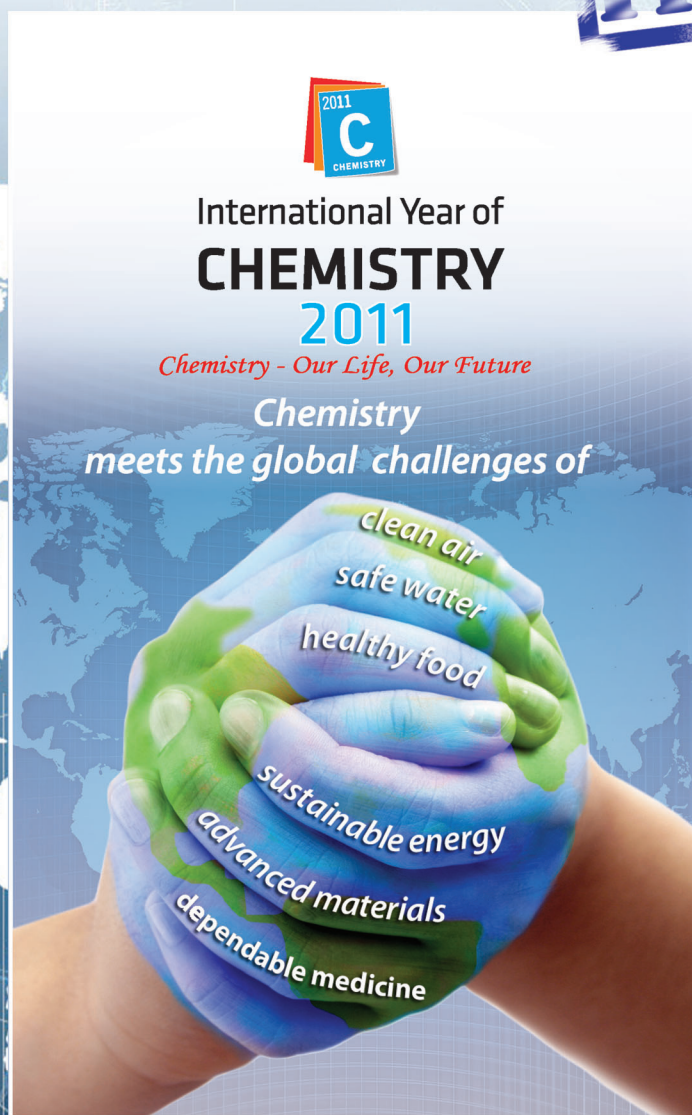


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IN SRI LANKA

IYC ISSUE



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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. 28 No. 1

January 2011

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Theme for the year -

"Chemistry Education for the Well Being of Society"

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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 May 2011.

- *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.

International Year of Chemistry 2011 and our seven decade contribution to the Profession of Chemistry in Sri Lanka

Professor J N Oleap Fernando

Honorary Dean, College of Chemical Sciences, Institute of Chemistry Ceylon



The global recognition given to CHEMISTRY by the United Nations Organization by declaring 2011 as the International Year of Chemistry is indeed very significant and noteworthy.

Chemistry is a well recognized basic academic discipline and together with

Physics is one of the two basic disciplines to be recognized for the annual award of the prestigious Nobel Prizes. It is also significant to note that Physics (in 2005) and Chemistry (in 2011) are the only two academic disciplines to have been recognized by the UNO for declaration as International Years. CHEMISTRY has also been widely recognized as the Central Science and is a basic key component in an interdisciplinary scientific matrix. The centrality of Chemistry is specifically brought into sharp focus when one considers the all pervading nature of Analytical Chemistry which directly interacts with all branches of science and occupies a central position in the growth of Chemistry.

It is however unfortunate that the position of CHEMISTRY as a specific profession similar to Medicine, Engineering, Law, Accountancy, etc is relatively less recognized particularly in our country. The Royal Society of Chemistry, UK (RSC) which is the oldest body of chemists in the world is one hundred and seventy years old and traces its origin to the Chemical Society established in London in 1841 as the learned society for the advancement of Chemical Sciences. The professional status of the RSC can be traced to the establishment in 1877 of its predecessor, the Royal Institute of Chemistry (RIC), to establish, uphold and advance the standard of qualifications, as well as the competence and conduct of those who practice Chemistry as a profession. However, even in the UK, the misuse and misapplication of the title CHEMIST to also include a pharmacist as one who sells medicines and toiletries has got reversed only in recent times. That has happened after the requirement for anyone wishing to register a company's name that contains the word 'Chemist' or 'Chemistry' to obtain prior approval of the Secretary for Trade who in turn would do so only after consultation with the RSC. The RSC and its parallel body in Australia (Royal Australian Chemical Institute, RACI, established in

1917) have over the past decades proved themselves to be fully fledged professional Institutes which maintain a status of recognition and acceptability on behalf of the Chemistry profession not only within the respective countries but even internationally.

It is also significant to note that the Chemical Society of Ceylon (founded 1941) as a learned society is the oldest such body to be established in any of the basic science areas in Sri Lanka. In 1944 it was this Society that took the initiative to establish the large umbrella body for Sri Lankan Scientists known today as the Sri Lanka Association for the Advancement of Science (SLAAS), which in turn played the midwifery role in establishing in 1976 the National Academy of Sciences of Sri Lanka (NASSL), which is the Sri Lankan counterpart of the Royal Society, UK. Our professional body of Chemistry can thus claim to have a daughter as SLAAS and a grand-daughter as NASSL!

Recognizing the imperative need and desire to further the profession of Chemistry in Sri Lanka, the Chemical Society of Ceylon transformed itself into a professional body in 1971 which was incorporated by Act No. 15 of 1972 as the Institute of Chemistry Ceylon. (It is interesting to note that it was around the same period that the Chemical Society, UK amalgamated with the RIC to become today's powerful Royal Society of Chemistry, UK).

From small beginnings but with considerable human resources in hand, the professional body of Chemists in Sri Lanka ventured in 1973 to meet an acute need of qualified technical personnel to provide services in furtherance of research, analytical testing and services by the provision of much needed support personnel at a middle level. It is no small achievement to provide over a period of nearly four decades what has developed today as the Diploma in Laboratory Technology (DLTC) programme. The Laboratory Technologists who have been produced so far are providing a yeoman service in numerous educational, research and service Institutions in Sri Lanka and is the only such programme in any of the basic science areas in Sri Lanka.

Proceeding further on a principal objective of our Act of Incorporation to conduct courses and examinations for all grades of membership and for the award of diplomas, certificates and other distinctions in Chemistry, our Institute strengthened the professional standing of Chemistry in Sri Lanka by

commencing a professional Graduateship Programme in Chemistry in 1979. This was in order not only to supplement the inadequate number of Graduate Chemists who were been produced through the state financed non fee levying university system but also to provide a second opportunity to adults, the matured, the employed and late developers to become professional Graduate Chemists. The RSC has assisted us in a number of ways including the provision of external examiners and an external standardization mechanism that has enabled our Graduate Chemists to obtain recognition for higher education in some of the best tertiary level institutions in the world. We had no office or staff when we commenced operations four decades ago. However today we have about forty members on our academic and non academic staff who together with a large number of visiting staff are providing teaching and training seven days a week in our own four storeyed building fully equipped with an air conditioned library, laboratories, instrumentation room, IT centre etc. Their services are not confined to the formal DLTC and Graduateship programmes but also directed to conduct of numerous other professionally related activities including training seminars, debating competitions, quiz competitions etc.

Having been personally involved in various capacities with the activities of our Institute over a period extending to over four decades, it gives me great joy and pleasure to note that we are now producing, at no expenditure to the national exchequer, an average of about 70 qualified graduate chemists annually representing over 40 percent of the Sri Lankan output of Graduate Chemists. Our College of Chemical Sciences is identified, since 1996, as the largest producer of such Graduate Chemists. Our formal educational programmes are making an indelible and recognizable mark in the tertiary educational scenario of Sri Lanka. The number seeking registration in our programmes has reached an all time high level. Indeed Adamantane House will stand as a lasting monument and testimony to the type of contribution a programme conducted by a professional body can make towards improving the infrastructure of a professional body in a productive and constructive manner.

It is therefore quite clear that the professionalism of Chemistry is today on a more stronger wicket and foundation than ever before. Not very many other professional bodies in Sri Lanka provide programmes of study for professional career development at the tertiary level and we are the only such body to do so amongst the basic sciences. It is unfortunate that no other professional body in the basic sciences has any type of headquarters building or occupies such a building even on a rented basis.

However a source of great regret for us who are involved in the administration of our educational

programmes is that most of our own Graduate Chemists (totaling 739 over 27 batches from 1983/84 to 2010) who comprise about 60% of the IChemC membership today have not, despite repeated appeals, thought it fit to provide support and assistance to the work of the Institute by serving on its numerous bodies and sub-committees so that the Institute can go from strength to strength and enhance the professionalism of Chemistry in Sri Lanka. The Chief Guest at our Third Convocation, Prof Arjuna Aluwihare, in his Convocation Address appealed to the Graduate Chemists to come forward in a determined manner and support what he termed their "Academic Parent". Then President, IChemC Mr. Mevan Pieris (on the eve of the International Conference CHEMTECH 2007) in his editorial contribution entitled "It is time that a new generation took control" to volume 24 No. 2, 2007 of Chemistry in Sri Lanka stated as follows:-

"A leader amongst the Alumni must emerge who could inspire the lot and bring them together. It is the principle of alignment which leaders must follow that enables the flock to fly in the same direction. It is reverently hoped that the Alumni will play a greater role in Institute matters..... That being said, it is high time that a new generation took control of the affairs of the Institute."

I have repeatedly echoed similar sentiments and if I may quote from my own Dean's Report at the last (sixth) Convocation on 22.01.10.

"Our alumni must realize that the future progress and sustainability of both the Institute and the College will have to increasingly depend on their cooperation by providing physical support to run programmes of both the Institute and the College. It is their moral duty and obligation and they should consider it their pride to take on the positions of office bearers of the College/Institute and/or help in numerous ways. I appeal to the Graduate Chemists passing out today to think over these matters very seriously since the future of the Institute and the College is to a large extent in your hands".

The number of CCS Alumni who are actively involved in assisting our activities can be counted within the ten fingers on one's hand. While thanking them most profusely, I wish to take this opportunity to once again appeal to all the other Graduate Alumni to extend much more support and assistance towards the activities of the Institute and College which are yours.

In that connection, we are very thankful and appreciative of Graduate Chemist (2001) Mr. N.M.S Hettigedara, who is one of the few Graduate Chemists who has taken even the onerous task of taking over as Chairman of the IYC Steering Committee with a bucketful of ideas and suggestions on how we can use 2011 as a spring-board to enhance the awareness of Chemistry and further the strengthening of Chemistry as a profession. With

very little help from the Graduate Chemists and Institute members energetic Hettigedara has taken over almost singularly to find sponsors and bear the brunt of the heavy work-load that has been initiated, undertaken, sustained and devolved in connection with IYC 2011. Here we have a splendid example of a Graduate Chemist Alumnus coming forward with innovative ideas that I hope and pray will enable Chemistry and Chemists of Sri Lanka to be on a very high pedestal at the end of 2011 and beyond.

We are deeply appreciative of UNESCO, at a global level, for having pledged a substantial amount of funds for IYC activities in 2011 and beyond. Locally, we are the beneficiaries of several principal sponsors including the House of Maliban, Unilever Sri Lanka, Ministry of Technology & Research to all of whom we are thankful for all the assistance given to enable the success of CHEMEX 2011!

In keeping with the declared objective in section 3 (k) of our Act of Incorporation which is to enhance the status of the profession of Chemistry in Sri Lanka,

we are required by section 9 to take steps as may be found necessary from time to time for the maintenance of professional standards and discipline among persons practicing or acting as Chemists in Sri Lanka. Although 40 years have elapsed since our establishment, we have still failed even to initiate necessary steps in these directions by having legislation enacted by Parliament to make the registration of Chemists and the accreditation of chemical laboratories mandatory. Referring, to this matter in 1992 in the Devanathan Memorial Lecture delivered by me at the 21st Annual Session of the Institute of Chemistry Ceylon I mentioned that Malaysia is one country in which such legislation has been enacted. Let us use IYC 2011 to stir up public awareness on this important matter amongst policy formulators so that we can make a distinct and positive contribution to enhance and further the professional status of Chemists and the profession of Chemistry in Sri Lanka.

Chemistry is our life and will ensure a better future!

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#### **Editor's note:**

The January issue of Chemistry in Sri Lanka is dedicated to the International year of Chemistry 2011 (IYC 2011). Under the international theme, 'Chemistry - our life, our future', a series of articles are included in this issue, written by the experts in the fields of medicine, energy, water, environment, materials, food and agrochemicals. These articles illustrate the contributions of chemistry for the well-being of society. Recognizing the fact that the year 2011 coincides with the 100<sup>th</sup> anniversary of the award of the Nobel Prize in Chemistry to Marie Curie, women's contributions to Chemistry are highlighted and given a pride of place by incorporating the 'life and work' of Marie Curie and the three other women who received the Nobel Prize in Chemistry to date: Irène Joliot-Curie, Dorothy Crowfoot Hodgkin and Ada E Yonath. This issue is sponsored by UNESCO.

#### **Cover Page**

The cover page carries a reprint of a leaflet prepared by the IYC 2011 Secretariat (Sri Lanka) depicting the contributions of Chemistry for the well-being of society. The centenary of the award of the Noble Prize in Chemistry to Marie Curie is commemorated by having her photographs.

#### **Deans Emergency Fund**

The Deans Emergency Fund was established to provide financial relief to G I C students in case of emergency. The Institute of Chemistry Ceylon welcomes donations to this fund from members, students and well wishers.

## International Year of CHEMISTRY 2011

### **“An opportunity to educate young people and general public about contribution of chemistry for the well-being of society”**

Professor M D P De Costa

*President, Institute of Chemistry Ceylon (IChemC)*



I consider it a privilege to be the President of the Institute of Chemistry Ceylon during the current year which coincides with the International Year of Chemistry 2011 (IYC 2011). IYC 2011 is being celebrated throughout the world with the support of the International Union of Pure and Applied Chemistry (IUPAC) and the United Nations Educational, Scientific and Cultural Organization (UNESCO). Recognition of Chemistry by the United Nations underscores the pivotal role it played in contributing much to the benefit of humankind. Chemistry contributed to improving the quality of life of people by helping to provide quality food and clean water which are essential to healthy living and by developing medicines to combat diseases. Advances in technology based on Chemistry dramatically improved personal care, shelter, transport and many other present day amenities in life.

The Institute of Chemistry Ceylon, as the professional body of chemists, has taken the leading role in organizing many events to celebrate IYC 2011 in Sri Lanka. Activities have been planned to be conducted throughout the year in the fields of education, continuous professional development and dissemination among the general public of knowledge in chemistry, that is useful in day to day activities. The inaugural ceremony of the IYC 2011 will be held on 27<sup>th</sup> January 2010 at the Sirimavo Bandaranaike Memorial Exhibition Centre together with a trade fair and exhibition, CHEMEX 2011 displaying “Wonders in Chemistry” at the same venue from 27<sup>th</sup> -30<sup>th</sup> January 2011. A large number of industries, research institutes, government organizations and universities will participate at this exhibition showcasing how the application of chemistry has a direct and positive effect on people's lives. Throughout the year many interactive and educational activities including seminars, workshops, an interschool chemistry quiz, an interuniversity debating competition, competitions among school children on day to day related topics, dramas and magic shows will be conducted to generate enthusiasm to engage young people in

chemistry. Activities including newspaper articles, radio and television programmes will be conducted for the general public to show the relevance of chemistry in our everyday lives.

This year's activity theme of the IChemC “Chemistry education for the well-being of society” goes hand in hand with the IYC international theme, “Chemistry - Our life, Our future”. Under our theme educational activities in Chemistry will be conducted throughout the year which will include teacher training programmes, school based “project” competitions and school chemistry days. The main event will be held in June with a theme seminar entitled, “Photochemistry for the well-being of society”. Two foreign experts in Photochemistry, Professor J A Pincock, Emeritus Professor, Dalhousie University, Canada and Professor A P de Silva Queen University, Belfast will participate at this event and topics related to medicine, industry, day to day life, education and research in photochemistry will be addressed at this seminar.

The concluding ceremony of IYC 2011 is planned for December highlighting the contribution to chemistry of women and to pay tribute to Marie Curie, recognizing the 100<sup>th</sup> anniversary of her receiving the Nobel Prize in Chemistry.

The Chairman of the IYC 2011 Secretariat (Sri Lanka), Mr. N M S Hettigedara played a valuable and commendable role in initiating and implementing IYC 2011 celebrations in Sri Lanka. He has seen to all aspects of organizing the trade fair and exhibition, IYC 2011 calendar, printing of a commemorative stamp and providing leadership for many other activities. On behalf of the IChemC, I wish to record our sincere appreciation and gratitude to Mr. Hettigedara for his untiring efforts to make IYC 2011 a memorable event in Sri Lanka. Our activities are supported by UNESCO and several other local industries.

I cordially invite all the members of the IChemC to take part in the activities organized throughout the year to make IYC 2011 in Sri Lanka a great success. Let us hope that our activities will inspire young people to learn chemistry and to make them understand the important role played by Chemistry in contributing to the well-being of society in innumerable ways.

## International Year of Chemistry 2011: *Chemistry our life, Our Future*

Mr. N M S Hettigedara

*Chairman, IYC Steering Committee, National Secretariat (Sri Lanka)*



Year 2011 will be a historically important year for science in general and chemistry in particular, in the world as well as in Sri Lanka, with the declaration of International Year of Chemistry (IYC- 2011).

The International Year of Chemistry is an opportunity to promote and celebrate advances of chemistry and chemical sciences in all its aspects. In fact, IYC 2011 is an important opportunity that we must fully exploit as it will not come again during our life time. The Institute of Chemistry Ceylon in its capacity as the National Adhering Organization for IYC 2011 through its IYC 2011 Secretariat, plays the key role in making this important event a success in Sri Lanka, with the cooperation of related state and private sector institutions, educational organizations and private sector industrialists.

### **Chemistry and Our life**

As we are aware, chemistry is all around us and every fabric of our life and society is touched by chemistry. Chemistry of food that we consume, clothes, plastics, rubber, metals, electronics, semi conductors, stationery, transportation and communication, cosmetics and drugs are all closely related to our day to day life. Chemistry is a creative science essential for the sustainability and improvement of our way of life. New materials and new processes are developed to make our lives healthier and our environment a safer place for all living organisms. Chemistry is central in understanding biological, physical material and medical phenomena. It provides a proper basis for understanding how nature works. Chemistry also plays a central role in the business, commerce and manufacturing sectors. Industries benefit from understanding and applying chemistry, which provides new products and manufacturing processes, which in turn generates monetary and commercial value leading to new business and employment. Drugs, material and machinery developments and improvements benefit us and simplify our daily life today. Further, extraction and purification in the oil industry, chemical and material storage as well as logistics and transportation industry which involves chemistry of fuel used to power vehicles are important aspects of chemistry. There is chemistry in the arson and disaster insurance industry. Chemistry is also involved in new business development and management. It has applications in

films, photography, sound records, painting, scalping. Thus without chemistry there is no life.

### **Origin and the goals of the IYC 2011**

The important decision to proclaim 2011 as the International Year of Chemistry was taken by the International Union of Pure and Applied Chemistry (IUPAC) at its General Assembly in Turin, Italy in August 2007. The IUPAC unanimously approved a resolution in favor of the proclamation. The UNESCO Executive Board recommended the adoption of such a resolution which subsequently led to the declaration in December 2008 by the UN General Assembly of 2011 as the International Year of Chemistry. Thus the global partners for the IYC 2011 are IUPAC and UNESCO. The official opening ceremony at UNESCO headquarters in Paris is from January 27<sup>th</sup> – 28<sup>th</sup> 2011. Its theme will be focused on how chemistry can help to meet the UN millennium development goals such as:

1. Eradicate extreme poverty and hunger
2. Achieve universal primary education
3. Promote gender equality and empower women
4. Reduce child mortality
5. Improve maternal health
6. Combat HIV/AIDs, Malaria and other diseases.
7. Ensure environmental sustainability
8. Develop a global partnership programme.

In the year 2011 countries including Sri Lanka hope to show how chemistry is vital if we are to meet the UN millennium development goals.

The goals of the International Year of Chemistry 2011 are three fold. Firstly, action will be taken to increase the public appreciation of chemistry in meeting world needs. Chemistry, which is considered the Central Science, is both a philosophical inquiry and an applied scientific endeavor. The science of chemistry is fundamental to humanity's understanding of the world. Chemistry is central to the production of foodstuffs, medicines, fuels, metals etc. Through IYC the chemistry community will publicly celebrate the art and science of chemistry, its key contributions to developing human knowledge, advancing economic progress and fostering a wholesome environment.

Secondly, programmes will be implemented to increase interest of young people in chemistry. In partnership with the United Nations, the International Year of Chemistry will make a strong educational contribution toward the goals of the UN Decade of Education for Sustainable Development. National and international activities carried out during the International Year will emphasize the importance of chemistry in helping to sustain the natural resource

base for life.

Thirdly, action will be taken to generate enthusiasm for the creative future of chemistry. Humanity's understanding of the world is grounded in our developing knowledge of chemistry. Chemists will inevitably play a key role in overcoming the challenges facing today's world, for example in helping to address the aforesaid United Nations Millennium goals. A deep understanding of the science is essential for developing molecular medicine, for creating new materials and sustainable sources of food and energy.

This important event also celebrates the 100<sup>th</sup> anniversary of the Nobel Prize in Chemistry awarded to Marie Sklodowska Curie, an opportunity to celebrate the contributions of women to science. 2011 will also be the 100<sup>th</sup> anniversary of the founding of the International Association of Chemical Societies, which provides an important opportunity to highlight the benefits of international scientific collaboration.

The world wide activities of the International Year of Chemistry 2011 will improve the understanding and appreciation of Chemistry by the public, enhance international cooperation by serving as a focal point of information source for activities by national chemical societies, educational institutions, industry, governmental and non governmental organizations, promote the role of chemistry in contributing solutions to global challenges and Build capacity by engaging young people with scientific disciplines, especially the scientific method of analysis developed by hypothesis, experiment, analysis and conclusions.

#### **Institute of Chemistry as the National Adhering Organization for IYC-2011**

The National Adhering Organization for IYC 2011 in Sri Lanka is the Institute of Chemistry Ceylon which is the successor to the Chemical Society of Ceylon (founded in 1941) established in the year 1971 for the general advancement of science and practice of chemistry. The Institute was incorporated by an Act of Parliament No. 15 of 1972. It is a learned society catering to chemical sciences as well as the professional, qualifying and examining body looking after and responsible for the maintenance and enhancement of the profession of chemistry in Sri Lanka. The Secretariat established for this purpose by the Institute has organized a series of events with a view to achieving the objectives and goals of the IYC 2011 with the cooperation of related organizations.

#### **Inauguration of IYC 2011 and the programmes**

In keeping with the official opening ceremony at UNESCO headquarters in Paris from January 27<sup>th</sup> – 28<sup>th</sup> 2011, Sri Lanka will inaugurate the IYC 2011 on 27<sup>th</sup> January 2011 at BMICH under the sponsorship of UNESCO. The occasion will consist of three

important events namely, Official Inauguration, Exhibition and Trade Fair. The IYC 2011 will be inaugurated by Hon. Tissa Vitarana, the Senior Minister of Scientific Affairs on 27<sup>th</sup> January 2011. Prof J.N.O. Fernando, Dean, College of Chemical Sciences who has experience in education in chemical sciences has been invited as the Guest of Honor. At the same time the occasion will be graced by Mr. R. Preethi Perera, Secretary General of the Sri Lanka National Commission for UNESCO.

The themes for the three day sessions will cover four important spheres in Chemical Science.

27<sup>th</sup> January: 'Chemical Research in Technology Development'. Keynote Address by Dr. A.M. Mubarak, Director, Industrial Technology Institute

28<sup>th</sup> January: 'Chemistry of Day to Day Life'. Keynote Address by Prof. S. Sotheeswaran, President Elect, Institute of Chemistry Ceylon.

29<sup>th</sup> January: 'Chemistry for Industry'. Keynote Address by Mr. Rajitha Kariyawasam, Managing Director, Haycarb PLC

30<sup>th</sup> January: 'Chemical Education for the Well-being of the Society'. Keynote Address by Prof. J.N.O.Fernando, Dean, College of Chemical Sciences. The ceremonial cancellation of the commemorative stamp will take place on the 30<sup>th</sup> January.

#### **Grand Exhibition and Trade Fair: CHEMEX 2011**

Chemistry is behind our life. All over the world, innovative and quality products are produced through the applications of chemistry, and hence our chemists will appreciate the declaration of IYC 2011. However, there is a need to generate and enhance the awareness of the general public on the importance of chemistry. Therefore, a grand exhibition *CHEMEX 2011* and trade fair has been organized with the sponsorship of Maliban biscuit Manufactories Ltd, Unilever Sri Lanka Ltd, ITN, Associated Newspapers, Ministry of Technology and Research, College of Chemical Sciences, Nelus Events Management at BMICH under the theme "Wonders of Chemistry" for the effective information exchange in chemistry, chemical products and importance of chemistry in our day to day life. The exhibition will be helpful for all sectors of the community including professionals, industrialists, researchers, students and general public who will be brought under one roof. This grand exhibition would be held from 27<sup>th</sup> January – 30<sup>th</sup> January 2011 at the BMICH. Entertainment activities, school dramas performed by school children and chemistry graduate students, chemical magic shows, chemistry quiz programmes and interuniversity debate competitions will boost the interest in chemistry. The raffle draw, public awareness lectures and discussions and several other activities have also been organized.

Further, among the activities for IYC 2011 an essay competition and an art competition have been planned with the aim of creating a better understating

of chemistry and its applications among the general public, university students and school children.

We intend to use the media effectively to enhance the profile of chemistry as viewed by the students, general public and decision makers. All concerned organizations will work closely and enthusiastically to achieve the goals of IYC 2011. The chemical industrialists, academics, researchers, university students and school children and general public are invited to visit the grand Trade Fair and Exhibition CHEMEX 2011.

Principal Sponsors of the IYC



## Graduateship Examinations in Chemistry, 2010

### LEVEL 1 – AWARDS LIST

|                                                                    |                     |
|--------------------------------------------------------------------|---------------------|
| First prize and Charles Jayaweera Memorial (Open) Scholarship      | Ms. H J Pereira     |
| Second prize and Nandawathie Jayaweera Memorial (Open) Scholarship | Ms H M Thirimanne   |
| Third Prize and Prof. R S Ramakrishna Scholarship                  | Mr. A M Casiechetty |

#### MERIT BURSARIES ( in order of merit)

Ms D D Dambutuarachchige

#### SUBJECT PRIZES

|                                                                           |                     |
|---------------------------------------------------------------------------|---------------------|
| Graduate Chemist Alumni prize for General & Inorganic Chemistry           | Ms. H M Thirimanne  |
| Emerine Fernando Memorial prize for Principles of Physical Chemistry      | Ms. H J Pereira     |
| Bennet prize for Mathematics for Chemists                                 | Ms. H M Thirimanne  |
| Somawathi Mathew Memorial prize for Biology for Chemists                  | Mr. A M Chasichetty |
| Prof & Mrs S Sotheeswaran Prize for Principles of Organic Chemistry       | Ms. H J Pereira     |
| Mr & Mrs J M Ranasinghe Banda for Application of Mathematics in Chemistry | Ms. R M I Bandara   |
| Henry Ashmore Pieris Memorial Prize for Management, Economics & Finance   | Ms. H J Pereira     |

### Level 3 Overall Awards List, 2010

|                                                                  |                       |
|------------------------------------------------------------------|-----------------------|
| First Prize & Mandrupa & Oleap Fernando Hall Opening Scholarship | Ms. P A M K Erangi    |
| Second Prize and Susila Jayaweera Memorial Scholarship           | Ms. T G Vithanage     |
| Third Prize & Graduateship Silver Jubilee Scholarship            | Ms. G D S Dassanayake |

#### Merit Bursaries (in order of merit)

Ms. G Mayoorini, Mr. U D Hewagamage, Mr. K A D S Ravinatha, Ms. P M D Amarawardena, Mr. U L A S Perera, Mr. D C Senivratne, Mr. R M J S Hunukumbura

### Level 3 Prize List, 2010

|                                                                     |                         |
|---------------------------------------------------------------------|-------------------------|
| P Rohan K Fernando Prize for Special Topics in Chemistry            | Ms. T G Vithanage       |
| Egodawatta G Somapala Prize for Food Chemistry and Technology       | Ms. T G Vithanage       |
| Prof. Eugene de Silva Prize for Industrial Chemistry & Technology   | Ms. P A M K Erangi      |
| Marina & ROB Wijesekera Prize for Molecular Biology & Biotechnology | Mr. R M J S Hunukumbura |
| Batch 2005 Prize for Information Technology                         | Mr. B A T N Gunasekera  |
| Prize for Atomic Absorption Spectrometry                            | Mr. J P T K Pathirana   |

## Women in Chemistry

*The year 2011 coincides with the 100<sup>th</sup> anniversary of the award of the Nobel Prize in Chemistry to Marie Curie. She is the first woman to receive the Nobel Prize in Chemistry and many women have been inspired by her work. As a tribute to Marie Curie, her "Life and Work" is given the pride of place in this issue. Internationally, the IYC has been announced in order to emphasize and celebrate the contributions of women to this discipline, and to encourage and inspire women to follow in the footsteps of their illustrious predecessors.*

### Marie Skłodowska- Curie: The legendary woman scientist

Dr. Sithy Iqbal

*Department of Chemistry, Open University of Sri Lanka*

Two Nobel Prizes in Physics and Chemistry for a woman from a poor province of Europe being challenged by life, losing her husband at the height of fame and bringing up two daughters, one of whom also became a Nobel Prize winner! This is the story of an extremely gifted, yet hard working, tough and ambitious woman-scientist, who discovered the radioactive elements polonium and radium, the glow from which she adored, unaware of the damaging effects of exposure to radiation which eventually killed her. She honestly believed that radioactivity will benefit mankind.

Marie Curie was born Maria Skłodowska in Warsaw on November 7, 1867, the fifth and youngest child of well-known teachers Bronisława and Władysław Skłodowski. Maria's older siblings were Zofia (born 1862), Józef (1863), Bronisława (1865) and Helena (1866). Her parents taught their five children the value of learning. They realized that only modern education could lift them, and Poland, from their lowly condition. Before she turned 11, her eldest sister had died of typhus and her mother had died of tuberculosis. Despite these losses, Maria attended a *gymnasium* for girls and graduated from there in 1883 at 15 with the highest honours.

