127
Coconut	5,340	72	8,156	13,568
Other field crops	2,580	2,247	5,295	10,122
Vegetable	3,287	947	2,355	6,589
Export agriculture sector	808	218	1,109	2,135
All other sectors	14	10	16	40
National consumption	423,079	103,551	137,988	664,618
National requirement	553,400	134,675	248,700	936,775

\*Tones <sup>1</sup>Triple Super Phosphate <sup>2</sup>Muriate of Potash  
Source; Sri Lanka National Fertilizer Secretariat

A study conducted by a group of researches from University of Peradeniya has also reported that the TSP fertilizer collected from Chronic Kidney Disease with unknown etiology (CKDu) endemic areas contained significantly higher amounts of uranium (200 ppm – 400 ppm) and Cd (Chandrajith, et al., 2009). Samples of fertilizer collected from various parts of Sri Lanka were investigated and it was revealed that most of the inorganic fertilizers containing phosphates that are commonly used in rice farming are contaminated with arsenic and mercury. The highest amount of arsenic contamination in fertilizer was reported from triple super phosphate (TSP) used in cultivation of rice and it was in the range of 25 mg/kg to 37 mg/kg. Since the annual consumption of TSP for cultivation of rice in Sri Lanka is around  $1.03 \times 10^6$  kg in the year 2010, our results revealed that amount of arsenic present in the TSP used in the agriculture in 2010 was around 2071 kg. The organic fertilizer prepared from decomposing plant matter was analyzed and confirmed that presence of arsenic is negligible in organic fertilizer (Fernando, et al. 2012). Therefore it is suggested to encourage farmers to use organic fertilizer and minimize the use of synthetic fertilizer in Sri Lanka and reduce the health problems caused due to excessive use of fertilizer.

**Table 2. Annual Chemical fertilizer consumption in South Asian region 2008**

No	Country	Fertilizer consumption (Kg/hectare of arable land)
01	Sri Lanka	284.3
02	Bangladesh	164.5
03	Pakistan	163.3
04	India	153.5
05	Bhutan	9.0
06	Nepal	7.7

Source - <http://data.worldbank.org/indicator/AG.CON.FERT.ZS>

Although use of pesticides includes enhanced economic potential in terms of increased production of food and fiber, they have resulted in serious health implications to man and the environment. There is now overwhelming evidence that some of these chemicals do pose a potential risk to humans, other life forms and unwanted side effects to the environment (Jayasumana, et al., 2013, WHO final report 2012).

Characteristics of an ideal pesticide developed for crop protection should be affects only target pests, harms no other animal or plant species, no genetic resistance, breaks down quickly in the environment (biodegradable) and more cost-effective. Despite the fact that the majority of pesticides available in the market is not targeting the pest and adverse affect on non-target plants and animals. Repeated application of synthetic pesticides develops genetic resistance, leads loss of biodiversity. They persist in soil, leach to groundwater and surface water, cause an increase in other pest species, residual effect, harm wildlife, bioaccumulate in food chains and potential influence in human health.

Most important characteristic feature of synthetic pesticides is persistent of activity (non-biodegradable) and accumulates in plants animals called bioaccumulation and become more concentrated at higher trophic levels of the food chain called biomagnifications. Bioaccumulation and biomagnifications of pesticide in the food chain have been explained using the potent pesticide, DDT.

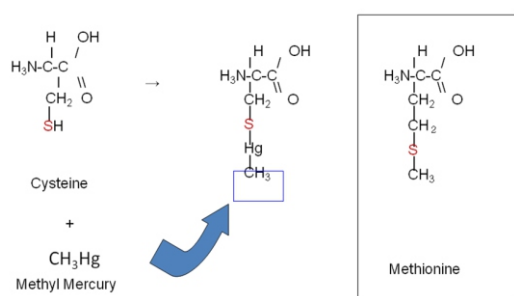
First warning signals about pesticides danger was pointed out by Rachel Carson in 1962. This was about indiscriminate spraying of pesticides, an example for bioaccumulation of Dichlorodiphenyltrichloroethane (DDT). DDT was developed in 1939 and the inventor was awarded the Nobel Prize as it helped to clear the malaria-causing mosquitoes during World War II.

There were only few scientists expressed environmental impacts of this miracle compound. One was nature writer, Rachel Carson, marine biologist from Pennsylvania. She had written a book '*Silent Spring*' to highlight the danger of DDT including the death of numerous birds around her property resulting from the aerial spraying of DDT and was published in 1962. It generated a storm of controversy over the use of chemical pesticides. In 1972, *Silent Spring* facilitated the ban of the pesticide, DDT in USA. Though this is a very old story, it helped to convince the chronic toxicity of pesticides. It describes entering of DDT to the food chain and accumulation in the fatty tissues of animals, including human beings as many pesticides are known to cause cancer and genetic damages. This book changed the view on pesticides and has stimulated public concern on pesticides and their impact on health and the environment (Gilliom, 2007 and <http://www.nrdc.org/health/pesticides/hcarson.asp>).

The problems of pesticide usage are not over. Although in many countries the old persistent, bioaccumulative pesticides have been banned, a lot of new pesticides have been developed and used in large quantities. For most of the new pesticides appear to have impacts on environment and sufficient amount of knowledge about their possible risks and adverse effects on the environment and chronic toxicity on human are not available.

Another disease of human caused due to contamination of water in Japan is named as Minamata disease and was caused by methyl mercury-contaminated effluent released into Minamata Bay by Chisso chemical factory in Japan in 1930's. It is a neurological syndrome caused by severe mercury poisoning. The effluent that contained methyl mercury was released into Minamata Bay from 1932 to 1968 and methyl mercury is highly toxic chemical, bioaccumulated in shellfish and fish in Minamata Bay. The sea foods were then eaten by the local population in these areas resulted in mercury poisoning. It took more than 38 years to confirm the cause of the disease and therefore the government took no action to stop contamination or prohibit fish consumption until it was confirmed. This is one of the most massive pollution problems to strike Japan and however, after 38 years the Japanese government admitted that methyl mercury was the etiologic agent of Minamata disease. It was also reported that methyl mercury is transferred across the placenta to affect the development of unborn children, resulting in serious mental and physical problems in

later life. The researches missed this point at first because of a medical disagreement that such transfer across the placenta was impossible (Harada, 1995). Since methyl mercury is volatile and a lipid soluble compound, it readily and completely absorbed by gastrointestinal tract. It was found to complex with free cysteine, with proteins and peptides containing that amino acid. Therefore the amino acid binds with methyl mercury was recognized by the amino acid transporting proteins as methionine (figure 2). Toxic effects of methyl mercury are well known now and it inhibits acetylcholine synthesis, impairs glycolysis, nucleic acid biosynthesis, aerobic respiration, and protein synthesis and neurotransmitter release. The injured neurons eventually die.



**Figure 3.** Reaction of meth mercury with cysteine

Similar health problem due to extreme use of agrochemicals has been observed in North Central Province (NCP) of Sri Lanka. During the last two decades, noteworthy numbers of patients with Chronic Kidney Disease were reported from Rajarata area of Sri Lanka especially in Medawachchiya, padaviya, Kebitigollawa, Medirigiriya (North Central Province), Nikawewa (North Western Province), Dehiattakandiya (Eastern Province) and Giradurukotte (Uva Province). Since this is different from other kidney diseases, this was named as Chronic Kidney Disease of unknown etiology (CKDu). CKDu is one of the biggest health issues in Sri Lanka. Majority of CKDu patients in Sri Lanka are farmers and they are heavily exposed to pesticides and fertilizers as very little attention is given to hazardous effects of these agrochemicals on human health. Being a pesticide using farmer who drinks well water has been identified to be of highest risk for CKDu (Wanigasuriya et al. 2007). The most recent publication on possible link of chronic arsenic toxicity with CKDu in Sri Lanka was performed by Jayasumana et al. (2013) with the intention of determining the prevalence of clinical features of Chronic Arsenic Toxicity among CKDu patients in

North Central Province, Sri Lanka. It was reported that abnormal skin manifestation were observed among CKDu patients (figure 3).



**Figure 3.** Abnormal skin manifestations of CKDu patients encountered in NCP (Jayasumana, et al., 2013)

In this study the hair and urine samples were collected from both CKDu patients and controls and analyzed for presence of arsenic. The results revealed that hair samples of CKDu patients has significantly higher concentration of arsenic when compared with the control group and 68% of CKDu patients and 28% of the controls had urine arsenic levels above 21  $\mu\text{g/g}$  creatinine, which is considered the point of threshold for manifestation of early renal changes that can be developed in to chronic kidney disease (Jayasumana, et al., 2013). An extensive research on CKDu patients in NCP in Sri Lanka was conducted by WHO (2012) and confirmed the arsenic toxicity among the CKDu patients. Further causative agents for CKDu have been identified and named as nephrotoxic agrochemicals, Cd and As (WHO, 2012). Similar CKDu has been reported in some other place in the world. As in Sri Lanka no exact theory has been formulated yet to explain the etiology for CKD in those occasions. The CKD recently observed among sugarcane farmers in Central America is predominantly affects young males resulting in substantial morbidity and mortality (Orantes et al 2011). Features are most consistent with tubulointerstitial disease. A similar picture is seen in upper Egypt where investigators have noted abnormal increase in CKD patients among male farmers who use Pesticides (kamel et al.2010).

Jayasumana, et al. (2011) has reported that source of arsenic contamination in CKDu patients in Sri Lanka is agrochemicals (both fertilizer and pesticides) used by these farmers. Despite the fact that importation of As-containing pesticides is illegal in Sri Lanka, results reported by Jayasumana, et al., (2011) revealed that 20 out of the 32 available pesticide brands in the local market contained As in the range of  $180 \pm 14$  -  $2586 \pm 58$   $\mu\text{g/kg}$  and it varied depending on the type of active ingredient, brand, batch of pesticides, importer and the area that it is used. World Health Organization

classifies pesticides with arsenic compounds as active ingredients to be highly hazardous. Arsenic containing pesticides are thus banned in Sri Lanka since 1995 and it has been officially notified in the extraordinary gazette notification no 1190/24 of the democratic republic of Sri Lanka of 6<sup>th</sup> June 2001. Arsenic is not even prescribed to include as an inert ingredient, except for six types of pesticides in which it is allowed (within limits) as an impurity and in Sri Lanka, copper- based pesticides only are legally allowed to contain (within limits) arsenic.

Presence of arsenic in locally-grown rice has been reported from Sri Lanka (Jayasekara and Freitas 2004, Yamil et al., 2008 and Chandrajith et al., 2010). Jayasumana (2013) reported the presence of arsenic in hair and urine of patients of Chronic Kidney Disease of unidentified etiology (CKDu) as well as in body parts of diseased CKDu patients from Sri Lanka's largest rice cultivation areas in the North-Central Province. This led to the hypothesis that presence of arsenic compounds in food is a potential cause of CKDu and the agrochemicals containing arsenicals are the potential source of it. It is an urgent need therefore to divert more resources to consolidate these findings and to plan and implement strategies to prevent/ abate pollution of Sri Lankan environment with arsenic derived from agrochemicals. Chronic arsenic poisoning evidently leads to many health hazards and it has been proved substantially that the entry of minute quantities of As to human body in microgram levels over several years can cause many non communicable diseases (Jayasumana, et al., 2013).

Contamination of milk powder with an agrochemical, dicyandiamide (DCD) is another serious health issue in Sri Lanka and this is an example for excessive use of agrochemical as DCD is used to reduce the emission of the greenhouse gas, nitrous oxide from urea. DCD is an effective inhibitor of nitrification enzymes of the bacteria in soil and in addition to the inhibitory activity, it contain 67% nitrogen and is also used as a nitrogen fertilizer as it is converted to ammonia and nitrate in the soil. However high doses of DCD are considered to be toxic for humans and the literature revealed that no extensive research has been conducted on DCD. A recent analysis conducted at ITI reported that milk powder imported from Newzeland and Australia was contaminated with DCD. It is also suspected that the milk powder containing DCD may be an adulteration of milk using nitrogen rich compounds as DCD whcih makes the protein content of milk appear higher than the actual

value. In 2007, melamine and cyanuric acid in milk powder and wheat gluten added to pet food, infant formula caused renal failure and sickened and killed large numbers of infants, cats and dogs. There were hundreds of thousands of victims as well as product recalls in many countries. Therefore, it is essential to confirm that traces of dicyandiamide are not found in milk powder imported to Sri Lanka and reassure there is no risk to health.

Considering the above issues, it is no doubt that we should move forward and take necessary precautions to establish sustainable agriculture. During the last 30 years, the agriculture was developed to provide food for growing populations at unsustainable rates. Fertilizers and pesticides are the major pollutants of soil and water in developing countries. Pesticides reduce biodiversity by destroying weeds, insects, the food species of birds and other animals. Hence there will be a growing demand for organic farming, food will be produced without chemical inputs and increased demand for ecological methods of pest control (IPM).

It is realized that protection of natural resources and improve both environmental quality and food security in the more crowded world become extremely difficult with excising agricultural methods. Therefore sustainable agriculture needs to encompass three key factors, environmentally friendly, socially acceptable and economically viable. By taking this approach, all agriculture systems need to reconsider a certain set of basic principles, which will help to protect natural resources and travel towards more sustainable practices. Land degradation, salinization, the over extraction of water and the reduction of genetic diversity in crops and livestock are the main factors that are affected on the future of sustainable agriculture. Since the long term consequences of these activities are difficult to quantify, adapting sustainable agricultural practices in the future would minimize the impacts of agriculture on the environment and help to address issues related to human health.

Sciencetists from universities and research institutes, private sectors, general public and politicians need work collaboratively to find right technological solutions combined with right policy directions to establish sustainable agriculture and minimize the environmental impacts caused due to existing methods. Consumers can play a critical role in strengthening sustainable agriculture through their purchases of organic food items as the quality of food has influenced consumer choices. Hence it is important to identify the issues that have been affected in developing sustainable

agriculture and establish criteria which help to develop sustainable agriculture, implement trade policies that will help to develop sustainable agriculture and propose specific action plan for a sustainable agriculture and ecosystems.

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**RSC** | Advancing the Chemical Sciences

### Accreditation of Graduateship Programme by the Royal Society of Chemistry, UK

Formal recognition has come from the **RSC**, which is the only recognized accreditation body for chemistry graduates in the UK. After an extensive examination of documentation submitted, a team visit last June, subsequent discussions with staff and students and our satisfying their requirements for upgrading our programme, the RSC has now accredited the Graduateship programme as fulfilling partially the academic requirements for the award of **Chartered Chemist (CChem)** status.

## Ninth Convocation of the College of Chemical Sciences

### Convocation Address:

### Education is a Chain Reaction that lasts a lifetime

Dr. Kingsley A. de Alwis, *BSc(Cey), PhD(Alberta), FNASSL, Hon. F.I. ChemC*  
*President National Academy of Science Sri Lanka,*  
*President elect. Science Council of Asia,*  
*Consultant Agronomist to FAO, WB and IFAD,*  
*Retired Science Advisor (Agriculture) to FAC,*  
*Former Head, Land Use Division, Irrigation Department*

Let me at the outset thank Prof. Sotheeswaran, Dean of the College, and Prof. J. N. O. Fernando Rector of the College for their kind invitation to me and my wife to be a part of this convocation. I am greatly honoured and it gives me great pleasure to have been asked to be the Chief Guest and to deliver the Ninth Convocation Address.

A convocation is a very special event in the academic calendar of the College of Chemical Sciences of the Institute of Chemistry Ceylon as it brings together the students, their parents and the academic staff to celebrate what is essentially a joint achievement of all three groups. I would like to take this opportunity therefore to address these remarks to each and all of them.

First, I would like to say a few words to those of you who are graduating today. I believe there are 83 Graduate Chemists, 34 DLTC Chemistry Technicians as well as a few Licentiate Chemists and Advanced Diplomates in the list. You are very fortunate indeed to have received such a high-quality education as the one you have had at the College of Chemical Sciences. This is especially true if you plan to go in for further studies in the field of chemistry or any of the sciences for that matter, since chemistry is the basis for the physical sciences, the life sciences, the earth sciences and the applied sciences. But it is also true if you plan to seek employment directly after graduation in the same or even some other field, because you are now equipped with the proven ability to carry out your assignments in any job with discipline and dedication.

I wish that you graduands would appreciate the role of your parents whose love, sacrifices and sometimes even reluctant pressure on you, have brought you this academic success. Give them a big hand. Stand up and look for your parents wherever they may be seated and wave to them or greet them from where you are. And after this ceremony, be sure to give them a big hug.

To the parents who are here, I would like to say how fortunate you are to have been able to give your

sons and daughters a tertiary education in chemical sciences which is the equivalent to that available at any high class university in the world, at such a reasonable cost.

To the faculty members who are present here today, I offer my congratulations for the great job you are doing, teaching with such dedication and such a high sense of professionalism, and thereby setting an example to the state universities and the education sector as a whole.

I can do no better to describe the educational service offered by the College of Chemical Sciences than to quote Prof. Oleap Fernando. In a recent article he says:

*"The two tertiary level programmes conducted by the College of Chemical Sciences (CCS) over the past four decades have proved to be typical examples of the type of tertiary education that can be provided at low cost, without delay, efficiently, effectively and without the constraining effects of state bureaucracy and political interference.*

*The Graduateship Programme in Chemistry of the CCS today produces annually well over 40 percent of Sri Lanka's Special Degree level Chemists within a four year period at an average cost of about Rs 3 lakhs which surely must be the cheapest of any such programme in any part of the world. With an average cost of well over Rs 1 million to produce a similar graduate in the Sri Lankan University system, it should be noted that the 905 Graduate Chemists produced by the CCS through 30 batches (1983-2011) represent a human resource development (HRD) which would have otherwise cost the national exchequer, well over one billion rupees.*

*Opening up educational opportunities outside the state university sector in Sri Lanka, particularly through the non bureaucratic and non-politically-oriented professional bodies, can in fact have a symbiotic and synergetic effect as well. The College of Chemical Sciences of the Institute of Chemistry Ceylon has convincingly proved how this could be done in*

*order to take Sri Lanka towards making it a knowledge hub in a very practical and efficient manner.”*

There is a lesson here for our politicians who are constantly shouting from the rooftops that only state education can deliver the goods.

I now wish to give you, both students and parents, an opportunity to show the feelings of gratitude, that I am sure you have, towards the faculty and staff of this fabulous institution, the CCS, for having contributed their time, energy, experience and erudition to impart their knowledge to those who are graduating today. So, let us give the faculty at CCS a big hand.

However, today is primarily the day of the students and a Convocation Address is traditionally expected to direct a few words of advice towards them. The convocation marks the culmination of a chapter in a student's education. It is a time of relief for the student and his or her parents - and in some cases, for the teachers as well. However, it is also a time of sadness caused by the realization that the bond with the teachers has to be severed and the student will now be out there in the world on his or her own.

I congratulate all of you who are graduating today. Some of you are being recognized and honoured for your outstanding performance and you deserve our highest appreciation. All of you have undergone a thorough grounding in the Chemical Sciences, which if all goes well, will start you off on a successful career. Considering the state of the economy, I am sure that many of you are anxious about whether you will have a long wait after your graduation to get a job. As you go back home and time passes, this anxiety is likely to increase. But remember that your anxiety will be nothing compared to that of your parents! But don't worry. Take heart from the fact that chemistry underlies every other branch of science and many non-scientific pursuits as well. I recently did a Google search for chemists' jobs. Not that I am searching for a job at my age, but I was curious about what sort of opportunities are available out there for young chemists graduating today. Here is the list I found in the New Scientist magazine of 2<sup>nd</sup> January alone; it gives the available jobs for chemists with the number of vacancies in each category in parentheses:

Agricultural Chemistry (16); Analytical Chemistry (70); Biochemistry (30); Catalysis (7); Chemical Engineering (21); Chemical Information (1); Computational Chemistry (4); Electrochemistry (4); Environmental Chemistry (14); Food Science & Nutrition (17); Forensics (1); Geochemistry

(5); Industrial Chemistry (13); Inorganic Chemistry (6); Materials Science (15); Medical Affairs (10); Medicinal Chemistry (6); Molecular Chemistry (4); Nuclear & Technology (2); Organic Chemistry (17); Petroleum chemistry (1); Pharmaceutical Chemistry (25); Pharmacovigilance (2); Physical Chemistry (15); Polymer Chemistry (12); Process Chemistry (14); Quality Control/QA (45); Regulatory Affairs (33); Spectroscopy (8); Synthetic Chemistry (6); Toxicology (5); Other (11) (A total of 440 openings in 32 job categories).

There are, of course, many other chemists' jobs that are not in this list that are available from time to time, even in Sri Lanka. A job for which a chemist could apply may also be clothed in different terminology e.g. as “analyst” or “technologist”. You could also end up as a chemistry teacher in a university or a school. Some of you are specifically trained as laboratory technicians and there are many openings in this field. So take heart and be sure that with the excellent training you have got, there is a job out there, waiting for you. One career I do not recommend for you, even though it is perhaps the most lucrative one in Sri Lanka today, is that of a politician. You could have gone into that profession without the qualification you are getting today or even after dropping out of school!

However, don't look out exclusively for a job dealing with chemistry. I would like to give an example from my own experience in this respect. I started with a special degree in chemistry from the University of Ceylon, as it was then called. My first job was as Assistant Soil Chemist in the Department of Agriculture, where I was involved mainly in Soil Survey and Land Classification, not just chemistry of the soil. I had to learn many new disciplines to carry out my work as part of the team that made the first National Soil Map for Sri Lanka. I learned that in this job chemistry, or even soil chemistry, was not enough to understand the principles of soil science. One also needed knowledge of soil physics, soil biology, soil microbiology, soil fertility, geology, mineralogy, hydrogeology, hydrology, geomorphology, climatology, remote sensing, cartography, agronomy and agriculture among other disciplines. Subsequently, I went for my Ph.D. training in Canada where I had to follow courses in all these subjects before getting down to my research program. On my return to Sri Lanka and in due course I became Head of the Land Use Division of the Irrigation Department.

In this position, I found that even knowing all these technical disciplines was not enough. I had to learn

something about administration to manage and motivate a team of soil scientists, soil surveyors, cartographers and laboratory staff. I had to learn how to deal with the stifling bureaucracy of Government Departments and Ministries, I had to learn how to deal with foreign agencies and the “experts” they sent, who in many cases, were not experts at all. And I had to learn how to say no to politicians who wanted jobs and contracts to be given to their friends and relatives without going through the proper procedures. And none of these things had to do with the Chemistry I learned at the University.

All this helped me when I took up a position as Agricultural Officer and later became Senior Adviser (Agriculture) with the FAO, the Food and Agriculture Organization of the United Nations, in Rome. But I had still more learning to do. In this job, I had to go on missions to many Franco phone countries, for which I had to quickly brush up my French, of which I had only a smattering to begin with. I also had to work with, and later lead, multi disciplinary teams to prepare projects in the agricultural sector for investment by the World Bank and other International Financing Agencies. These projects involved agricultural development, research and extension, irrigation, livestock development, forestry, tree crops development, etc. and I had to teach myself the basics of all these disciplines. I also had to study some economics, economic and financial analysis, and the associated computer programs.

The point I am trying to make with all this is that the learning process, be it formal education at an academic institution such as the College of Chemical Sciences, or learning on the job, is *never* finished. If you are not learning something new every day in your job, you will never progress. The way knowledge and technology are progressing today, you will surely fall behind and the work you do will become irrelevant if you don't keep up with new developments in your field. This stagnation is illustrated by some lecturers who repeat the same lectures year after year and claim to have 20 years of teaching experience, but what they really have is one year's experience repeated 20 times! It is also illustrated by senior professors who are unable to access the large amount of knowledge available on the internet, to communicate with fellow scientists abroad and to keep up-to-date with new developments in the scientific world, simply because they are computer illiterate.

So, do not think of this as the end of the book, it is only the end of a chapter. Learning is a lifelong experience. As Socrates said, “Education is the kindling of a flame, not the filling of a vessel”. Learn something new today. So, do not think of this as the end of the book, it is only the end of a chapter. Education is a lifelong process and may be compared to a chain reaction which lasts a lifetime.

Good luck and God bless you all.

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The Report of the Honorary Rector

Looking forward to the completion of four decades of Professional Chemical Education (at Graduateship and Technician levels) in Sri Lanka.....

Professor J. N. Oleap Fernando, *CChem; CSci*
Honorary Rector & Honorary Professor, CCS,
Emeritus Professor Open University of Sri Lanka

It is with a continuing sense of humble accomplishment, immense satisfaction, justifiable pride and looking forward to the completion of the fortieth year of professional chemical education at a tertiary level by the Institute of Chemistry Ceylon that I present to you once again the Annual Report of the multifarious and varied activities of the College of Chemical Sciences.

Graduateship Programme in Chemistry

The 30th batch of 83 Graduate Chemists receiving their certificates today comprise the fifth batch to be

admitted to Adamantane House in February 2009 as the 31st incoming batch. Our average annual output of 83 over these past four years (2009 – 2012) is in striking contrast to an average annual output of 45 over the previous four years (2005-2008). This (virtual) doubling of the output has however not been at any expense of quality and standards; it has in fact occurred with a considerable increase in facilities provided including a remarkable increase of the number of internal academic staff from one in 2005 to nine in 2012 representing increased accessibility of regular staff to students; the number of regular teaching assistants

employed by the College has increased from 3 in 2005 to about 20 in 2012. The total regular staff of the Institute (including non academic staff) increased from 16 in 2005 to 50 in 2012.

In 2004 when we celebrated the 25th Anniversary of the establishment of the Graduateship programme (in 1979) we were happy to graduate the daughter of a Graduate Chemist who joined the inaugural batch. We are now happy to record the passing out of the daughter (Ms. Lakmini Egodewatte) of a very senior, respected and loyal member of our institute, though not our own Graduate Chemist - Mr E.G Somapala. Over the past three decades we have had about six children of Chemists joining the programme but this is the first time that a child of a non CCS Chemist has passed out. I wish to extend on this occasion an invitation to more of our members to enroll their children in our programme, thereby not only benefiting to become a Graduate Chemist in the shortest possible time but also with the complete waiver of tuition fees. I should also record that Lakmini has done very well to be placed overall third in the final pass list.

Our current output of Graduate Chemists without any delay within a four year period at a very low personal cost to students (of about Rs. 350,000 over 4 years) constitutes well over 40% of Sri Lanka's total production of Graduate Chemists from several tertiary level institutions. The total output over 34 years from 30 batches has increased to 905 and we look forward to a total output of almost 1000 within the next nine months when the 31th batch will pass out, during the 40th year of the provision of tertiary chemical education by the Institute of Chemistry Ceylon. Using the most recently available average national figure of over Rs. 1 million for the production of a four year BSc graduate in the university system, our production turns out in notional financial terms to a human resource monetary equivalent of well over one billion rupees. Such an unexpected and unpredicted human resource development has been realized by the Institute of Chemistry Ceylon at no expense whatsoever to the national exchequer. Our professional body of Sri Lankan Chemists can be justly proud and satisfied with this most wonderful achievement which quite clearly stands as a unique model for any educational programme that can be offered by any institution in Sri Lanka.