Women were not permitted to study at the University of Warsaw at that time. So Maria and her older sister Bronisława (Bronya or Bronia in Polish) joined other students secretly at a "floating university" (or 'flying university'). The classes met at night, at changing locations to avoid detection by the authorities. Maria and Bronisława knew that to get a true professional education, they would have to go to a major university in Western Europe. Maria made an agreement with her sister Bronisława that she would work as a governess and give her financial assistance during Bronisława's medical studies in Paris. As soon as Bronisława was trained and began to earn money, she would help cover the costs of Maria's university training. Maria took a position as governess first with a lawyer's family in Krakow (part of Austria), then for two years in Ciechanow (of Russia) with a landed family and a family in Sopot (of Prussia), where she spent the next year, all the while financially assisting her sister. At the beginning of 1890, Bronisława, a few months after she married Kazimierz Dłuski, invited Maria to join them in Paris. Maria declined because she could not afford the

university tuition. She returned home to her father in Warsaw, where she remained till the autumn of 1891. She tutored, studied at the clandestine floating university and began her practical scientific training in a laboratory at the Museum of Industry and Agriculture in Warsaw. The laboratory was run by her cousin, Józef Boguski, who had been an assistant to the great Russian chemist Dmitri Mendeleev in St. Petersburg. Shortly before she turned 24, she found out that she had saved up just enough money for university studies in Paris. She had looked forward to this moment for a long time. All the same, she took leave of her beloved father and Poland with sadness. She promised to return after finishing her studies.

In Paris, Maria briefly found shelter with her sister and brother-in-law for a few months before renting a primitive garret and proceeding with her studies of Physics, Chemistry and Mathematics at the Sorbonne (the University of Paris). Skłodowska studied during the day and tutored evenings, barely earning an income to pay for expenses. In 1893 she was awarded a degree in Physics. Her **superior work** in physics won her a scholarship and a group of industrialists, the Society for the Encouragement of National Industry, paid her to investigate the magnetic properties of different steels. To carry out the work she needed a laboratory. The same year she was introduced to Pierre Curie, who was the Laboratory Chief at the Paris Municipal School of Industrial Physics and Chemistry, École Supérieure de Physique et de Chimie Industrielles de la Ville de Paris (ESPCI). Meanwhile she continued studying at the Sorbonne and in 1894, earned a degree in Mathematics. She worked hard hoping that one day she would be able to return to native Poland and work in her chosen field of study. However, when she was denied a place at Jagiellonian University in Kraków merely because she was a woman, she returned to Paris. Almost a year later, in July 1895, she and Pierre Curie married, and thereafter the two physicists hardly ever left their laboratory. Marie Skłodowska-Curie had found a perfect partner and scientific collaborator upon whom she could depend.

Over the next two years, Marie completed her research on the magnetic properties of steels. She submitted her final results shortly before giving birth to their first daughter, Irène, in September 1897. Pierre's

father, a retired doctor, moved in with them and helped raise Irène. Marie began looking for a research topic that would earn her a doctorate in science. No woman in France had yet completed that degree.

In December 1895, a German physicist, Wilhelm Roentgen, had discovered rays that could travel through solid wood or flesh. A few months later a French physicist, Henri Becquerel, discovered that minerals containing uranium also gave off rays. Roentgen's X-rays amazed scientists, who took to studying them with great energy, while mostly ignoring Becquerel's rays, which seemed much the same, only weaker. Marie decided to investigate the uranium rays (rays emitted by uranium) as a possible field of research for her doctoral thesis under the supervision of Becquerel. She carried out systematic studies using two uranium minerals, pitchblende and chalcocite. Using the electrometer invented by her husband and his brother (Curie electrometer), she found that the activity of uranium compounds depended only on the quantity of uranium present. If you had a certain amount of uranium which means a certain number of uranium atoms, then you have a certain intensity of radiation. She had shown that the radiation was not the outcome of some interaction of molecules, but must come from the atom itself. Her electrometer showed that pitchblende was four times as active as uranium itself, and chalcocite twice as active. She figured that the pitchblende must contain another element, extremely radioactive and never seen before. The promise of a strange new element was so exciting that Pierre put aside his work on crystals to help speed up the discovery. Together they processed tonnes of uranium ore in a makeshift shed, unaware of the deleterious effects of radiation exposure on their health. They worked as a team, each responsible for a specific task. Her paper, giving a brief and simple account of her work, was presented for her to the *Académie* on 12 April 1898 by her former Professor, Gabriel Lippmann. In July 1898, Marie and her husband published a paper together, announcing the existence of an element which they named "polonium" in memory of her native Poland. While working with polonium, they had also discovered that, accompanying the barium separated from the pitchblende, there was another new element. After several months more of close work, they were able to separate this second new substance, which was shown afterwards to be much more important than polonium. In December 1898 the Curies announced the discovery of this new and famous element, which they named "radium", from the Latin word for ray.

The scientific community did not trust the announcement, for the Curies did not have enough polonium and radium to see and weigh. The existence of elements was known only from their radioactivity. Pitchblende contains both elements and chemical separation of its constituents was an arduous task. By 1898 the Curies had obtained traces of radium, but appreciable quantities, without being contaminated

with barium, was still beyond reach. The storeroom at Pierre's school was too small for such work, and the Curies continued their experiments in an abandoned shed nearby. While Marie undertook the delicate task of purification of radium salt by fractional crystallization, her husband was busy studying the physical properties of the rays emitted by the new substances. From a tonne of pitchblende, a mere decigram (100 mg) of very pure  $\text{RaCl}_2$  was separated. The isolated substance showed all the characters of a pure chemical compound. Radium gives a characteristic spectrum and in 1902 she was able to determine for it an atomic weight much higher than that of barium. It had taken her almost four years to produce the kind of evidence that chemical science demands, that radium was truly a new element. She believed that if reasonable means had been at her disposal, one year would probably have been enough for the same purpose. Later on she was able to prepare several decigrams of pure radium salt, to make a more accurate determination of the atomic weight and even to isolate the pure radium metal. However, 1902 was the year in which the existence and character of radium were definitely established.

In 1903 she completed her doctoral thesis, becoming the first woman to receive a doctorate in France. The committee of examiners declared that her work had done more for science than any previous thesis project. The same year, the Royal Swedish Academy of Sciences awarded Pierre Curie, Marie Curie and her supervisor, Henri Becquerel the Nobel Prize in Physics, "in recognition of the extraordinary services they have rendered by their joint researches on the radiation phenomena discovered by Professor Henri Becquerel". This means that she had received the Nobel Prize in Physics just a few months after receiving her doctorate from the University of Paris and that she had got it for her doctoral work!



By 1910 she had isolated pure radium metal. In an unusual decision, Marie Skłodowska-Curie intentionally refrained from patenting the radium-isolation process, so that the scientific community could benefit from her research.

The Sorbonne gave Pierre a professorship and permitted him to establish his own laboratory, in which Marie became the chief of work (or director of research). The public and industrialists were fascinated by the discoveries of the Curies. Radium, inexhaustibly giving out energy, hinted at great mysteries and perhaps amazing inventions. Moreover, Pierre proved that radium could damage living flesh. That opened a new

way to treat cancer and other ailments. Industrial firms saw an opportunity in the Curies' research. They helped the Curies by providing additional laboratory space, raw materials, and support staff. A thriving industry grew up, extracting radioactive substances for medical uses (and other uses too, like watches that glowed in the dark). Radium was also used by scientists for experiments on atoms. But, Marie lost nearly 20 pounds while doing her doctoral research; Pierre was often exhausted and in pain. Was it overwork and stress or was radiation the cause of their frequent illnesses? Marie refused to believe that radiation was very harmful.

Pierre and Marie were overtired and had a succession of failures of health that it was not until 1905 that they were able to go to Stockholm where Pierre delivered the traditional lecture accepting the Nobel Prize. The following spring Pierre was finally feeling more positive about his research. Although rainy, April 19, 1906, promised to be a productive day for him. After working in the laboratory in the morning, he was on his way to a library. Walking across the Rue Dauphine in heavy rain, he slipped on the wet street and fell in front of a heavy horse-drawn wagon. It ran over his head, killing him instantly.

Skłodowska-Curie was devastated by the death of her husband. She noted that as of that moment she suddenly had become "an incurably and wretchedly lonely person". On 13 May 1906, the Sorbonne Physics Department decided to retain the Chair that had been created for Pierre Curie who held it for only one year and a half and they entrusted it to Skłodowska-Curie together with full authority over the laboratory. This allowed her to emerge from Pierre's shadow. She became the first woman to become a Professor at the Sorbonne and in her exhausting work regime she sought a meaning for her life. Still more important, she decided to establish a scientific institution worthy of Pierre's memory. Helped by her scientist friends, she persuaded the French government and the private Pasteur Foundation to fund the Radium Institute. Marie would head a radioactivity laboratory, and an eminent physician would lead its medical research laboratory.

Recognition for her work grew to new heights, and in 1911 the Royal Swedish Academy of Sciences awarded her a second Nobel Prize, this time for Chemistry, "in recognition of her services to the advancement of Chemistry by the discovery of the elements radium and polonium, by the isolation of radium and the study of the nature and compounds of this remarkable element". Curie became the first person to win a second Nobel Prize. She pulled herself together and traveled to Sweden to accept the 1911 Nobel Prize for Chemistry for her discovery of radium and polonium. A month after accepting the Nobel Prize, she was hospitalized with depression and a kidney ailment. Many months passed before Curie was able to work again. Curie finally returned to work in late 1912. She never remarried, devoting her life to the Radium

Institute. By August 1914, the building was nearly completed.

In 1921, Skłodowska-Curie toured the United States to raise funds for research on radium and returned with a gram of radium as well as expensive equipment and cash for the Radium Institute. Her second American tour in 1929 succeeded in equipping the Warsaw Radium Institute, founded in 1925 with her sister Bronisława as the director, in her native Poland that regained independence after World War I.

Marie Curie was busy not only with her teaching, research and efforts to set up the Radium Institute, but also as a mother of two daughters Irène (born 1897) and Eve (1904). Between 1906 and 1908 she taught Physical Science once a week at a cooperative school, where her daughter Irène and a few other children got lessons from their parents. Her father-in-law helped raise Irène and Eve, but he died in 1910. She hired a series of Polish governesses to teach her daughters her native language, and sent or took them on visits to Poland.

Curie continued to carry out research on radioactivity, but her main focus shifted to running the Radium Institute. She made the Institute a centre for measuring the radium content of various products used by doctors and others and a world centre for research. The researchers at the Radium Institute made many discoveries. In 1934, she was delighted when her daughter Irène and Irène's husband, Frédéric Joliot, discovered artificial radioactivity at the Radium Institute; bombardment of aluminium with alpha rays produced neutrons and phosphorus 30 which was the first artificially produced radioactive isotope of an element. Curie did not live to see Irène and Frédéric receive the 1935 Nobel Prize for Chemistry for their discovery.

Skłodowska-Curie visited Poland for the last time in the spring of 1934. Only a few months later, on July 4 1934, she died of aplastic anemia, a blood disease that was almost certainly contracted from exposure to radiation. The damaging effects of ionizing radiation were not then known, and much of her work had been carried out in a shed, without proper safety measures. She had carried test tubes containing radioactive isotopes in her pocket and stored them in her desk drawer, remarking on the pretty blue-green light that the substances gave off in the dark.

She was interred at the cemetery in Sceaux, alongside her husband Pierre. In 1995, in honour of their achievements, the remains of both were transferred to the majestic Panthéon in Paris, where they now lie alongside France's greatest citizens. The president of France declared that the transfer demonstrated the nation's respect for all those, like the Curies, "who dedicate themselves to science". Her laboratory is preserved at the Musée Curie, Curie Museum. Because of their levels of radioactivity, her papers from the 1890s are considered too dangerous to handle. Even her laboratory note book is contaminated with radioactive

material. They are kept in boxes lined with lead and those who wish to consult them must wear protective clothing.

Madame Curie was decorated with the French Legion of Honour. In Poland, she had received honorary doctorates from several universities.

The curie (symbol **Ci**), a unit of radioactivity, is named in honour of her and Pierre and also curium (**Cm**), the element with atomic number 96.

Three radioactive minerals are named after the Curies: curites, skłodowskite and cuproskłodowskite.

## References

1. [http://en.wikipedia.org/wiki/Marie\\_curie](http://en.wikipedia.org/wiki/Marie_curie)
2. [http://www.aip.org/history/curie/brief/01\\_poland/poland\\_3.html](http://www.aip.org/history/curie/brief/01_poland/poland_3.html)
3. Marie Skłodowska-Curie. Autobiographical notes and Pierre Curie (2006). Dom Wydawniczo-Promocyjny GAL, Totem, Warszawa, Poland

## Acknowledgement

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*Following Marie Curie, to date, three other women have been awarded the Nobel Prize in Chemistry: Irène Joliot-Curie, Dorothy Hodgkin and Ada Yonath. The "Life and Work" of these three brilliant women chemists are recorded in this issue.*

## Inspirational Women in Chemistry

Professor Ramanee D Wijesekera

*Department of Chemistry, University of Colombo*



**Irène Joliot-Curie**  
**Chemist/ Nuclear Physicist**  
**(1897 – 1956)**

Irène, the elder daughter of Marie and Pierre Curie, was born in Paris on 12<sup>th</sup> September 1897. She had a sister Eve who was seven years her junior. Her grandfather Eugene Curie, a doctor who had distinguished himself with his services during the uprising in Paris (1848) and the Commune (1871), came to live with Marie and Pierre Curie from 1898 till his death in 1910. With her parents spending long hours in the lab, he played a big role in her early upbringing, and exerted a great influence on her personality. After a year of traditional schooling when she was six years old, her parents, realizing her exceptional talent in mathematics, educated her at "The Cooperative", a private gathering of some of the most distinguished academics in France, each of whom contributed to educating one another's children in their respective homes. The teachers included Marie Curie, Paul Langevin and Jean Perrin who taught mathematics, physics and chemistry respectively. The curriculum at The Cooperative was varied, including not only science but diverse subjects such as Chinese and Sculpture. After two years of The Cooperative, Irène received a more orthodox education at Collège Sévigne, a high school in Paris (1912 – 1914). The on-going conversations she had with her mother, and the maths puzzles that concluded the letters from her when they were apart, were also important in Irène's intellectual development.

Irène then went on to the Faculty of Science at the Sorbonne in October 1914 to prepare for the

Baccalaureate in mathematics and physics. Her studies at the Sorbonne were interrupted by World War I, when she took a break to serve as a nurse radiographer in the war (1914 – 1917). She worked alongside her mother Marie Curie, who, realizing the potential of X-rays in helping doctors detect bullets, shrapnel and broken bones in soldiers, convinced the government to empower her to set up the first military radiology centre in France. As the Director of the "Red Cross Radiology Service" she established twenty mobile radiology field hospitals (known as "Petite Curies") to transport X-ray apparatus to the battle front. Marie Curie having no hands-on experience in working with X-rays, gave herself a cram course in operating of the equipment and auto-mechanics. After training Irène as a nurse radiographer, mother and daughter made their first trip to the battle front in the autumn of 1914. They worked tirelessly, uncaring of the dangers of over-exposure to X-rays, helping to save the lives of countless soldiers. In one instance, Irene was solely responsible for installing radiographic equipment in an Anglo-Canadian hospital a few miles from the front in Flanders. She was 18 years of age at the time. The French government awarded Irène a military medal in recognition of her enormous contribution.

After the war, Irène returned to Paris (1918) to work as her mother's assistant at the Institut du Radium (Radium Institute), which had been built by her parents. While working there, she began her Doctoral studies at Sorbonne (1921), on the alpha rays of polonium. This was the second element discovered by her mother and named after Poland, her country of birth. Irène became a Doctor of Science in 1925.

In the same year, Frédéric Joliot (19<sup>th</sup> March 1900 –

14<sup>th</sup> August 1958), on the recommendation of the eminent French physicist Paul Langevin, one of his teachers at the Paris Municipal School of Industrial Physics & Chemistry, was employed at the Radium Institute as a junior assistant to Marie Curie. Very soon, a romantic relationship developed between Irène and Frédéric and they were married on 29<sup>th</sup> October 1926. Thereafter, both Irène and Frédéric used the surname Joliot-Curie.

Irène, quiet and aloof, was very different in personality to the charming, gregarious and fun loving Frédéric, or Fred as everyone called him. She was also two-and-a-half years older than him. Cynics claimed that the gregarious “prince consort” was wooing the awkward “crown princess” of the Radium Institute only to advance his career! Marie Curie, although delighted with the romance, was doubtful that the marriage would last and insisted on a pre-nuptial agreement. According to this, Irène would inherit the radium in the lab as well! However, Irène and Frédéric shared not only a love of scientific research, but also similar political outlooks and a love of sports. He said of Irène “I discovered in this girl, whom other people regarded as a block of ice, an extraordinary person, sensitive and poetic.”

The young couple struggled financially, so Frédéric took on some teaching to ease the burden. At one time, he even contemplated leaving research for a better paying career in industry. However, he continued to be with the Radium Institute and obtained his Doctorate in 1930, for his work on the properties of compounds of polonium.

Much of the Joliot-Curies' research at the Radium Institute resulted in frustrating near-misses of great discovery. In 1931 for instance, they showed that on bombarding beryllium with alpha particles from polonium, powerful rays that were able to make protons emit at high speed were given off from the atomic nuclei of paraffin wax. They concluded that the rays were a new type of gamma ray, the most powerful form of atomic radiation known at the time. The British physicist James Chadwick on carrying out further studies realized that the rays included a new kind of sub-atomic particle. He called it a neutron. He was awarded the Nobel Prize for Physics in 1935 for this work. Thereafter, once again, having failed to interpret their results completely, C. D. Anderson was able to claim the discovery of the positron. Later on, their observation of these very particles led to their discovery of artificial radioactivity.

Finally, in mid January 1934, working in their basement lab at the Radium Institute, they created scientific history! Building on the work by Marie and Pierre Curie who had isolated naturally occurring radioactive elements, they discovered that bombarding stable elements with alpha particles could produce radioactive elements. They found that when polonium was placed beside aluminium foil, instead of the expected protons, neutrons and positrons were given off the foil. Furthermore, when the polonium was moved

away, the positrons still kept streaming from the aluminium foil. A Geiger counter which detects radioactive species, ticked for several minutes when placed near the aluminium. Somehow, the alpha particles from the polonium had made the aluminium radioactive. Irène and Frédéric concluded that the nuclei of the aluminium atoms had absorbed alpha particles from the polonium, ejecting a neutron in the process and changing to a radioactive form of phosphorus (<sup>30</sup>P), that did not exist in nature. The phosphorous nuclei then emitting a positron, decomposed (half life of ~3 min) to a stable, non-radioactive form of silicon. Irène, using her chemical expertise, devised a test that proved the existence of the short-lived phosphorus. The production of radioactive elements from boron and magnesium were explained in a similar way: Boron produced an unstable nitrogen isotope (<sup>13</sup>N, half life of ~11 minutes) and magnesium an unstable silicon (<sup>27</sup>Si) isotope (Published in Nature, 1934, See also Comptes Rendes, 1934). The Joliot-Curies were the first to produce an artificial radionuclide and to experimentally confirm transmutation, the conversion of one element into another.

Irène and Frédéric Joliot-Curie were awarded the Nobel Prize for Chemistry in 1935; “the results of your research is of capital importance for pure science, in addition to physiologists, doctors and the whole of suffering humanity.” Unfortunately, Marie Curie was unable to witness their triumph, having died of leukaemia in July 1934. For their discovery, they were also awarded America's Bernard Gold Medal for meritorious service to science (1940), the Henri Wilde Prize and the Marquet Prize of the French Academy of Science. Honours did not change Irène. She remained her simple and unassuming self throughout her life. It is ironical however, that Irène was never admitted to the French Academy of Science due to her gender! She was also not given membership in the American Chemical Society due to her gender and politics.

The use of radioactive materials in medicine was growing rapidly. The tedious laboratory work involved in the separation of naturally occurring radioactive elements, such as radium from their ores was no longer necessary. Radioactive materials could now be prepared quickly, cheaply and in plenty. This discovery helped immensely in the progress of nuclear physics and medicine.

Although close in private life, the Joliot-Curies did not do any research together after they won the Nobel Prize. Frederic became a Professor at the College de France (1937), the country's foremost research institute, and Irene continued to direct research at the Radium Institute and also became a Professor at Sorbonne (1937 – 1956), having been a lecturer there since 1932.

Irène did her most remarkable individual work in the years preceding World War II. Like several other eminent scientists in the late 1930's she attempted to explain the phenomena that occurred when uranium, the

heaviest natural element, was bombarded with neutrons. What was expected was that the neutrons would penetrate the nuclei of the uranium atoms, creating artificial elements, probably short-lived and radioactive, that were heavier than uranium. Therefore, when in 1938, working in collaboration with Yugoslav physicist P. P. Savitc, Irène detected what appeared to be lanthanum, an element lighter than uranium, she assumed that she had made a mistake. Soon after, from a similar experiment, German scientist Otto Hahn obtained barium, another light weight element. Initially, he also doubted his results! However, later, he concluded that the neutron had split the uranium atom into two atoms of comparable mass, i.e., the phenomenon of “fission” was discovered. He was awarded the Nobel Prize in Chemistry in 1944 for this discovery. As stated by James Chadwick “she came to within a hair's breadth of recognizing that the phenomenon involved in the production of these elements was that of fission.”

The Joliot-Curies also adopted Marie and Pierre Curie's policy of publishing all their work for the benefit of the global scientific community. However, they stopped this practice fearing the dangers that might result should it be developed for military use. On 30<sup>th</sup> October 1939, they placed all their documents on nuclear fission in the vault of the Académie des Sciences, where it remained till 1949.

During World War II, Irène contracted tuberculosis which forced her to spend a few years convalescing in Switzerland. However, during this period she made several trips back to France, to visit her husband and children left behind in occupied France. On one such visit (in 1943), she was stopped at the Swiss border when she attempted to enter the country at Porrentruy. She spent several days with hundreds of other refugees fleeing the Nazis, sleeping on a straw mat in a communal room in a detention centre. The Prefect of the district finding this, arranged to have her moved. However, she refused to be given preferential treatment and insisted on remaining there until her release. In 1944, a few months before the liberation of Paris, the Communist Resistance Organization of which Frédéric was President, fearing that she might suffer reprisals for her husband's resistance activities smuggled her and the children into Switzerland (her husband had gone underground).

In 1946, Irène was accidentally exposed to polonium when a sealed capsule of the elements exploded on her lab bench, causing extensive radioactive scalding. She received extensive treatment but her condition deteriorated. In spite of this she continued to work, dividing her efforts in the following years between setting up the Radium Institute's large new lab at Orsay, a Southern suburb of Paris and working with women's pacifist movements. The centre was equipped with a synchro-cyclotron of 160 meV, and its construction was continued by Frédéric after her

death. Irène became actively involved in promoting Women's education and served on the Comité National de l'Union des Femmes Françaises (National Committee of the Union of French Women) and the World Peace Council. She was an advocate for peace, socialism and equal rights for women.

The Joliot-Curies opposed the ideals of the growing Fascist movement and joined the Socialist Party in 1934, the Comité de Vigilance des Intellectuels Antifascistes a year later, and in 1936, actively supported the Republicans in the Spanish Civil War. When the Popular Front was elected into power in France in 1936, Irène served as the Undersecretary of State for Scientific Research, becoming one of France's first women cabinet ministers. In this capacity she helped to found the Centre National. By pre-arrangement, she relinquished the post after three months to return to her beloved lab. In recognition of their work for the resistance, the Joliot-Curies were given membership (1939) in the French Légion d'Honneur (Legion of Honour): Irène as an officer and Frédéric as a commissioner.

Irène was a commissioner (1946 – 1951) in the Commissariat à l'énergie Atomique (French Atomic Energy Commission), and participated in its creation and in the construction of the first French atomic pile (1948). In 1951, because of her involvement with the French Communist party founded by her husband, she was required to relinquish this post. She served as Director of the Radium Institute from 1947 till her death in 1956.

Irène was a lover of nature, enjoyed rowing, sailing, swimming and hiking in the mountains during vacations in Brittany. She also enjoyed the works of French and English authors such as Victor Hugo and Rudyard Kipling; she even translated some of Kipling's poems. She found great joy in motherhood and in spite of her long hours in the lab, devoted time to her children until their adolescence.

The Joliot-Curie's have a daughter Hélène (b. 17<sup>th</sup> September 1927) and a son Pierre (b. 12<sup>th</sup> March 1932). Hélène is a nuclear physicist and a Professor at the University of Paris. She was married to Paul Langevin's grandson, Michael Langevin. Pierre is a biochemist at the Centre National de la Recherche Scientifique.

When Irène was diagnosed with Leukaemia, the same disease that her mother died of, she told a longtime friend “I am not afraid of death. I have had such a thrilling life.” In 1956, after a final convalescent period in the French Alps, Irène was admitted to the Curie Hospital in Paris where she died of leukaemia on 17<sup>th</sup> March, at the age of 58.

*Eve Curie on her sister Irene:*

*“The fame and achievements of her parents neither discouraged nor intimidated her. Her sincere love of science and her gifts, inspired in her only one ambition: To work for ever in the laboratory which she had seen go up.”*

From the obituary by Sir James Chadwick (*Nature*, 1956)

*"Her parents were both persons of strong and independent minds and Irene Joliot-Curie inherited much of their character as well as their scientific genius. She had a powerful personality, simple, direct and self-reliant. She knew her mind and spoke it, sometimes perhaps with devastating frankness; but her remarks were informed with such regard for scientific truth and with such conspicuous sincerity that they commanded the greatest respect in all instances. In all her work, whether in the laboratory, in discussions or in committees, she set herself the highest standards and was most conscientious in the fulfillment of any duties she undertook."*



The Joliot-Curies



Irène Joliot-Curie

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References

- <http://www.aboutnuclear.org/Irene-Joliot-Curie>
- <http://www.woodrow.org/Irene-Joliot-Curie>
- http://www.nuclearfiles.org/menu/library/biographies/bio_curie-irene.htm
- <http://www.nndb.com/people/410/000100110>
- <http://en.wikipedia.org/wiki/Irene-Joliot-Curie>
- <http://www.physics.ucla.edu/~cwp/Phase2/Joliot-Curie>
- <http://gos.sbc.edu/c/curie1935.html>
- <http://www.encyclopedia.com/topic/Irene-Joliot-Curie.aspx>
- <http://pagerankstudie.com/Blog/2010/09/irene-joliot-curie>
- <file:///D:/1%20CHEM/ICHEM%20nobel%20women/2ndgen1.htm>
- file:///D:/1%20CHEM/ICHEM%20nobel%20women/i_curie.htm
- <http://www.aip.org/history/curie/2ndgen1.htm>
- <http://www.aip.org/history/curie/radinst1.htm>
- <http://www.chemicalheritage.org/discover/chemistry-in-history/themes/stomich-and-nuclear-structure>



Dr Dorothy Crowfoot Hodgkin:
Chemist, Crystallographer,
Humanitarian
(1910 – 1994)

Dorothy Crowfoot, the first of four daughters, was born in Cairo, Egypt on 12th May 1910, where her father, John Winter Crowfoot (1873 – 1959), a British archaeologist and scholar of classics was serving in the Ministry of Education. He was later appointed as both Director of Education and Antiquities in Sudan. He retired in 1926, but continued his work in archaeology by serving as the Director of the British School of Archaeology in Jerusalem. Her mother, Grace Mary Crowfoot, nee Hood, (1877 – 1957) was an authority on early weaving techniques (Coptic textiles) and an excellent amateur botanist and nature artist. She spent her spare time illustrating the flora of Sudan.

Dorothy spent the first four years of her life in Sudan. With the outbreak of World War I, she and her sisters were sent to their paternal grandmother in Norfolk, England, till their mother returned to England at the end of the war. Dorothy was initially educated at home and in a succession of small private schools till she attended Sir John Leman School in Beccles, England (1921-1928). Dorothy and another girl were allowed to join the boys to study chemistry at school! Although her formal schooling was in England, she spent a significant part of her youth in the Middle East and North Africa where her parents were stationed.

Dorothy became interested in chemistry and crystals at a very young age, and she was encouraged both by her parents and their scientific acquaintances. Dr A. F. Joseph, a soil chemist and a friend of her parents in Sudan, gave her a mineral analysis kit which allowed her to set up a home laboratory. An unforgettable experience for Dorothy was one of mixing solutions of alum and copper sulfate which were then allowed to evaporate to produce sparkling crystals. She later wrote "I was captured for life by chemistry and by crystals." She enjoyed using this kit to analyze pebbles that she and her sisters found in the stream running through their garden in Sudan. When she was fifteen, her mother gave her Sir William Henry Bragg's "Concerning the Nature of Things", which contained intriguing discussions on how scientists could use X-rays to "see" atoms and molecules. She was fascinated.

After a period of intense tutoring to prepare her for the entrance examination, Dorothy entered Somerville College for women only in the University of Oxford, where she studied chemistry and physics (1928 – 1932). In her final year research project she examined the structure of thallium dialkyl halides using X-ray crystallography, under the supervision of H. M. Powell. Although Sir W. H. Bragg and his son were awarded the Nobel Prize in Physics in 1915 for their work in crystallography, X-ray crystallography was still a new area of science. In 1932, Dorothy graduated from Somerville College with a degree in Chemistry.

In 1933, Dorothy began work on her doctoral studies in physicist J. D. Bernal's laboratory at the

University of Cambridge. She was financed by her aunt Dorothy Hood, who paid all her college bills, and by a £75 scholarship from Somerville to be held for one year at Cambridge and the second at Oxford. Bernal who had worked five years with the senior Bragg was a well reputed crystallographer. Guided by him, she began X-ray studies of large molecules such as sterols and proteins (The Braggs had worked primarily with inorganic molecules). Crystals of such large molecules were extremely difficult and tedious to work with in the early 1930's because of the lack of technology. In 1934, Bernal took the first X-ray photograph of a protein crystal, pepsin, and Dorothy carried out the analysis to determine its structure. The fact that proteins functioned by assuming specific three-dimensional shapes was not well understood at the time. Hence Dorothy's results began a new era; crystallography could establish not only the structural layout of atoms in a molecule, but also the overall molecular shape which contributed to its biological activity. They also determined that protein crystals should be studied with their mother liquid surrounding them and not air-dried as was the practice at the time. This marked the beginning of macromolecular crystallography which still dominates current structural biology.