I had the great privilege and pleasure over the past few months (during my personal holiday in the North American Continent) to meet, see and observe personally the most impressive and heartening

achievements of about 35 of our Graduate Chemists, mostly in Graduate studies and a few in employment. I was also able to personally meet some of the supervisors of the former students who are pursuing PhD studies in USA and Canada. Particularly in contrast to a similar visit I made to the North American Continent in 2006, I could very clearly gauge the increased degree of positive feedback from supervisors as well as the enhanced level of confidence, zeal and maturity exhibited by our own Graduate Chemists. I was indeed proud to observe the manner and language in which they described the graduate work they were carrying out and how they were able to do so in the midst of numerous obstacles!

I am extremely glad to report that at least one such student has submitted three papers for the forthcoming annual meeting of the American Chemical Society after a mere three months of graduate research. According to the ongoing surveys carried out by us, it is not unlikely that there would be about 100 with PhD degrees at the end of 2013 in contrast to about fifty at the end of 2011. Increasing numbers of our Graduate Chemists are proceeding to numerous universities in many developed countries with the goal of obtaining post graduate degrees.

Increasing numbers of secondary students are also knocking at the doors of Adamantane House. We had 95 such applicants before the release of the 2011 A/L results and in striking contrast, we had 175 applicants before the release of 2012 A/L results. Recognizing the customary increase in number of applicants soon after A/L results are announced, we took steps, without disappointing any such potential Graduate Chemists, to duplicate the Graduateship Programme on three week days in addition to the traditional weekend programme with effect from this year. The total number of registrants after the A/L results were released has thus climbed up to a record number of 205.

Formal Accreditation of the Graduateship Programme by the Royal Society of Chemistry, UK.

We accepted an offer made last year by the Royal Society of Chemistry, to consider accreditation of our Graduateship Programme. A three member team for the RSC visited Adamantane House during the Institute Annual Session in June 2012. This visit involved active and independent discussions with the lecturers, staff and students. Invaluable suggestions to improve the programme have been made and numerous documents regarding our activities were submitted to the team. We have now been informed that once certain adjustments

and improvements are made, we are likely to be accredited later this year. This would be another important milestone in our tertiary education history.

Diploma in Laboratory Technology Programme in Chemistry (DLTC)

As one of the very few present here who witnessed the historic commencement of our first formal educational programme in 1973 (at the Technician level) at Aquinas University College at a time when the Institute of Chemistry Ceylon was a crawling baby, I am indeed extremely happy to record that this 2 year tertiary programme at a middle level, open basically to those even with GCE (O/L) qualifications, has also progressed exponentially upwards with the shift of the programme to our own Adamantane House in 2005. 34 have passed out this year as the 38th batch bringing the overall total to 864. The average output has also doubled from 21 (2000-2006) to 42 (2007-2012).

The DLTC programme continues to date as the only such programme producing Chemistry Technicians at a middle level in Sri Lanka. As we approach the 40th year of the commencement of this wonderful and useful programme and the completion of four decades of professional chemical education in Sri Lanka, we remember with gratitude and respect the foresight, forethought and the altruistic sense that enabled our respected predecessors to even think of such a Technician level programme in order to meet a serious lacuna and need at the middle level in Sri Lanka. I used the word *altruistic* since very small payments were made to lecturers and the Institute as a body did not make any charge for all the academic services provided (including even the issue of the Institute Certificate to successful students) over the first decade of the programme. Increasing numbers of DLTC diplomates are also now registering to follow the Graduateship programme.

The annual intake into the DLTC programme has also registered an astronomical increase over the past few years from 50-60 to a record number of 130 as the 40th batch which commenced their programme last December. This increase too has now necessitated the duplication of this programme as well on week days.

Building Programme

Our continuing inability, despite written promises and even the payment of an advance three years ago, to obtain on lease a much needed additional block of land, which is still available, from the UDA in close proximity to Adamantane House has unfortunately

been more than a tragedy and a typical example of the lack of appreciation of the contribution of a professional body to supplement human resource development at a tertiary level in Sri Lanka. Land is being allocated for various purposes which do not meet any of the altruistic ideals of bodies such as ours. We have therefore been compelled to embark on a five/six storey building on the balance half of the small 25 perch block of land surrounding Adamantane House although it will make the limited space we have very crowded! The piling work was undertaken between July and November 2012 at a cost of 18 million rupees while the main building construction which commenced in November is progressing well and is due for completion at an estimated cost of 40 million rupees before the end of 2013. The total cost of the new building and subsequent refurbishment will therefore be around 80-90 million rupees.

The extension will add a further 9250 square feet of additional space increasing the total area at Rajagiriya to about 20,300 square feet. There will be a bridge at every level between the two buildings. It is hoped that with the completion of the extension, we will be able to provide overall additional space for lecture halls, undergraduate laboratories, library, toilets and staff rooms together with provision for a research laboratory. Increased numbers of students for both our programmes have already compelled us to establish an additional lecture hall in level 3 at the existing building as well as open a Supplementary Campus comprising 2000 square feet of space rented nearby from the College of Surgeons. These modifications will be able to ameliorate the current acute lack of space at least until the permanent extension is completed at the end of this year.

We would wish to make the enlarged building we will have, at least modestly, even more attractive, comfortable and user friendly than what we have at present. It should be a model example to what a professional body could achieve even without any financial input from the government or any other funding agency. Practically all the funding so far for our buildings has come from the fees collected from our students which has been well collected, well spent, well saved and well invested! It is worthwhile to mention and record that so far not a single official/officer has gone abroad on Institute/College expense for any activity. No space in our buildings has ever been rented out since, whatever space we have is used entirely for the conduct of our own use including the educational programmes. This is in striking contrast to perhaps all

similar allocations of land that have been made by the UDA over the past 3-4 decades. Some of the buildings on land allocated are used by some bodies entirely for earning rental income. What a tragic catastrophe?

A very well respected senior member and former President of our beloved Institute (Dr. R. O. B. Wijesekera) has in a recent letter to us indicated how much he is filled with admiration for the effort made by the CCS to convert a very modest narrow academic outfit that threatened to remain as such forever into a vibrant agent for the national Chemical professional community to give our Institute dimension and stability. We are indeed energized, inspired, motivated and emboldened by such genuine expressions while appreciating and taking note also of critical comments made by others. May I therefore use this opportunity to appeal to and encourage our wider chemical professional community, young and old, which includes 905 Graduate Chemists who have directly benefited from our unique efforts to make a positive contribution, financial or otherwise, big or small, towards the refurbishment costs of the extension and improvements to the refurbishment of the existing building. That would be in the fortieth year of the commencement of formal educational programmes, an expression of your joy, pleasure, satisfaction and commitment to make your own contribution towards supplementing the financial resources generated from our students over the past four decades. Will that not be a genuine practical appreciation and formal expression of what the Institute and the College have been able to now achieve starting from very small beginnings?

Ruby Anniversary of Chemical Educational Programmes of the Institute over four decades

It has been decided to hold an International Symposium/Conference on Chemical Education on the theme "Professional Chemical Education and Research for Industrial Development and Sustainable Economic Growth" to commemorate this welcome anniversary in early April 2014. Amongst the preliminary suggestions / decisions already in the pipeline for this purpose are

- (i) to hold our tenth Convocation as part of the Ceremonial Inauguration of the Conference
- (ii) to invite the Federation of Asian Chemical Societies to hold an Executive Committee meeting in Colombo in conjunction with the Conference
- (iii) to organize a CHEMEX – 3 Exhibition together with the formal hard opening of our extension

Your help, advice and assistance towards this endeavor will be much appreciated.

Full time Academic Staff of the College of Chemical Sciences

The appointment of the Dr. (Ms)Thiripuranathan Gobika as a Senior Lecturer (on contract) from January 2012 has increased the total number of our Graduate Chemists on our regular academic staff to five and the total number of regular academic staff to ten.

With the commencement of week-day lectures, for both the Graduateship and DLTC programmes, we would require more regular academic staff of high academic caliber to be recruited. We look forward therefore to the return of Chemistry Graduates with good academic records (whether produced by us or elsewhere) for consideration for appointment in the CCS for both full time and part time assignments.

Sixth Research Session

The sixth Research Session of the College was held on 26th October 2012 with Mr. K.R Dayananda, Graduate Chemist (1984), as Chief Guest. 25 Graduate Chemists passing out today presented the results of their research/ study on this occasion as part of their examination process.

National Titration Competition

The National Titration Competition amongst A/L school students was conducted for the 2nd year in succession in November 2012 and was once again very ably co-ordinated by Prof. H. D. Gunawardena. 139 students from 22 schools participated. Students from Devi Balika Vidyalaya won the first three places in the competition for the second successive year.

The **Inter Level Debating Competition** organized by the College was continued for the fifth consecutive year on 15th December 2012.

Extra Curricular Activities

Our College increasingly encouraged numerous extracurricular activities to enable our students to enhance their leadership, sporting and organizational skills as well as display their hidden talents in a formal manner. College involvement also now includes substantial financial contributions towards such activities organized by and/or through the Student Association. These activities included Aura-2013 (talent-show), Religious activities, Social Action Programmes, Entertainment, the commencement of a Roract Club and Sports. A Cricket Club has already been established and Swimming facilities are about to be provided. We look forward to enhancement of such

activities since we are of firm opinion that such involvement enhances the academic outputs of students as well as making them better and stronger in the wide world to which they will depart after their studies with us. The All-rounder Awards initiated and donated by past Student Association President, Mr. Chamikara Wijesinghe, that are being awarded today for the 3rd year in succession, are no doubt a welcome initiative to enhance such extra-curricular activities. It is noteworthy to record that the Shireen Jayasuriya Gold Medalist for the best academic performance this year has also emerged as the best All-Rounder. Let this be a good example and model for the future!

Acknowledgements

I wish to acknowledge with grateful thanks the receipt of an increasing number of prizes at various levels of the Graduateship Programme. These include

1. Deepa Sotheeswaran Gaschik Prize for Agrochemicals donated by Ms. Deepa Sotheeswaran Gaschik in Germany
2. Dharmarathne Wasala Prize for Computational Chemistry endowed by Dr. Wishva Herath, one of our own Graduate Chemists, now employed in Singapore
3. Piyadasa & Kalyanawathi de Silva Memorial Prize for Quality Management donated by Ms. Nalini De Silva
4. Professors Saman & Asoka Pathirathne Award for overall excellence in Analytical Chemistry donated by Professor K.A.S Pathirathne
5. Mr. A.M Jayasekara & Mrs. Kusum Aththanayaka Family Prize for Separational Techniques donated by Mr. A.M Jayasekara

I am happy to record that 15 Scholarships & 105 Prizes/Merit Bursaries have been awarded this year

through endowments as well as annual awards. The total value of these awards at all four levels during the current year amounted to Rs. 800,000. We thank all our numerous donors for their great generosity and support which has enabled us to award valuable prizes and medals for all the courses we offer at all levels. We award subject prizes for almost all our courses and most of them are donated / endowed. However a few are still available for sponsorship and the welcome support of donors is eagerly solicited and awaited.

Conclusion

We continue to go forward with confidence, enthusiasm, satisfaction and a sense of fulfillment that the Institute of Chemistry Ceylon has been able over the past four decades to make an immense contribution towards Human Resources Development of Graduate Chemists and DLTC Diplomates in Sri Lanka. From very small beginnings we have in the language of a former president, been able to convert a very modest narrow outfit that threatened to remain as such forever into a vibrant agent to give our Institute dimension and stability. Savings have been used to improve the human resources available for all work of the Institute and to improve and enhance Institute and College infrastructure 65 % of the membership of our Institute now constitutes our own Graduates Chemists. It is therefore very clear that the future progress and development of the Institute and the College are increasingly dependent on our own alumini who as Institute members are also collectively share holders and stake holders. I am glad that both Institute secretaries continue to be our own Graduates Chemists. I therefore repeat my plea and express our fervent hope and expectation that our alumini will take on this responsibility more fully and seriously treat the Institute and the College as their academic parent.

Thank you all very much.

Yet Another Senior Professor appointed to CCS

We are glad to note that **Professor E Dilip de Silva**, PhD (Hawaii), BSc (Colombo) will be joining the CCS as a full time senior Professor on contract from 1st November 2013. Professor de Silva, who is a Senior Professor at the University of Colombo will be using the major part of his sabbatical leave until July 2014. The **Sixth Professorial** Oration of the CCS titled “**Manoalides to Dhilirolides; A Fascinating Journey from Pacific Marine Reefs to Tropical Rain Forests**” will be delivered by Professor de Silva on **22nd November** at 4 pm at Adamantane House.

43rd Annual Sessions of the Institute of Chemistry Ceylon 2014

Theme:

Curricula and Evaluation in Chemistry for a Sustainable Economy

Date: June, 2014

CALL FOR ABSTRACTS AND EXTENDED ABSTRACTS

Last Date for receiving abstracts and extended abstracts is 31st January 2014

AWARDS 2014

The following awards will be presented at the Annual Sessions 2014 of the Institute of Chemistry Ceylon.

- **Dr. C.L de Silva Gold Medal Award**

Awarded for an outstanding research contribution in any branch of Chemical Sciences and/ or the use of such research for National Development during the last five (5) years in Sri Lanka. Credit will be given for the utilization of local raw materials, and where the contribution has already resulted in (i) a publication in a Citation Indexed Journal or (ii) Registering a Patent or (iii) where the contribution has already resulted in a positive impact in the development and innovation in the industry.

- **INSTITUTE OF CHEMISTRY SILVER MEDALS**

Devanathan Memorial Award

Awarded for an exceptional research contribution of an original nature in the field of Physical Chemistry and or related areas, such as Physical-Inorganic, Physical-Organic and Biophysical chemistry.

Chandrasena Memorial Award

Awarded for an exceptional research contribution of an original nature in the field of Organic Chemistry and/ or related areas such as Biochemistry, Pharmacognosy, Molecular Biology and Bioactivity studies.

Ramakrishna Memorial Award

Awarded for an exceptional research contribution of an original nature in the field of Inorganic and/ or Analytical Chemistry and/ or related areas such as Bio-inorganic Chemistry or Bio-analytical Chemistry.

- **INSTITUTE OF CHEMISTRY BRONZE MEDALS**

Kandiah Memorial Awards

Awarded for the best research contribution in Chemistry carried out by a postgraduate student registered for a postgraduate degree by either course work or/ and research at a Higher Educational Institute in Sri Lanka and for work carried out in Sri Lanka, with the exception of special analysis that cannot be done in the country. Such results should be less than 20% of the findings from the work. Sandwich programs carried out partially abroad do not qualify for the award.

Kandiah Award for Basic Chemistry

For research predominately in basic Chemistry (Organic, Inorganic, Physical, and Analytical).

Kandiah Award for Applied Chemistry

For research in Chemistry related areas such as polymer, food, biochemistry, biotechnology, where interdisciplinary research is involved and provided that chemistry has a central role and comprises at least 50% of the content.

Kandiah Memorial Graduateship Award

For the best piece of research in the Chemical Sciences carried out by a Graduate Chemist of the College of Chemical Sciences/ Institute Chemistry Ceylon registered with a Higher Education Institute for a Post Graduate Degree.

- **Professor M. U. S. Sultanbawa Award for Research in Chemistry**

Awarded for the best research paper presented at the Annual Sessions of the Institute of Chemistry Ceylon, for work carried out and completed in Sri Lanka.

Closing date for receiving applications/ nominations for the above awards: 28th February 2014

Further information could be obtained from the Registrar, Institute of Chemistry Ceylon or www.ichemc.edu.lk

Metal-Organic Frameworks (MOFs)

Dr. Vajira P. Bulugahapitiya

Department of Chemistry, University of Ruhuna

Metal-organic frameworks (MOFs) are a new class of hybrid inorganic-microporous crystalline materials. MOFs possess the properties of both organic porous material (eg: Charcoal) and inorganic porous material (eg: Zeolites) and unique properties associated with hybrid material. MOFs are formed using metal or metal clusters linked by organic ligands (linkers) using coordinative bonds. Metal Organic Frameworks are also named as Metal – Organic microspores materials, porous coordination networks or porous coordination polymers. These materials can be one-dimensional (1-D) chains, 2-D layers, or 3-D networks MOFs have attracted a great deal of attention since last two decades due to their enormous structural and chemical diversity, unique porous properties (nano-scale pore size between 0.4–6 nm) and superior surface area. Therefore, large number of MOFs have been synthesized so far and different applications has been explored such as gas storage, gas capture, gas separation, enantiomeric separation, enantio-selective catalysis, molecular recognitions, luminescent and fluorescent materials, sensors, energy conversions, ion exchange, drug storage and drug delivery etc.[1,2].

Metals used in MOFs

A large number of MOFs have been prepared using different metals. The most common metals employed in MOFs are Cu or Zn. Other transition metals such as Ni, Mn, Cr and Cd are also used in some preparation. In recent development of MOFs, the metals, Pt, Pd and Rh have been successfully used. Use of lighter metals such as Be, Al in MOFs has also been explored recently [2].

Organic linkers used in MOFs

The organic molecules used in coordination networks are typically, mono-, di-, tri-, or tetravalent ligands [6, 21]. Those compounds are mainly carboxylic acids (Figure 1). Organic linkers can be achiral or chiral molecules [16]. Chiral molecules are important in preparing MOF with chiral recognition ability. In addition to carboxylic acids, some pillar ligands are being used in preparing microporous materials. These pillar ligands are usually aliphatic or aromatic amines as shown in figure 2 [7]. As new development of MOFs, some complex ligands

prepared from metals and organic acids have been utilized in MOFs [3,4].

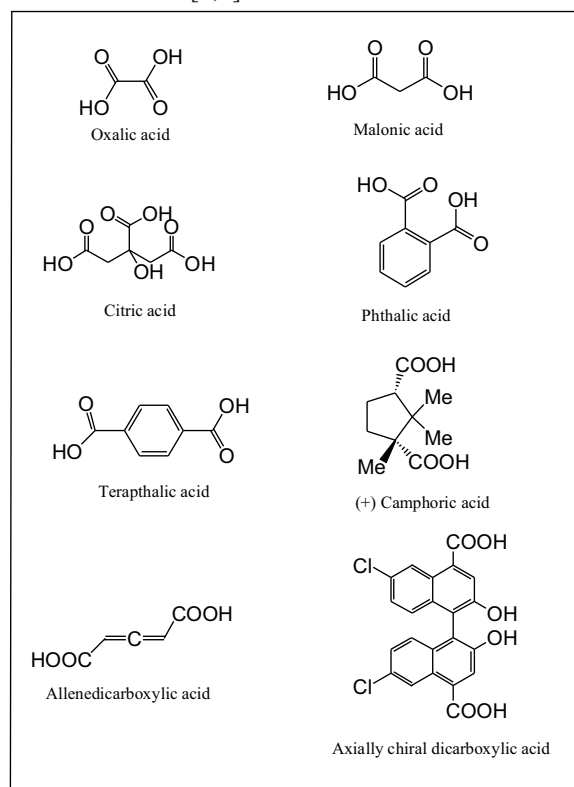


Figure 1 : Possible organic linkers in MOF

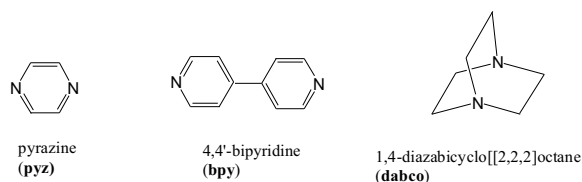


Figure 2 : Possible pillar ligands in MOF

Synthesis of Metal Organic Frameworks

Following synthesis methods are being used in preparing of MOFs

(a). Conventional Synthesis (solvothermal and nonsolvothermal synthesis)

The term conventional synthesis is usually applied to reactions carried out by conventional electric heating [2,17, 21]. The reaction temperature is one of the main parameters to be considered in the synthesis of MOFs. The two temperature ranges are normally used.

- i. solvothermal
- ii. nonsolvothermal

Solvothermal procedure involves loading ligands, metal salts, and solvents in a closed vessel, and heating

the mixture above the boiling points of the solvents. Solvothermal reactions have proven to be an effective synthetic approach for the formation of 3D networks with high crystallinity [4]. Therefore, this method is frequently used in the synthesis of MOFs. Sometimes template molecules are added to facilitate the formation of networks [1].

In nonsolvothermal procedure, reactions take place below or at the boiling point under ambient pressure.

The solvents used in above two process are H₂O, DMF, DMSO, DMA etc. Acetonitrile and methanol are used in low temperature synthesis. Some potential MOFs have even been obtained at room temperature by just mixing the starting materials [2].

b. Mechanochemical Synthesis

In mechanochemical synthesis, the mechanical breakage of intramolecular bonds followed by a chemical transformation takes place [2]. Its use for the synthesis of porous MOFs was first reported in 2006.

Mechanically activated MOF synthesis has many advantages:

- It is a green synthetic process. The reactions can be carried out at room temperature under solvent free conditions. Therefore organic solvents can be avoided.
- Short reaction times, normally synthesis completes within 10 - 60 min, can lead to quantitative yields.
- Some cases, metal salts can be replaced by metal oxides which results in the formation of water as the only side product.
- The use of minute amounts of solvents, the so-called liquid-assisted grinding (LAG), is possible in mechanochemical synthesis.

c. Sonochemical Synthesis

Sonochemical synthesis takes place upon application of high-energy ultrasound to the reaction mixture. [156-157]. Ultrasound is cyclic mechanical vibration with a frequency between 20 kHz - 10 MHz [2].

As the wavelength is much larger than the molecular dimensions, no direct interaction between ultrasound and molecules, but when high-energy ultrasound interacts with liquids, cyclic alternating areas of high and low pressure are generated and it accelerated the reactions.

In addition to above methods, some other specific methods such as microwave assisted synthesis

electrochemical synthesis etc. are used for the preparation of MOFs [1,2].

Some examples for the potential MOFs, their synthesis, structure and properties

HKUST-1 : Cu₂(C₉H₃O₆)_{4/3}

HKUST-1 is porous coordination network which consists of copper as the metal and benzene-1,3,5-tricarboxylic acid as the organic linker. This was first reported in 1999 by Williams and co-workers [5]. HKUST-1 forms as a blue colour crystals and it has been synthesized by heating Copper nitrate hemipentahydrate with benzene-1,3,5 tricarboxylic acid in solvent mixture of equal parts of DMF, ethanol and deionized water. The structure of Cu₂(C₉H₃O₆)_{4/3} is shown in Figure -1. HKUST-1 is a commercially available product named as Basolite TMC300.

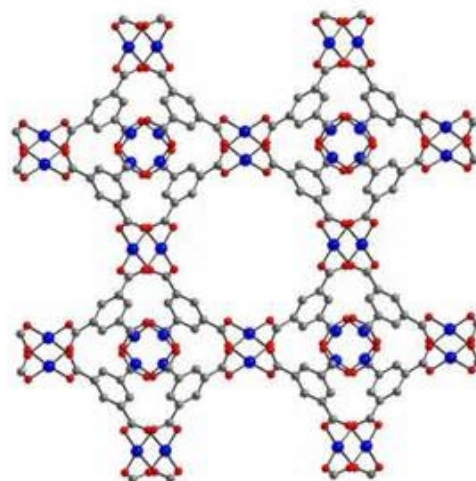


Figure. 1 : Ball and stick representation of HKUST-1.

HKUST-1 is a 3D system of large square-shaped pores (9 Å). HKUST-1 membranes have also been prepared from a pre-oxidised copper net as the porous support under solvothermal synthesis conditions. Many investigation of HKUST-1 for different applications such as H₂ storages, gas separations, catalysis etc. have been reported [8].

Zn₄O(BDC)₃

The MOF prepared using Zn²⁺ and benzenedicarboxylic acid is named as Zn₄O(BDC)₃ (BDC = 1,4-benzenedicarboxylate) (Figure 2) [9, 10]. One of the first metal-organic frameworks investigated for hydrogen storage was Zn₄O(BDC)₃, which is cubic carboxylate-based framework. This compound has been widely studied for its hydrogen storage ability. At 77 K, Zn₄O(BDC)₃ has showed an excess gravimetric uptake of hydrogen ; 1.3 wt% at 1 bar and 5.1 wt% at 50

bar. The gas storage properties obtained for $\text{Zn}_4\text{O}(\text{BDC})_3$ depends on the methods utilized in its preparation and activation.

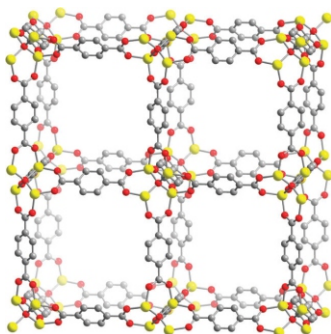


Figure 2: A portion of the crystal structure of $\text{Zn}_4\text{O}(\text{BDC})_3$.

$\text{Zn}_4\text{O}(\text{BTB})_2$

MOFs with a very high surface area exhibit an increased micropore volume. Low bulk density for the MOF is obtained when the micropore volume is high [9]. For example, the MOF: $\text{Zn}_4\text{O}(\text{BTB})_2$ where BTB is 1,3,5-benzenetribenzoate, in this MOF, tetrahedral 6, $[\text{Zn}_4\text{O}]$ units are linked via a large, triangular tricarboxylate ligand (Figure. 3). At 77 K, this compound has shown a maximal excess H_2 uptake of 76 mg H_2 per 1076 mg compound.

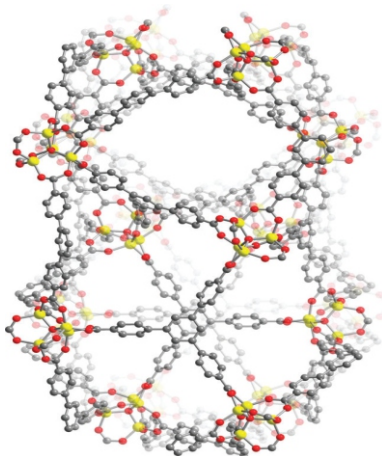
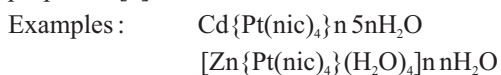


Figure 3: crystal structure of $\text{Zn}_4\text{O}(\text{BTB})_3$.