In 1934, Dorothy returned to Oxford as a teacher at Somerville College. She also continued with her doctoral work on sterols which she had begun in Cambridge, and in 1937, obtained her doctorate from Cambridge. It was a difficult decision to move from Cambridge, but she needed the income and jobs were scarce. The laboratory facilities at Somerville College, Oxford were extremely primitive: She had to climb a rickety circular staircase, several times a day, to reach the only window with sufficient light for her polarizing microscope. This was made all the more difficult because she suffered severely most of her adult life, from rheumatoid arthritis which badly crippled her hands and feet. Furthermore, Oxford officially barred her from attending research meetings of the Faculty Chemistry Club because she was a woman, a far cry from the intellectual camaraderie and support she had encountered in the Bernal labs. She however, quietly persevered. Sir Robert Robinson assisted in getting funding to buy better equipment and the Rockefeller and Nuffield Foundations awarded her a series of small grants. Her talent was recognized and she soon became very much a part of the Faculty. She was an invited speaker at the students' Chemistry Club meetings which Faculty members also began to attend, and graduate students signed on to do research with her.

At Oxford, success came early for Dorothy. Using X-ray diffraction, she determined the three-dimensional structure of Cholesterol iodide (1941 – 1942, Published in 1945) and over 100 sterols: She reported their unit cell dimensions, showed the molecules crystal packing and their H-bonding scheme. At the time, such work was not being done by anyone else because of the

formidable calculations involved. This was a breakthrough in crystallography because it was the first analysis based on three-dimensional calculations and it established the stereochemistry at each carbon atom of the sterols.

Dorothy also began working on insulin (1934). It was one of her most extraordinary research projects. It began when she received a sample of crystalline insulin from Sir Robert Robinson. However, at the time, X-ray crystallography was not sufficiently developed to cope with such a complex molecule and determining the crystal structure of even simple molecules was a challenge. Dorothy and her colleagues believed that it might be possible to determine the structure of insulin by working with an isomorphous crystal. She replaced the zinc atoms in insulin from pig, with atoms of three heavier elements, namely, lead, uranium and mercury and mapped the electron densities of these three derivatives of insulin. She and her colleagues spent many years improving their techniques and in 1969, 35 years later, finally resolved the structure of the 777-atom insulin molecule (Published in *Nature*, 1969 & 1971). The advancements in computer technology played a major role in their ability to do so.

Dorothy began work on the structural analysis of penicillin in 1942, during World War II. After penicillin was discovered, chemists worldwide worked extensively to determine its chemical structure, as it was an antibiotic of immense importance during and immediately after the War. To everyone's amazement, Dorothy determined its structure using X-ray analysis (1945). Previously, from chemical analysis, only fragmentary and conflicting evidence of its structure was available. Although penicillin is not a particularly large molecule, it has an unusual ring structure, at least four different forms and crystallizes in different ways, making it a difficult crystallographic problem. She was fortunately able to use one of the first IBM analog computers to help with the calculations in the X-ray analysis. This was the first instance of the use of an electronic computer to solve a biological problem. The determination of the structure of penicillin (Published in *Nature*, 1949) marked the beginning of the synthesis of "modified" penicillins. While completing her work on penicillin, Dorothy was named a Fellow of the Royal Society (1947), Britain's premier scientific organization.

Dorothy began her work on Vitamin B₁₂ in 1948, and in 1955 obtained the first X-ray diffraction photographs of its crystals. The crystals were obtained from the Glaxo drug company. This molecule was four times larger than penicillin and "the usual" chemical methods had revealed very little about its central part. They collected complete three-dimensional data for four B₁₂ crystals, namely, air-dried, wet, molecule with CN of B₁₂ replaced by SeCN and a hexacarboxylic acid derived from B₁₂. She began her analysis by locating the positions of the heavy atoms. By using Patterson maps

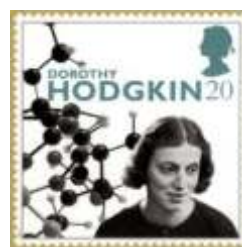
she was able to obtain an approximation of the correct electron density maps and was able to determine the crystal structure of the hexacarboxylic acid derivative from B₁₂. Dorothy used the cobalt atom to obtain phase information for the hexacarboxylic acid derivative against the advice of others, who believed that the scattering power of the cobalt atom was too weak with respect to the rest of the molecules. Using the techniques developed by her, the three-dimensional structure of vitamin B₁₂ was determined. Her discoveries opened up an exciting new avenue within the field; the use of heavy atoms to determine the structure of biological macromolecules. She collaborated with Kenneth Trueblood, a crystallographer at the University of California in Los Angeles, as he had a high-speed digital computer, one of the first of its kind that helped speed up the calculations. Mail and telegraphs were used to communicate their information between California and England. It was later found that this molecule was not the naturally active vitamin and in 1961, Dorothy & co-workers determined the structure of the natural vitamin. Vitamin B₁₂ coenzyme was the first naturally occurring organometallic compound to be discovered. This discovery allowed for the vitamin to be synthesized and used in the treatment and prevention of pernicious anemia, a deadly disease at the time.

After Dorothy returned to Oxford in 1934, she remained there except for brief intervals. She served as Official Fellow & Tutor, Somerville College, Oxford (1935 – 1955), Demonstrator & Lecturer, Oxford University (1946 – 1956), University Reader, Oxford University (1956 – 1960), Wolfson Research Professor, Oxford University (1960 – 1977), Professorial Fellow, Somerville College, Oxford (1977 – 1983) and Professor Emeritus, Oxford University (1977 – 1994). She worked at first in the Department of Mineralogy & Crystallography. In 1944, when the department was divided, she worked in the sub-department of Chemical Crystallography.

Dorothy Hodgkin has been honoured with numerous awards and accolades, some of which are listed here: In 1956, she received the Royal Medal from the Royal Society of London. She was the first Royal Society Wolfson Research Professor at University of Oxford (1960 – 1977), an endowed Chair financed by the Royal Society. In 1964, Dr Hodgkin was awarded the Nobel Prize for Chemistry “for her determination by X-ray techniques of the structure of important biological substances.” She was the first British woman and the third woman to win this prestigious award. In 1965, she was named by Queen Elizabeth II, as a member of the Order of Merit. This is the United Kingdom's highest royal order and she was only the second woman to be bestowed this honour, the first being Florence Nightingale. In 1970 she was elected Chancellor of Bristol University. In 1971 she became a member of the United States National Academy of Sciences. From 1972 – 1978 she was the President of the

International Union of Crystallography. Western governments were somewhat alarmed because she invited crystallographers from behind the Iron Curtain to participate in conferences. As a result of her affiliations with such organizations, she had problems with getting an entry visa into the United States. However, as she gained recognition and the Soviet Union disbanded in 1990, the restrictions on her visa to the United States were finally lifted. In 1976 she received the Copley Medal from the Royal Society and became a member of the USSR Academy of Sciences. From 1977 – 1978 she was the President of the British Association for the Advancement of Science. In 1982 she was awarded the Mikhail Lomonosov Gold Medal because of her high standing within the Soviet scientific community and in 1987 she was awarded the Lenin Peace Prize for her commitment to the Soviet cause and her efforts towards easing tensions between the East and West. She helped form Pugwash, a group to promote communication between scientists on opposite side of the Iron Curtain at the time of the Cold War. During her tenure as its President (1976 – 1988), she was able to get 111 Nobel scientists to sign a declaration against nuclear weapons.

Buildings at Bristol University and Keele University were named after her. Dorothy Hodgkin was one of five “Women of Achievement” selected for a set of British stamps issued in August 1996.



She received Honorary D.Sc.'s from the Universities of Bath, Brown, Cambridge, Chicago, Delhi, East Anglia, Exeter, Ghana, Harvard, Hull, Kent, Leeds, London, Manchester, Mount Sinai, Oxford, St. Andrews, Sussex and Warwick. She was the Honorary Fellow of several universities including, Somerville College Oxford, Girton College Cambridge and Bristol University. She was a member of numerous Academic Associations around the globe.

After her official retirement in 1977, in spite of her life long struggle with rheumatoid arthritis, Dorothy travelled extensively throughout the world, promoting her causes: She was a champion of World Peace and Disarmament, a strong supporter of National liberation struggles and proponent of the development of Third World countries. She supported the establishment of the Hodgkin Scholarships which aided students from Third World countries and founded Hodgkin House which accommodated overseas students.

In 1937, Dorothy married Thomas Hodgkin, an expert on African affairs, who later became a well known lecturer in Oxford. He was the son of Robin H.

Hodgkin provost of Queen's College at Oxford and cousin to Prof. A. L. Hodgkin, a recipient of the Nobel Prize for Medicine in 1963. They had three children and they all took up their parents scholarly and nomadic habits. Luke (b.1938) taught at a University of Algiers before taking up a Faculty position in Mathematics at the University of Warwick, Elizabeth (b.1941), like many of her ancestors taught history at a girls' school in Zambia and Toby (b.1946) worked in India in a volunteer service similar to the American Peace Corp and then went on to study Botany and Agriculture at Newcastle, U.K. By 1993, Dorothy was a grandmother nine times over and had three great-grandchildren.

The Hodgkins' were hospitable and kept an open house. Their guests included the powerful, the famous, revolutionaries and refugees as well as their own countless students, colleagues and friends.

Dorothy Hodgkin is regarded as one of the pioneer scientists in the field of X-ray crystallographic studies of biomolecules. Through her research she was able to improve the methods used in X-ray diffractions. She developed three-dimensional views of the molecular and atomic structure of extremely complex organic compounds. Her research paved the way for others to develop and expand their ideas. She helped, advised and encouraged hundreds of crystallographers and scientists around the world and was a "motherly figure" to this international family of hers. She was also involved in a wide range of peace and humanitarian causes in many nations. To her students, she was a "teacher, mother,

friend and guide all rolled into one." Her colleagues, found her a "warm, simple, affectionate and caring human being."

On 29th July 1994, at 84 years of age, Dr Dorothy Crowfoot Hodgkin died from a stroke at her home in Shipston-on-Stour, Warwickshire, England.

Prof. J. D. Bernal said of her "She was one of those masters whose method of work is as exciting and beautiful to follow as the results that flow from it."

A colleague, Cambridge scientist Max Perutz said of her "She will be remembered as a great chemist, a saintly, gentle and tolerant lover of people and devoted protagonist of peace."

Interesting Snippet:

In the 1940's one of her research students was Margaret Thatcher, a former Prime Minister of the UK.

References

- http://en.wikipedia.org/Dorothy_Hodgkin
- nobelprize.org/nobel_prizes/chemistry
- www.zephyrus.co.uk/dorothyhodgkin.html
- nobelprizes.com/nobel/chemistry/dch.html
- www.chemheritage.org/discover/chemist
- [http://www.pugwash.org-Pugwash_Review-Dorothy_Hodgkin:A life](http://www.pugwash.org-Pugwash_Review-Dorothy_Hodgkin:A_life)
- <http://www.sdsc.edu/sciencewomen/hodgkin.html>
- www.answers.com/topic/dorothy-crowfoot

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Dr Ada E. Yonath
Cryo Bio-Crystallographer
1939 –

Ada E. Yonath (pronounced 'ada jo'nat) was born on 22nd June 1939 in Jerusalem, to Zionist Jewish parents who immigrated to Palestine before the creation of Israel. They settled there and ran a grocery store to earn a living. Her father was a rabbi. The family was not well-to-do and had to share a rented four room apartment with two other families. Although her parents had no formal education, they endured many hardships to make certain that Ada had a good education by sending her to Beit Hakerem, the very prestigious secular grammar school.

Her father was in poor health. Frequently hospitalized, he underwent many operations and passed away at age 42, when she was 11 years old. To help her mother's earnings, Ada took on a variety of jobs from cleaning, baby sitting to tutoring younger children. These earnings however, were still insufficient for their needs. A year later, they moved to Tel Aviv, to be near her mother's sisters. The school fees at Tichon Hadash High School were unaffordable to her mother. Ada taught

mathematics to the students there in lieu of fees. However hard the times, her mother was fully supportive of Ada's desire to further her studies. In her youth, Ada was inspired by Marie-Curie.

Ada completed her compulsory army service in the "top secret office" of the medical forces where she was fortunate to be exposed to various clinical and medical issues. Thereafter, she enrolled at the Hebrew University of Jerusalem and graduated with a Bachelors Degree in Chemistry in 1962 and a Masters Degree in Biochemistry in 1964. Her doctoral studies were carried out at the Weizmann Institute of Science, Israel, where she worked on the high resolution X-ray structure of collagen. She obtained her PhD in 1968. She continued her work on fibrous proteins (muscle) during her first post-doctoral year at Carnegie Mellon University (1969), and then moved to the Massachusetts Institute of Technology (1970) to work on the structure of a globular protein, *Staphylococcus nuclease*. During this period, she also spent some time in William N. Lipscomb Jr.'s (Nobel Prize Winner for Chemistry, 1976) laboratory at Harvard University, U.S.A.

After completing her post-doctoral work, she returned to the Weizmann Institute at the end of 1970 and established a protein crystallography laboratory.

This was the first laboratory of its kind in Israel and remained so for almost a decade. From 1979 – 1984 she was a group leader with Prof. H. G. Wittmann at the Max-Planck Institute for Molecular Genetics in Berlin. She was a Visiting Professor at the University of Chicago (1977 – 1978) and she headed the Max-Planck Institute of Structural Biology at DESY (Deutsches Elektronen Synchrotron) in Hamburg, Germany (1986 – 2004) in parallel with her research activities at the Weizmann Institute. At the Weizmann Institute, she was the director of two scientific Centres, the Mazer Centre for Structural Biology and the Kimmelman Centre for Biomolecular Structure & Assembly.

As a young researcher at the Weizmann Institute she says “my ambitious plan was to shed light on one of the major outstanding questions concerning living cells: the process of protein biosynthesis.” In order to do so, she wanted to determine the three-dimensional structure of ribosomes. This was the beginning of a long journey that took her over two decades during which she was met with reactions of disbelief and even ridicule by the international scientific community. “I can compare this journey to climbing Mount Everest only to discover that a higher Everest was always in front of us” Ada says.

She began these studies in collaboration with Prof. H. G. Wittmann of the Max-Planck Institute of Molecular Genetics in Berlin, who supported them both academically and financially. She also maintained her laboratory at the Weizmann Institute, initially with a very modest budget and a grant given by the United States of America National Institute of Health. Over the years a “Centre for Macromolecular Assemblies” from all around the globe was established by Mrs. Helen Kimmel at the Weizmann Institute for researchers. Ada was the head of this Centre.

The ribosome being central to life, attracted the attention of scientists around the world. It is the cell's factory for translating the instructions written in the genetic code into proteins. However, without any knowledge of its three-dimensional structure, there was little hope of being able to understand the mechanics guiding the process. Crystallization of ribosomes was an extremely formidable and challenging task: The ribosome is a complex protein with an extraordinarily intricate structure, unusually flexible, unstable and lacks symmetry.

At the beginning of the 1980's the first micro-crystals of ribosomes were obtained by Ada & co-workers. Her strategy was to use ribosomes from thermophilic (heat-loving) and halophilic (salt-loving) bacteria. Ribosomes from these bacteria yielded well-diffracting crystals while ribosomes from *E. coli* and all other sources had failed to crystallize. Her inspiration had come from an article on hibernating bears! Just before hibernation, these bears pack their ribosomes in an orderly way in their cells, where they remain intact and functional for months. Assuming that this was

nature's way of maintaining ribosomal activity over a long period, Ada looked to ribosomes from organisms that live under harsh conditions, such as from thermophiles and from hardy bacteria living in the extreme environments of the Dead Sea and thermal springs.

However, even after obtaining the preliminary diffraction indications, her plans to determine the ribosome structure were greeted with sarcasm and disbelief, and she was regarded as “the World's dreamer, the village fool, the so-called scientist and the person driven by fantasies” by many distinguished scientists!

During the course of her research, she developed a number of new techniques that are now widely used in structural biology laboratories around the world. One such, is cryo-bio-crystallography, i.e. flash-freezing crystals. This involves exposing the crystals to extremely low temperatures, -185 °C, in order to minimize the disintegration of the crystalline structure under X-ray bombardment.

In the mid 1990's, several groups from leading universities and research institutes, using her procedures, initiated efforts to obtain crystals of ribosomes. At the end of the 1990's, with the improvement in crystal quality, the facilities for detecting the X-ray diffraction patterns and ways to determine phases, the resolution barrier was overcome. The first real breakthrough came with the first electron-density map of the small (30S) ribosomal subunit. In the September 1, 2000 issue of *Cell*, she published the 3.3 Å structure of this subunit. In 2000 and 2001, Ada and co-workers published the first complete three-dimensional structures of both sub-units of the bacterial ribosome.

These discoveries were clearly a high point in her research of over two decades and paved the way for her research to progress in another direction. Because ribosomes are so essential to life, and because they have slightly different structures in microbes, many antibiotics function by targeting their action. Analysis of crystals of the bacterial ribosome-antibiotic complexes showed that the antibiotics bind in specific “pockets” in the structure, located at or close to functional centres, thus blocking them and preventing the ribosomes from manufacturing proteins (published in *Nature*, 2001). Since then, the mode of action of almost all the antibiotics that target ribosomes has been revealed by Ada & co-workers. Such studies have the potential to improve existing antibiotics or help in designing new ones to aid the fight against antibiotic resistant bacteria, one of the biggest medical challenges of the 21st century.

Dr Ada Yonath's prizes and honours are numerous: At the Weizmann Institute, she is the incumbent of the Martin S. & Helen Kimmel Professorial Chair. In 2002, she was the first recipient of the European Crystallography Prize established to recognize

significant achievements in the past 5 – 10 years by European crystallographers. She received the Israel Prize for Chemistry (2002), the Wolf Prize in Chemistry (co-reipient with George Feher, 2006) for “ingenious structural discoveries of the ribosomal machinery of peptide-bond formation and the light-driven primary processes in photosynthesis”, and the Paul Ehrlich and Ludwig Darmstaedter Prize (2007). In 2008, she became the first Israeli woman to win the L'Oréal UNESCO Award for Women in Science for her vital work in identifying how bacteria became resistant to antibiotics. In 2009, she was awarded the Nobel Prize in Chemistry (co-recipient with Thomas Steitz and Venkatraman Ramakrishnan) for her studies on the structure and function of ribosomes which translates the information encoded in the DNA into protein sequences. She was the first Israeli woman, of the nine Israeli Nobel laureates, and the first woman in 45 years to be awarded this prestigious prize. She has also been the recipient of the Harvey Prize, the Kilby Prize, the Cotton Medal of the US Chemical Society, the Anfinsen Award of the International Protein Society, the Paul Karrer Gold Medal from the University of Zurich, the University of Southern California's Massry Award and Medal, the Datta Medal of the Federation of European Biochemical Societies, the Fritz Lipmann Award of the German Biochemical Society and the

Louisa Gross Horwitz Prize from Columbia University.

She is a member of the National Academy of Sciences, the American Academy of Arts and Sciences, the Israeli Academy of Sciences and Humanities, the European Academy of Sciences and Art and the European Molecular Biology Organization, to name some.

In their future work, Ada plans on looking to the distant past to find answers to these questions: How did these first ribosomes come into being? How did they begin to produce proteins? How did they evolve into the sophisticated protein factories in today's living cells?

Ada has one daughter, Hagit, a doctor at Sheba Medical Centre, Israel and a granddaughter

Interesting snippet:

Noa, Ada's five year old granddaughter invited her to talk about the ribosome to her kindergarten class!

References

- en.wikipedia.org/wiki/Ada_Yonath
- www.weizmann.ac.il/sb/faculty-pages/Yonath
- [www.nigms.nih.gov/Biographic sketch:Ada E. Yonath](http://www.nigms.nih.gov/Biographic_sketch:Ada_E.Yonath)
- <http://www.nobelprizes.com - Ada E. Yonath>
- <http://www.lindau-nobel.org-laureate>

Diploma in Laboratory Technology in Chemistry 36th Batch (2008/10)

Honours Pass (5)

R L Nihiluwage, C W Chandrasekaran, K P A I Kumara, G D A Kaumadi, L N C Liyanage

Merit Pass (23)

D A Markalanda, H P Anthony, M M F Nursa, W M S Wijekoon, B Selvendran, G L G I S Seneviratna, N A I R Siriwaitana, D S C Kumara, L P N Damayanthi, M M S Perera, P K A Senarathna, U K Samarasinghe, A R N L Gamage, R A M Asiri, R M R N K Rathnayake, A R Abeyweera, A U E Indeketiya, U G L Sampath, W C K Wickramasinghe, H M R Weerasinghe, D W M Jayasinghe, R Umakanth, P A J P Pohorabawa

Ordinary pass (17)

M N S Shifana, N Fasmiya, U H N Shiyamanthi, D S Kandage, M H P Ishara, D A S Wijesinghe, S W S E Gunaratne, D M Senanayake, K M U S Kumara, N D Bogahalanda, P I A Rodrigo, A M N U Shantha, E K D Jayarathna, Dilina Fernando, A D C Damayanthi, Rohan Gunathilaka, Renuka Gunasekara

DLTC Overall Prize List-2010

First Prize

G C N Jayasuriya Award for the Best Performance

R L Nihiluwage

Second Prize

C W Chandrasekaran

Third Prize

K P A I

Kumara

First in Industrial and Food Chemistry

R L Nihiluwage

First in Clinical Laboratory Technology

G D A Kaumadi

Pharmaceuticals from nature

Professor E. Dilip de Silva

Department of Chemistry, University of Colombo

Modern physicians are equipped with a formidable array of drugs to effectively treat numerous diseases that continue to challenge humankind. The vast array of pharmaceuticals currently available include anti-infective agents, anticancer drugs, immunomodulators, drugs for cardiovascular and metabolic diseases, central nervous system drugs, anesthetics and analgesics. In fact, the unprecedented increase in human life expectancy, which has almost doubled in a hundred years, is mainly attributed to the successful use of drugs. It is an undisputed fact that the spectacular advances in medicinal chemistry and related fields that has brought about this change.

A vast majority of pharmaceuticals in clinical use today are relatively low molecular weight organic molecules. Based on their origins these drugs can be divided into two fundamentally different groups. The first group consists of secondary metabolites isolated mainly from terrestrial plants or cultures of microorganisms. (Often known as natural products, secondary metabolites have no known primary biochemical role in the producing organism and have restricted distributions among organisms.) Also included in this category are the semisynthetic derivatives and structural analogs of the natural products where chemists have modified the original structures to produce drugs with superior qualities. The second group of pharmaceuticals is totally synthetic, designed by humans and synthesized in the laboratory. These synthetic drugs have no relationship to natural products. A number of surveys have shown that over 50% of the drugs in clinical use are either natural products or are based on natural products pointing to the important role nature plays in drug discovery.

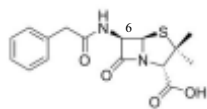
There seems little doubt that even in ancient times, long before the advent of chemistry as a scientific discipline, humans relied on nature for cures. The use of therapeutic plants and minerals, in their crude form, to treat human disease is recorded from the ancient civilizations of the Chinese, the Hindus, the Mayans of Central America, Egyptian and the Mediterranean peoples of antiquity. However, the nineteenth century saw a great advancement in the knowledge of chemistry and the emphasis was shifted from using crude plant preparations to finding the active ingredients that accounted for their pharmacological properties. The isolation of morphine from opium by Sertürner in 1803 marked the beginning of a new era where pure substances would be used as therapeutic agents. Additional drugs isolated from plant sources in the nineteenth century included atropine, caffeine, cocaine, nicotine and strychnine. As a result of these discoveries

and the progress made in organic chemistry the pharmaceutical industry came in to being at the end of the nineteenth century. Aspirin was one of the first drugs to be manufactured, by the German company Bayer in 1899. However, it was only with the subsequent introduction of the antimicrobial drugs that the pharmaceutical industry really took off to become the multi-billion dollar industry that it is today.

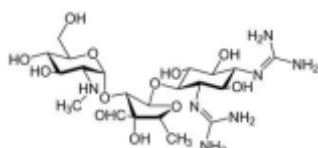
Prior to the 1940s, infectious disease was the principal cause of human death. The introduction of prontosil and penicillin in to the medical arsenal, however, ushered in an era of chemotherapy that revolutionized the treatment of infectious diseases. Prontosil (2,4-diaminoazobenzene-4'-sulfonamide) is a synthetic dye that was shown by the German chemist Gerhard Domagk in the mid 1930s to be effective against systemic streptococcal infections of humans and animals. This discovery in fact was an outgrowth of the German chemist Paul Erlich's systematic search for "Magic Bullets", man-made compounds that would selectively kill pathogenic microorganisms without harming the cells of the human host. Penicillin, in contrast, is a secondary metabolite biosynthesized by the fungus *penicillium notatum*. Its ability to kill pathogenic microorganisms *in vitro* was discovered by Fleming in the late 1920's and was subsequently developed into clinical use through the work of Florey and Chain in the early 1940s. As an antibacterial drug penicillin was a phenomenal success; even nearly 70 years after its introduction penicillin G (**1**) is still in use and is commercially produced by the fermentation of selected high-yielding strains of *Penicillium chrysogenum* (new name for *P. notatum*) in the presence of phenylacetic acid.

With the discovery of penicillin, scientists recognized the value of microorganisms as a source of antibiotics and it became widely accepted that a large proportion of microorganisms produce substances that inhibit the growth of other species and these antibiotics help the producing organism compete for space and nutrients in their natural habitat. (Antibiotics are microbial metabolites or synthetic analogues inspired by them that, in small doses, inhibit the growth and survival of pathogenic microorganisms without serious toxicity to the host.) In the ensuing years a great deal of research efforts were directed at finding new antibiotics from actinomycetes and soil bacteria and soon many new antibiotics were discovered in rapid succession. Important classes of antibiotics that have been developed from microbial sources include the aminoglycosides, cephalosporins, glycopeptides, macrolides, rifamycins and tetracyclins. In this connection the work of Selman

Waksman is especially noteworthy. His work led to the isolation of several new antibiotics, including the two clinically useful drugs streptomycin (2) in 1943. Streptomycin, derived from *Streptomyces griseus*, was the first antibiotic used to treat tuberculosis.



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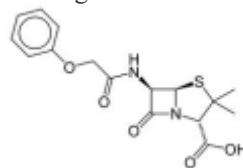


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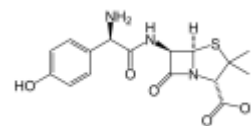
Antifungals, such as griseofulvins, the polyenes, and the avermectins, such as the antiparasitic drug ivermectin, also are of microbial origin. These discoveries ushered in the era of powerful antibiotics and it is not an exaggeration to say that a significant percentage of the present population owe their longevity to these agents.

The antibiotics mentioned above are all natural products designed by nature. However, even with the modern knowledge we have at hand today, scientists are not even close to designing entirely new classes of compounds that would elicit a biological activity such as shown by these molecules. However, once a new class of compounds is found, medicinal chemists have demonstrated their ability to improve on nature by enhancing the performance of these drugs by modifying their structures. As a classic example, let us briefly look at the developments that have taken place with penicillin antibiotics. Today there are about fifteen commercially significant penicillins, each having its unique properties. These have been produced mainly by modifying the side chain attached to the carbon-6 of the penicillin molecule. These changes have affected the penicillins in a variety of ways including their shelf lifetime, GI tract (*i.e.*, *in vivo*) stability, improved stability toward bacterial metabolism, and their spectrum of activity. The most labile part of the penicillin molecule is the highly strained β -lactam ring and, because this is an essential part of the pharmacophore, its hydrolysis deactivates the antibiotic. (Pharmacophore of a drug molecule is the portion of the molecule containing the essential organic functional groups that directly interact with the receptor active site and, therefore, confers on the molecule the biological activity of interest.) In fact, Penicillin G is administered parenterally because its β -lactam ring decomposes under the acidic conditions of gastric juice. Phenoxymethylpenicillin or Penicillin V (3), in contrast, is orally active. Penicillin V has been made to be acid resistant by the introduction of an electron-withdrawing oxygen atom into the side chain. This electron-withdrawing effect inhibits the β -lactam ring opening reaction under acidic conditions. Penicillin V has value in treating respiratory tract infections and tonsillitis. Penicillins with side chains containing a basic amino group, e.g. ampicillin and amoxicillin (4), are also acid resistant and these were

found to have the added advantage that they are also active against some Gram-negative bacteria.

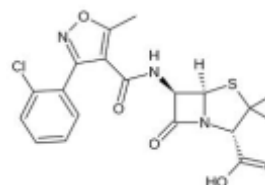


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Despite the initial success a major drawback with penicillin G was that many bacterial species that were initially susceptible were found to develop resistance to this agent. The main mechanism of resistance is the ability of the infecting bacterium to produce β -lactamase enzymes that are capable of hydrolyzing the β -lactam ring of the penicillin. However, chemists have been able to produce penicillins which are resistant to β -lactamase by introducing bulky groups to the side chain, which prevent the approach by β -lactamase. Examples are oxacillin and cloxacillin (5) (both β -lactamase and acid resistant) and termocilin, which, in addition, is also highly active against some Gram-negative bacteria. Methicillin which was the first penicillin resistant to β -lactamase is no longer in use.

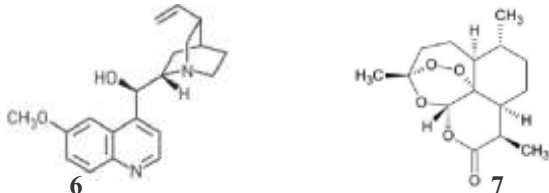


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These examples amply demonstrate the role played by medicinal chemists in improving the properties of a natural drug. It should, however, be emphasized that such improvements do not come about easily. In the case of penicillins, an enormous amount of money and research efforts by the pharmaceutical industry and academic institutions have gone into their development. It is estimated that the number of experimental synthetic and semi-synthetic penicillin derivatives that were made in these efforts, in the late 1970s alone, is well in excess of 10,000. Such efforts to improve the therapeutic value of natural product drug candidates are a standard practice and this practice has produced numerous new drugs in almost all categories of pharmaceuticals.

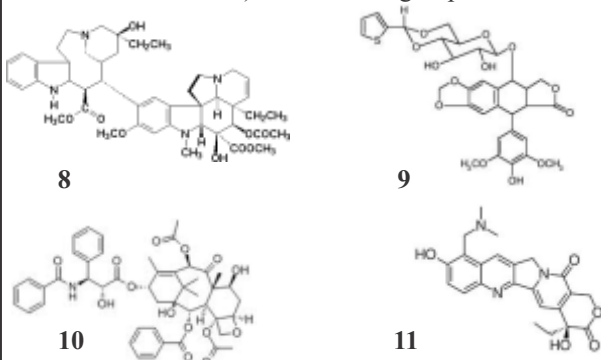
Microorganisms are not the sole producers of anti-infective agents. Higher plants too have afforded important anti-infective agents. Perhaps the most significant is the antimalarial quinoline alkaloid quinine (6), obtained from the bark of several *Cinchona* spp. found in South America. Quinine also was the template molecule for the synthetic antimalarials chloroquine, primaquine and mefloquine. Malaria is known to kill between one and three million people each year and there still is an urgent need for new more effective chemotherapeutic agents. In 1972 artemisinin (7), a sesquiterpene lactone with an endoperoxide group, was introduced as a new

class of anti-malarial drugs. This compound was isolated from *Artemisia annua*, a plant used for centuries in China to treat fevers and malaria. In addition a number of derivatives of this compound, including arteether and artemether have been developed for the treatment of malaria. Artemisinin-based combination therapy is now used for treating drug-resistant falciparum malaria.