MOFs with hetero bimetallic networks

In the recent development of MOFs, coordination networks consisted of two metal units (hetero bimetallic network) have been prepared with improved properties [3].



In these MOFs, two metals such as Cd/Pt and

Zn/Pt are included as metal ends. Nicotinic acid is used as the organic linker. At first, complex ligand, $[\text{Pt}(\text{nic})_4]$ is synthesized by a solvothermal method in water solution containing of $[\text{PtCl}_4]$ and nicH (nicotinic acid). Then, MOFs, Cd-Pt and Zn-Pt have been synthesized by one-pot slow evaporation method [3].

The above heterobimetallic MOFs act as useful heterogeneous photoreduction catalyst for water as well as selective H_2 gas adsorption materials versus N_2 gas. A novel three-dimensional interpenetrated coordination polymer containing Zn and Pd metals with isonicotinic acids has been synthesized by Mory and co workers [11]. This MOF is $[\text{Zn}\{\text{Pd}(\text{INA})_4\}]_n$ (INA = isonicotinate) and it has been utilized as a hydrogen production catalyst for photochemical reduction of water.

The use of Pt(II) or Pd(II) complex ligand will be an effective approach because Pt(II) and Pd(II) complexes have been widely used as homogeneous catalysts in catalytic reactions such as hydrogenation reactions, water photoreduction reactions and activation of C-H bonds in hydrocarbons etc.

MOFs with accessible metal sites

Some metal-organic frameworks have been synthesized with incorporation of accessible metal sites (AMSs) or functional building blocks into porous MOFs [12]. Examples for the AMS containing building blocks : metallosalens, N-heterocyclic carbene (NHC) complexes, and metalloporphyrins. Metalloporphyrins can be found in nature and have unique catalytic, electronic, and optical properties. Therefore MOFs with accessible metal sites are expected to have higher gas-adsorption capacity and as well as to act as specific catalysts.

Many porphyrin-based MOFs have been synthesized.

Example -1: rhodium carboxylate microporous MOFs incorporating various metallo-TCPPs: $[\text{Rh}_2(\text{MTCPP})]$ ($\text{M} = \text{Cu}^{2+}, \text{Ni}^{2+}, \text{Pd}^{2+}$). This has been used as catalysts for the hydrogenation of olefins with high turnover frequencies [13,14].

Example-2 : $[\text{Cu}_2(\text{MDDCPP})]$ [$\text{M} = \text{Zn}^{2+}, \text{Ni}^{2+}, \text{Pd}^{2+}, \text{Mn}^{3+}(\text{NO}_3), \text{Ru}^{2+}(\text{CO})$], which have been synthesized using MDDCPP [$\text{M} = \text{Zn}^{2+}, \text{Ni}^{2+}, \text{Pd}^{2+}, \text{Mn}^{3+}\text{Cl}, \text{Ru}^{2+}(\text{CO})$] building blocks. These complexes have exhibited permanent porosity and good N_2 and H_2 adsorption properties.

The structure of DDCPP is shown below with the analogue structure of H_4BPTC (Figure 4)

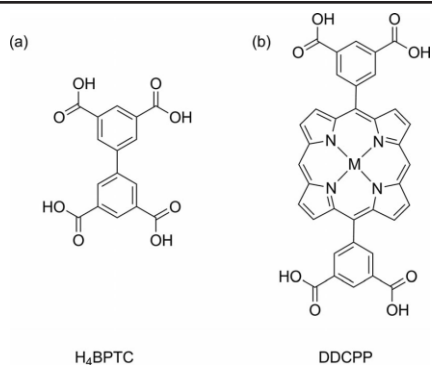


Figure 4: Structure of DDCPP

There are advantages for incorporating porphyrine moieties in MOFs. The physical and chemical properties of metalloporphyrins can be controlled by proper functionalization of the porphyrin core through some chemical reactions in order to enhanced the properties of corresponding MOFs.

Characterization of MOFs

Metal-Organic Frameworks are supramolecules having complex structures and higher molecular weights. Those are oligomers and polymers with definite crystalline structures. After synthesis, characterization of MOFs is a difficult task due to their complex structure. The following techniques are commonly used in characterization [17, 18, 19].

- Elemental analyses.
- X-ray crystallographic analysis
- NMR spectroscopy
- UV-visible spectroscopy
- FT-IR spectroscopy

Application of MOFs

MOFs have shown wide range of applications in their first twenty years of existence. As there is fast growing interests in this field and the possibility of preparing infinite number of MOFs with diverse structures and unusual properties, many more potential applications will be explored in future as well.

Some applications of MOFs are described below;

Gas storage

MOFs have received much attraction as potential gas storage material ie: hydrogen and methane [1,9,10,20]. Hydrogen is important as a vehicular fuel source. Microporous materials have pores less than 20Å is important in strong interactions between gas molecules and the pore walls making them good candidates for gas storage and gas separation applications. It has been reported that highest hydrogen storage capacity is possible when the pore

size is about 7 Å⁰. In addition to pore sizes, higher surface areas, low densities, and thermal stability of MOFs are good properties for gas storages.

Usually gases are stored in tanks under higher pressure. In contrast, tank charged with a porous adsorbent (MOFs) enables a gas to be stored at a much lower pressure. Thus, high pressure tanks and multi-stage compressors can be avoided providing a safer and more economical gas storage method using MOFs. This gas storage application of MOFs gives alternative solution for global fuel crisis anticipated due to gradual reduction of fossil fuel.

Selective gas adsorption and separation

MOFs are very promising candidates for selective gas adsorption, which can lead to gas separation [1, 21]. Gas separations is an essential element in petrochemical and other industries. Conventional separation methods used are distillation and condensations process which are high energy consumptions process. Polymer based membrane separation techniques and adsorption-based techniques using zeolites, molecular sieves, carbon nanotubes, aluminosilicates, and silica gel are also used.

As a low energy and environmentally friendly gas separation process, application of MOFs is promising. MOFs can act as material for gas separations layers based on two principles, which are adsorbate-surface interactions and size-exclusion effect(molecular sieving effect). The two effects are capable of working independently as well as cooperatively.

Eg: Selective gas adsorption of O₂ over N₂ based on size-exclusion of MOFs and separation of alkane isomers from natural gas based on adsorbate-surface interactions.

Recently, MOFs thin film have been prepared for gas separation purpose using many MOFs under solvothermal conditions [22].

MOFs as heterogeneous catalysts

At present, MOFs are explored to be used as heterogeneous catalysts [1, 11]. Active sites are generated in MOFs due to their high metal content and highly crystalline nature.

The catalytic systems based on three-dimensional interpenetrated MOF, [Zn{Pd(INA)₄}]_n (INA = isonicotinate), has been developed for the catalysis of decomposition of water into hydrogen and oxygen using sunlight (11). This will be a promising solution for the global fuel crisis and environmental problems

associated with that. The MOF, $[\text{Ni}_8\text{L}_{12}]^{20+}$ ($\text{H}_3\text{L} = 4,5\text{-imidazolecarboxylic acid}$) has shown stable catalytic activity for the oxidation of CO to CO_2 .

The MOF, $[\text{In}(\text{OH})\text{L}] \cdot x\text{Py}$ ($\text{L} = 4,4\text{-(hexafluoroisopropylidene)bis(benzoic acid)}$) has proven to be an efficient heterogeneous catalyst for acetalization of aldehydes [1]. The catalysis activity of MOF which is doped with other metal catalysts has been demonstrated for oxidation of hydrocarbon etc. The 3D MOF, $([\text{Cd}(\text{4btapa})_2(\text{NO}_3)_2] \cdot 6\text{H}_2\text{O} \cdot 2\text{DMF})_n$, has been synthesized and successfully accommodated Knoevenagel condensation reactions of benzaldehyde with active methylene compounds.

MOF as molecular switches

The porosity of MOFs provides interesting phenomena in regards to magnetic properties.

Due to the magnetic properties of functionalized MOF, MOFs with electronic switching centers have been developed [1].

MOFs as luminescence material and sensors

Some MOFs exhibit photophysical properties. The photophysical properties arise due to the metal ions, or specific organic ligands. Lanthanide metal ions have been widely used in MOF syntheses due to their coordination diversity and luminescent properties. Example for the MOF with luminescence properties $[\text{Ba}_2(\text{H}_2\text{O})_4[\text{LnL}_3(\text{H}_2\text{O})_2](\text{H}_2\text{O})_n\text{Cl}]$, ($\text{L} = 4,4\text{-disulfo-2,2-bipyridine-N,N-dioxide}$, $\text{Ln} = \text{Sm, Eu, Gd, Tb, Dy}$) [1]. Stilbene-based MOFs have shown luminescence properties. In addition, some guest molecules are incorporated into MOFs without disturbing the structure in order to achieve luminescence. The MOFs that possess luminescent properties together with size- or shape-selective sorption properties are being used as sensing devices.

MOFs in Analytical Chemistry

Unusual properties of MOFs such as high surface area, good thermal stability, uniform structured nanoscale cavities, and the availability of in-pore functionality and outer-surface modification are attractive for diverse analytical applications [23]. Therefore, different MOFs have been explored for various analytical applications from sampling to chromatographic separation etc.

Examples for the analytical application encountered with MOFs are,

- (1) bulk micro-sized MOFs as sorbents for in-field sampling and solid-phase extraction

- (2) nanosized MOFs and engineered thin films of MOFs as coatings for solid-phase microextraction
- (3) MOFs as stationary phases for high-resolution gas chromatography
- (4) MOF-based tandem molecular sieve platform for selective extraction and high-resolution GC
- (5) micro-sized solvent resistant MOFs as stationary phases for high-performance liquid chromatography etc.

MOFs in drug storage and drug delivery

After administration, delivering of drugs into blood stream at controlled rate is a very important task in human body. Some delivery systems have been developed which include polymeric-based systems, liposome based systems, microporous zeolites, mesoporous silicon, and other mesoporous materials etc. As MOFs possess tunable structures and high porosities make them excellent drug delivery vehicles. Many investigations are being carried out in order to apply MOFs in drug delivery and storage purpose (1, 16).

As mentioned above, the field of hybrid inorganic–organic framework materials, MOFs, represents one of the fastest growing areas in materials chemistry because their enormous structural and chemical diversity make large opportunities for creating many technologically important properties. There is a huge scope for creating unusual properties or unique combinations of properties with MOFs that are not possible in purely inorganic or organic systems alone. The mechanical properties such as elasticity, hardness, plasticity, yield strength, and fracture toughness characteristics are very important properties associated with the application of MOFs []

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Organometallic Chemistry – Part 1

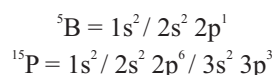
Dr Buddhie S. Lankage

Introduction

Organometallic chemistry is a branch of coordination chemistry and it is a study of chemical compounds containing M-C bonds. Transition and non-transition metal complexes are widely used as organometallic reagents (e.g. MeMgI and *n*-BuLi) and catalysts (e.g. [RhCl(PPh₃)₃] and [Pd{P(C₆H₅)₃}]₄) to prepare organic compounds.

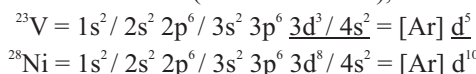
The types of **metals** bonded to carbon are,

1. The *main group elements* such as the alkali and alkaline earth metals, and the more metallic elements in *p* block ($ns^2 np^x$ - *p* orbitals contain valence electron(s)) the vertical groups of 3, 4, 5 and 6, i.e.



Generally, most electropositive elements form M^+R^- ionic type compounds, e.g. $\text{Na}^+(\eta^5\text{-C}_5\text{H}_5)^-$. Less electropositive metals such as Li and Mg form covalent M-C bonds, e.g. PhMgCl.

2. *Transition metals* (*d* block elements), i.e.



The types of **ligands** are alkyl ($\text{R} = \text{-CH}_3$), carbonyl ($\text{C} \equiv \text{O}$), olefin {acetone $\text{-(CH}_3)_2\text{C=O}$ }, acetylene ($\text{HC} \equiv \text{CH}$), arenes (conjugated cyclic compounds, i.e. phenyl=benzene and aryls=functional groups attached to benzene) and allyl (C_3H_5^- / $\text{=CH}_2\text{=CH-CH}_2$) groups.

Organometallic compounds are distinguished by the prefix "organo-" e.g.

- Organopalladium compounds – $[\text{PdCl}(\eta^3\text{-allyl})_2]$
- Organomagnesium compounds – Grignard reagents, e.g. iodomethylmagnesium (MeMgI) and diethylmagnesium (Et_2Mg)
- Organolithium compounds – *n*-butyl lithium (*n*-BuLi)
- Organozinc compounds – diethylzinc (Et_2Zn)
- Organocopper compounds – lithium dimethylcuprate ($\text{Li}^+[\text{Me}_2\text{Cu}]^-$).

The term "metalorganics" usually refers to metal-containing compounds lacking direct metal-carbon bonds but which contain organic ligands. Metal β -diketonates, alkoxides and dialkylamides are representative members of this class.

$[\text{Ni}(\eta^3\text{-allyl})_2]$ and ferrocene $[\text{Fe}(\eta^5\text{-C}_5\text{H}_5)_2]$ are examples of organometallic compounds containing organic ligands.

In addition to transition metals, lanthanides, actinides and semimetals, elements such as boron, silicon, arsenic and selenium do form similar compounds, e.g. organoborane compounds – triethylborane (BET_3).

Organometallic chemistry combines aspects of inorganic chemistry and organic chemistry.

Organic chemistry:

- more or less covalent C-A bonds (i.e. A = OH, OR and CH₃)
- rigid element environments
- fixed oxidation states

Inorganic chemistry:

- primarily ionic M-B bonds (i.e. B = O and Cl), coordinate/dative-covalent M-L bonds (i.e. L = bpy-bipyridine)
- variable and often fluxional environments
- variable oxidation states

Organometallic chemistry:

Knowledge of inorganic and coordination chemistry is useful to understand geometries, electron counts and oxidation states of organometallic compounds. Similarly organic chemistry knowledge is useful in understanding and the tuning reactivity. This starts with analyzing reaction mechanisms and identifying the use of specific organic reagents such as solvents.

Organic vs organometallic reactivity

Organic chemistry:

- C-C/C-H: nearly covalent
- $\text{C}^{\delta+}\text{-X}^{\delta-}$: polar (partly ionic)

- reactivity dominated by nucleophilic attack at C S_{N2} and S_{Ni} like reactions.

Organometallic chemistry:

- C is the negative end of the M-C bond ("umpolung")
- reactivity dominated by electrophilic attack at C or nucleophilic attack at M, associative and dissociative substitution at M

Factors governing the reactivity of organometallic compounds

- M-C, M-X bond strengths
- Electronegativity of M (polarity of M-C bonds)
- Number of *d* electrons
- Coordination number
- Steric hindrance

Basic chemistry that needs to know for organometallic chemistry

It is important to know the basic chemistry of elements in the periodic table and their physical and chemical properties.

1. Electronegative/Electropositive concepts

The tendency of an atom to attract an electron to itself is called its electronegativity. The electronegativity/electropositivity of an element can be regarded as being related to ionization energy and electron affinity, and can be evaluated in various ways.

Where do the partial positive and negative charges in a molecule reside? e.g. $H^{\delta+}-F^{\delta-}$. This is important for determining how much electron density will be donated from a ligand to a metal and where a nucleophile or electrophile will attack for chemical reactions.

2. Lewis dot structures and valence electron counts

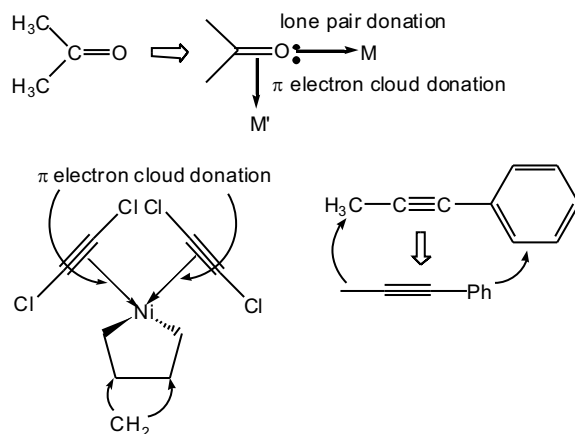
Important for determining the number of electrons on a ligand and what is the charge of the ligand. Generally, deal with ligands with even number's of electrons. If a ligand has an odd number of electrons add additional electrons to get to an even number, usually to form a closed shell electron configuration with a formal negative charge(s). Common Exceptions are B and Al.

3. Oxidation States (OS)

Oxidation state of a metal in a coordination compound can be defined as the charge left on the

metal when all the ligands are removed from the metal. For example, $[MX_2L_3]$ when L is a neutral ligand and X is a mono-anionic ligand, the OS of M is +2. This number relates to the total charge of the negative ions.

4. Organic line notation for drawing structures



5. Electron Density

The presence of energetically accessible valence electrons around an atom. Electrons are represented by a probability distribution spread out over a region of space defined by the nature of the orbital: s, p, d, f, and/or hybrid orbitals such as sp^3 , sp^2 , sp , etc. Atoms with large number of valence electrons or completely filled valence orbitals such as Pt(0) d^{10} and/or contracted orbitals (due to the attractive forces between the nucleus and the electrons) have a high electron density. Atoms with fewer valence electrons (e.g. $^{37}Rb(0) = [Kr] 5s^1$) and/or diffuse orbitals (electrons spread out over a larger region of space) can be considered to have low electron densities. Do not confuse electron density with electronegativity.

6. Electron-rich

Atoms that are willing to donate electron pairs readily to other atoms are considered electron rich. Ease of ionization is another property associated with electron-rich atoms. The willingness to share or donate electron pairs is related to lower electronegativity, larger numbers of valence electrons, good donor groups on the atom in question, negative charges, or some combination of these factors. Using organic terminology can consider an electron-rich atom to be a good nucleophile (electron pair donor).

7. Electron-deficient (poor)

Atoms that are NOT willing to donate or share electron pairs to other atoms are called electron

deficient. These atoms typically have lower lying empty orbitals that can accept electron pairs from other atoms. The un-willingness to donate or share electron pairs could be caused by high electronegativity, cationic charge(s), lack of electron pairs, or some combination of these. In General, many (but not all) electron-deficient atoms/molecules can be considered to be good electrophiles (electron-pair acceptor) and certainly poor donors.

Examples:

Fluoride anion, F^- : This anion has high electron density due to the negative charge, filled octet of electrons, and small size. But cannot consider it to be electron-rich, meaning a good electron donor. The extremely high electronegativity of a fluorine atom means that it desperately wants to pick up an extra electron to form the fluoride anion, which is extremely stable. The filled valence orbitals are fairly low in energy for F^- and generally poor donors. It is certainly not electron-deficient as it doesn't have any low-lying empty orbitals and does not want to accept any more electrons. It is not electron-rich either since it is a very poor nucleophile and generally a poor ligand for most metals (except those in high oxidation states). It is almost impossible to chemically oxidize F^- .

Methyl anion, CH_3^- : This anion is very electron-rich and a powerful nucleophile. The electron-richness comes from the lower electronegativity of carbon and the high energy of the anionic sp^3 -hybridized lone pair that makes it a strong donor group. It is also very easily oxidized, pointing to the presence of a high-energy lone pair orbital.

8. Ionisation Energy (IE/ kJ mol^{-1})

IE is the energy required to remove an electron in the gas phase, $M(g) \rightarrow M^+(g) + e^-$.

The distinction between IE and electrode potential (EP) should be clearly understood. The EP applies to the loss of an electron not in the gas phase, $M(s) \rightarrow M^+(aq) + e^-$.

The electrochemical series is a list of metals in order of electrode potential. The order of IEs is not necessarily the same.

9. Electron Affinity (EA/ kJ mol^{-1})

EA is the energy change when one mole of isolated gaseous atoms gains one mole of electrons to form a mole of negatively charged ions, $X(g) + e^- \rightarrow X^-(g)$.

10. General trends in periodic table

Main group elements

The 1st IE decreases down the group as the outer electrons become progressively further from the nucleus and also there is more shielding because of the extra filled orbitals.

In any group there is a decrease in electronegativity down the group. Across a period there is an increase in electronegativity from left to right.

In any period there is a decrease in atomic radius from left to right. There is a net increase in atomic radius down the group.

Also down the group, the metallic character increases because of shielding of outer most electrons from the nucleus due to large number of electrons in between. Therefore, these electrons are easier to be lost. In case of non-metals, they have high electron negativity, so it becomes extremely difficult for them to lose an electron, hence in their case, oxidation number decreases.

For example, group 4 elements (C, Si, Ge, Sn and Pb), Pb^{2+} is more stable than Pb^{4+} (e.g. $PbCl_4 \rightarrow PbCl_2 + Cl_2$) and Sn^{4+} is more stable than Sn^{2+} . This is due to the *inert-pair effect* and *relativistic contraction* (heavier the element greater the effect).

Transition metals

The relatively small increase in successive IEs causes most of the transition metals to exhibit multiple oxidation states separated by a single electron. E.g. Mn, forms compounds in every oxidation state between -3 and $+7$. Because of the slow but steady increase in IEs across a row, high oxidation states become progressively less stable for the elements on the right side of the *d* block.

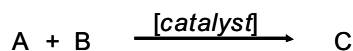
The occurrence of multiple oxidation states separated by a single electron causes many, if not most, compounds of the transition metals to be paramagnetic, with one to five unpaired electrons. This behaviour is in sharp contrast to that of the *p*-block elements, where the occurrence of two oxidation states separated by two electrons is common, which makes virtually all compounds of the *p*-block elements diamagnetic.

| d^3 | d^4 | d^5 | d^6 | d^7 | d^8 | d^9 | d^{10} | $d^{10}s^1$ |
|------------------------------|------------------------------|-----------------------------|-------------------------------|-------------------------------|------------------------------|----------------------------|------------------------------|---------------------------|
| 21
Sc
Scandium | 22
Ti
Titanium | 23
V
Vanadium | 24
Cr
Chromium | 25
Mn
Manganese | 26
Fe
Iron | 27
Co
Cobalt | 28
Ni
Nickel | 29
Cu
Copper |
| 39
Y
Yttrium | 40
Zr
Zirconium | 41
Nb
Niobium | 42
Mo
Molybdenum | 43
Tc
Technetium | 44
Ru
Ruthenium | 45
Rh
Rhodium | 46
Pd
Palladium | 47
Ag
Silver |
| 57
La
Lanthanum | 72
Hf
Hafnium | 73
Ta
Tantalum | 74
W
Tungsten | 75
Re
Rhenium | 76
Os
Osmium | 77
Ir
Iridium | 78
Pt
Platinum | 79
Au
Gold |

Early Transition Metals
low electronegativities
higher oxidation states
"harder" metal centers

Late Transition Metals
higher electronegativities
lower oxidation states
"softer" metal centers

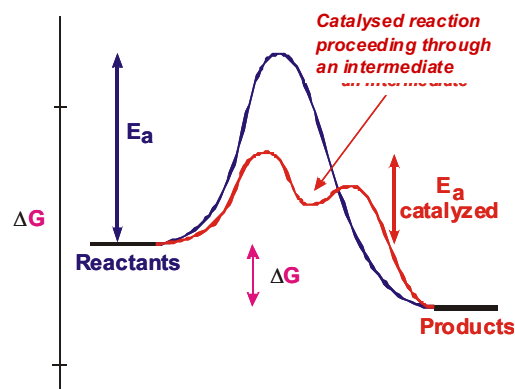
11. Metal catalysis



A catalyst is a substance that increases the rate of the reaction without itself being consumed (but it is involved) in the reaction. After the reaction has finished the unchanged catalyst should be able to recover from the reaction mixture.

A catalyst speeds up the rate at which a chemical reaction reaches equilibrium. The overall thermodynamics of the reaction is NOT changed by the catalyst. Therefore, very endothermic (non-spontaneous) reactions are usually NOT suitable for catalytic applications.

A catalyst provides a lower energy pathway for the production of products from reactants, thus allowing the reaction to proceed faster. It lowers the activation energy for a reaction (kinetics) – it does NOT change the thermodynamics of a reaction.



A catalyst provides an alternate mechanism (or pathway) for the reactants to be transformed into products. The catalyzed mechanism has an activation energy that is lower than the original uncatalyzed reaction. An excellent catalyst will lower the activation energy the most.

To be continued in the next issue.

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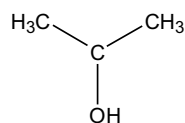
## Synthesis of Alcohols from Alkenes

Dr. Ireshika De Silva

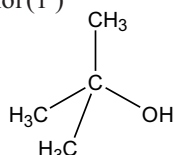
Alcohols are organic compounds which contain a hydroxyl (-OH) group/s on a saturated carbon atom of the molecule. These compounds are very common in the laboratory and are useful in nature, our homes and industries. These can be categorized as primary, secondary and tertiary.

CH<sub>3</sub>OH  
Methyl alcohol

CH<sub>3</sub>CH<sub>2</sub>OH  
Ethyl alcohol (1°)



2-Propanol (2°)

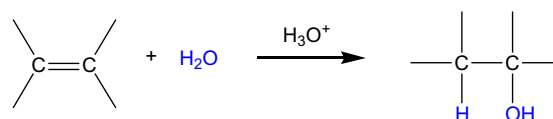


2-Methyl-2-propanol (3°)

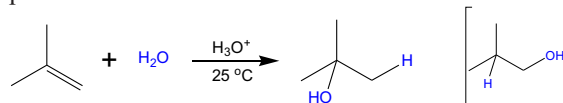
Alcohols can be directly synthesized from alkenes, alkyl halides, and carbonyl compounds such as aldehydes, ketones and esters. This article describes the synthesis of alcohols from alkenes.

### 1) Acid-catalyzed hydration of alkenes

In an acidic medium, alkenes react with water to produce alcohols. This is known as hydration. This is an addition reaction. In general, a hydrogen atom from water adds to one carbon of the double bond and a hydroxyl group adds to the other carbon.

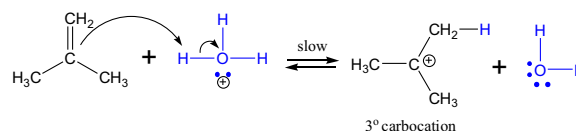


This reaction follows **Markovnikov's rule**. That means, the electrophile (ie H<sup>+</sup>) adds to the less substituted end of the double bond to give more stable carbocation. The order of the carbocation stability is 3° > 2° > 1° > CH<sub>3</sub>. Consider the acid-catalyzed hydration of 2-methylpropene. 2-Methyl-2-propanol is the only product of this reaction.