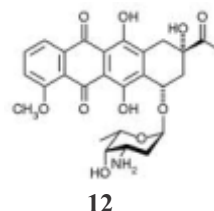


Due to the tremendous success of antimicrobial chemotherapy, infectious diseases are no longer a leading cause of human death. Cancer, on the other hand, has emerged as a major contributor, being second only to heart disease, in terms of the number of human fatalities, in North America. A major goal of cancer research since the early 1950s has been to develop antineoplastic agents which would be as effective against malignant tumor cells as antibiotics are against bacterial infections. The progress in comparison has been slow but now there are a number of effective anticancer agents (both natural and synthetic) available to oncologists to supplement surgery and radiation therapy in cancer treatment.

The clinically important anticancer drugs derived from nature are of either of plant or microbial origin. Four main classes of plant derived antitumor agents are known. The first group consists of the bisindole alkaloids, vincristine and vinblastine (**8**), isolated from the Madagascar periwinkle *Catharanthus roseus* and the semi-synthetic derivatives vinorelbine and vindesine. The semisynthetic epipodophyllotoxin derivatives (etoposide, teniposide (**9**) and the water-soluble pro-drug etoposide phosphate) originating from *Podophyllum* spp. growing in India, China and North America constitute the second group. The taxanes (the natural product paclitaxel (**10**) originally isolated from the pacific yew, *Taxus brevifolia* and its semi-synthetic derivative docetaxel) make up the third group while camptothecin analogues, irinotecan and topotecan (**11**) (original source plant *Camptotheca acuminata* from China) are the fourth group.

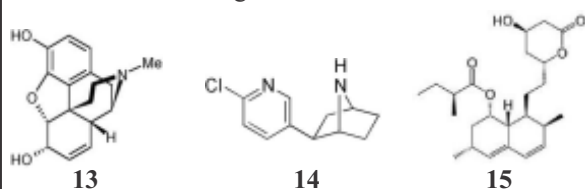


The antitumor antibiotics isolated from cultures of various species of *Streptomyces* include the anthracyclines (daunorubicin **12**), doxorubicin, epirubicin, idarubicin and valrubicin), bleomycin, dactinomycin and mitoxantrone. These natural antineoplastic agents are structurally diverse with relatively complex structures. They have different modes of action and have become invaluable in the treatment of a wide variety of systemic cancers.



The importance of natural products in medicine is certainly not confined to anti-infective agents and anticancer drugs. Natural products have played an important role in the discovery of pharmaceuticals used to treat almost any disease. Let us look at some examples. The steroidal glycoside digitoxin isolated from *Digitalis purpurea* is used in the treatment of congestive heart failure and atrial fibrillation. A more widely used drug today is digoxin, a constituent of *Digitalis lanata*, which has a rapid action and is more rapidly eliminated from the body than digitoxin. The cardiovascular agents, captopril and enalapril (which are angiotensin converting enzyme inhibitors) are derived from teprotide, a nonapeptide isolated from the pit viper, *Bothrops jararaca*. Bivalirudin is a specific and reversible direct thrombin inhibitor and is used to reduce the incidence of blood clotting in patients undergoing coronary angioplasty. This compound is a synthetic 20-amino-acid peptide modeled on hirudin, a substance in the saliva of the leech, *Haementeria officinalis*. The fungal derived immunosuppressive agent, cyclosporine A, is useful in organ and tissue transplant surgery. Two further natural product-derived immunosuppressants that have been introduced more recently are mycophenolate sodium and everolimus. Mycophenolis acid is obtained from several *Penicillium* spp., while everolimus is a semisynthetic derivative of rapamycin and was originally obtained from *Streptomyces hygroscopicus*. The analgesic morphine (**13**) from *Papaver somniferum* (opium poppy) is an isoquinoline alkaloid and is the most abundant constituent of the dried latex of the opium poppy. Many thousands of derivatives of this lead compound have been prepared in attempts to obtain derivatives with strong analgesic potency but without the addictive tendencies associated with morphine. Another natural product which is attracting much attention as an analgesic is the pyridine alkaloid epibatidine (**14**) isolated from the dendrobatid frog, *Epipedobates tricolor*, from Ecuador. Epibatidine activates nicotine receptors and has analgesic activity 200-fold more potent than that of morphine. The drug potential of

epibatidine is limited by its concomitant toxicity, but it is an important lead compound for the development of future analgesics. The “statin” drugs used to lowering elevated blood cholesterol levels are based on the lead compound mevastatin (also known as compactin) produced by cultures of *Penicillium citrinum*. Mevastatin was discovered by the Japanese chemist Akira Endo, in 1973 using a 3-hydroxy-3-methylglutaryl-coenzyme A reductase (HMG-CoA reductase) assay. (HMG-CoA controls the biosynthesis of cholesterol.) Because hypercholesterolemia is considered to be a major risk factor for coronary heart disease, several semisynthetic and synthetic compounds based on mevastatin structure (atorvastatin, fluvastatin, pravastatin, and simvastatin) have extremely widespread current use as cholesterol lowering drugs. Lovastatin (**15**) is a natural product drug of this type isolated from *penicillium brevecompactum*. Statins have been a blockbuster for the pharmaceutical industry with annual sales exceeding US \$ 30 billion.



Fleming's discovery of penicillin is a classic example of serendipity while the discovery of the multitude of antibiotics that followed was due to the systematic investigation of soil microorganisms for their antimicrobial activity. Biological activity evaluation is at the heart of drug discovery process. Historically, drug discovery programs have relied on *in vitro* cell-based or intact tissue assays to screen libraries of natural product extracts or synthetic compounds for pharmacologically relevant properties. Such assays are labor intensive and relatively expensive and time consuming. Currently, aided by advances in the fields of robotics and computer technologies, drug companies rely on 'high-throughput screening' (HTS) where large numbers of compounds or extracts are screened in an automated fashion for activity to identify lead compounds. The bioassays used in HTS programs are either *in vitro* screens against purified enzymes or receptors or cell-based assays using engineered eukaryotic cells or microorganisms. Typically, a HTS program of a major drug company can handle 3000 enzyme inhibitions or 4800 engineered cell-based assays per day facilitating the screening of huge numbers in short periods.

The chemical entities that are tested in drug screening programs belong to three distant groups: traditional directed-synthesis chemical libraries, combinatorial synthetic libraries and natural product extracts. The chemical diversity of each group is vital for the success of such screening programs; greater the chemical diversity greater is the chance of finding a lead. Of the three groups, the chemical diversity of the

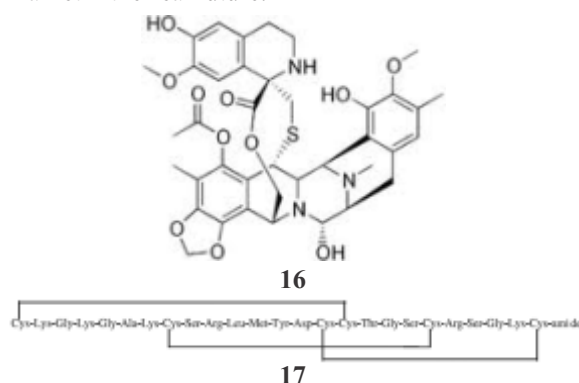
first two is limited by the imagination of human mind, synthetic methodologies available, efficacy and the ease of procedures employed for the synthesis. Combinatorial synthesis which has emerged only in recent times has the potential to generate very large numbers of compounds and was expected to be very productive in the search for lead compounds. But results so far have been very disappointing. The chemical diversity presented by natural product extracts on the other hand is extremely varied. Chemical structures of natural products range from relatively simple to very complex and are rich in stereochemistry, concatenated rings and functional groups. Furthermore, in a number of recent studies to investigate the physicochemical parameters of natural products it has been concluded that natural products exhibit a higher degree of “drug-likeness” when compared to compounds in either synthetic or combinatorial chemical libraries. This characteristic might well be expected because natural products are produced in living systems and have been selected by millions of years of evolution to afford the producing organism an adaptive advantage over their competitors in their survival. Natural products are a part of living systems being subjected to transport and diffusion at a cellular level. They are known to modulate protein-protein interactions and, thus can be expected to affect cellular processes that may be modified in diseased states. Furthermore, it is considered that natural products and synthetic compounds tend to occupy different regions of “chemical space” and thus compliment each other in providing chemical diversity so vital in the drug discovery process.

There are a number of approaches to the choice of organisms that are evaluated in drug discovery programs. In one approach known as “biodiversity prospecting” large numbers of flora and fauna are screened randomly for biological activity. Such programs may focus, for example, on tropical rain forests to take advantage of the inherent biological diversity prevalent there. Intense competition resulting from the high species diversity in such locations, combined with continuous growing season under high temperature and humidity are expected to yield a high degree of chemical diversity in the molecules biosynthesized by the numerous inhabiting organisms. Other approaches may depend on a selection of specific taxonomic groups such as families or genera. Or the selection may take a chemotaxonomic approach where a restricted group of secondary metabolites, such as alkaloids are sought. In an “information-managed approach” selection of organisms will depend on database surveillance. Finally, a popular approach is to base the selection on folkloric clues where for example plants used in traditional remedies are investigated. In fact, a large number of natural product based drugs in clinical use have been discovered due to this approach. Common examples

are quinine, aspirin, morphine, digitoxin, tetrahydrocannabinol and atropine. Sometimes, the pursuit of folkloric clues has led to totally unexpected results. The discovery of vincristine and vinblastine is an example. The Madagascar periwinkle *Catharanthus roseus* was initially investigated for its potential hypoglycemic activity because of its folklore usage as a tea for diabetics. In test rabbits, the plant extract had no effects on blood sugar levels. However, the test animals succumbed to bacterial infection due to depleted white blood cell levels (leucopenia). This selective action suggested anticancer potential for the plant extract and ensuing investigations led to the identification of the bisindole alkaloids vincristine and vinblastine as anti cancer agents. Another interesting example is the development of a number of muscle relaxants, useful in certain surgical procedures, through the investigation of curare, the arrow poisons of South American Indians.

As demonstrated by the examples mentioned above, modern medicine would not be what it is today without the major contribution from natural products. When one considers the Earth's biodiversity the variety of organisms available for natural products drug discovery is immense ranging all the way from unicellular organisms to mammals. For example consider the marine ecosystems. Oceans occupy over 70% of the Earth's surface and account for over 90% of the biosphere. In addition to numerous animal and algal species millions of microorganisms live in the oceans. An estimated 200,000 species of invertebrate and algal species are found in the seas. Of the 28 major animal phyla, 26 are found in the sea with eight of these exclusively marine. Maximal biodiversity in the marine environment is found on tropical reefs where intense competition for attachment space exists among sessile invertebrate and algal species. However, until recently marine organisms have received only scant attention from the natural products chemists. Relative lack of folkloric clues on medicinal uses of marine organisms and the difficulties in accessing and collecting these organisms may explain this lack of interest in the past. However, during the past four decades the situation has drastically changed. There has been a flurry of activity especially on marine invertebrates (such as sponges, corals and tunicates) and algae and to a lesser extent on marine microorganisms. Motivation for this work has come from the realization that marine organisms due to their different lifestyles and environmental pressures are likely to biosynthesize molecules with novel features and biological activities that are best suited to serve their needs and it is highly likely that some of these secondary metabolites would be significantly different from their terrestrial counterparts. Results have been exciting; Over 10,000 novel metabolites with unique structural features (hitherto unseen in terrestrial natural products) and various biological activities have

resulted from this work. Over the past few decades, marine natural products chemists and the biomedical community have keenly awaited, with great anticipation, the arrival of a true marine drug into clinical practice. Recently they have been rewarded with the approval of two marine drugs. One of them, Yolenis (**16**, trabectedin, ET-743), an anticancer agent active against soft tissue sarcoma, is a tetrahydrorquinoline alkaloid isolated from the tunicate *Ecteinascidia turbinata*. The second is the nonopioid analgesic, ziconotide (**17**), which is prescribed for the amelioration of chronic pain. This drug is a synthetic version of the peptide W-conotoxin produced by the cone snail, *Conus magus*. Ziconotide selectively binds to N-type voltage-sensitive neuronal channels, causing a blockage of neurotransmission and a potent analgesic effect. Presently, a large number of marine natural products are in various stages of drug development in a variety of drug categories pointing to the vast potential of the oceans as repositories of future drugs. Currently marine natural products chemists together with marine biologists and pharmacologists are vigorously continuing collaborative research to further exploit marine resources and it is reasonable to expect additional marine based drugs to appear in the market in the near future.



From the account given above it is abundantly clear that natural products have a prominent place among pharmaceuticals used today. In the thirteenth revision of the "World Health Organization Model List of Essential Medicines", of approximately 300 drugs considered necessary for the practice of medicine, approximately 210 are small molecular agents. Of these, more than 40 are unmodified natural products, 25 are semisynthetic drugs based on natural products prototypes, and more than 70 are either synthetic drugs based on natural product prototype molecules or synthetic mimics of natural products. It should however, not be thought that, after nearly two centuries of investigation, the prospect of finding new drugs of natural origin are nearing exhaustion. So far, only a small portion of the world's biodiversity has systematically been investigated for drug potential. If one considers plants (which are among the most investigated organisms) only 20% have been evaluated. Moreover, many groups of organisms have,

so far, not received the attention that they deserve to realize their potential. Endophytic fungi (fungi living inside the tissues of other organisms), marine actinomycetes and cyanobacteria are but a few among the thousands of organisms waiting to be investigated by natural products chemists. Today, spurred by advances in modern chromatographic techniques and spectroscopic methods natural products chemists are vigorously pursuing this endeavor. In their search for new leads, they are venturing into increasingly inhospitable locales throughout the world, such as deep caves in the terrestrial areas and thermal vents on the ocean floor. Thus one could reasonably assume that new drugs from nature will continue to be found even at a greater pace than before.

A new paradigm in modern therapeutics

Dr. R.O.B. Wijesekera & Dr. A.L. Jayewardene

Link Natural Products Pvt. Ltd.

Introduction

Following in the wake of the realization of the successful use of herbal polyprescription in both Ayurveda and Chinese Traditional Medicine in particular, there is the emergence of a new approach in research into phytomedicine. In recent years 'Synergy research' has established itself as a key approach in attempting to find a scientific rationale for the therapeutic superiority of some of the traditional therapies over the single constituents isolated from them. In Ayurvedic theory for instance, there is present the concept that the components of a polyprescription, involve those that are responsible for the intended therapeutic effect as well as those that synergize that effect, together with others that counter any toxic manifestations. The many polyprescriptions that form the basis of Ayurvedic herbal preparations take this into account, and this is the reason why there is involved sometimes ten to twenty plants in a single preparation.

Hildebert Wagner of the Centre of Pharma-Research of the University of Munich, in Germany who pioneers one of the leading schools of scientific research in Europe writes:

"The gradual transition from the longstanding use of mono-drug therapy in classical medicine to the new concept of a multidrug and multitarget therapy has great implications for the research strategies of natural products chemistry and phytomedicine."

This realization opens out new and exciting challenges that are possible at the present time due to the spectacular advances that have been made in instrumental analytical methodology. To derive rational explanations as to how these drugs work in combination and are more effective than the pure compounds, requires much effort in standardization of the multicomponent preparations, the use of all the high-tech analytical methods and the adaptation of them for specific use; of equal importance is the

Bibliography:

1. Medicinal Natural Products A Biosynthetic Approach, P.M. Derwik, John Wiley & Sons, New York 1997
2. Magic Molecules: How Drugs Work, S. Aldridge, Cambridge University Press, Cambridge 1998
3. Foye's Principles of Medicinal Chemistry, Sixth Edition, Editors: T.M. Lemke, D.A. Williams, Lippincot Williams & Wilkins 2008
4. Pharmaceuticals from the Sea, R.J. Andersen and D.E. Williams in Chemistry in the Marine Environment, Ed. R.E. Harrison, The Royal Society of Chemistry, Cambridge, UK, 2000

examination of extracts using modern molecular biological bioassays, controlled clinical trials, pharmacokinetic and bioavailability investigations. In the words of Wagner the objective is to evolve evidence based Phytotherapy. Some of the very first experiments in this new direction according to Wagner: "show the therapeutic superiority of many plant extracts over single isolated constituents as well as the bioequivalence of many Phytopharmaceuticals with synthetic chemotherapeutics."

The nature of the change in approach.

The nature of the oncoming change in approach or paradigm shift, can be seen in two stages.

- Firstly a gradual withdrawal from the existing dogma of a single substance therapy and an increasing transition to the idea of treating patients with combinations of drugs as is now done in diseases such as malaria, AIDS, and certain cancers. This is termed the multi drug approach.
- The second is a transition to a multi-target therapy. This is directed towards the activation of the body's own mechanisms for defense, protection, and repair. This is in contrast to the existing method of approach which aims at destroying the offending agents such as pathogenic microorganisms, or tumour cells.

These strategies that are now being proposed by a new generation of clinicians and pharmacologists are clearly based or inspired by traditional Ayurvedic and Chinese medical concepts. In general Phytotherapeutic approaches in nearly all continents have always followed such strategies. They have utilized crude extracts of single plants or extracts of a combination of plants with the established aim of

sensitizing the human body's own mechanisms of protection and healing. The concept of strengthening the protective system of the body to enable it to counter hostile disease bringing organisms which existed and were recognized for example in both the Chinese as well as the Ayurvedic systems for several millennia. It is now realized that a very complicated pathological cum physiological process that causes an illness is influenced more effectively and with fewer or no side effects by a combination of several low dosage compounds or several corresponding extracts than by a highly dosaged single compound.

The target areas for research

It becomes clear that to achieve a rationalized approach to the vast region of Phytotherapy is a daunting task indeed. It requires the combined efforts of many disciplines including phytochemists, pharmacologists, molecular biologists, clinicians and others. The research objectives as outlined by Wagner who is now a well established traveler on the road to realization of a Phytomedicine Goal, are these:

- Use of the entire gamut of available high-tech methods to standardize phytopreparations prior to conducting systematic pharmacological investigations and clinical studies.
- Integration of new molecular biological assays into the screening of plant extracts, and isolates, to evaluate their pharmacological profiles, to elucidate synergistic effects of the constituents of an extract, and thereby, to gain a better understanding of the various mechanisms underlying these pharmacological effects.
- Controlled clinical studies paralleled or followed by pharmacokinetic and bioavailability studies.

With the spectacular progress that has been made with analytical methods and instrumentation such studies can be considered a possibility today, but such could not have even been envisaged a couple of decades before. We have the tools today to analyze even complex extracts such as are Ayurvedic *rasayanas* and *kwathas*, if only in respect of the major constituents. The successful accomplishment, of the analysis by three dimensional high performance liquid chromatography (HPLC), and the finger print assessment of a multiple extract of *Kampo* medicine by Japanese researchers, and quantification of the major constituents, illustrate the effectiveness of the techniques now available.

No doubt improvements to these very methods in the years to come will bring more benefits. These methods are recognized as meeting the standards of quality required by drug authorities and the reproducibility of pharmacological studies, along with performance of good clinical practice (GCP) which conforms to clinical trial requirements.

Some examples of recent research

1. **Phytopreparation Iberogast^R**
This is composed of nine plant extracts* and can be considered in Germany and Europe as a leading phytopreparation for treatment of functional dyspepsia and motility related intestinal disorders. Twelve clinical studies, among them two in comparison with synthetic drugs Cisapride and metoclopramide, showed a complete therapeutic equivalence of Iberogast with the two synthetics with the advantage that the phytopreparation showed few or no side effects. Iberogast leads to multitarget effects by, balancing the disturbed gastrointestinal motility function, alleviating gastrointestinal hypersensitivity, inhibiting the inflammation and suppressing of gastric juice secretion and effects on GI autonomic afferent function
2. There are more than 40 placebo controlled clinical studies of standardized Hypericum (St. John's wort) extracts for the indications of mild, moderate and even moderately severe depression, among them several in comparison with synthetic anti-depressive drugs (e.g. Imipramine, flumazenil, fluoxetine and amitriptylin). Most of these studies indicate that several constituents of Hypericum must be involved in its effectiveness. The hypothesis is corroborated by several in-vitro neuro-chemical studies with different CNS receptors using radio-ligand binding techniques.

Other mono-extracts which exhibited synergistic effects are *Ginkgo biloba* extracts, *Glycyrrhiza glabra* or liquorice extracts which potentiates other substances and acts as a detoxifier etc. Another example where, an attempt to rationalize the cardiogenic activity of hawthorn (*Crataegus oxycantha*) extract preparations, verified by numerous clinical studies indicated that procyanidins and flavones C-glycosides appear to be the main constituents of the herb responsible for the therapeutically relevant cardiogenic activity.

It has been recently reported that hawthorn extracts containing these same products exhibiting in-vitro angiotensin-converting enzyme (ACE)-inhibiting effects, which together with endothelin-dependent, smooth muscle relaxing effects found recently in an aorta model, might account for the dilating effect on the coronary vessels and a simultaneous reduction in blood pressure. Also because flavonoids act as antioxidants and cyclooxygenase and 5-lipoxygenase-inhibitors among other effects, it is necessary to produce special hawthorn extracts which contain both active classes of compounds in enriched form and standardized in

content of these procyanidins and flavones C-glycosides. It can be stated that pharmacological multivalence of hawthorn constituents justifies the therapeutic application of hawthorn for the treatment of cardiac insufficiency grades I and II.

Concluding observations:

At the present time about 500 controlled mono and double blind placebo-controlled clinical trials which meet all international requirements of performance and efficacy, have been performed. About 80% of the existing studies have been made with standardized versions of long used mono extracts including Ginkgo, Hypericum, Harpagophytum, Valarian etc. Clinical evidence is available for therapeutic superiority of Salix root extract over isolated single constituents thereof and for herbal drug combinations Valarian/Piper methysticum and Ginkgo/Ginseng over one of the two herbal extracts. It can be concluded that the therapeutic superiority of an extract over a single isolated constituent thereof and of an extract of a combination over one extract of a combination of herbs is caused by additive or potentiating effects of the mixtures of constituents in the extract.

Prospects for examining Ayurvedic Polyprescriptions of herbs (Sinhala: *Wattoruwa*) on

similar lines emerge, with exciting possibilities for development of effective therapeutic agents. **It is a challenge for future researchers.**

Reference:

1. H. Wagner and G. Ulrich Merzenich. Synergy research: Approaching a new generation of phytopharmaceutical; **Phytomedicine**, **16** (2009) 97-110
2. H. Wagner. Natural Products Chemistry and Phytomedicine in the 21st Century: **Pure and Appl.Chem.** **77**, (2005) 1, 1-6.
3. U Kroll and C. Cordes, Pharmaceutical prerequisites for multi-target therapy, **Phytomedicine**, **13** (2006) SV 12-19
4. H. Woelk, Comparison of St.John's Wort and imipramine for treating depression: randomized controlled trial. **Br. Med. J.** **321** (2000) 536-539
5. V. Schulz, Incidence and clinical relevance of the interactions and side effects of Hypericum preparations. **Phytomedicine**, **8** (2001) 2, 152-160
6. M.C. Berenbaum, What is synergy? **Pharmacol. Rev.** (1989) **41**, 93-141
7. U. Franck, B. Gunther, W. Vierling, H. Wagner. **Phytomedicine**, **3** (1996) 93

Integration of chemistry for the advancement of the herbal pharmaceutical industry in Sri Lanka

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Health is the supreme wealth of mankind and is a dream and a goal which humanity at large shares and strives to achieve it. Modern medicine has played an important role to improve the living conditions of people by using numerous scientific medical strategies and synthetic drugs. Unfortunately, it has now been proven, without doubt, that modern pharmaceuticals alone are not sufficient to reach a large proportion of the human population for its well-being for the foreseeable future. Therefore, new trends have been developed to probe and upgrade "other" human knowledge related to health sciences, to provide health benefits for people. The Ayurveda system of medicine, Chinese traditional system of medicine and the African and South American tribal medicines that are largely herbal in nature are considered as "Traditional Medicine", have had an important place in maintaining human health for over 3000 years. About 65-80 % of the world's population, which lives in developing countries, depend essentially on plants for primary health care. The World Health Organization (WHO) has encouraged governments and provided guidelines to effectively utilize local knowledge of herbal

medicines for prevention of disease and health promotion since early 1970. With this background, the herbal pharmaceutical industry has become a worldwide business. In olden times, Vaidyas used to treat patients on an individual basis, and prepared drugs according to the requirements of the patients using locally available, well identified herbals and minerals, but the scenario has changed now. Due to their empirical use in folk medicines, wide range of therapeutic value, suitability for chronic disorders, lack of undesirable side effects, tendency towards self-medication, and affordable cost, public interest in herbal medicines has increased dramatically, not only in developing countries but also in industrialized countries. As the herbal pharmaceutical industry becomes more commercialized, consumers are highly concerned about quality, efficacy and safety of its products. Therefore, not only the manufacturers, but also the legislative bodies for controlling of the herbal pharmaceutical industry have decided to maintain good quality standards for products and the production processes, and to evaluate the efficacy and safety of products. Use of quality control, quality assurance and

quality management systems and applying good manufacturing practices have contributed to upgrading the various aspects of the herbal industry. But one of the major problems faced by the herbal drug industry is the non availability of quality parameters and standards for herbal pharmaceuticals. Establishing rigid parameters for quality and standards of herbal pharmaceuticals is important in justifying quality, safety and efficacy for their acceptability in modern society and especially in the modern system of medicine. Chemistry, the branch of natural sciences dealing with the composition of substances, their properties and reactions, has contributed to overcoming this problem. Developed countries have introduced several quality parameters using modern techniques used in analytical chemistry. Due to the usage of plants or parts of plants and natural minerals as raw materials and subjecting these to various simple and complicated manufacturing processes, establishing quality and standard parameters for herbal pharmaceuticals is a complicated task. It is however essential, in order to minimize the malpractices of the trade and to enhance acceptability of quality, safety and efficacy of herbal products among consumers.

The formulation of pharmaceuticals based on traditional knowledge or evidence, the collection of raw materials, and the manufacturing process are key events of the industry. Hence, each step should be carefully monitored by experts in the industry. Identification and authentication of plant materials, purity and contents of the materials, state and condition of the manufacturing processes, chemical, physical, or biological properties of raw materials and the finished products are used as acceptable quality and standard parameters for herbal pharmaceuticals. Microscopic evaluation, determination of foreign matter, ash, heavy metals, pesticide residues, and radioactivity, identification and determination of chemical constituents of raw materials and finished products and the determination of microbial contaminants and toxins are all essential to evaluate and upgrade the quality and safety of herbal pharmaceuticals. New analytical methods are being introduced for this purpose. Quantitative determination of constituents has been made easy by recent developments in analytical instrumentation. Chemotaxonomy, Thin Layer Chromatography (TLC), High Performance Liquid Chromatography (HPLC), Gas Chromatography (GC), Quantitative Thin Layer Chromatography and High Performance Thin Layer Chromatography (HPTLC) can determine the homogeneity of a plant extract or natural compound in the finished product. Atomic Absorption Spectrophotometry including Flame, Furnance and Hydride generation have been used for the determination of bulk metals and heavy metals. TLC

fingerprinting is one of the key methods for the identification of herbals where macroscopy and microscopy fail. HPLC is the preferred method for the quantitative analysis of more complex mixtures of poly-herbal formulae. Separation of volatile components such as essential and fatty oils can be achieved with HPLC, GC or GC/MS.

HPTLC can be used to determine the homogeneity of plant extracts. Over-pressured layer chromatography (OPLC), infrared (IR) and UV-VIS spectrometry, Mass spectrometry (MS), GC, liquid chromatography (LC), used alone, or in combination with GC/MS, LC/MS and MS/MS and nuclear magnetic resonance (NMR) spectroscopy, electrophoretic techniques, especially by hyphenated chromatographies, are powerful tools, often used for standardization and to control the quality of both the raw materials and the finished products. Results of these sophisticated techniques provide a chemical fingerprint as to the nature of chemicals or impurities present in the plant or extract.

Though Sri Lanka has a 3000 year old history of the usage of Ayurveda and Traditional medicines, together with a strong biodiversity, the current market potential of the herbal pharmaceutical industry has to be developed. While developing legislation for regulating and maintaining of standards of the industry, research and development programs for upgrading the quality, safety and efficacy of herbal products should be carried out. In this context, the contribution and integration of professional chemists in the field of herbal pharmaceuticals is essential and can direct the herbal pharmaceutical industry in Sri Lanka towards the horizon of the globe.

References

1. Kamboj, V. P., 2000, 'Herbal Medicine', *Current Science*, **78**(1), 37-44.
2. Sudha, A., Murty, V.S. and Chandra T.S., 2009, 'Standardization of Metal-Based Herbal Medicines', *American Journal of Infectious Diseases*, **5**(3), 193-199.
3. Tatiya A. U., Shastri K. V. and Surana S. J., 2008, 'Preparation and Standardization of Polyherbal Rasayana by Fermentation Process', *Phcog Mag.* **4**(15), 100-108.
4. Oyetayo V. O., 2008, 'Microbial load and antimicrobial property of two Nigerian herbal remedies', *African Journal of Traditional Complementary and Alternative Medicines*, **5**(1), 74-78.
5. Bandaranayake, W. M., 2006, 'Quality Control, Screening, Toxicity, and Regulation of Herbal Drugs,' *Modern Phytomedicine: Turning Medicinal Plants into Drugs* WILEY-VCH Verlag gmbh & Co. Kgaa, Weinheim pp 25-57.

Genomic medicine

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Chemistry is often the central science of many scientific disciplines because it plays a major role in connecting life sciences and applied sciences such as medicine and engineering. Chemistry constitutes the basis of life. From the first moment and in every second over thousands of complex biochemical reactions are taking place in our body to sustain life. All developmental stages of life follow biochemical processes and the biomolecules are the key player of those reactions. The biomolecules produced by living organisms constitute large polymeric organic molecules such as nucleic acids (DNA/ RNA), proteins, polysaccharides and as well as small molecules such as fatty acids, steroids, vitamins etc. The precise chemistry of latter molecules and precise kinetics and thermodynamics which drives biochemical reactions are imperative to keep a healthy life. Therefore, undoubtedly chemistry has a bigger role in medicine, as chemistry is not only describes the structures of biomolecules and biosynthetic pathways, but also explains how a disease arises and how a disease gives rise to symptoms. Further, chemistry also provides diagnostic and treatment strategies for diseases.

One of the most important biomolecules of life is DNA, which is the molecule of inheritance and carries characters from one generation to another and constitute information for body's function. Nearly every cell in a person's body has the same DNA. The information in DNA is stored as a code made up of four chemical bases: adenine (A), guanine (G), cytosine (C), and thymine (T). Human DNA consists of about 3 billion bases, and more than 99 percent of those bases are the same in all people. The order, or the sequence, of these bases determines the information available for building and maintaining an organism. The information for a proteome (collection of entire proteins) of the organism is encoded in the DNA, and through the processes of transcription and translation, this information is decoded into functional and structural entities of the organism, i.e. proteins.

Over the years of research into DNA and RNA by the molecular scientists paved the way to unlock many of the interesting mysteries behind these molecules. The knowledge derived from such research did not merely sit in books on the shelf and neither was it confined to the workbenches of laboratories. The findings of these research have been used to pinpoint the causes of many diseases, such as sickle cell anemia, cystic fibrosis, cancers, chronic myelogenous leukemia etc. Further, scientists have translated mysteries they unraveled about DNA and RNA into several treatments and therapies prompting a bridge between the laboratory bench and the patient's bedside.

With the mapping of human genome in 2003, the pace of discovery steadily and gradually increases. One of the areas that have enormously benefited from the discovery of genome projects is medicine and through the identification of errors/ polymorphisms in genetic materials scientists were able to explain the genetic basis for diseases, phenotypes, therapeutic responses etc. Subsequent to knowledge derived from genome projects, most awaited disciplines such as pharmacogenomics, genomic medicine, molecular medicine etc are coined and integrated to the stream of medicine. With the advent of genomic projects and high throughput techniques such as DNA microarrays followed by bioinformatics to analyze the person's entire genome for Single Nucleotide Polymorphisms (SNPs) / mutations make possible to predict individualized risk and to decide tailor-made treatment according to individual genetic makeup, which is currently known as personalized medicine.

Personalized medicine is an extension of traditional approaches to treat disease with greater precision. A profile of a patient's genetic variation can guide the selection of drugs or treatment protocols that minimize harmful side effects or ensure a more successful outcome. It can also indicate susceptibility to certain diseases before they become manifest, allowing the physician to set out a plan for monitoring and prevention. In personalized medicine, SNPs have received increased and special attention as the latter has shown to have a direct bearing on phenotypic differences between individuals, and have been shown to affect the development of diseases in humans and the response to drug treatment and environmental stress.

SNPs are DNA sequence variations that occur when a single nucleotide (A,T,C,or G) in the genome sequence is altered. For example a SNP might change the DNA sequence AAGGCTAA to ATGGCTAA. For a variation to be considered a SNP, it must occur in at least 1% of the population. SNPs, which make up about 90% of all human genetic variation, occur in every 100 to 300 bases along the 3-billion-base human genome. Two of every three SNPs involve in the replacement of cytosine (C) with thymine (T). SNPs can occur in coding and noncoding regions of the genome. Currently, more than 1.4 million single nucleotide polymorphisms (SNPs) in the human genome have been identified. SNPs have a great commercial potential for pharmaceutical industries and techniques such as high throughput SNP microarrays have been developed by many companies to screen all known SNPs of human genome in a single platform.

The two "genomes" that each one of us carry, inherited from our parents most often differ from each

other and from the genomes of other humans in terms of single base changes and of which SNPs are the most frequent type of variation in the human genome, and they provide powerful tools for a variety of medical genetic studies. Although more than 99% of human DNA sequences are the same, variations in DNA sequence can have a major impact on how humans respond to disease; environmental factors such as bacteria, viruses, toxins, and chemicals; and drugs and other therapies, and hence SNPs have become valuable markers for biomedical research and for developing pharmaceutical products or medical diagnostics. SNPs are also evolutionarily stable and not changing much from generation to generation, and making them easier to follow in population studies.

Scientists are optimistic that SNP maps will help them to identify the multiple genes associated with complex ailments such as cancer, diabetes, vascular disease, and some forms of mental illness. These associations are difficult to establish with conventional gene-hunting methods because a single altered gene may make only a small contribution to the disease. The main use of human SNP map is to dissect the contributions of individual genes to diseases that have a complex, multi gene basis. Knowledge of genetic variation directly affects patient care to some degree. For example, gene variation leads to tissue and organ incompatibility, affects the success of transplant. The main stay of medical genetics has been the study of rare gene variations that lie behind inherited diseases such as cystic fibrosis. But variation in genome sequences underlies differences in our susceptibility or protection from all kind of diseases, in the age of onset and severity of illness; and in the way our bodies respond to treatment. For example, we already know that single base difference in the APOE gene is associated with Alzheimer's disease and a simple deletion within the chemokinin receptor gene CCR5 leads to resistance to HIV and AIDS. The benefits of the SNP map are that it covers SNP in the entire genome. So by comparing the patterns and frequencies of SNPs in patients and controls, researches can identify which SNPs are associated with which diseases. Further, SNPs and mutation analysis technologies are integrated to develop personalized therapies for specific therapeutic areas such as genotyping for drug resistance in HIV, hepatitis B and C infections, personalized therapy of cancer, antipsychotics for schizophrenia, antidepressant therapy, antihypertensive therapy and personalized approach to neurological disorders.

Personalized medicine is based on pharmacogenetics, pharmacogenomics, pharmacoproteomics, and pharmacometabolomics. Pharmacogenetics is the study of influence of genetic factors on drug action and metabolism and is used for predicting adverse reactions of drugs. On the other hand, pharmacogenomics is a term that overlaps with pharmacogenetics, and deals with optimized drug

discovery and developments to treat patients effectively using their genetic variations. Pharmacoproteomics deals with patient-to-patient variation in functional proteins as markers for treatment and is an important contributor to personalized medicine. A 'pharmacometabolomic' approach to personalizing drug treatment is emerging area of Medicine. Currently, pharmacogenomic approaches are an area which is widely discussed in the arena of modern medical sciences.

Pharmacogenomics is the marriage of functional genomics and molecular pharmacology in many ways. It was quite appealing when functional genomics emerged on the scene as the high-value-added discipline that identifies gene function, and equally appealing was the idea that genes could be sorted by function even for disease involvement. However, it quickly became apparent that the number of diseases that were single-gene in origin was limited, and that most disease developed as a result of a network of genes failing to perform correctly. Compounding the difficulty in developing drugs to effectively control gene networks was that, while the disease symptoms might appear to be uniform, individual to individual variations in these polygenic networks made drugs that were healing for certain individuals and were toxic for others. Pharmacogenomics attempts to correlate gene variations with differential responses to the same drug leads, thereby hoping to accelerate novel drug discovery dramatically by defining specific populations that will benefit from a drug.

The impact of genetics on medicine will be even more widespread. The pharmacogenomics approach for predictive drug responsiveness will be a standard practice for quite a number of disorders and drugs. New gene based "designer drugs" will soon be introduced in the market for diabetes mellitus, hypertension, mental illness and many other conditions. Improved diagnosis and treatment of cancer will likely be the most prominent clinical consequences of genetics. A vast amount of molecular information can be collected about the genetic basis of malignancy and on that basis every tumor will have a precise molecular fingerprint. Cataloging the genes and therapy will be individually targeted to that fingerprint. Many of the diseases can be identified where common variants in genes involved in drug metabolism or drug action are associated with the likelihood of a good or bad response.

Harping on the human genome, single nucleotide polymorphism and better understanding of potential disciplines such as pharmacogenomics, pharmacoproteomics, pharmacometabolomics personalized medicine etc will give a fruitful return in the form of better understanding of complex diseases by deciphering metabolic pathways, reducing of drug toxicity, developing predictive genetic test and this will lead ultimately to the development of

individualized medicine in modern medicine prescribing practices.

References

1. Lagoumintzis G, Poulas K, Patrinos GP. Genetic databases and their potential in pharmacogenomics. *Curr Pharm Des.* 2010;16:2224-31.
2. Winkelmann BR, Herrington D. Pharmacogenomics--10 years of progress: a cardiovascular perspective. *Pharmacogenomics.* 2010;11:613-616.
3. Kirmani S, Babovic-Vuksanovic D. Towards individualized medicine: insights gained from genomic studies. *Bosn J Basic Med Sci.* 2009;9:11-16.
4. Nebert DW, Zhang G, Vesell ES. From human genetics and genomics to pharmacogenetics and pharmacogenomics: past lessons, future directions. *Drug Metab Rev.* 2008;40:187-224.
5. Roberts R. Personalized medicine: a reality within this decade. *J Cardiovasc Transl Res.* 2008;1:11-16. Epub 2008.

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Role of Chemistry in unraveling the mysteries of the brain

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Brain is a very complex organ and human brain is usually regarded the apex of the evolution of biological matter. Throughout most of history, the structure and function of the brain has been a mystery, which started unraveling only recently. Developments in the field of chemistry or biochemistry cast much light on this. Understanding the chemistry of brain helps us to see how it works, a challenge both scientific as well as philosophical that has been faced by us all the time.

Human brain averages about 1500 g in weight and it controls a vast range of body functions, from simple behavior like eating, sleeping or walking to complex activities such as speech, thinking and postulating. It is the organ which makes us human bringing in qualities, both good and bad, not usually seen among other animals. Virulent racism and never ending compassion both originate in this unique organ. Why and how it happens, chemistry may tell us.

Brain and the spinal chord together with the peripheral nervous system is responsible for receiving and processing information from the environment and responding to them. The cells of the central nervous system are called neurons, which are highly specialized cells to process information. They have a cell body, fibers called dendrites and axons protruding out from the cell body. (figure 1)

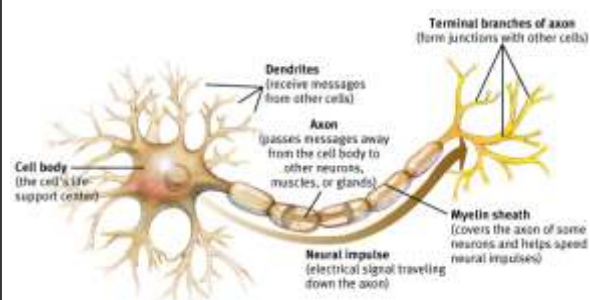


Figure 1

All animal nervous systems are basically made up of these neurons, from a few hundred in simple invertebrates to the billions in human brain. A fact that must be emphasized here is that the power of the brain is not determined by the characteristic of the neurons but by the number of neurons and how they are put together.

In all nervous systems, sensory neurons detect changes in the internal and external environment of the organism and transmit this to a network of inter neurons, which organizes, processes and stores it and responds by giving instructions via motor neurons to muscle or gland cells that are effectors of the nervous system. (figure 2)

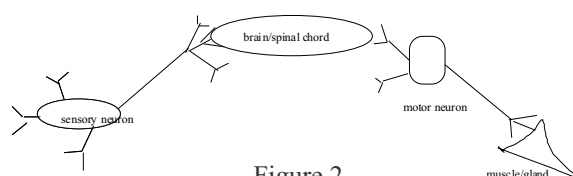


Figure 2

A single discipline alone cannot solve all the mysteries of this complex activity. Neuroscience had developed over the past few decades, envisaging many areas of science including chemistry. The role of neuroscience is to explain the functioning of the brain and relate that to behavior. In this context, the brain functions involve biochemical reactions which ultimately manifest as behavior. Therefore, behavior is in fact chemically controlled. Different patterns of behavior are due to changes in the brain chemistry.

The signals to and from the brain are transmitted initially as an electrical signal and then by chemical transmitters. These transmitters play an important role in functioning of the brain. The structure of these organic compounds varies from simple low molecular weight compounds or gases to complex peptides. Neurons maintain a voltage difference of about 60 mV across its membrane, the inside of the membrane being

more negative compared to the outside. This difference in voltage is important in signal propagation.

When the neurons sense a signal, the voltage difference across the neuronal membrane is increased to about 100 mV. This is referred to as the depolarization of the membrane. The permeability of the cell membrane changes and as a result, Na^+ ions enter into the cell while a few K^+ ions move out. The potential thus generated is referred to as the action potential. It is described as an 'all or none' process because, the change in the membrane will either generate an action potential which will result in a signal or will not generate any signal at all. The intensity of the signal will depend on the number of neurons that are excited and not by the magnitude of the actions potential on each individual neuron.

Neurons are the only cells that are specialized to propagate an action potential. A series of depolarization along the axon and dendrites leads to the propagation of a signal. Once the depolarization reaches the end of the axon, chemical transmitters are released to the space known as the synapse that occurs between the neurons. The chemical transmitters from neurons diffuse through the intercellular synapse and interact with the post synaptic membrane receptors of the post synaptic neurons. The outcome of the signal depends on the receptor properties with which the neurotransmitter interact with. Neurotransmitter, together with the receptor is responsible for the outcome of the signal. Some changes, like the opening of an ion channel, are instant, whereas certain changes initiate a cascade of biochemical reactions which last for a longer period of time.

In finding solutions for most of the neurological disorders, the key points those need to be looked into will be these biochemical pathways of neurotransmitter synthesis, degradation, receptor stimulations and inhibition.

Biochemistry of brain trauma

A stroke is caused when the blood supply to the brain is impaired. This can be due to the formation of a clot or due to hemorrhage. It is the most common cause for disability in adults and the number two cause of death in the world. In Sri Lanka too it has been a major health concern. Death and paralysis (described as 'ansabthagaya' in Sinhala) also pose a huge financial burden on the economy.

Neurons are very sensitive to the supply of oxygen and glucose, the key requirements for the synthesis of required energy. If the supply of glucose and oxygen to the brain is impaired (ischemia) the brain cells respond immediately to the trauma. If the blood supply is not restored within a short span of time, it leads to cell death (infarction). The damage will be irreversible because, unlike most other cells in our body, neurons do not regenerate, except for a few.

The recovery from such an episode can, however,

be improved by early intervention. An intervention here requires detailed understanding of biochemistry involved. In order to study the biochemical and behavioral changes of ischemia, several animal models and neuronal cell cultures have been used. These methods have their own merits and draw backs.

Energy depletion:

Ischemia leads to rapid depletion of energy (ATP) due to non-functioning of oxidative phosphorylation. Anaerobic pathways of energy production are not rapid enough to supply ATP for function of neuron cells. In addition to energy deprivation, other biochemical processes such as acidosis, release of the neurotransmitter glutamate, calcium ion influx, phospholipid degradation, free radicals are believed to be responsible for neurodegeneration.

Acidosis:

Anaerobic oxidation caused by oxygen depletion leads to formation of lactic acid inside the cells. Accumulation of lactate as well as carbon dioxide within cells causes acidosis. The pH can drop down to 6 during severe conditions. Apart from this, as the mitochondrial function is compromised due to the lack of oxygen, the proton recycling declines which leads to the increase in the protons in the cytosol, contributing to acidosis. Acidosis in turn affects several biochemical pathways in the cell. It inhibits re-uptake of neurotransmitters, promotes the generation of free radicals and delays restoration of mitochondrial function.

Loss of calcium homeostasis:

Calcium is responsible for the regulation of many enzymes in neurons. For example, Ca^{2+} ions activate kinases, phosphor lipases as well as proteases. In neurons, Ca^{2+} ion concentration is highly regulated by a variety of membrane pumps. The Ca^{2+} ions are stored inside the endoplasmic reticulum and released under a regulatory mechanism. Several lines of evidence suggested that calcium homeostasis is disrupted during ischemia induced neuronal degeneration showing that Ca^{2+} channel blockers were effective in protecting neurons from ischemia related neurodegeneration.

Development of edema:

Edema, which is commonly observed in many injuries and diseases, is defined as the increase of tissue volume as the result of accumulation of water and Na^+ ions. When ischemia led edema develops inside the brain, it increases the intracranial pressure leading to serious complications including brain damage.

Phospholipid metabolism:

Ischemia induces the breakdown of membrane phospholipids which, in turn, disrupts the ionic gradient. Influx of Ca^{2+} ions, which catalyze

phospholipases, into the cells is the possible cause of phospholipid breakdown in the nerve cells. The fatty acids released from lipid degradation causes several detrimental effects. As they are ionized under physiological pH, they can act as detergents breaking down membranes, proteins and DNA. This drastically affects the structure and function of the brain.

Role of glutamate:

Glutamate is a very important neurotransmitter in the brain by being responsible for generating an excitatory potential in neurons. Glutamate interacts with several receptors to mediate its function. During ischemia, it has been observed that there is an excessive release of glutamate into the extracellular space. The release of this excitatory transmitter into the synapses leads to over-excitation of cells, which contributes to neuronal damage, a phenomenon known as excitotoxicity. There has been much endeavor by neuroscientists to figure out the exact cause of excitotoxicity and to develop methods to control it.

Role of free radicals:

Free radicals are extremely reactive intermediates. They can be generated within cells due to processes like acidosis as described earlier. Free radicals readily react with lipids, enzymes and other proteins and DNA causing serious damage. They react with membrane lipids and proteins disrupting the membrane integrity, altering its structures such as receptors and functions such as enzyme activity or selective permeability.

Metabolism of proteins and nucleotides:

Protein and nucleotide metabolism is also affected by ischemia. As described earlier, as ischemia sets in, a cascade of biochemical reactions are initiated in the brain. The outcome will be determined by the duration of ischemia and the severity of it. Despite many advances in understanding the biochemical changes during cerebral ischemia, very little progress has been made to arrest, prevent or reverse ischemic injury. Untiring efforts by scientists, however, has led to the discovery of a few pharmacological agents that can be used, but, none of these are capable of completely reversing a damage to the brain.

Among these pharmaceuticals, calcium channel blockers such as Lidoflazine, Flunarizine and Nimodipine are used to block the entry of calcium ions into the cells. Vitamin E, vitamin C and Glutathione are used as antioxidants to prevent free radical damage. Streptokinase and Urokinase are used in the dissolution of blood clots. Several receptor antagonists have also been useful in the management of ischemic damage to the brain.

Biochemistry of behavioral disorders:

Damage caused by oxygen and glucose depletion is not the only cause of brain malfunction. Biochemical

changes occur in human brains due to various other reasons, including genetically inherited problems, can result in abnormal functioning of brain. Mental disorders fall into this category.

If a person has impaired perception of reality, illogical thoughts, hallucinations and delusions, it is considered as a mental illness. These disorders impose crushing burden on the individual and, in turn, on the society as well. For an individual to be functional in full potential, both physical and mental health must be maintained. Although the exact causes of some mental imbalances are not clear, much of the relevant biochemistry has been understood during the last decade or two. Some narcotic substances such as amphetamines, lysergic acid diethylamide (LSD), phencyclidine, severe hormonal imbalances, tumors, renal and hepatic failure are known causes of altered behavior.

Schizophrenia:

Schizophrenia is a mental disorder that is characterized by severely affected perception, thought, language and behavior. The symptoms and progression of the disease varies. Initially, there is usually a progressive withdrawal and increasing introversion. Gradually, it becomes clear that the individuals are hearing voices often with a feeling of being guided or forced by others, humans or non-humans. Hallucinations are characteristically perceived by the Schizophreniac as coming from some outside world, from gods or sometimes from the CIA. Although hallucinations can be manifested by any of the senses, auditory hallucinations are the most common type of schizophrenia, usually in the form of voices talking to or about the individual.

Delusions are another common component of schizophrenia. Delusions are entailing an unshakable belief in something that is improbable or impossible. Type of delusions include belief in the possession of magical powers, or being manipulated by others for complex but improbable reasons. For instance, an individual may become convinced that he can read the minds of those around him. Another would insist that he or she is receiving messages from gods or spirits. Most patients suffer from failure to express their emotions. These individuals lack the capacity to convey their thoughts meaningfully and their behavior can be inappropriate and bizarre at times. However, it does not mean that Schizophrenia, which is described also as fractured personality, always disrupt a life completely. There can be fluctuations in the severity of the illness and the person may be free from a serious problem for months. There also can be instances where the patient may be able to continue some aspects of life without being affected by the illness. John Nash, who was a professor at MIT was an unfortunate victim of schizophrenia. However, unlike most victims of this disease he was aware of his mental disorder. He was

intelligent enough to come to terms with his delusions without imposing any danger to himself or to people around him. The motion picture 'Beautiful mind' is based on his life story. Russel Crowe who played the role of John Nash won the Oscar for his performance in this movie.

Several studies suggested that genetic factors may play a role in schizophrenia. Many neuro-imaging studies on the live brain have indicated that most schizophrenics have brain abnormalities. Apart from the anatomy of the brain, it is also believed that the neurochemistry of it is altered. Relative excess or deficiency of neuroregulators or imbalances in two or more neurotransmitters may play a role in observed behavioral changes. There is a school of thought which describes that excessive stimulation by the neurotransmitter dopamine may be one of the causes of schizophrenia. Antipsychotic drugs such as chlorpromazine, clozapine and haloperidol have been effective in relieving some of the symptoms of this illness. It should be noted that these drugs may have severe side effects on the patients and have little or no impact on some. Neuropeptides and the neurotransmitter serotonin may also play a role in causing schizophrenia. Hallucinogens like LSD binds to serotonin receptors. Hence, there is an interest to relate the hallucinations observed with schizophrenia to alteration in the serotonin system. Despite many such findings, it has not been possible to figure out an exact mechanism for the precipitation of the disease. In Sri Lanka there are many who suffer from this condition, but, they have not been recipients of the medical care and support, mainly due to lack of understanding in the society and due to shortage of trained medical personnel. Untreated schizophrenia sufferers sometimes are a threat to themselves and to others. Some may commit suicide while another would commit murder under imaginary orders. Some are convinced that they can read minds of others or even have magical powers to cure diseases. The tragic consequence here is that the one who needs to be treated taking the responsibility of treating others instead.

Neurochemistry of mood and anxiety disorders:

There is enormous interest to find the relevant biochemical alterations that are associated with mood and anxiety disorders. The goal has been to find pharmacological agents that may be effective in relieving some of the symptoms of these conditions. Mood disorders refer to disturbances that affect cognitions, judgment, and interpersonal relationships. Everyone undergo periods of feeling sad, discouraged or disappointed. But these feelings normally pass away without impairing any significant change in behavior. In contrast, patients with clinically significant depression undergoes such profound changes in the way that they perceive things. Very little interest in pleasure, low energy level, fatigue, diminished ability to think and feeling of worthlessness are some of the symptoms. Those who suffer from such mental disorders have poor

interpersonal relationships and anti-social behavior may also be apparent. One may suffer from depression while another suffer from the opposite, the condition called mania. Patients who suffer from depression only are considered as unipolar and those who suffer from both mania and depression are called bipolar.

One of the biochemical causes for depression is depicted in the monoamine hypotheses. It states that depression is caused by a functional deficiency of catecholamines, especially epinephrine, and mania is caused by the functional excess of catecholamines.

Other biogenic amines such as serotonin, norepinephrine and dopamine may also be linked to depression and mania.

Several therapeutic strategies have been adopted based upon this hypothesis. These include administering precursors of these amines to treat depression and, using inhibitors of the relevant enzymes for manic patients. However, there are several inconsistencies in these therapies. Sometimes manic patients do not respond well to enzyme inhibitors. Drugs such as lithium acts on both manic and depressed patients and, in fact, is a universally accepted agent for the treatment of bipolar disorders.

Apart from the monoamine hypothesis, there is also the concept that receptor alterations are involved in mood disorders.

In Sri Lanka, it is known that a significant percentage of the population suffer from transient to severe mood disorders. However, ignorance and social stigmas has often prevented most people from taking medical treatment for these conditions.

However, it must be emphasized that taking lithium for depression is not very different from taking paracetamol for flu, both being agents to correct some biochemical disorders in cells.

As life is nothing but an assortment of thousands of biochemical reactions, the key to solve some mysteries in life also must be with the same subject. As there is strong interest and enthusiasm to unfold the mysteries of the brain we can look into the future with hope and courage even though the progress is slower than what we anticipate.

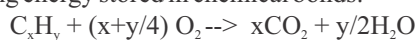
References

1. Anirvan Ghosh and Michael E. Greenberg, (1995) Calcium signaling in neurons, molecular mechanisms and cellular consequences, Science, 268, 239-247.
2. Bruce G Lyeth and Ronald Hayes, (1992), Cholinergic and opiod mediation in traumatic brain injury, Journal of Neurotrauma, 9, 463-474.
3. Basic Neurochemistry, (1993), editors, George J Siegel, Bernard W. Agranoff, R. Wayne albers, Perry B. Molinoff, fifth edition, Raven press, New york.
4. Tracy K McIntosh, (1992) Pharmacological strategies in the treatment of experimental brain injury, Journal of Neurotrauma, 9, 201-207.

Energy and chemistry

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Human civilization entered into a rapid phase of change with the discovery of fire, making use of chemical reactions to generate energy for their convenience. Today we use numerous chemical processes to generate energy needed to power devices as tiny as wrist watches and as large as rockets which carry tons of material to distant planets. The very basic process associated with energy generation is the combustion of fuels which constitute of hydrocarbons, releasing energy stored in chemical bonds.



Although the combustion of hydrogen has simple chemistry, than that of the combustion of hydrocarbons, its use has been delayed until the development of modern technology due to the unavailability of natural hydrogen sources.

The branch of science called thermodynamics has developed along with the understanding that the chemical reactions are associated with energy changes. Breaking and forming of chemical bonds are associated with absorption or release of energy in the form of heat (to describe in the simplest way, at constant pressure). The heat energy can be converted to mechanical energy and then to electrical energy. All such changes are governed by the rules stated in chemical thermodynamics and are associated with efficiencies less than 100%. In addition to low efficiencies, the most convenient ways of generating energy come with a negative impact that is "pollution". Today we have begun to face the consequences of conveniences we have enjoyed in the past. Despite all the undesirable side effects, coal and liquid petroleum fuels have been the primary sources of energy in the present world supplying over 85% of the total energy requirement.

The amount of energy received by the earth from the sun within one hour is equivalent to the total amount of energy produced by mankind in one year, making the solar power an attractive energy source. Energy from the sun can be utilized in many ways, where heating and conversion to electricity have been the most popular methods. Although, the utilization of solar thermal energy is a simple and direct process, the conversion of solar energy into electrical energy requires deeper involvement of chemistry. The device that converts solar energy into electrical energy is the solar cell and a solar cell works by absorbing photons from solar radiation. In a solar cell, an electron conducting region of a solid joins with a hole (positive charge conducting region) forming a junction. Photons with sufficient energy generate electron - hole pairs at the junction between the two regions. Energetic electrons are drained in to the external circuit, which utilizes

electricity and recombined with the holes in the solid. In order to achieve high efficiency, solar cells are produced using extremely pure and crystalline materials. For example, pure crystalline silicon is used in the production of silicon based solar cells. Controlled addition of boron or phosphorous in to the silicon lattice changes silicon to a p-type semi conductor (hole conductor) or an n-type semiconductor (electron conductor) respectively.

In a typical silicon solar cell, a thin transparent layer of electron conducting silicon resides on a layer of hole conducting silicon forming a junction. Electrons and holes generated by photons at the junction are taken to the external circuitry by means of conducting layers on the n-side and p-side of the solar cell. A solar cell absorbs photons having energies greater than the minimum energy (band gap energy) required for electron hole pair separation, which is specific to the materials of construction. A solar cell does not absorb photons having energy less than the band gap energy. When photons having energy greater than the band gap energy are absorbed, excess energy is released as heat. This is one of the factors that limit the efficiency of a solar cell. Therefore, the efficiency of a solar cell can be improved by having several layers of carefully chosen n-type and p-type materials deposited on top of each other. Such a device can absorb photons in a wide spectrum of energy and convert to electricity. Efficiencies as high as ~40% have been achieved using such devices and are referred to as multijunction solar cells. Although, solar cells based on many different materials are available, silicon based solar cells are the most popular due to durability and efficiency. Typical silicon based solar cells are reported to have life times over 20 years at ~20% efficiency.

Production of silicon based solar cells starts from the conversion of quartz (SiO₂) into silicon by reacting with carbon at high temperature (SiO₂ + C → Si, SiC and CO_x). These must be further purified, as the impurities, if present greatly degrade the performance of solar cells. Silicon is purified by reacting with hydrogen chloride gas and converting to trichlorosilane (HSiCl₃) and by fractional distillation. The purified trichlorosilane is vaporised and reacted with hydrogen gas (1100°C) so that the elemental silicon is retrieved. Further purification is achieved by zone refining, where a section of a solid silicon rod is heated and the heated region is moved from one end to the other. All the steps mentioned above are carried out at high temperatures and requires the use of extremely pure chemicals leading to high production costs. Therefore, cheaper alternatives such as solar cells

based on organic semiconductors, dye sensitized semiconductors and nanocrystalline materials are being extensively studied. Research is being conducted in order to increase the efficiency and durability of such devices and it is needless to mention the importance of chemical principles in these developments.

Even with the perfect solar energy converter, the direct use of solar energy is possible only during the day time and under clouds free conditions. Therefore, the storage of energy in large quantities is of high priority. This is an area, where chemistry knowledge has come in handy. Obviously the most successful way of storing energy is by means of chemical synthesis. Nature over millions of years has stored solar energy by photosynthesis generating reservoirs of hydrocarbons known as petroleum, coal and natural gas. Energy in the form of chemicals can be stored for a long time, can be transported easily and can be supplied in quantities large or small. Chemicals that exist in liquid form at normal temperatures are the most desirable due to the ease of handling and transport. For example, the fuels used in the transport sector are mostly in the form of liquids. Therefore, the conversion of solar energy to chemical energy remains an important area of chemical research. Generation of hydrogen by electrolysis of water and by photocatalytic water splitting have received the attention of researchers worldwide. Although a considerable research effort has been invested in the development of processes such as photocatalytic reduction of CO_2 to methanol, synthesis of hydrocarbons from CO_2 , photocatalytic reduction of nitrogen to ammonia, use of organic waste in photocatalytic production of fuels, none has reached the practically viable levels yet.

During the recent years, fuel cells have come up as an attractive alternative to produce clean energy. There are fuel cells operating on hydrogen, natural gas and liquid fuels such as methanol or ethanol. A fuel cell is capable of converting chemical energy directly to electrical energy. This is much simpler when compared to the sequence of steps; chemical energy $\rightarrow$ heat energy $\rightarrow$ mechanical energy $\rightarrow$ electrical energy, present in a fossil fuel combustion based electrical energy producing system. Since the transformation of energy from one form to another is always associated with an energy loss, a process with fewer energy transformations operates at high efficiency. The fuel cell therefore is the most efficient system that converts chemical energy to electrical energy.