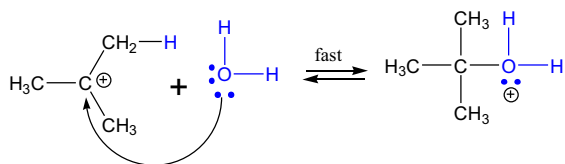


Only product    Does not form

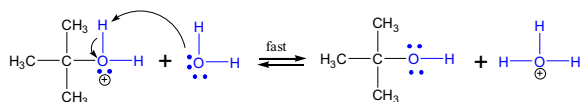
Let us consider the mechanism of this reaction to understand why it is so. The first step of this reaction is the protonation of the double bond. A proton (H<sup>+</sup>) adds to the less substituted end of the double bond giving the 3° carbocation. This is more stable than the 1° carbocation which forms if H<sup>+</sup> adds to the more substituted end.



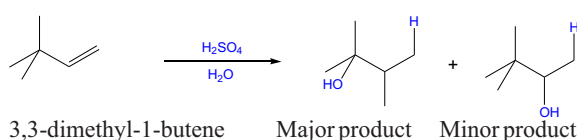
Now, water attacks (Nucleophilic attack) the positively charged carbon to form a protonated alcohol.



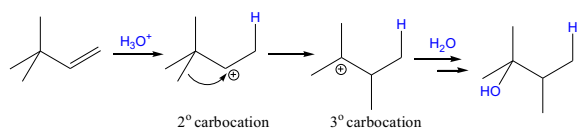
Finally, deprotonation of the protonated alcohol by water gives the alcohol.



One of the major limitations of the acid-catalyzed hydration method is rearranging of the initial carbocation to a more stable one, if it is possible. This can lead to a mixture of constitutional isomeric alcohol products. The acid-catalyzed rearrangement of 3,3-dimethyl-1-butene produces 2,3-dimethyl-2-butanol as the major product.

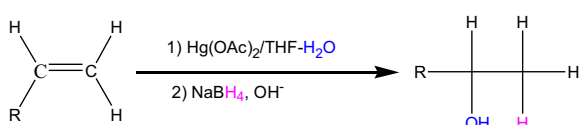


A methyl group shifts to the 2° carbocation to form the 3° carbocation which is more stable. Finally, reaction with water gives the 2,3-dimethyl-2-butanol as the major product and 3,3-dimethyl-2-butanol as the minor product.



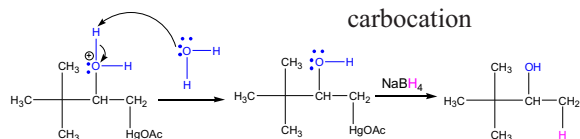
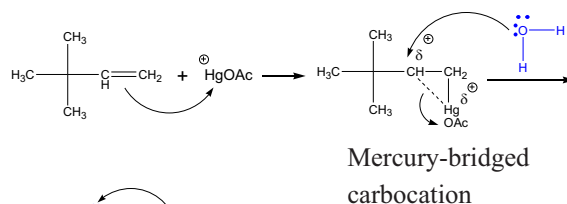
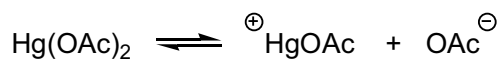
## 2) Oxymercuration-demercuration of alkenes

This is a one-pot, two step reaction.

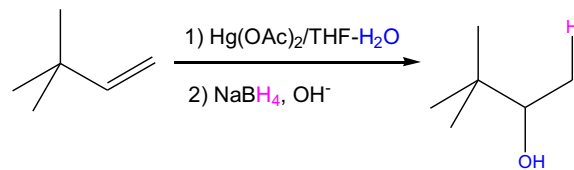


Mercuric-acetate,  $\text{Hg}(\text{OCOCH}_3)_2$  [ $\text{Hg}(\text{OAc})_2$ ] is involved in the first step. It dissociates to form positively charged mercury species  $\text{Hg}(\text{OAc})^+$ , which acts as the electrophile in this reaction. In oxymercuration,  $\text{Hg}(\text{OAc})^+$  attacks the double bond and form mercury-bridged carbocation. Then water attacks the more substituted carbon (Why?) leaving -HgOAc on the less substituted carbon. Note the anti orientation of the -OH and the -HgOAc.  $\text{NaBH}_4$  (a reducing reagent) is used in demercuration step. It

replaces  $\text{Hg}(\text{OAc})^+$  with a hydrogen atom. The reaction that replaces the -HgOAc with hydrogen is not stereo controlled. Therefore, though, the -OH and the -HgOAc are in anti orientation, the final product is a mixture of both syn and anti addition of -OH and -H.

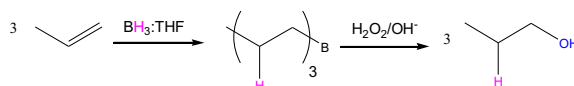


In the final product, H is on the less substituted carbon and -OH on the more substituted carbon. That means the oxymercuration-demercuration of alkenes also follows the **Markovnikov's rule**. Rearrangements of intermediates do not occur in this reaction. Oxymercuration-demercuration of 3,3-dimethyl-1-butene forms only 3,3-dimethyl-2-butanol in contrast to its acid-catalyzed hydration we discussed earlier.

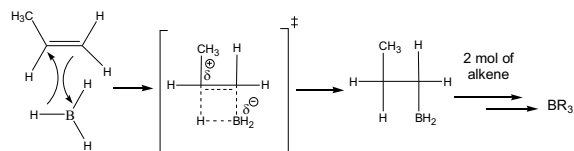


## 3) Hydroboration of alkenes

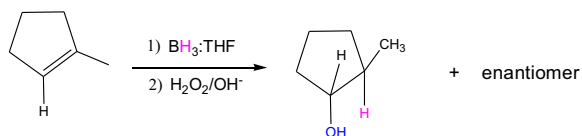
This is also a one-pot, two-step reaction. Hydroboration of alkenes is carried out with a solution of borane in tetrahydrofuran ( $\text{BH}_3 \cdot \text{THF}$ ). When alkenes are treated with  $\text{BH}_3 \cdot \text{THF}$ , boron hydride adds successively to the double bonds of three alkene molecules.



The boron atom always adds to the less substituted carbon due to the steric hindrance at the more substituted end, and the hydrogen atom adds to the more substituted carbon atom. The addition of borane to alkene is a one-step reaction and it proceeds via a cyclic transition state. This trialkylborane is oxidized and hydrolyzed by adding hydrogen peroxide in an aqueous base to give the alcohol.



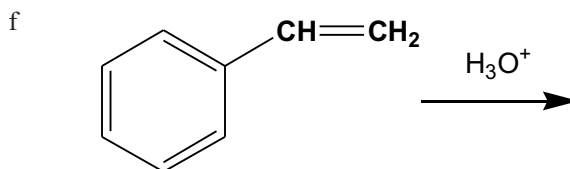
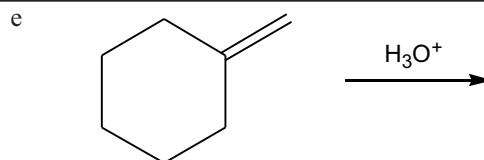
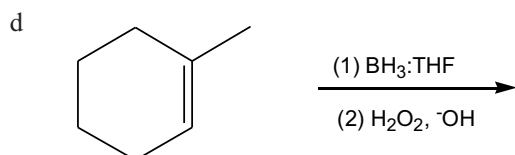
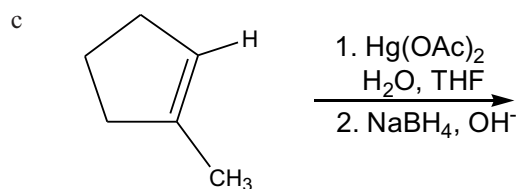
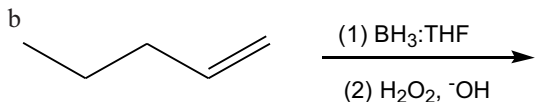
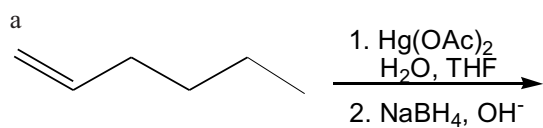
In the final product, the hydrogen is attached to the more substituted end and the  $\text{-OH}$  to the less substituted end. Therefore, not like above two methods, this method gives the anti-Markovnikov's addition product. The addition of H and boron takes place from the same face (*syn* addition) of the double bond. The oxidation with  $\text{H}_2\text{O}_2$  does not change the stereochemistry. Hence the final product has the *syn* stereochemistry.



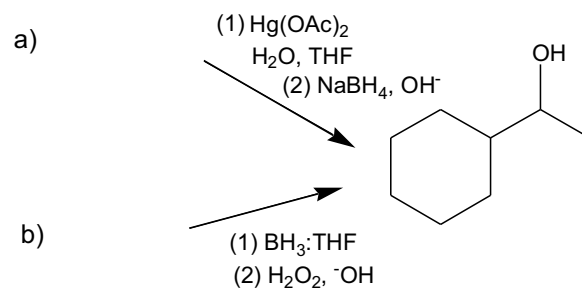
The three methods which have been discussed in here are useful for the synthesis of alcohols from alkenes with different regiochemistry and stereochemistry. Acid-catalyzed hydration and oxymercuration–demercuration of alkenes follows the Markovnikov's rule. Rearrangement of the initial carbocation in acid-catalyzed rearrangement leads to mixture of products. However, rearrangements do not take place in oxymercuration–demercuration and hydroboration–oxidation of alkenes. Further, acid-catalyzed hydration and oxymercuration–demercuration give both *syn* and *anti* addition products. Hydroboration–oxidation of alkenes gives only the *syn* addition product.

#### Exercise

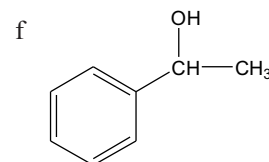
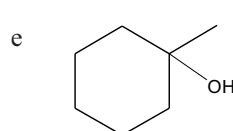
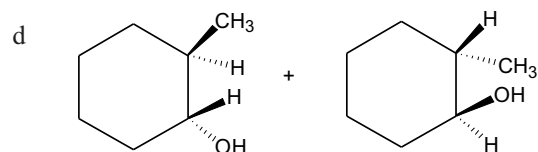
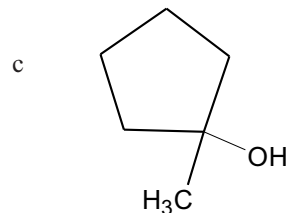
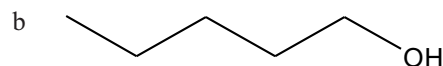
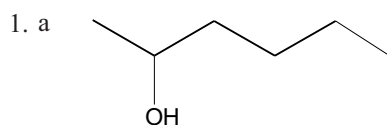
1. Predicts the major products of the following reactions.



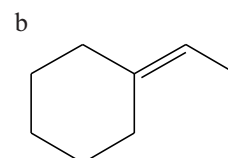
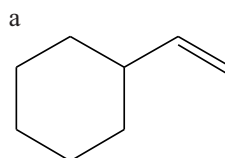
2) What alkenes might the following alcohol have been prepared from?



#### Answer Key



2.



## IUPAC - sponsored events in 2014

- 1] 12 – 17 January 2014, Bangalore, India  
*27<sup>th</sup> International Carbohydrate Symposium (ICS 2014)*  
Contact person: Prof. N. Jayaraman [ics27@orgchem.iisc.ernet.in](mailto:ics27@orgchem.iisc.ernet.in)
- 2] 27 – 28 February 2014, Blankenberge, Belgium  
*Chemistry Conference for Young Scientists*  
Contact person: Prof. Thomas Vranken [Thomas.vranken@chemcys.be](mailto:Thomas.vranken@chemcys.be)
- 3] 5 – 7 March 2014, Suva, Fiji  
*International Conference on Applied Chemistry 2014*  
Contact person: Prof. S. Sotheeswaran, [sotheeswaran@hotmail.com](mailto:sotheeswaran@hotmail.com)
- 4] 3 – 4 April 2014, Colombo, Sri Lanka  
*Professional Chemistry Education and Research for Industrial Development and Sustainable Economic Growth*  
Contact person: Prof. Ramanee D. Wijesekera [ramanee@chem.cmb.ac.lk](mailto:ramanee@chem.cmb.ac.lk)
- 5] 2 – 6 June 2014, St. Petersburg, Russia  
*8<sup>th</sup> International Symposium on Molecular Mobility and Order in Polymer Systems*  
Contact person: Prof. Tatiana Birshtein [birshtein@imc.macro.ru](mailto:birshtein@imc.macro.ru)
- 6] 26 – 30 June 2014, Kharkiv, Ukraine  
*Modern Physical Chemistry – 2014 (MPC '14)*  
Contact person: Dr Olexander Lebed [beketov2014@karazin.ua](mailto:beketov2014@karazin.ua)
- 7] 13 – 18 July 2014  
*23<sup>rd</sup> International Conference on Chemistry Education (ICCE-23)*  
Contact person: Prof. Judith C. Poë [Judith.poe@utoronto.ca](mailto:Judith.poe@utoronto.ca)
- 8] 13– 18 July 2014, Bordeaux, France  
*XXV<sup>th</sup> IUPAC Symposium on Photochemistry*  
Contact person: Dr Dario M Bassanid. [bassani@ism.u-bordeaux1.fr](mailto:bassani@ism.u-bordeaux1.fr)
- 9] 10 – 14 August 2014, San Francisco, California, USA  
*13<sup>th</sup> International Congress on Pesticide Chemistry*  
Dr Kenneth D. [Rackekracke@dow.com](mailto:Rackekracke@dow.com)

## IUPAC & ChemRAWN Sponsored event

8 – 11 November 2014, Dakha, Bangladesh  
*ChemRAWN Conference on Herbal Medicine – 2014*  
Chairperson, Task Group: Prof. Mohammed Mosihuzzaman [mmosihuzzaman@yahoo.com](mailto:mmosihuzzaman@yahoo.com)

Note: See also [www.iupac.org/home/conferences.html](http://www.iupac.org/home/conferences.html) for further details

## BIG Event in 2015

The 48<sup>th</sup> General Assembly (Aug 6 – 13, 2015) and the 45<sup>th</sup> World Chemistry Congress (Aug. 9 – 14, 2015), Busan, Korea. **Smart Chemistry Better Life**

## Call for Nominations for Institute of Chemistry Gold Medal 2014 by 31<sup>st</sup> March *(Under Revised Rules)*

This Gold Medal was the very first of such awards to be donated to the Institute and was made possible through a generous donation made by **Mascons Ltd** in memory of their founder **Mr A Subramaniam** in 1978/79. It recognised contributions made to National Development through research and development involving Chemical Sciences. The Gold Medal Fund was supplemented recently through a further contribution from Mascons Ltd. This criteria governing the award were changed in 2011 since there were no applicants since 2007 in order to enable the award to be made to a mid-career Chemist in recognition of honorary services to the Institute.