Typical example of a fuel cell is the hydrogen oxygen fuel cell, where the oxidation of hydrogen takes place. The two half reactions in an alkaline electrolyte containing hydrogen-oxygen fuel cell are $\text{H}_2 + 2\text{OH}^- \rightarrow 2\text{H}_2\text{O} + 2\text{e}^-$ and $\text{O}_2 + 4\text{e}^- + 2\text{H}_2\text{O} \rightarrow 4\text{OH}^-$. Platinum (Pt) has been the material of choice for fuel cell electrodes. Promoters such as Iridium (Ir) and

Ruthenium (Ru) are known to increase the reaction rates. Hydrogen-oxygen fuel cells are also constructed using ion conducting polymer membranes such as nafion. Production costs have been significantly lowered by using carbon based Pt nano particle systems and alloys. Impurities, mainly carbon monoxide are known to poison Pt based electrode systems used in fuel cells. Therefore, the fuels used must be of highest purity to ensure a long operational life and high efficiency. High cost of Pt has been one of the obstacles in promoting the fuel cell technology. Therefore, alternate electrode systems based on low cost materials are being searched.

Solid oxide fuel cells are fuel cells that can use hydrogen as the fuel. The purity of hydrogen is not very much of a concern in solid oxide fuel cells. Therefore, hydrogen generated from various processes can be used as the fuel in solid oxide fuel cells. For example, hydrogen generated by the reaction of steam and methane, or steam and any other hydrocarbon fuel such as diesel or heavy oil can be used. The electrolyte in solid oxide fuel cells is an oxygen ion conducting solid such as yttria stabilized zirconia (Y_2ZrO_7). Oxygen undergoes reduction at the cathode and travels to the anode as O^{2-} . At the anode, the fuel is oxidized releasing electrons. Operational temperature of the solid oxide fuel cell is around 800°C . High temperatures are required to achieve sufficiently high oxygen ion conductivity in the electrolyte. Due to high operational temperatures, solid oxide fuel cells are less vulnerable to poisoning by impurities such as carbon monoxide.

Molten carbonate fuel cells are another category of fuel cells where the electrolyte material is a molten carbonate. Carbonates of lithium or potassium are used as electrolytes in these fuel cells. Hydrogen or any other hydrocarbon that can produce hydrogen by reforming with carbon dioxide can be used as the fuel in a molten carbonate fuel cell. High operational temperatures are required to maintain the carbonate in liquid form. High temperature fuel cells are also associated with problems such as corrosion and coking. They must be constructed using materials that can withstand extreme operating conditions. In addition to the above mentioned fuel cells, many new types of fuel cells with the ability of using different types of fuels have been developed. They use different electrolytes and operate at different temperatures. Since there are no moving parts in fuel cell systems, they require no maintenance and operate continuously as long as the fuel supply is available. These features have made fuel cells as an attractive option for energy production.

Although the production of electricity using fuel cell technology is attractive, several hurdles are to be overcome before large scale commercialization. One is the production of hydrogen and other fuels necessary for their operation. Electrolysis of water and

reforming of fossil fuels are the major sources that produce hydrogen for fuel cells. Both processes are having their limitations as the former requires a source of electricity and the latter is associated with energy inputs from fossil fuels once again. Storage and transport of hydrogen has been a difficulty associated with hydrogen fuel cell technology. Although the use of liquid fuels such as methanol in fuel cells has somewhat eased the situation, their production is comparatively complex compared to the production of hydrogen. Research in chemistry continues to contribute in the development of fuels, electrodes and electrolytes for the production of efficient and cheaper fuel cells.

Use of renewable sources such as biomass for energy production is an area where chemistry is heavily involved. The chemical process where a hydrocarbon reacts with water vapor ($C_xH_y + H_2O \rightarrow CO + H_2$) generating carbon monoxide and hydrogen is the underlying principle of wood gasification. In principle solid wood, agricultural residues and organic waste can be used in gasification processes. Products of gasification can be used as the fuel in a traditional internal combustion engine or can be fed to a fuel cell for the generation of electricity. The process is environmentally friendly as the fuel source is renewable and does not contribute to a net increase in the concentration of green house gases in the atmosphere. Thermal efficiencies in the range of 50 to 80% have been reported in gasifier electricity generation systems. Catalysts such as nickel(Ni), cobalt(Co) supported on oxides of aluminum or magnesium have been used to improve the yields in gasification process.

Direct production of liquid fuels from biomass has also become an interesting area of chemical research. Production of methanol from synthesis gas (a mixture of carbon monoxide and hydrogen), originated from biomass gasification has been demonstrated. Copper and zinc oxide based catalysts have been employed for the conversion of synthesis gas to methanol. Conversion of carbon dioxide to methanol by reacting with hydrogen is another interesting application derived from chemistry. An attractive feature of this technology is that it uses carbon dioxide as the feedstock, which is the major contributor to the greenhouse effect. Recovering carbon dioxide from power plants and using it for the production of methanol has been suggested as a greener way of energy production. Methanol can be used in motor vehicles which use gasoline as the fuel without making any alterations in their engines.

Glycerol esters of fatty acids known as oils derived from plants can be converted to a fuel similar to petroleum diesel by the process known as transesterification. Biodiesel can be synthesized by transesterification of glycerol esters of fatty acids with methanol or ethanol. The product, fatty acid-methanol

(or ethanol) esters, have properties identical to conventional diesel fuel. Compared to conventional fossil fuel based diesel, the content of pollutants such as sulfur is low in biodiesel. Strong bases, acids and ion exchange resins have been used as catalysts in biodiesel synthesis. Alternatively, direct reaction of fattyacid-glycerol esters with alkoxides can also be used to generate biodiesel.

Synthesis of hydrocarbons by means of Fischer-Tropsch process using Co catalysts and biomass based synthesis gas has also been demonstrated. Ability to produce hydrocarbons in the range of diesel fuel is interesting as the product can be used directly in conventional diesel engines. Liquefaction of solid biomass to produce fuels is also an interesting area where chemists have made significant contributions. Application of high pressure (200 atm) and temperatures (300 °C) over a slurry containing lignin and sugars derived from solid fuels has made it possible to synthesize liquid fuels. The process has many variants. Addition of hydrogen to the reaction mixture and the use of strong alkali such as sodium hydroxide and use of metal oxide catalysts (Co, Mn) have been reported. Lignin liquefaction producing phenols has been achieved by using Fe(II)S with a metal promoter (Cu, Sn or Cr etc) in an aqueous solution and in a hydrogen atmosphere (150-450 atm) at 250 - 450 °C.

Application of chemistry is not limited to the synthesis of fuels and development of chemical process to extract chemical energy. It plays a vital role in the area of nuclear power generation. Nuclear reactors utilize the energy released during fission of heavy nuclei (^{235}U , ^{239}Pu) to smaller stable nuclei. To activate the fission reaction to a level possible to generate sufficient amount of heat, the nuclear fuels must be extracted from the ore, purified and concentrated. In the extraction of uranium, the ore is crushed into a fine powder and then leached with either an acid or alkali. The leachate is subjected to several sequences of precipitation, solvent extraction, ion exchange and oxidation to produce uranium oxide known as yellow cake. This is then reacted with hydrogen fluoride gas and converted to UF_6 gas. Further purification is achieved by distillation and finally the fuel is enriched in ^{235}U isotope by centrifugation of UF_6 . All the above procedures together with handling of spent nuclear fuel and environmental clean up have been possible due to the developments in chemistry.

To achieve development targets, a country must have the capability of generating sufficient power to propel its industries. In Sri Lankan perspective, the role of chemistry in power generation is most useful in the areas of solar energy and utilization of renewable materials. Wood and biomass gasification, biodiesel production and methanol/ethanol production can be identified as priority areas for development.

Bibliography

1. International energy outlook (2007), US Department of Energy.
2. Tatsuya Takamoto, (2009), CS MANTECH Conference, May 18th-21st, Tampa, Florida, USA.
3. D.J. Bents and V.J. Scullin, (2005), NASA/TM—2005-213381.
4. George W. Crabtree and Nathan S. Lewis, (2007), Physics Today, Issue-March.
5. M. Grätzel, (2001), Nature 414, 338.
6. D. Maldas and N. Shiraishi, (1997), Biomass and Bioenergy, Volume 12, Issue 4.
7. E. H. Stassen, (1942), World Bank technical paper, Energy series, ISSN 0253-7494; no. 296.
8. R.L. Bain (1992), Technical Report, National Renewable Energy Laboratory, 1617, Cole Boulevard, Golden, Colorado 80401-3393, USA.
9. Wood gas as engine fuel (1985), FAO Forestry Paper No.72.

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Molecular fuel tanks: hydrogen storage in microporous metal-organic frameworks

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Background:

Our energy-hungry world has become increasingly dependent on new methods to store and convert energy for new, environmentally friendly modes of transportation and electrical energy generation as well as for portable electronics. Concern about finite petroleum reserves and climate change has reinvigorated interest in alternative fuel technologies. In this context, finding new energy sources is considerably more challenging and researchers are working to replace fossil-fuel sources with hydrogen in a variety of applications. Hydrogen, which can be produced with little or no harmful emissions, has been projected as a long term solution for a secure energy future. For this reason hydrogen based fuel cells have attracted considerable attention for power generation. A hydrogen-based economy, however, requires the technology that guarantees safe transport and storage of the hydrogen fuel.

Transferring from petroleum to hydrogen may offer major benefits in terms of pollution, energy security, and other issues. The change to a hydrogen economy would not happen overnight and would need to overcome numerous scientific and technological hurdles before the switch to hydrogen can be implemented on a large scale. Scientists are working towards that goal by developing a variety of new materials and methods for producing and storing hydrogen. Economical and environmentally clean production of hydrogen is crucial to hydrogen based power generation.

Hydrogen is attractive as an energy carrier for several reasons. Its energy content is about three times that of liquid hydrocarbons. The gas can be reacted or burnt with oxygen in a fuel cell configuration to release energy and produce water with no pollutants, a particularly attractive feature for transport in congested urban areas where pollution is a concern. The beauty of these reactions is that, those reactions do

not generate greenhouse gases. In addition, hydrogen can be produced from plentiful sources such as water, thereby reducing a growing dependence on fossil fuels. However, economical and environmentally clean production of hydrogen from these sources is crucial to hydrogen based power generation. Safe transport, storage, and delivery are equally important.

The benefits of using hydrogen as a fuel is tremendous, however the production of fuel cell powered automobiles is challenging. One reason is that the ordinary motorists are not in a position to acquire hydrogen conveniently and safely due to lack of infrastructure. And also there is no uniform procedure for storing the fuel in a car's gas tank. Scientists believe that one of the key enabling technologies on which a future hydrogen economy rests is hydrogen storage. The public will accept hydrogen as a transportation fuel only when the technological barriers are overcome to meet the demand for onboard storage of the gas in an automobile in suitable quantities. The modern cars can travel few hundred miles on a tank of gasoline and can be refueled in a few minutes. United States, Department of Energy (DOE) has set similar goals and targets for the performance of hydrogen-powered cars.

As mentioned earlier, hydrogen has roughly three times the energy content of gasoline on a per-weight basis, however, on a volumetric basis, hydrogen has an energy content of only 8 MJ/L for the cryogenic liquid compared with gasoline's 32 MJ/L. The target of DOE in 2010 was to develop a hydrogen-storage system with an energy density of 7.2 MJ/kg and 5.4 MJ/L. Energy density refers to the amount of usable energy that can be derived from the fuel system. The 2010 values work out to be 6 wt % of hydrogen and 45 kg of hydrogen per cubic meter. The targets will be even more stringent for the future. For 2015, DOE is

calling for fuel configuration with 9 wt % of hydrogen and 81 kg of hydrogen per cubic meter, which is greater than the density of liquid hydrogen (approximately 70 kg/m³ at 20 K and 1 atm).

Many investigations have been started to explore the possibility of packing a large quantity of hydrogen in low-weight and low-volume. Research on liquid and high-pressure gas-storage systems is underway, and international safety certifications have been issued recently for compressed gas cylinders designed to hold hydrogen at 10,000 psi. But those methods cannot satisfy long-term storage goals especially in automobiles. Therefore considerable safety concerns associated with hydrogen storage in high-pressure containers have prompted researchers to search for materials capable of sequestering hydrogen at low pressures and ambient temperatures. Most scientists working on the problem are focusing on storing the gas in solids and solid matrices in which it is possible to exceed the density of liquid hydrogen. In this context metal organic frameworks (MOFs) (Figure 1) have received the much attention from scientist from all over the world especially from the US where DOE has listed this as the high priority project in this century.

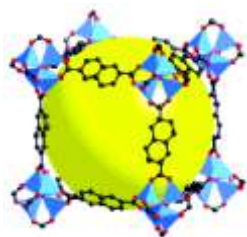


Figure 1: Example for a MOF: The diameter of the MOF is defined by the distance between the van der Waals surfaces of the framework atoms.

Introduction:

Over the past few decades the material research received a prominent attention due to the growing demand for hydrogen storage methodologies. The initiative of the Department of Energy (DOE) of United States has captured the attention of industrial and academic researchers around the world. The exponential increase of research activities in the field is due to the growing recognition of the negative consequences of petroleum based energy dependency. The storage of this lightweight hydrogen fuel is just one of the challenges restricting the realization of its potential benefits, but its solution will be mainly for the transportation sector. The transportation uses the major part of the oil and this consequently a major source of airborne pollutants. The storage of dihydrogen is primarily an issue of volume due to its low critical temperature. There are two ways for the storage of hydrogen; the gas must be compressed under very high pressure (several hundreds of atmospheres) or maintained as a liquid at very low temperature (20 K). In both these instances, the issue of safe handling and refueling is paramount. Development of these physical methods is thought to be insufficient for widespread use of hydrogen as a

transportation fuel source. Therefore, chemical storage methods are being investigated. There are two categories of hydrogen storage materials; those that dissociate the molecules and chemically bind them as hydrides and those that physisorb the molecules on their surfaces. The most important aspects of the second class are strong binding potential and enormous surface area. Therefore microporous adsorbents such as activated carbons and zeolites have been examined. Omar Yaghi (University of California, Los Angeles, previously at University of Michigan, Ann Arbor) reported a new class of microporous adsorbents which received the attention due to their comparable, if not greater, apparent surface areas and pore volumes. The discovery of hydrogen adsorption in porous metal-organic frameworks (MOFs) and subsequent related studies has firmly established these materials as interesting candidates for hydrogen storage applications.

Metal-organic frameworks (MOFs) are crystalline, infinite networks assembled by the bonding of metal ions with polyfunctional organic molecules. Their attributes include high porosity, spatial and chemical tailoring, and synthetic scalability. Application of these functional materials, particularly toward gas storage and separation, is now a focus of considerable research. Reticular synthesis (logical construction of networks from molecular building blocks) has yielded this new class of crystalline porous materials in which metal ions and clusters are linked by organic units. Specifically, the chemistry of MOFs has provided an extensive class of crystalline materials with high stability, tunable metrics, organic functionality, and porosity. Following discussion gives an insight into their novel synthetic strategies and properties.

Reticular synthesis:

The difficulty in controlling the character of solids produced from the traditional synthetic methods is directly related to the fact that the starting structures do not maintain their configuration during the reaction, leading to poor correlation between reactants and products. It was shown that the design of an extended network can be materialized by starting with well-defined and rigid molecular building blocks that will maintain their structural integrity throughout the construction process. Alternatively, the use of well-defined conditions that lead to the formation of such building blocks in situ is an equally viable approach to the design of extended structures and one that has been especially fruitful in MOF chemistry. The researchers have shown that the practice of logical synthesis must start with clear understanding of the target network 'blueprint' and identification of the required building blocks for its assembly. This process is central to the true design of

solid-state materials. This is known as reticular synthesis.

In contrast to the retrosynthesis of organic compounds, reticular synthesis can be described as the process of assembling thoughtfully designed rigid molecular building blocks into predetermined ordered structures (networks), which are held together by strong bonding. The structural integrity and rigidity of the building blocks in reticular synthesis remain unaltered throughout the construction process. This is an important aspect that could help to realize fully the benefits of design in crystalline solid-state frameworks. Similarly, reticular synthesis should be distinguished from supramolecular assembly, because in the former, building blocks are linked by strong bonds throughout the crystal.

It should be mentioned that enormous number of extended structures successfully prepared by copolymerization of metal ions with organic links, have been reported and reviewed under the heading of 'crystal engineering', a term which has evolved somewhat over the years and which is now rather broadly defined. The more precise term reticular synthesis (or chemistry) is to describe the logical approach to the synthesis of robust materials with predesigned building blocks, extended structures, and properties. Thus, it might be considered a subclass of crystal engineering.

Research investigations in the area of MOFs and, inorganic frameworks, has recently progressed far enough to provide examples which show the feasibility of the building-block approach and the scope of reticular synthesis. Few selected examples of MOFs to highlight the ideas involved are described in this article. There have been intensive studies on structural and thermal stability characterization with in-depth studies of surface area and gas sorption capacities.

The Cambridge Structure Database (CSD) contains the crystal structures of more than 11,000 extended metal-organic compounds in which a metal ion or cluster has been linked by an organic moiety in which the linking functionality is a cyanide, pyridyl, phosphate or carboxylate. Out of which nearly 3,000 compounds have three dimensional (3D) structures and about double that number have 2D structures. MOFs composed of the first-row transition metals and organic links such as cyanide, glutamate, formate, triazole, oxalate, and 1,2,4,5-tetracarboxylates have long been known. Also, expanded diamond structures based on linking of Cu(I) with various carboxylate and other ligands represent the numerous forerunners of the extended structures constructed from molecular building blocks. Clarification of some terminology is given here. **Reticular:** (adjective) having the form of a (usually periodic) net, **Isoreticular:** Based on the same net (having the same topology), **MOF-n:** Metal-organic framework (with n an integer assigned in

roughly chronological order), **IRMOF-n:** Isoreticular MOF (with n an integer referring to a member of the series), **SBU:** The term 'secondary building unit' has been used for some time to describe conceptual fragments of zeolites; in the context of reticular chemistry it refers to the geometry of the units defined by the points of extension such as the carboxylate C atoms in most carboxylate MOFs.

By examining the pool of crystal structures, in particular of MOFs, has motivated the researchers to identify two important questions for reticular synthesis. First, of the almost unlimited possible networks, which can be expected to form and how can they be synthesized? Second, with few exceptions, MOFs based on M-N linkages in which the vertex of the network is just a single atom have a tendency to form structures which collapse upon removal of 'guest' atoms from the pores, rendering the structure nonporous.

Secondary building units (SBU):

It is difficult (although not impossible) to attempt the synthesis of structures, such as those presented in this article, from simple metal ions and organic links due to insufficient directional information of ions. This relative lack of directionality often results in flexibility around the metal ion, a multiplicity of possible structures and a general lack of control as exemplified by frameworks based on Cu ions and bipyridine and related links. This article highlights the use of the carboxylate functionality (Yaghi and co-workers) to chelate metal ions and lock them into rigid and thus directional metal-oxygen-carbon clusters, with the points of extension (in this example, carboxylate C atoms) defining geometrical shapes referred to as secondary building units (SBUs). The involvement of SBUs in successful design of rigid frameworks was demonstrated for the first time in MOF-2 and MOF-544. The design principles employed for MOF-5 will be discussed extensively. This shows that the SBUs have intrinsic geometric properties that will facilitate network design and also help to address the issues of network synthesis.

General features of MOF-5:

In MOF-5 (Figure 2a), $\text{Zn}_4\text{O}(\text{CO}_2)_6$ units containing four ZnO_4 tetrahedra with a common vertex and six carboxylate C atoms that define an octahedral SBU are joined together by benzene links. This leads to a cubic network in which the vertices are the octahedral SBUs and the edges are the benzene struts. In practice, this compound was prepared from Zn(II) and Benzene dicarboxylate (BDC) acid under conditions pre-determined to yield the octahedral SBU in situ. Because the SBU and benzene links are relatively large and rigid entities, the structure produced has exceptional porosity (indicated by its sorption), and stability (indicated by thermal analysis

and single crystal X-ray diffraction studies on the completely evacuated framework).

The exceptional stability of MOF-5 can be understood by comparing its basic network, composed of single atom vertices (Figure 2b), with the actual structure of MOF-5, which has cationic clusters at those vertices (Figure 2a). The basic network has no resistance to shear if the links are considered to be universal joints. However, in the actual MOF-5 structure, the cationic clusters have a truncated tetrahedral envelope (Figure 2c), and the rigidly planar $\text{O}_2\text{C}-\text{C}_6\text{H}_4-\text{CO}_2$ linkers have a planar slat envelope. The linkage of these two groups produces an inherently rigid structure held together by mutually perpendicular hinges.

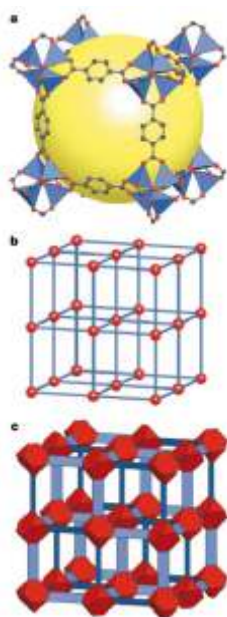


Figure 2: The MOF-5 structure and its topology.

Figure 2a: The MOF-5 structure shown as ZnO_4 tetrahedra joined by benzene dicarboxylate linkers to give an extended 3D cubic framework with interconnected pores of 8 Å aperture width and 12 Å pore diameter. The largest sphere can occupy the pores without coming within the van der Waals size of the framework.

Figure 2b: The topology of the structure (primitive cubic net) shown as a ball and stick model.

Figure 2c: The structure shown as the envelopes of the $(\text{OZn}_4)\text{O}_{12}$ cluster and benzene dicarboxylate (BDC) ion. Note that opposing slats are all at 90° .

This approach, based on the concept of SBUs, has been useful in rationalizing the topologies of MOF structures, and more importantly, it has allowed the synthesis and use of a large number of inorganic and organic SBUs with varying geometries (Figure 3).

Synthesis and properties of MOF-5:

The preparation, properties and gas adsorption sites of MOF-5 are discussed here to understand the gas sorption capacities and mechanism. The diffusion of triethylamine into a solution of zinc (II) nitrate and H_2BDC in N,N' -dimethylformamide (DMF)/chlorobenzene resulted in the deprotonation of H_2BDC and its reaction with Zn^{2+} ions. A small amount of hydrogen peroxide was added to the reaction mixture in order to facilitate the formation of O^{2-} expected at the centre of the secondary building unit. Elemental microanalysis of the resulting colourless cubic crystals suggested that their formula

was $\text{Zn}_4\text{O}(\text{BDC})_3 \times (\text{DMF})_8(\text{C}_6\text{H}_5\text{Cl})$; MOF-5.

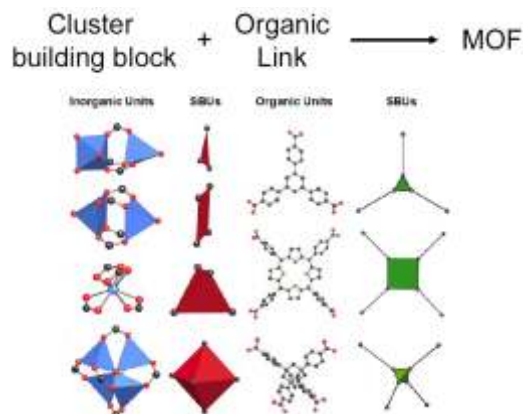


Figure 3: Examples of SBUs from carboxylate MOFs.

The detailed single-crystal XRD study of Ar and N_2 adsorbed on the internal surface of a large-pore open-framework material, MOF-5 is extensively studied. The researchers have identified the metrics and geometry of five different primary adsorption sites on the $\text{Zn}_4\text{O}(\text{CO}_2)_6$ and the C_6H_4 units of MOF-5 and uncover edgewise $\text{C}_6\text{H}_4 \dots \text{Ar}$ and $\text{C}_6\text{H}_4 \dots \text{N}_2$ interactions previously unknown in gas-phase studies of aromatic van der Waals complexes.

Diffraction-quality single crystals of MOF-5 were evacuated ($<10^{-3}$ Torr) to remove any gas or volatiles, and its stability was checked by thermal gravimetric analysis, which revealed a large temperature range (100 to 470°C) of stability with no observable weight loss (Figure 4). The crystal specimens were mounted in capillaries connected to a gas manifold for evacuation before being backfilled with Ar or N_2 and flame-sealed. The amount of gas available for adsorption has been estimated from the backfill pressure, crystal size, and the dimensions of the capillaries to be about 5 to 10 gas molecules per formula unit of MOF-5, $\text{Zn}_4\text{O}(\text{BDC})_3$, which is less than half the established saturation uptake for MOF-5.

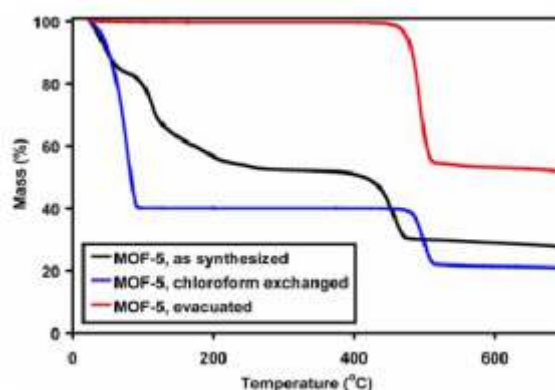
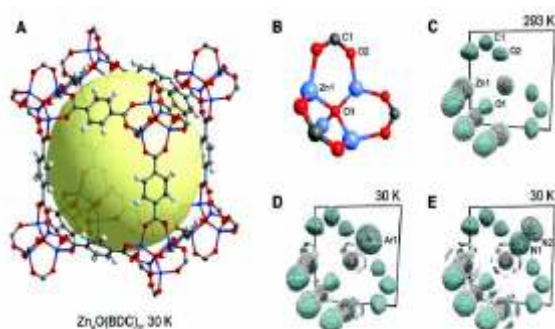


Figure 4: Thermal behavior of MOF-5 in the as-synthesized, chloroform exchanged, and evacuated states.

The as-synthesized material (Figure 4) displays a multistep weight loss of 48% up to 300°C , attributed to the desorption of 7.0 N,N -diethylformamide molecules per formula unit before the onset of

decomposition at 410 °C. In contrast, the chloroform guests in the exchanged material are completely removed by 100 °C (60% weight loss, equivalent to 9.7 chloroform molecules per formula unit). The evacuated framework shows no weight loss to 470 °C.

XRD data of MOF-5 were collected by using a Single crystal diffractometer equipped with a charge-coupled device camera and an open flow helium cryostat at temperatures between 293 and 30 K was used to capture XRD data. The evacuation procedure was confirmed by the data collected at 30 K on a single crystal of MOF-5 sealed under vacuum. Refinement of these data confirmed the maintainance of the cubic symmetry of MOF-5 and the absence of guest molecules in the pores as shown in the thermal ellipsoid plot of Figure 5A.



$\text{Zn}_4\text{O}(\text{CO}_2)_6$ units connected by phenylene links (atoms shown as thermal ellipsoids of 90% probability), which define large pseudocubic pores that can be completely evacuated. (B) A magnification of the corner of the pore schematically shows the location of adsorption site $(\text{CO}_2)_3$, located equidistant to the three carboxylates. (C) The corresponding three-dimensional electron density map (F_{obs}) of this site at 293 K. (D) Electron density assigned to adsorbed Ar at 30 K. (E) Electron density assigned to adsorbed N_2 at 30 K.

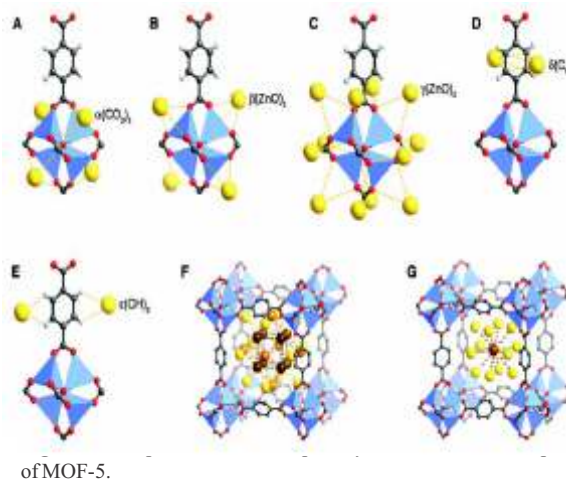
Further XRD data collected from crystals of MOF-5 loaded with Ar or N_2 between 293 and 30 K especially the refinement of data collected at 293 K revealed no significant peaks of electron density attributable to guests in the extra framework region in either case, as would be expected from their weak interaction (Figure 5, B and C). As the temperature was lowered, many local maxima were located in the observed structure factor (F_{obs}) Fourier maps, providing evidence of the localization of the gas atoms.

This localization is most apparent at 30 K in the regions proximal to the $\text{Zn}_4\text{O}(\text{CO}_2)_6$ unit. The shape and amplitude of the electron density contours of Ar and N_2 atoms near this unit are shown in figure 5, D and E, respectively. This first site, denoted $(\text{CO}_2)_3$, lies on a triangular face of the octahedron. The vertices of the octahedron are defined by the carboxylate C atoms. This site exhibits the highest occupancy in all refinements over the temperature range examined and has been identified as the primary adsorption site. Its symmetry allows the adsorption of up to four

adsorbates per formula unit. At this site, the curvature is higher than anywhere else on the framework surface, which allows the adsorbates to interact with three carboxylates and three Zn atoms. The Zn–O and C–O dipoles are presumably most effective in polarizing the gas atoms and lead to comparatively strong interactions.

More adsorption sites were identified from local maxima of electron density, which are partially occupied by Ar at 30 K. In total, there are five primary adsorption sites, including $(\text{CO}_2)_3$, that are closest to the framework, and three secondary ones that form a second layer of adsorption in the pores (Figure 6 A–G). These include (Figure 6 A to C) three sites primarily associated with the secondary building unit and those above the (Figure 6 D) face and (Figure 6, E) edges of the linker.

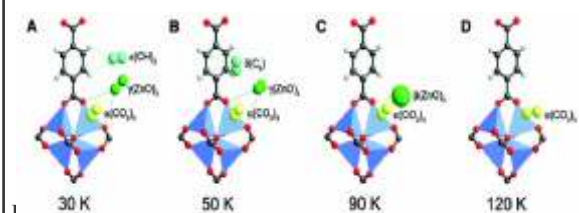
The adsorption sites of N_2 has also been studied using XRD data which were determined to be the same as those found for Ar. Even at a temperature as high as 120 K, significant electron density was located at the primary adsorption site $(\text{CO}_2)_3$. At 30 K, the two distinct atoms of the N_2 molecule can be modeled at three adsorption sites equivalent to $(\text{CO}_2)_3$, $(\text{ZnO})_2$, and (CH_2) of the Ar loaded structure (Figure 6 A).



of MOF-5.

The presence of multiple adsorption sites in MOF-5 and the location of their positions led to a rare insight into MOF structures. Specifically, the C_6 phenylene rings are profoundly altered by the presence of the zinc oxide units as evidenced by the observation of Ar and N_2 adsorption sites on the edges of the phenylene ring, $(\text{CH}_2)_2$; a mode, unlike that of the phenylene face, (C_6) , previously unobserved in the gas-phase studies of van der Waals complexes of gases with benzene. As the MOF-5 structure shows (Figure 7A), one finds that each C_6 ring is attached to two six-membered rings of $-\text{O}-\text{C}-\text{O}-\text{Zn}-\text{O}-\text{Zn}-$ composition. These heterorings are coplanar to the C_6 ring and undoubtedly alter its electronic character relative to C_6 rings of free benzene, graphite, and carbon nanotubes. Confinement effects enhancing

adsorbate-adsorbate interactions may also contribute to the stabilization of binding at these edge sites. This finding by Yaghi *et al.* has shed some light on the basis of H_2 binding in MOFs.



crystallographically identified as partially occupied by Ar atoms in the pores of MOF-5.

Hydrogen gas uptake by MOF-5 has been measured at 78 K by introducing small amounts of H_2 into a chamber containing the guest free form of the material and monitoring the weight change as a function of increasing doses of H_2 . The measured sorption isotherm shows a type I behavior, in which the saturation is reached at low pressures followed by a pseudo-plateau at higher pressure of H_2 with a maximum uptake of 45 mg of H_2 per gram of MOF-5 [4.5 weight % = 17.2 H_2 per $Zn_4O(BDC)_3$ formula unit] (Figure 8 A) The observed sharp uptake of H_2 at lower pressure indicates favorable sorption interactions between the MOF-5 framework and H_2 molecules. Similar to the reversible sorption of gases and organic vapors (N_2 , Ar, CO_2 , $CHCl_3$, CCl_4 , C_6H_6 , and C_6H_{12}) in MOF-5, adsorbed H_2 molecules can also be reversibly desorbed from the pores by reducing pressure.

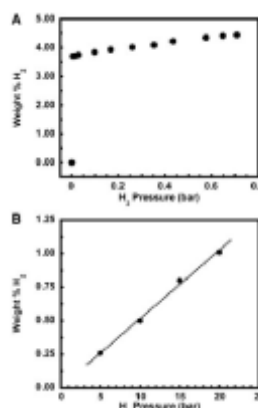


Figure 8: Hydrogen gas sorption isotherm for MOF-5 at 298 K.

The evolution of H_2 sorption in conditions that mimic a typical application environment, namely, room temperature and pressures was carried out. These conditions are considered to be safe for mobile fueling. A sorption apparatus constructed by Yaghi and co-workers, in which a 10-g sample of guest-free MOF-5 was charged with H_2 up to 20 bar and the weight change was monitored as a function of H_2 uptake and release. MOF-5 has shown substantial H_2 uptake that increased linearly with pressure, giving 1.0 weight % at 20 bar (Figure 8B). These findings demonstrated the potential of MOFs for H_2 storage

applications. The isotherm at ambient temperature is expected to be approximately linear as observed because the material is noticeably undersaturated with H_2 in the pressure range explored and at higher pressures can take up more H_2 , up to at least the amount observed at 78 K (compare Fig. 8, A and B). Inelastic Neutron Scattering (INS) spectroscopy has been used to identify the hydrogen binding sites by studying the rotational transitions of the adsorbed hydrogen molecules.

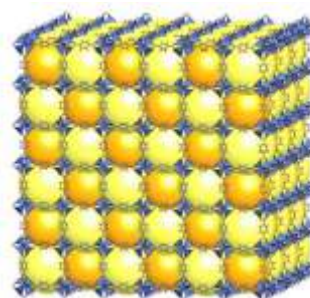
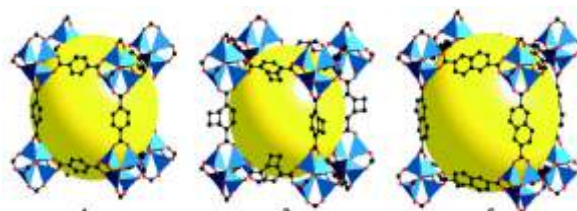


Figure 9: Extended MOF-5 structure

The INS results for hydrogen in MOF-5 point to the importance of the organic linkers in determining H_2 uptake levels. Accordingly, using the same experimental setup and details outlined above for the room-temperature measurements on MOF-5, the H_2 sorption in IRMOF-6 and IRMOF-8 (Figure 10, B and C) has been investigated.



(B), and IRMOF-8 (C). On each of the corners is a cluster $[OZn_4(CO_2)_6]$ of an oxygen-centered Zn_4 tetrahedron that is largest sphere that would fit in the cavities without touching the van der Waals atoms of the frameworks. Hydrogen atoms have been omitted.

Here they found that the specific H_2 uptake is approximately doubled and quadrupled, respectively, for IRMOF-6 and -8 relative to that found for MOF-5 at the same (room) temperature and pressure (10 bar). Specifically, for IRMOF-8, the H_2 uptake under those conditions is 20 mg of H_2 per gram (2.0 weight %)-a capacity well above those found for “active” carbon (0.1 weight %) (CECA, France) and “graphitic” carbon (0.3 weight %) (BASF, Germany). The uptake found for MOF-5, IRMOF-6, and IRMOF-8 at room temperature and 10 bar is equivalent to approximately 1.9, 4.2, and 9.1 H_2 per formula unit, respectively. These capacities are well below the saturation level as determined at 78 K for MOF-5 (17.2 H_2 per formula unit), which points to the potential for higher uptake at ambient temperature and higher pressures.

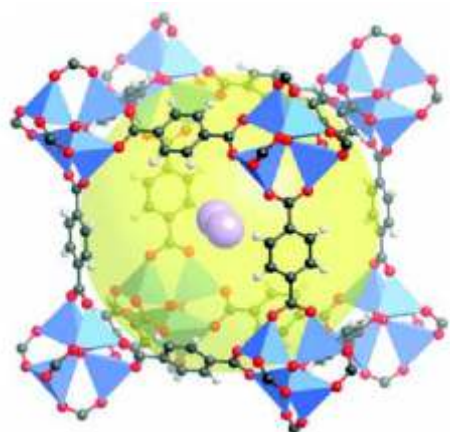
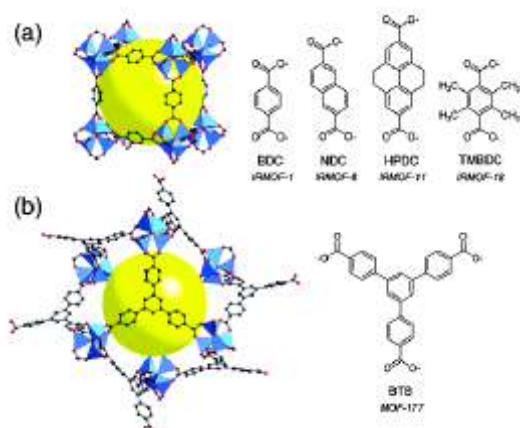


Figure 12. The structure of MOF-177, $Zn_4O(BTB)_2$, is much larger than the size of a hydrogen molecule (shown with atomic van der Waals radii of 1.2 Å) which has a kinetic diameter of 2.89 ÅD.

The capacity of these structures for hydrogen at room temperature is comparable to the highest capacity achieved for carbon nanotubes at cryogenic temperatures, although the capacity of those materials is very sensitive to preparation conditions and appears to saturate at lower pressures. Further increases in performance can be expected, with other IRMOFs discussed below having similar but larger organic linkers.



metalorganic frameworks, $Zn_4O(L)_3$, are constructed by linking zinc oxide clusters with linear carboxylates L such as those shown. (b) The structure of MOF-177, $Zn_4O(BTB)_2$, is formed by linking the same clusters with a trigonal carboxylate. The large void regions equal to the distance of separation between the frameworks' van der Waals surfaces.

Five new materials have been prepared from the carboxylate links shown in Figure 12. These include IRMOFs-1, -8, and -11, MOF-177 and IRMOF-18; The structures of these have been determined by single crystal X-ray diffraction analyses. Crystalline samples of these materials were synthesized in large quantities (typically 1-2 g) by solvothermal reaction of $Zn(NO_3)_2 \cdot 6H_2O$ or ZnO with the respective organic carboxylic acids.

The N_2 sorption isotherm was measured gravimetrically for each of the samples to confirm their porosity, followed by measurement of H_2 uptake

at 77 K (see Table 1).

Table 1: Sorption Data for Metal-Organic Frameworks Measured Gravimetrically at 77 K

material	N_2 (mg/g)	A_{surf} (m ² /g)	H_2 (mg/g)	H_2 per f.u. ^b
IRMOF-1	965	3362	13.2	5.0
IRMOF-8	421	1466	15.0	6.9
IRMOF-11	548	1911	16.2	9.3
IRMOF-18	431	1501	8.9	4.2
^a MOF-177	1300	4526	12.5	7.1

with a cross-sectional area of 16.2 Å²/molecule.

^bAt 1 atm, f.u.) $Zn_4O(L)_3$ formula unit.

These materials received the attention due to their large surface areas and subtle chemical diversity. The construction of each framework is achieved by octahedrally linking $Zn_4O(CO_2)_6$ clusters with organic units. Therefore the surface sites on the inorganic component should be identical in each case, and any differences in hydrogen capacity can be attributed to differences in the organic units. The structures have minor differences and these have not interfered with the interaction of the material with hydrogen. IRMOFs-1, -8, and -18 each exhibit a simple cubic topology while IRMOF-11 contains two catenated frameworks of this type. The topology of the net underlying MOF-177 has mixed connectivity due to the tritopic linkage of BTB.

The hydrogen sorption behaviour is dependent on the chemical differences of the organic units. The isotherms in figure 13 each display distinct initial slopes and curvatures. When the isothermas were normalized to each formula unit, these differences become more apparent. At the highest pressure achieved in these experiments the maximum uptake varies considerably, from 4.2 molecules of H_2 per formula unit in IRMOF-18 to more than twice this value in IRMOF-11 (Table 1). The maximum uptake scales with the number of organic rings per formula unit. The similar capacities of IRMOFs-1 and -18 also demonstrate a potential lack of dependence on the pendant groups adorning the phenylene spacer. Although they differ in gravimetric capacity of H_2 , this is mainly due to their difference in density. Notable is the large value of the initial slopes of the IRMOF-8 and -11 isotherms, indicating higher affinity for molecular hydrogen. Surface areas (A_{surf}) have been calculated from the measured nitrogen sorption isotherms and are listed in Table 1 along with the maximum measured gravimetric uptake of hydrogen by each compound.

The surface excess weight percentage of hydrogen uptake in MOF-177 samples is 7.5 wt% at 70 bar, which corresponds to an absolute adsorbed amount of 11 wt%. Considering its well-known structure and its significant H_2 uptake properties, researchers believe MOF-177 is an excellent material to serve as a benchmark adsorber.

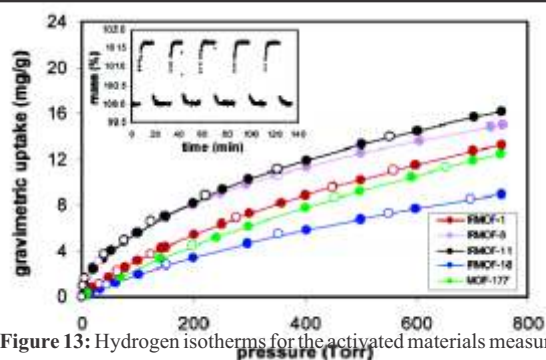
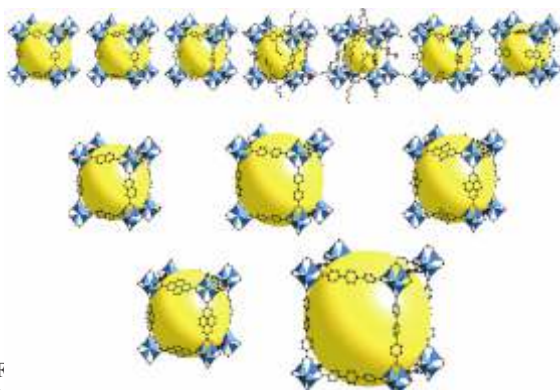


Figure 13: Hydrogen isotherms for the activated materials measured gravimetrically at 77 K (adsorption, ; desorption, O). The inset shows the time-dependent cycling of IRMOF-11 between 0 and 1 atm of H_2 .

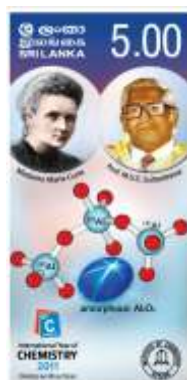
Figure 14 shows some of the MOFs with the same architecture prepared by Yaghi group at University of Michigan, USA and University of California, Los Angeles, USA. All of these show extremely high intake of H_2 at 77 K and according to his predictions the improvement of H_2 uptake at ambient temperature is not very far and the General Motors of USA has already started testing with these materials as fuel tanks in automobiles.



F University of Michigan, USA and University of California, Los Angeles. The large void regions are equal to the distance of separation between the frameworks' van der Waals surfaces.

References

1. H. Li, H. M. Eddaoudi, M. O'Keeffe, O. M. Yaghi *Nature* **1999**, 402, 276–279.
2. B. Chen, M. Eddaoudi, S. T. Hyde, M. O'Keeffe, O. M. Yaghi *Science* **2001**, 291, 1021–1023.
3. N. L. Rosi, J. Eckert, M. Eddaoudi, D. T. Vodak, J. Kim, M. O'Keeffe and O. M. Yaghi, *Science*, **2003**, 300, 1127.
4. Yaghi, O. M.; O'Keeffe, M.; Ockwig, N. W.; Chae, H. K.; Eddaoudi, M.; Kim, J. *Nature* **2003**, 423, 705–714.
5. H.K. Chae, D.Y. Siberio-Perez, J. Kim, Y-B. Go, M. Eddaoudi, A.J. Matzger, M. O'Keeffe, O.M. Yaghi *Nature* **2004**, 427, 523–527.
6. Jesse L. C. Rowsell, Elinor C. Spencer, Juergen Eckert, Judith A. K. Howard, Omar M. Yaghi, *Science*, **2005**, 309, 1350–1354.
7. B. Wang, A. P. Côté, H. Furukawa, M. O'Keeffe, O. M. Yaghi, *Nature*, **2008**, 453, 207–211.
8. R. Banerjee, A. Phan, B. Wang, C. Knobler, H. Furukawa, M. O'Keeffe, O. M. Yaghi, *Science*, **2008**, 319, 939–943.
9. H. Furukawa, N. Ko, Y. B. Go, N. Aratani, S. B. Choi, E. Choi, A. O. Yazaydin, R. Q. Snurr, M. O'Keeffe, J. Kim, O. M. Yaghi, *Science*, **2010**, 329, 424–428.
10. H. Deng, M. A. Olson, J. F. Stoddart, O. M. Yaghi, *Nature Chem.*, **2010**, 2, 439–443.
11. C. J. Doonan, D. J. Tranchemontagne, T. G. Glover, J. R. Hunt, O. M. Yaghi, *Nature Chem.*, **2010**, 2, 235–238.
12. H. Deng, C. J. Doonan, H. Furukawa, R. B. Ferreira, J. Towne, C. B. Knobler, B. Wang, O. M. Yaghi, *Science*, **2010**, 327, 846–850.



Postage Stamp

The Commemorative postage stamp will be issued on January 30th, the last day of the Exhibition CHEMEX 2011 at BMICH. The stamp includes the IYC and IChemC logos. IYC 2011 also commemorates the centenary of the award of the Nobel Prize in Chemistry to Marie Curie, whose portrait as well as that of Prof. M U S Sultanbawa, one of the most distinguished Chemists of Sri Lanka, are included in the stamp. It contains the image of the Sri Lankan gem - the Blue Sapphire together with the structure of one of its chemical constituents, aluminium oxide (Al_2O_3).

Water is our life – Chemistry for sustainable consumption of water

Professor H. Dasaratha Gunawardhana

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1. Historical aspects of water conservation in Sri Lanka

The conservation of water in Sri Lanka commenced with the construction of the first reservoir by King Pandukabhaya (380 – 310 B.C.). He constructed the first 'wewa' or 'vāpi' (tank or reservoir) based on the knowledge of Science and Technology during that period. Since then there has been nearly 35,000 'wewa' or 'vāpi' (reservoirs) constructed in Sri Lanka. The conservation and the subsequent usage of the conserved water in this manner is unique to Sri Lanka and not found in Europe or American Continent. There are similar types of reservoirs in some Asian countries, but the scientific aspect is confined only to Sri Lanka. With the availability of water for healthy living and for irrigation agriculture (Food Security) the economic development was achieved during the Anuradhapura period. Subsequently it was also evident in the Polonnaruwa period. (King Parakramabahu the Great, 1153 – 1186 A.D.) 'Let not a drop of water be sent to the sea without utilizing it for the benefit of man kind' said King Parakramabahu the Great and constructed 'wewa' or 'vāpi' (reservoirs). 'Wewa' or 'vāpi' and 'Dagaba' were the main theme of the ancient sociological village unit concept in Sri Lanka which led to sustainable development. Two main objectives in the conservation of water are:

- (i) to provide water of suitable quality for irrigation during the dry season such that an uninterrupted agricultural activity with the production of food is maintained,
- (ii) to improve the health of the people by making the water of suitable quality available for domestic purposes.

It seems that an economic prosperity of ancient Sri Lankans was dependent on the conservation and subsequent continuous availability of water of suitable quality for human needs. Even today the conservation of water still plays a significant role in economy of the country through healthy living and food security. Therefore, the three terms "Water Quality, Water Conservation" and "Food Security" cannot be separated from one another. In his book on "*Environmental Aspects of Sri Lanka's Ancient Irrigation System*", Prof. C.G. Weeramanthri has stated that traditional **wisdom** has much to teach us. He further says that the concept of **sustainable development** was a part of our ancient culture associated with the irrigation agriculture. The modern international environmental law has only recently

appreciated the necessity of this concept of sustainable development and often discusses the concept as it is a modern invention. In the Sri Lanka context, sustainable development is "a reinvention of the wheel".

It is undoubtedly obvious that Science and Technology was directly responsible for the food security and economic development of Sri Lanka during that era. Those who are not familiar with Science wrongly argue that ancient Sri Lanka had only the Technology without Science. It is true that ancient Sri Lankans did not have the so-called **modern science** which is not more than 500 years old. The ancient technology was based on **unwritten science** and is not the modern science. The survival of the ancient technology was possible for several years due to its association with this unwritten form of science which would have been in some cases a kind of family secrets.

The survival of technology is dependent on science. The economic development through food security in ancient Sri Lanka was due to the application of 'Sciences' to the technological needs during that period. The concept of '**sustainability**', implies meeting human needs while preserving the environment and natural resources needed by **future generations**. Therefore, the technology based on the 'unwritten science' preserved the natural resources for us to use even after 2400 years i.e. sustainability. The unwritten science which led to the sustainable economic development in the ancient period does not exist today. Therefore, a need arises to apply modern science to ancient as well as modern technologies to meet the **current human needs** which are quite different from the human needs of our ancestors. The development of the so-called modern science during 19th and 20th centuries led to the changes of the human needs. The highest priority during this period was to meet the human needs at any cost. This was not the sustainable development. It was only during last two decades more emphasis was paid on the economic development by providing human needs without affecting the environment – sustainable development. The **sustainable development achieved during the ancient time** was completely ignored or disregarded. Often, the concept of sustainable development is taken as a modern invention. In fact, it is a concept regarded as a part of **our ancient culture**. It would be fruitful for us to have some understanding on the application of unwritten science to ancient technology in order to achieve economic development by the application of modern science which is familiar to us now for the existing technology.

2. The awareness of water quality:

Nearly 2400 years old irrigation agriculture which was responsible for sustainable development of Sri Lanka in the ancient time has not been given adequate consideration in the Education system in Sri Lanka. Is the irrigation water quality a part of our school curriculum? No! Because there are no 'wewa' or 'vāpi' (irrigation tanks or reservoirs) in United Kingdom or in United State of America. Sri Lanka blindly followed UK and USA and has taken no steps to incorporate irrigation water quality criteria in teaching even though we have about 35,000 'wewa' or 'vāpi' (irrigation water tanks). The Chemistry curriculum of the G.C.E. (A/L) is designed to maintain the International Standard such that students of the affluent families who fail to gain admission to local Universities may find places in foreign Universities without sitting for another examination. It is suitable for less than 4% of the students who pursue tertiary education. There is a very high resistance from many sectors in the revision of the curriculum suitable for local conditions such that about 96% students who could not gain admission to local Universities are benefited.

A report issued in advance to the Earth Summit, August 2002 in Johannesburg reveals that more than 76 million people, mainly children will die from water related diseases by 2020 unless urgent action is taken to clean planet's water supplies. The World Health Organization (WHO), in a report issued in 2000, estimated that there are already 4000 million cases of diarrhea each year, killing as many as 5 million people. It has been reported that the per capita availability of water in the Asian region has declined by 40-60 per cent from 1955 to 1990 (35 year period). If this trend continues there would be a severe water problem in Asia in the year 2025. Water like any other matter cannot be created or destroyed, but water can be made unsuitable due to pollution which will ultimately lead to insecurity on the availability of food. There is now a need to care water resources in Sri Lanka such that we will not face the anticipated water crisis in 2025. i.e. Preparedness! It has also been reported in Sunday Observer, 26th June 2005 that water shortages and water pollution cause four million deaths per year around the world. This means one person dies every eight seconds. The Science Education plays a vital role in the **preparedness** for such a disaster. Our school children are well aware of global warming, depletion of ozone layer etc. There are no direct deaths due to these atmospheric effects but these can affect developed (rich) countries. Therefore, developed countries ensure that these aspects are incorporated into teaching curricula by convincing the 'Educationalists' in Sri Lanka. In Sri Lanka, a student is well aware of the depletion of ozone layer, global warming but he is not aware of the quality of water he deals with, in his day to day life. The water pollution does not affect the

developed countries since they have very expensive modern methods to purify water. Since water pollution is a localized problem affecting us directly our 'Educationalists' are not convinced by the 'Consultants' from developed countries to incorporate water into the teaching curricula. Can we have an indigenous curriculum suitable for Sri Lanka taking all our aspects into consideration? The only way to increase the awareness of water quality is to incorporate it to school curricula disregarding the advice from so-called 'Consultants' from developed countries. This will ultimately help in the maintenance of the food security.

3. Water - the most important 'limited' natural resource.

The 'hydrosphere' is the collective term given to all the different forms of water on the earth's surface, whether oceans, shallow seas, lakes, rivers, groundwaters or glaciers. Less than 0.5% of the total hydrosphere is present on the continents as lakes and rivers. About 70% of the earth's surface is covered by the oceans thus constitutes 98.8% of the hydrosphere as marine waters. The major part of fresh water (0.7% of the hydrosphere) is trapped as fresh water glaciers, and only 0.5% of hydrosphere is available to fulfill our needs such as drinking, cooking, agriculture, industry etc. This is an estimate, it may be less today.

The oceans are linked with the other fresh water bodies in the hydrosphere through the hydrological cycle, in which water evaporates from the oceans into the atmosphere and falls as rains or snow on the continent and returns via rivers and lakes to the oceans again. The average composition of fresh and marine waters in the hydrosphere remains unaffected. A major percentage of fresh water is stored in aquifers as ground water resources. Groundwater is the traditional potable water resource for about 70% Sri Lankans. Surface water stored in reservoirs ('wewa' or 'vāpi') is the main source of water used for agriculture in Sri Lanka.

In many important aspects of public life the term "quantity" is always given a predominant position whereas the term "quality", applicable to the same aspect, is either ignored or not being given adequate consideration in Sri Lanka. This is true for water, which is the most important natural resource vital for life. However, some consideration is given for the quality of "potable" (drinking) water since there is an obvious undesirable effect of the potable water of poor quality, but little or no consideration is given for irrigation water quality in Sri Lanka even though we have about 35,000 'wewa' or 'vāpi' (irrigation water tanks or reservoirs). An example for the priority for quantity is given below. In the past 1000 years, about 100 hectares of paddy fields have been cultivated using water from a small tank ('wewa' or 'vāpi'). An irrigation scheme was introduced to this area about 50 years ago. In this program, a canal was diverted into the tank to increase the '**quantity**' which generally makes the cultivators

happy. The poor **quality** of water in this canal led to loss of soil permeability and the 100 hectares of paddy fields were abandoned. The villagers in the area who lost their paddy fields due to an attempt to increase the 'quantity' at the expense of the 'quality' by engineers provide evidence for such disaster. This is an example of a small scale loss of food security due to the poor quality of water used for irrigation. There is no guarantee that this type of disaster is not possible in large scale irrigation projects. Such disasters have occurred affecting millions of hectares in countries such as Pakistan, Egypt etc. This necessitates the incorporation of water quality in all aspects of the use of water to prevent such disasters.

4. Potable water quality:

The healthy living is directly related to the availability of potable water of suitable quality. Groundwater is the main source of drinking water for

about 70% Sri Lankans. The water in the 'wewa' or 'vāpi'(reservoirs), rivers and streams also provides drinking water for healthy life. River water is the main source of water in water supply schemes to many cities in Sri Lanka. In the past, the reservoirs ('wewa' or 'vāpi') also supplied drinking water during the long drought. Hydrogeological study shows that the nature of rocks affects the quality of groundwater. Dissanayake and Weerasooriya (1985) have reported that the groundwater in some areas of North-Central Province contains excessive amounts of fluoride. The health effects of these have been studied extensively. It is generally assumed that water is purified and becomes suitable for drinking by boiling. Boiling only makes the harmful pathogens inactive and occasionally reduces hardness due to the precipitation of calcium / magnesium carbonates. However, boiling cannot remove the ions listed in the WHO guidelines.

Table 1. Drinking water standards (WHO)

<i>Criterion</i>	WHO Recommended limit	International Acceptable limit	<i>Tolerance limit</i>
Total residue, mg dm ⁻³	500	1500	-
Turbidity, NTU	5	25	-
Alkyl benzene sulphate mg dm ⁻³	0.5	1.0	-
Arsenic (As) mg dm ⁻³	-	-	0.05
Barium (Ba) mg dm ⁻³	-	-	1.0
Cadmium (Cd) mg dm ⁻³	-	-	0.01
Calcium (Ca) mg dm ⁻³	-	200	-
Chloride (Cl) mg dm ⁻³	250	600	-
Chromium(Cr(VI)) mg dm ⁻³	-	-	0.05
Copper (Cu) mg dm ⁻³	1.0 – 2.0	1.5	-
Cyanide (CN) mg dm ⁻³	-	-	0.2
Fluoride (F) mg dm ⁻³	1.5	1.0 – 1.5	-
pH	6.5 – 8.5	6.5 – 9.2	-
Iron (Fe) mg dm ⁻³	0.3	1.0	-
Lead (Pb) mg dm ⁻³	-	-	0.05
Magnesium (Mg) mg dm ⁻³	-	150	-
Manganese (Mn) mg dm ⁻³	0.1 – 0.5	0.5	-
Nitrate (NO ₃) mg dm ⁻³	50	45	-
Phenolic compounds (as phenol) mg dm ⁻³	0.001	0.002	-
Selenium (Se) mg dm ⁻³	-	-	0.01
Sulphate (SO ₄) mg dm ⁻³	250	400	-
Zinc (Zn) mg dm ⁻³	3 - 5	15	-

The concept “*Respect Water*” helped the ancient Sri Lankan to re-use water without any adverse effect. It is now clear that the re-use of water today in domestic, agriculture and industrial spheres will lead to adverse effects. This is true for irrigation waters (the increase of SAR values and subsequent loss of soil permeability). It is also applicable to potable and industrial waters as well. A requirement thus arises to carry out continuous monitoring of water quality in all spheres of human activities. It is essential to incorporate 'Water Quality' in school curricula and the water quality testing can become a part of school projects.

5. Irrigation water quality

The largest user of water in Sri Lanka is irrigation agriculture. The irrigation water flows through a system of tunnels, streams, reservoirs ('wewa' or 'vāpi'), canals etc. before it reaches the field where crop is grown. During this flow some soluble salts are always dissolved in and the water becomes saline containing high dissolved salts. Man's activities such as industries, deforestation etc. in and around water flow **enhance dissolution of salts**. In the fields, the water will undergo evapotranspiration resulting the accumulation of dissolved salts, which will affect the soil properties especially the soil permeability and subsequently the crop growth. It has been reported that in countries such as Afghanistan, Pakistan, Egypt etc. **millions of hectares** of irrigated lands have been abandoned due to the loss of soil permeability which affected the crop growth. The previous example is the abandoning of about 100 hectares of paddy fields in Sri Lanka due to the loss of soil permeability. This may be possible in all the other irrigation schemes if the priority is given only for the quantity rather than the quality. Therefore, it is essential to take adequate precautionary measures, especially in the areas irrigated by Mahaweli waters, in order to prevent any such salt danger caused by the increased utilization of irrigation water resources. **Prevention is better and less expensive than cure.**

The Mahaweli irrigation project involves utilization of water of the Mahaweli Ganga to irrigate an extensive area of dry zone. When complete, the Mahaweli Development project is expected to supply water for the irrigation need of 900,000 acres for two crops a year. The master plan also envisages the generation of 2,037 million kilowatt hours of hydroelectric energy. The phase 1 of the project, (Kala Oya, Abanganga) covers 132,000 acres of existing lands and 91,000 acres of new lands. A monitoring programme was initiated in 1978 to check the quality of irrigation waters in the system H of the Mahaweli diversion scheme. The block 302 of the system H of the Mahaweli development scheme was selected for this purpose. It was reported that there is a remarkable increase of Sodium adsorption Ratio (SAR) and Residual sodium

Carbonate (RSC) values especially in the drainage waters in April and in November. This coincides with the Maha and Yala harvesting seasons of the system H. Usually, a heavy rainfall leads to the decrease of these values significantly. Balalu Wewa is the reservoir which supplies irrigation water to Block 302 through the left Bank Canal (L.B.C.). Seasonal variation of the filterable residue and total residual contents of waters from Balalu Wewa, Left Bank Canal and at the beginning of D₁ Channel of Block 302 shows similar trends. It was seen that there was an increase in the filterable residue as well as the total residue of the irrigation waters in April 1978 and 1979. The Maha harvest starts in March and ends in April. During this period the water supply to the field being completely cut off and consequently, as a result of rapid evaporation of existing water, the filterable residual content increases.