**Nominations** are now being invited for the 2014 Award from amongst **Corporate Members** of the Institute who have fulfilled the following minimum criteria;

- Nominees should be not more than 55 years of age and should have been Corporate members of the Institute for at least 10 years on 1<sup>st</sup> of June 2014
- Nominees should have made significant contributions towards the activities of the Institute through yeoman services in an honorary capacity during the period of membership. These activities could include holding office, membership in committees, coordination of events such as workshops, social events etc.

Nominations could be made by any **corporate member** of the Institute and should include the consent of the nominee and details of the contributions made by the nominee in accordance with the above guidelines. The Award will be presented at the 43<sup>rd</sup> Annual Sessions. **Nominations should be forwarded to reach the Hony. Secretary, IChemC not later than 31<sup>st</sup> March 2014.**

## CALL FOR NOMINATIONS – IUPAC AWARDS/ PRIZES

### 1] **Thieme - IUPAC Prize 2014**

The prize is awarded to a scientist under 40 years of age as of 1 January 2014, whose research has had a major impact in synthetic organic chemistry.

Deadline for nominations: 13 December 2013

For more details visit: [www.thieme-chemistry.com/en/our-service/conferences/thieme-iupac-prize/call-for-nominations.html](http://www.thieme-chemistry.com/en/our-service/conferences/thieme-iupac-prize/call-for-nominations.html)

### 2] **Polymer International-IUPAC Award**

The 4<sup>th</sup> Polymer International-IUPAC Award for Creativity in Applied Polymer Science or Polymer Technology is now open. Nominees must be under the age of 40 on 31 December 2014

Deadline for nominations: 31<sup>st</sup> October 2013

For more details visit:

[http://onlinelibrary.wiley.com/journal/10.1002/\(ISSN\)10970126/homepage/polymer\\_international\\_iupac\\_award.html](http://onlinelibrary.wiley.com/journal/10.1002/(ISSN)10970126/homepage/polymer_international_iupac_award.html)

## ChemRawn/IUPAC Conference on “WASTE MANAGEMENT”

Rome, May 2015

Nominations are requested from the members for the **International Advisory Board** of distinguished scientists who can do the lectures on the following.

### **Topics**

Urban waste management

Organic waste management

Energy recovery from waste

Waste recycling

Waste management in the medical industry

Waste management in developing countries



## Ruby Anniversary International Conference

organized by the  
**College of Chemical Sciences (CCS)**  
of the  
**Institute of Chemistry Ceylon (IChemC)**

### Theme:

## **Chemical Education & Research for Industrial Development & Sustainable Growth in a Knowledge Based Economy**

The International Conference on **Chemical Education** that is being held on 3<sup>rd</sup> – 4<sup>th</sup> **April 2014** to commemorate the completion of four decades of formal professional chemical education provided by our institute is expected to be attended a large number of distinguished chemists from many countries throughout the world. We are expecting support and international funding from IUPAC, TWAS, Chemical Weapons Convention and RSC to enable a wider participation. The **Inauguration** on 3<sup>rd</sup> April at **Waters Edge, Capital City** will incorporate the **10<sup>th</sup> CCS Convocation** with distinguished Chemist **Professor Atta-ur-Rahaman**, former Federal Minister of Higher Education in Pakistan, as Chief Guest, delivering the Convocation Address. An Ex-Co meeting of the Federation of Asian Chemical Societies (FACS) will also be held in Colombo in conjunction with the conference on **2<sup>nd</sup> April 2014**.

Deadline for abstracts is 15<sup>th</sup> November 2013 and further details are available on the website [www.ichemc.edu.lk/icce2014/](http://www.ichemc.edu.lk/icce2014/) and preliminary flyer. The Second announcement will be released in September 2013.

The Conference Secretariat is located at the Headquarters of the Institute of Chemistry Ceylon at Adamantane House, 341/22, Kotte Road, Rajagiriya, Sri Lanka

Category of Participants	Overseas Participants	IChemC Members Residing in Sri Lanka	Local Participants
Early Bird Registration Until 31 <sup>st</sup> January 2014	US \$ 150	LKR 3000.00	LKR 5000.00
Regular Registration Until 28 <sup>th</sup> February 2014	US \$ 175	LKR 4000.00	LKR 6000.00
Late Registration After 28 <sup>th</sup> February	US \$ 200	LKR 5000.00	LKR 7000.00

### Contactus

**Chairman:** Prof. J N O Fernando ([oleap@ichemc.edu.lk](mailto:oleap@ichemc.edu.lk))

**Co-Chairs:** Prof. H D Gunawardhena ([hdg@chem.cmb.ac.lk](mailto:hdg@chem.cmb.ac.lk))  
Prof. S Sotheeswaran ([sotheeswaran@ichemc.edu.lk](mailto:sotheeswaran@ichemc.edu.lk))

### **Joint Honorary Secretaries:**

Ms. Kumudhini Goonatilleke ([kumudinigoonetilleke@yahoo.com](mailto:kumudinigoonetilleke@yahoo.com))

Ms. Dulanjalee Attanayake ([dula@ichemc.edu.lk](mailto:dula@ichemc.edu.lk))

Telephone: +94 11 2861653, +94 11 2861231, +94 11 4015230

Email: [ichemc@sltnet.lk](mailto:ichemc@sltnet.lk)

## PUBLICATIONS OF THE INSTITUTE OF CHEMISTRY CEYLON

Monograph	Title	Author	Price
01	Textile Fibers	Mr T Rajasekeram	Rs.50/-
02	Principles of Food Preservation	Prof U Samarajeewa	Rs.75/-
03	Biotechnology	Prof C P D W Mathew	Rs.75/-
04	Recombinant DNA Technology	Prof J Welihinda	Rs.75/-
05	Natural Toxins in Foodstuffs	Prof E R Jansz & Ms A S Perera	Rs.50/-
06	Fat Soluble Vitamins	Prof E R Jansz & Ms S Malavidana	Rs.50/-
07	Nucleic Acid and Protein Synthesis	Prof J Welihinda	Rs.75/-
08	Extraction of Energy from Food	Prof J Welihinda	Rs.50/-
09	Corrosion of Materials	Dr A M M Amirudeen	Rs.75/-
10	Vitamin C-Have all its mysteries been Unravalled ?	Prof E R Jansz & Ms S T C Mahavithanage	Rs.75/-
11	*Environmental Organic Chemistry (second edition)	Prof S Sotheeswaran	Rs.150/- (US \$3)
12	Enzyme Kinetics and Catalysis	Prof (Mrs) S A Deraniyagala	Rs.100/-
13	Insecticides	Prof (Mrs) Sukumal Wimalasena	Rs.95/-
14	Organotransition Metal Catalysts	Dr S P Deraniyagala & Dr M D P De Costa	Rs.75/-
15	Some Important Aspects of Polymer Characterization	Dr L Karunanayake	Rs.75/-
16	Hard & Soft Acids & Bases	Prof (Mrs) Janitha A Liyanage	Rs.65/-
17	Chemistry of Metallocenes	Dr Sarath D Perera	Rs.65/-
18	Lasers	Dr P P M Jayaweera	Rs.65/-
19	*Life and Metals	Prof (Mrs) Janitha A Liyanage	Rs.75/-
21	*Silicones	Prof Sudantha Liyanage	Rs.65/-
22	Pericyclic Reactions: Theory and Applications	Dr M D P De Costa	Rs.65/-
23	Inorganic NMR Spectroscopy	Prof K S D Perera	Rs.65/-
24	Industrial Polymers	Dr L Karunanayake	Rs.75/-
25	*NMR Spectroscopy	Dr (Mrs) D T U Abeytunga	Rs.65/-
26	Mosquito Coils and Consumer	Ms D K Galpoththage	Rs.100/-
27	Atomic Absorption Spectrometry	Dr K A S Pathiratne	Rs.100/-
28	Iron Management on Biological Systems	Dr (Ms) R D Wijesekera	Rs.100/-
29	Nutritional Antioxidants	Prof. (Mrs) Sukumal Wimalasena	Rs.100/-
30	*f-Block Elements	Prof Sudantha Liyanage	Rs.65/-
31	Scientific Measurements and Calculations	Prof (Mrs) S A Deraniyagala	Rs. 80/-

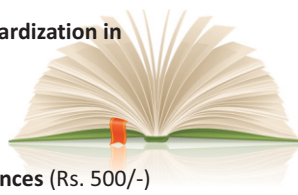
\* - Second Edition /new print published on popular demand

### CCS Publications

01	Functional Group Analysis in Organic Chemistry	Prof A A L Gunatilake	Rs. 175/-
02	Zinc Metalloproteins	Prof S Sotheeswaran Prof (Ms) R D Wijesekera	Rs. 175/-

### General Publications

- ★ **Chemist & The Environment** (Rs.300/-)
- ★ **Infrastructure Support Services for Industrial Development** (Rs.200/-)
- ★ **Chemical Industries in Sri Lanka – Part II** (Members: Rs. 200/-, Non-members: Rs.275/-)
- ★ **Proceedings of the Workshop on the Technological aspects of the Production & Processing of Essential oils in Sri Lanka** (Rs.100/-)
- ★ **Proceedings of the Training Seminar on Towards a Cleaner Industrial Environment in the New Millennium** (Rs.150/-)
- ★ **A-Level Chemistry Facts, Patterns & Principles by Dr. Seetha I Rodrigo** (Rs.1500/-)
- ★ **Proceedings of the Prof R S Ramakrishna Memorial Training Seminar on Modern Analytical Methods** (Rs.200/-)
- ★ **Historical Accounts of the Educational Activities (1972 - 2004)** (Rs.350/-)
- ★ **Proceedings of the Training Seminar cum Workshop on Sampling, Statistics and Standardization in Chemical Analysis and Environmental Management** (Rs.150/-)
- ★ **Polymer Industries of Sri Lanka** (Rs. 200/-)
- ★ **Industry & Environment** (Rs. 200/-)
- ★ **Herbal Medicine Phytopharmaceuticals and Other Natural Products: Trends and Advances** (Rs. 500/-)
- ★ **Chemistry in Sri Lanka** (Rs. 150/-)





# RSC NEWS

## THE ROYAL SOCIETY OF CHEMISTRY SRI LANKA SECTION

### 1. Membership

According to the records sent to us from the parent body, a breakdown of the membership is as follows:-

Category	Number
CChem, FRSC	11
FRSC	05
CChem, MRSC	10
MRSC	20
AMRSC	08
Affiliate /Under Graduate.	<u>06</u>
<b>Total Membership as at July 2013</b>	<b><u>60</u></b>

### 2. Committee of Management

The following were elected to the Committee at the 52<sup>nd</sup> Annual General Meeting held on 27<sup>th</sup> July 2013.

Chairman	- Prof. Sudantha Liyanage
Vice Chairman	- Mr. W J P D Jayalath
Chairman Elect	- Mr. I M S Herath
Hony. Secretary	- Dr. Positha Premaratne
Hony. Treasurer	- Mr. R M G B Rajanayake

Committee Members - Prof. W S Fernando  
Dr. M P Deeyamulla  
Mr. W A P Silva  
Mr. S Perasiriyana  
Mr. Sulith Liyanage  
Dr. P A N Punyasiri

### 3 Activities

3.1 Contributions to Activities of the Institute of Chemistry Ceylon

(a) Full page advertisement of "Chemistry in Sri Lanka".

(b) Contribution for the Interschool Chemistry Quiz

(c) Award for the Best Performance at the Graduate ship Examination in Chemistry Part II Theory Examination

(d) Contributions for the International Conference

3.2 All - Island Inter School Chemistry Essay Competition.

3.3 Inter - University Chemistry Competition.

3.4 A/L teacher workshops.

3.5 Advanced Level chemistry seminar.

3.6 Book donation programmes

3.7 Industrial Visit.

### 4. Web Site

The members are reminded of the web site of our Section, the address of which is as follows:-  
[www.rsc.org/Membership/Networking/InternationalSections/SriLanka/index.asp](http://www.rsc.org/Membership/Networking/InternationalSections/SriLanka/index.asp).

Dr. Positha Premaratne  
*Hony Secretary*

A/L teacher workshop at Jaffna



A/L teacher workshop at University of Sri Jayewardenepura