The knowledge of the quality of irrigation water is important in judging its suitability for irrigation. Suitability of irrigation water depends upon several factors associated with characteristics of water, soil, plant and climate, and can be expressed by the following relationship.

$$SI = f(QSPDC)$$

Where,

SI = Suitability of irrigation water,

Q = Quality of water i.e. the total salt concentration, cationic and anionic composition

S = Physico-chemical properties of the soil profile,

P = Salt tolerance characteristics of the crop plant at different stages of growth,

D = Drainage conditions.

C = Climatic parameter.

It is difficult to suggest a single water quality criterion because of the interaction of several factors. The degree of adverse effects on soil properties is mainly related to the chemical composition of irrigated water. The adverse effect of a particular quality water on soil-plant system depends upon the total salt concentration, relative proportion of sodium to other cations, boron concentration and bicarbonate content. Waters of low electrical conductivity are generally composed of higher proportion of calcium, magnesium and bicarbonate ions whereas those of high electrical conductivity contain mostly of sodium and chloride ions. The relative proportion of sodium to other cations is determined by the sodium adsorption ratio (SAR). Any increase in the SAR of irrigation water increases the SAR of the soil solution, which ultimately increases the exchangeable sodium by the soil leading to the loss of soil permeability by replacing calcium (and/ or magnesium) ions on the surface by sodium ions.

$$SAR = \frac{Na^+}{\sqrt{Ca^{2+} + Mg^{2+}}} \quad \text{where ionic concentration of each is in mmol dm}^{-3}.$$

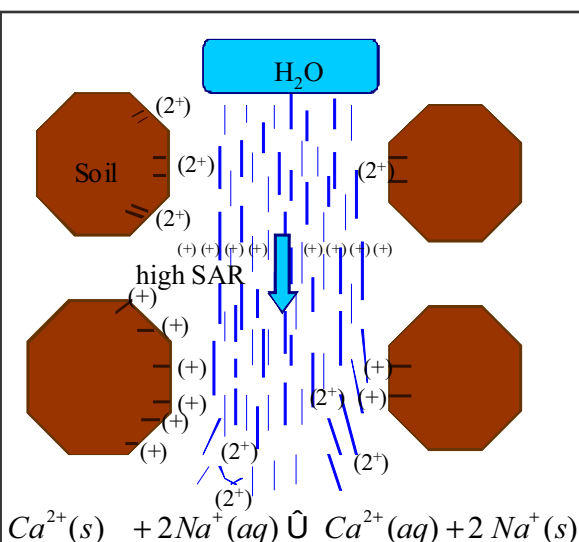


Figure 1: Illustration of the loss of soil permeability when waters of high SAR values are used for irrigation.

Table.2.: FAO Guideline for interpretation of water quality for irrigation.

IRRIGATION PROBLEM	DEGREE OF PROBLEM		
	No Problem	Increasing Problem	Severe Problem
Salinity (affects crop water availability) ECw (mmhos/cm)	< 0.75	0.75 – 3.0	> 3.0
Permeability (affects infiltration rate into soil) ECw (mmhos/cm)	> 0.5	0.5 – 0.2	< 0.2
adj. SAR (or ESP)			
Montmorillonite (2:1 crystal lattice)	< 6	6 – 9	> 9
Illite – vermiculite (2:1 crystal lattice)	< 8	8 – 16	> 16
Kaolinite – sesquioxides (1:1 crystal lattice)	< 16	16 – 24	> 24
Specific toxicity (affect sensitive crops)			
Sodium (adj. SAR)	< 3	3 – 9	> 9
Chloride (meq/dm ³)	< 4	4 – 10	> 10
Boron (mg/dm ³)	< 0.75	0.75 – 2.0	> 2.0

The history of the conservation of water in Sri Lanka could be traced to the reign of King Pandukabhaya (380 – 310 B.C.) who constructed the first reservoir ('wewa' or 'vāpi') at Anuradhapura. Thereafter, several hundred of reservoirs have been constructed mainly to conserve the rainwater. Very little evidence could be gathered on the construction of reservoirs by building dams across flowing streams or rivers. In such instances **a forest cover** was maintained in an around the streams carrying water to the reservoirs and also the canals which supplied water to paddy fields. The belief such as divine being living in trees assisted to preserve the forest cover. In addition, powerful dictatorship and good governance prevented people even clearing a forest. One method of **achieving sustainability** in the ancient irrigation projects is to maintain the forest cover. The modern science reveals that clearing of forest increases the sodium ion concentration of irrigation waters thus making the water unsuitable ultimately leading to loss of soil permeability. The ancient water management was based on this type of ancient scientific views (unwritten science).

Kalawewa is one such reservoir constructed by

King Dathusena (6th Century A.D.) by building a dam across a stream (presently Dambulu Oya – Kala Oya). He may have constructed this to fulfill his wishes and may have gone against the opinion of his advisors in making the decision. Three or four hundred years after the continuous use of Kala Wewa waters for irrigation, the Anuradhapura kingdom was shifted to Polonnaruwa. One could attribute reason for the shift is a crop failure due to the loss of soil permeability. The administrative failure during the period of 6 – 9 century resulted in the poor water management which ultimately led to the crop failure. The continuous irrigation with poor quality water and consequent crop – failure affected the agricultural economy in the Anuradhapura area, resulted the shift of the kingdom to Polonnaruwa in the 10th century.

The recurrence of large scale crop – failure can not be ruled out today. However, it is now impossible to shift the population in the affected area unlike in the 10th century. A possible crop failure today will lead the disaster and the destruction of the development achieved during last two decades. A proper water management programme guided by the results of continuous monitoring programme and water quality criteria undoubtedly, prevent such disasters.

In the case of a natural resource such as water it was revealed that the per capita availability has declined to alarming levels affecting the future generations. To maintain the sustainability without curtailing the current human needs it is essential to develop technologies on the reuse or recycling of water, effluent treatment processes etc. The development of such technology is impossible without the scientific knowledge on the water bodies. The immediate requirement is to assess the water quality and its seasonal variation by monitoring programmes and subsequent use of scientific principles to monitor the sustainability without a decrease in the per capita availability.

6. The “Preparedness” to prevent water crisis:

Daily News, Tuesday May 17, 2005

“Tensions over water will increase as scarcity increases, but outright conflict can be avoided” By Steve Loneragan

It is important to take following steps to prevent the anticipated water crisis in 2025.

- A gift from God – *Respect Water* – Not practicable today
- A suitable Legal framework – *Water Policy*
- The restructuring of economy away from water – intensive sectors – *A change of the crop pattern*
- The awareness of Water Quality – *Regular Monitoring*
- Regulations on Re-use – *Industrial recycling*

All ancient civilizations in the world were associated with water bodies such as rivers. The anticipated water crisis in 2025 can be mitigated by

regular water quality monitoring programmes which ultimately leads to the development of water quality criteria based on the human needs. These criteria will provide guidance for water management problems. The modern methods of this nature could be guided by the history which provides evidence for the existed excellent sustainable water management system without any, so called modern scientific inputs. It was really the input of unwritten science ('*Respect water*') to water management technology. Good governance in the ancient period prevented people even clearing a forest. One method of **achieving sustainability** is to maintain the forest cover. The modern science reveals that clearing of forest increases pollution of water thus making the water unsuitable. The ancient water management was based on this type of ancient scientific views (unwritten science). The re-introduction of good governance is essential to prevent the water crisis in 2025. The strict implementation of the Water policy plays an important role. It should be mentioned that all stakeholders including me should be accountable for use of water. The accountability should be a part of water policy. The accountability should be associated with the water entitlement. Historical aspects on this could be considered and a suitable modification could be made acceptable to all. The water quality cannot be generalized as 'quantity'. The water quality should be associated with the purpose that water is used. E.g. potable water quality, irrigation water quality, industrial water quality etc. Re-use of water especially by industries should be emphasized.

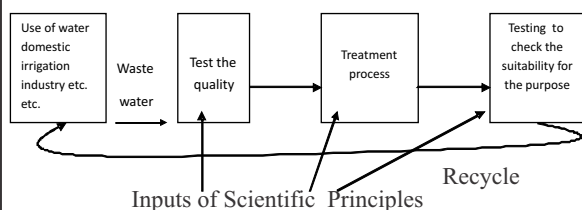


Figure 2: Recycling of water.

7. Conclusion:

The operation of the “water cycle” in the earth is affected and will be affected due to anthropogenic inputs. The regular monitoring of the quality of water in all parts of the island will be helpful to take timely remedial measures leading to a meaningful integrated development in 21st century. It is suggested that the water – quality testing should be carried out at provincial levels even as a part of school curriculum. The data even though may not be very accurate, will be useful in the water management programmes.

The existing nine provinces (regions) have been demarcated by British rulers without any basis. If the watershed of rivers would be the major criteria for the division of the country into provinces, each province can take adequate steps for proper water management thus prevent the pollution of water resources confined to it. The sustainable water

management will thus be a reality. In this way Sri Lanka can be divided into five regions (provinces).

1. **The Mahaweli region :** This includes the catchments of the Mahaweli river and Maduru Oya. The southern limit is the Morawewa catchments.
2. **The Ruhuna Rata region :** This would be the region east of Mahaweli including the catchments area of Walawe ganga and Matara district.
3. **The Maya Rata region :** This is the region south to Maha Oya including the present Galle district with an eastern limit of Mahaweli region.
4. **The Raja Rata region :** This comprises the area limited by Maha Oya in the south, Mahaweli region boundary in the east and the northern limit is the catchments area of Malwathu Oya.
5. **Yalpanam region :** This comprises of Jaffna Peninsula and Mannar area including the catchments area of Aruchi Aru.

There is also some historical evidence that the administrative division of the country was based on the water resources. Each administrative division (province) can optimize the use of its water resources without being polluted. This would be the first step that should be taken to safeguard the country against the severe water crisis in the future. Preparedness leads to the prevention or mitigation of Disasters. Prevention is always better than cure.

The historical records reveal that there were no human settlements in the central hill country over 800 hundred years ago (Fig. 3) The hill country was the reservoir of water feeding most of the man made wewas even during a severe draught.

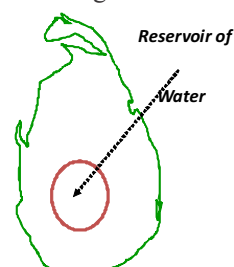


Figure 3: Central hill country was kept as a reservoir of water in the ancient times.

Should we reconsider the history for continuous availability of suitable quality water leading to uninterrupted food security? It is possible for us to export good quality water and earn much needed foreign exchange since Sri Lanka is the country blessed with the highest rainfall in the region.

It is also important to impose rules and regulations on the recycling of the water used by industries. In the case of a natural resource such as water, it was revealed that the per capita availability has declined to alarming levels affecting the future generations. To maintain the sustainability without curtailing the current human

needs, it is essential to develop technologies on the reuse or recycling of water, effluent treatment processes, etc. The development of such technology is impossible without the scientific knowledge on the water bodies. The immediate requirement is to assess the water quality and its seasonal variation by monitoring programmes and subsequent use of scientific principles to monitor the sustainability without a decrease in the per capita availability. The recycling of water should be a law. In the long run this will help in the maintenance of the food security.

8. References:

1. Geiger, Wilhem, “*Mahavamsa – The Great Chronicle of Ceylon*” Buddhist Cultural Centre

- Sri Lanka
2. Arumugam, S. (1976). Ground water observation in the Kala Oya basin. *Proceedings of Sri Lanka Association for the Advancement of Science, December 1976.*
3. Sri Lanka Standards Institution- Guidelines for the Surface & Groundwater Quality for Designated Uses of River Basins in Sri Lanka- Part 1: Kala Oya Basin (Draft Standards for Public Comments) December 2005.
4. Dissnayake, C.B. and Weerasooriya, S.V.R., (1985) *Hydro-geochemical Atlas of Sri Lanka*,
5. Central Environmental Authority- Guidelines for Water Quality 2003

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Dissolved oxygen in water: Its importance and detection

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Oxygen and water are our primary food supplies, and hence water we drink should be in pure form. Although the consumption of naturally oxygenated water provides many benefits to the humans, this valuable resource is removed during water purification processes, thus restricting the intake of oxygen with drinking water. Industrial development has also shown a negative impact on the naturally dissolved oxygen levels in water owing to the discharge of industrial chemicals, even if the effluent is properly treated, causing aquatic organisms to consume water with low levels of dissolved oxygen. It is therefore necessary to determine the levels of dissolved oxygen in water resources with high accuracy and precision. The Winkler method, the first reliable method reported more than 100 years ago, colorimetric methods and electrochemical methods are attractive in this regard.

Dissolved oxygen and mankind

The man used to drink surface water as the primary source of nourishment in the past, probably up to the mid 20th century. Surface water, which was in contact with the atmosphere, was available in springs, streams, lakes and rivers. Hence, it was naturally aerated, having dissolved oxygen levels (Dissolved oxygen index or DO) ranging from 4 to 14 ppm O₂ depending on atmospheric conditions. It can be argued that the development of mankind and consequently, the physiology and the biochemistry of the humans are strongly interconnected with the consumption of naturally oxygenated water. Nature has probably intended that the humans drink water with naturally dissolved oxygen and that our physiology is built accordingly.

Although the human body can function without

any solid food up to several weeks, it cannot go on without water longer than 2-3 days, and without oxygen in air for even several minutes. It is undoubtedly stated that drinking water must be clean and fresh, meaning that it should have no dissolved chemicals, and that it should be enriched with natural oxygen. However, this requirement is only partially reached in many instances, because unnecessary substances together with oxygen are removed from water at high expenses during water purification processes. In some processes, dissolved gases including oxygen are removed, and carbon dioxide is subsequently added. Carbon dioxide in water not only improves the taste, but also improves the shelf life.

Dissolved oxygen and medical observations

It is alarming to see the number of especially young individuals suffer from some kind of depression. There seem to be a problem in the metabolism of the brain in victims of depression. Although it is not conclusive, consumption of naturally oxygenated water works in favor of many functions of human body without any side effects, and more importantly, the following positive effects are reported.

- It supports the microcirculation of the blood.
- It is antibacterial and antiviral.
- It supports the regeneration of tissue.
- It participates in detoxification processes.
- It regulates blood pressure.
- It improves metabolism.
- It raises the energy supply of cells.
- It improves physical fitness.
- It eases radiation damage.
- It reduces negative effects of air pollution.
- It is interconnected with vitamin deficits.

- It reduces negative side effects of drugs.

The above list which could continue with many more positive effects compel the humans to respect and live within the natural oxygen limits in water as well as in air.

Industrial development and water pollution

With the continuous development of industrial activities, which has become a necessity to meet the demand of the humans in the modern world, surface water sources have become polluted. Even if treated industrial effluents are in conformity with the guidelines imposed by authorities, treated water is not as pure as unpolluted water that was existent in the past. Nevertheless, water treatment is necessary to prevent many undesirable effects, such as water-borne diseases, bioaccumulation of heavy metals, eutrophication, contamination of soil, etc. Consequently, consumption of surface water cannot be recommended in many instances.

It has become routine that many urban population consumes bottled water although relatively pure natural water or pipe water may be available, which is partly due to the conception that bottled water is free of pollutants. Properly prepared bottled water would not probably contain pollutants - however, bottled water would not have natural concentration of oxygen. The reader should thus decide what water to be consumed.

Effect of dissolved oxygen on aquatic life

Although the humans have the option to consume purified water, bottled water, or any other form of water of their choice, aquatic organisms do not have this option because they have to consume water in which they live. Dissolved oxygen is absolutely essential for the survival of all aquatic organisms, such as fish, clams and zooplankton, etc. How much DO an aquatic organism needs depends on its species, its physical state, water temperature, types and concentrations of pollutants present, and many more. For example, trout use about 50 mg of oxygen per hour at 5 °C, which is increased five to six times when the temperature of water is increased up to 25 °C. Research on this subject indicates that 4-5 ppm of DO is the minimum amount required for the survival of fish population. When the DO level in water drops below 5.0 ppm, aquatic life is put on stress, and when it drops below 2.0 ppm, no aquatic life would probably survive.

Determination of dissolved oxygen

Having a high DO level in water is important on human life, aquatic life and other forms of life. Measurements of oxygen are thus important in many diverse fields as shown below:

- Determination of the quality of potable water
- Assessment and monitoring of patient health (by

- monitoring partial pressure of O₂)
- Monitoring of activity of sewage treatment plants
- Spoilage determination and quality control of food
- Biosynthetic pathways of some pharmaceuticals
- Environmental control

Consequently, among many different types of water quality parameters, DO level in water is arguably among the most important water quality parameters.

The solubility of oxygen in pure water is calculated using the Henry's law, which considers the equilibrium of molecular oxygen between the two phase system of air and water, as shown in Equation (1).

$$K_H = \frac{P_{O_2}}{[O_2]_{aq}} \quad (1)$$

where K_H is the Henry's law constant, which is temperature dependent, P_{O_2} is the partial pressure of oxygen and $[O_2]_{aq}$ is the concentration of molecular oxygen in the aqueous phase, which is the solubility of O₂ in water. The solubility of O₂ at different temperatures is shown in Figure 1.

The experimental DO values are less than that is calculated by theory because there is no pure water available in the world. Higher the level of pollution, higher the deviation of the actual DO value from that of the solubility. Salinity also affects the solubility of oxygen in water, and about 20% decrease in DO levels is expected between fresh water and sea water, which has an average salinity of 35 parts per thousand (35,000 ppm) as shown in Figure 1

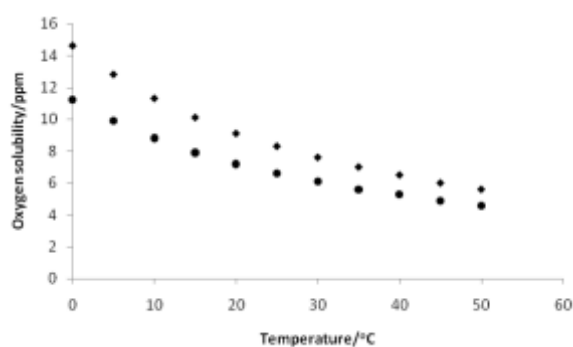


Figure 1: Comparison of oxygen solubility in fresh water (♦) and sea water (●).

Therefore, it is always a necessity to determine the DO value of water experimentally. The experimental methods used should not only be accurate and precise, but also be quick and economical. Before the advent of polarography, only classical wet-chemistry techniques were available for the determination of O₂. The first standard test for DO was reported in 1888 by L.W. Winkler, colorimetric and amperometric methods for the determination of DO have later become attractive.

Winkler method

The Winkler method is still used almost exclusively in many disciplines. It is a titrimetric method based on three redox reactions. According to the original procedure, Mn^{2+} , added at the sampling point, is oxidized by molecular oxygen in basic medium, and upon subsequent acidification, iodide is oxidized to free iodine by the oxidized Mn^{2+} . The free I_2 is then determined by titration with thiosulfate.

This method has been subject to some criticisms and modifications since its inception. One modification that has now been used is the addition of azide ions to minimize the interference of nitrite ions. Nitrite, in the absence of azide, oxidizes iodide to iodine giving higher apparent oxygen values. Another important aspect of this determination is that the medium pH should be above 2, to avoid aerial oxidation of iodide, which would also result in high apparent oxygen values. Although many other methods have been developed, the Winkler method with azide modification is probably the most-used analytical method in chemistry of natural waters.

When oxygen concentrations are less than 10% of the saturation value, the Winkler method is imprecise. In this context, atmospheric contamination should be avoided as much as possible, and special analytical and sampling procedures must be used. The colorimetric method developed for the determination of DO has addressed these issues.

Colorimetric method

This method is based on the determination of absorbance of triiodide ion at 352 nm that is produced when Winkler reagents are added. To avoid the contamination of atmospheric oxygen and other contaminants, samples are drawn into syringes as soon as sampling is done into bottles. Further, to minimize oxygen contamination of reagents, which would be significant at low oxygen levels, all reagents are saturated with dry N_2 and stored in closely tight bottles. This method has been used to determine oxygen concentrations up to 0.05 ppm with a low relative standard deviation of 1%. In this determination, phosphoric acid is used as it permits better pH control.

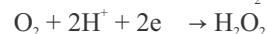
In some oxygen deficient environments, compounds are present that can produce or remove iodine. Substances such as sulfite, thiosulfate and sulfide reduce I_2 resulting in low DO values. Separate analysis is thus required to determine the iodine equivalence of these interfering substances.

Electrochemical methods

Heyrovsky's work with the dropping mercury electrode (in polarography) in the early 1920's was conducive to the acceptance of electrochemistry as a routine analytical tool. He was able to identify the direct relationship between DO level and limiting current, suggesting that polarography can be used for the determination of DO.

Clark electrode is one of the first membrane-covered amperometric oxygen sensor, invented by

Clark in 1954, and patented in 1956. It consists of a permeable membrane selective to O_2 . The mechanism of detection is amperometry, where the current associated with the electrochemical reduction of O_2 .



at a constant potential is used for the determination of the DO level in water, while the extent of the chemical reduction of O_2 is used in the classical method.

There are many advantages of using the O_2 electrode as compared to the chemical method. It can be used as a sensor, recommended for field measurements, fast and simple and can be interfaced to a computer. However, the chemical method is more reliable.

The major components of the oxygen electrode are the O_2 permeable membrane (e.g., Teflon, polyethylene, silicone rubber, cellophane or silica gel), a filter paper soaked with the electrolyte, a platinum working electrode and a silver reference electrode. Two point calibration is usually performed for measurements of DO using an air saturated solution (maximum response) and a deoxygenated solution (minimum response). In certain instances, oxygen meters are calibrated against air.

Many O_2 sensors have been developed using a variety of materials and configurations, yet using the same chemical principle used by Clark. Modern commercial models have digital display of the measurement in ppm O_2 or % O_2 saturation with a high resolution of 0.01 ppm together with automatic temperature compensation. Water resistant electrodes are also available with 4 to 10 m long cables for direct measurements of O_2 in water at different depths.

It is predicted that DO level would continue to be one of the most important water quality parameters. Purified water recommended for consumption would, in future, include the DO index in addition to other parameters.

References

1. C. Hecht, *Water with Naturally Dissolved Oxygen*, Society of Naturopathy, Germany, 2000.
2. E. Moosavi, V. Martirosyan, S. Ayrapetyan, *Int. J. Biol. Biomed. Eng.* **3** (2009) 1.
3. Why oxygen dissolved in water is important, Lenntech Water Treatment and Purification Holding, The Netherlands (www.lenntech.com/index.htm - searched on 15/12/2010).
4. Oxygen solubility in fresh and sea water (www.EngineeringToolBox.com – searched on 05-01-2011)
5. L. W. Winkler, *Deut. Chem. Ges.* 21(1888)2843.
6. L. S. Buchoff, N. M Ingber, J. H. Brady, *Anal. Chem.* 27(1955) 1401.
7. I. M. Kolthoff and J. J. Lingane, *Polarography*, 2nd ed., Vol. 2, Interscience, NY, 1952.
8. L. C. Clark, *Biosensors Bioelectronics* **8** (1993) 3.
9. D.T. Sawyer, R.S. George and R.C. Rhoades, *Anal. Chem.* **31** (1959) 2.
10. D. Falck, *Curr. Sep.* **16** (1997) 19.

e-waste; The next tsunami

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Introduction

Prior to 25th of December 2004, tsunami was an unknown phenomenon to Sri Lankans. When tsunami waves struck the coastal belt of this paradise island, Sri Lanka, people were unaware of how to respond to it. The ignorance of the general public contributed to a high death toll which could have been reduced significantly if people had known about this natural disaster. The nonchalant general public in Sri Lanka was of the view that natural disasters are limited to landslides floods and droughts. In fact as children we used to sing a song which says that there are no volcanoes or earth quakes in Sri Lanka. The school text books also stressed this fact. The normal situation has now been changed, in addition to frequent flooding episodes, landslides and periodical droughts primary stages of the volcanoes (as hot springs) do exist and several minor tremors have been reported during the last decade. The greatest natural devastation was due to the tsunami in 2004.

To worsen the situation, the anthropogenic inputs aggravate the existing natural disasters paving the way for more disasters. This prompts the establishment of a cabinet ministry on disaster management. Excessive use of pesticides & fertilizers, polythene menace, outdoor air pollution due to emissions from industries and motor vehicles (photochemical smog), indoor air pollution due to indoor activities (silent killer), contamination of ground water due to effluents and improper waste management practices are among the disasters that can be counted as non-natural or anthropogenic disasters. Much of these non-natural disasters are linked to industrialization, urbanization and population growth. In today's context, these cannot be eliminated, but minimized with the understanding of the problems by controlling the possible sources (inputs) while favoring the sinks (removals or eliminations). The scope of this article is twofold. One is to stimulate researchers to investigate the impact of pollution on the environment and people while finding solutions to abate the problems. The second is to educate and alert the general public on the e-waste problem in order to ensure their health and well being.

e-waste

The term "e-waste" is used to identify all the waste originated from electronic and electrical equipment and related accessories. The impact of e-waste has already been witnessed by the developed countries and they are attempting to mitigate the problem by dumping e-wastes in poor countries. Rapid technology change, low initial cost, high obsolescence rate have resulted in

e-waste being the fastest growing problem, making yesterday's electronic dream machines become today's environmental nightmare. The average obsolescence rate for a computer is estimated to be 7 years, and it is 15 years for a television, a refrigerator or a washing machine while a mobile phone has a life span of 1.5 years only. The developing countries are recipients of the second hand (used but still workable) electronic equipment and their growing economic status compel them to use more sophisticated equipment which were not in their possession in the past. These countries, including Sri Lanka, are yet to experience the severity of the problem. The poorest countries who are depending on donor countries for their technological developments have automatically become the recipients of the outdated or used electrical and electronic equipment.

Some countries including China, Malaysia, India, Kenya, Ghana and various African countries are becoming the recipients of the e-waste from the developed countries. The environmental impact to these nations will be much more severe than the mere gains for them by accepting to recycle or dump (land fill) them into their lands. Guiyu in the Shantou region of China, Delhi and Bangalore in India as well as the Agbogbloshie site near Accra, Ghana have electronic waste processing areas. Uncontrolled burning, disassembling, and disposal can cause a variety of environmental problems such as groundwater contamination, atmospheric pollution, or even water pollution either by immediate discharge or due to surface runoff, as well as health problems including occupational safety and health effects among those directly involved, due to the methods of processing the waste. Thousands of men, women and children are employed in highly polluting, primitive recycling technologies, extracting the metals, toners and plastics from computers and other electronic waste.

e-waste in Sri Lanka

Sri Lanka has a severe impact from both the electronic and electrical waste including unwanted, obsolete or unusable electronic products electrical accessories such as computers, computer peripherals, televisions, VCRs, DVD players, stereo equipment, cellular phones, refrigerators, condensed fluorescence bulbs and batteries. Along with the open economy, there was a boom of importing electrical and electronic equipment to the nation in the 80's. Nearly all of them have become unusable or outdated and started compiling them as waste or have dumped along with non e-waste contaminating soil and water. In terms of

electronic equipment, the philosophy of “new and improved” creates “old and obsolete” leads to the simple realization that what was once a prized possession is now of little worth. Although the products themselves may not physically change society's perception, the perception moves from “*highly sought after material possessions*” to discarded “*unwanted junk*”. Every discarded, unwanted, piece of electronic “junk” is a self-contained toxic container. In order to understand the gravity of the problem let's take several hazardous components of e-waste and discuss their environmental impact along with the damage to human health.

Lead in e-waste

Lead is commonly used in the electrical and electronics industry in solder, lead-acid batteries, electronic components, cable sheathing, in the glass of cathode ray tubes (CRTs) *etc.* In addition, mobile phone coatings are often made up of lead; hence if unusable phones are disposed of in landfills, it will result in lots of lead being released to the environment which is indeed harmful. CRT originally developed by German scientist Karl Braun in 1897 is a vacuum tube in which images are produced when an electron beam strikes a phosphorescent surface. In a CRT, lead is primarily used to shield users from harmful X-ray. The total lead in a CRT constitutes, on average, 0.9 kg for a 17 inch monitor. Unbroken CRT tubes are relatively safe and do not release lead to the environment but crushing CRT glass releases solid lead into the environment. Thus the CRT is not suitable for land filling and it must be recycled to recover the lead, glass and other components in the CRT.

An adult human body (70kg) contains approximately 0.08 g of lead. Moderately increased lead concentrations become toxic from the health point of view. The large affinity of Pb^{2+} for thiol and phosphates containing ligands inhibits the biosynthesis of heme and thereby affects membrane permeability of kidney, liver and brain cells. Thus the disruption of the biosynthesis of hemoglobin, a rise in blood pressure, miscarriages, disruption of nervous system, brain damage, declined fertility of men through sperm damage and behavioral disruptions of children, such as aggression, impulsive behavior and hyperactivity are common health problems associated with lead exposure. Short-term exposure to high levels of lead can cause vomiting, diarrhea, convulsions, coma or even death. Continued exposure can affect the kidneys. At high levels, inorganic lead is a general metabolic poison. Lead is particularly dangerous for young children because it can damage nervous connections and cause blood and brain disorders. Lead breaks the blood-brain barrier and interferes with the normal development of brain in infants lowering the IQ levels in children. Moreover, lead is transferred post-natally

from the mother in her breast milk.

Mercury in e-waste

It is estimated that 22% of the yearly world consumption of mercury is used in electrical and electronic equipment. It is basically used in thermostats, position sensors, relays and switches (e.g. on printed circuit boards and in measuring equipment) and discharge lamps. Furthermore, it is used in data transmission and telecommunications and in mobile phones. The lighting and electrical equipment contributed an estimated 11% to total anthropogenic mercury emissions to air in Europe in the mid 90s. Many laptops have a small fluorescent lamp in the screen that contains mercury, which is toxic when inhaled or digested. Mercury is also found in computer circuit boards, along with lead and cadmium. Circuit boards can also include batteries made of mercury, as well as mercury switches. Many computer chips contain semiconductors that are made up of various poisons such as gallium arsenide, cadmium and beryllium and mercury.

Perhaps the one of the biggest mercury inputs to the environment in Sri Lanka is through the dumping of used compact fluorescence bulbs (CFLs). One CFL contains an average of 4 mg of mercury. This mercury is essential to a fluorescent bulb to emit the light efficiently where most of the other metals fail. As effective as light emitting, mercury is toxic to humans; it is especially harmful to the brain of both fetus and children. High exposures of mercury vapour can cause brain, kidney and lung damage to adults as well. Mercury being a semi-volatile metal, escaping of gaseous mercury from CFLs can pose a greater threat to the environment and human health. The nervous system is sensitive to metallic mercury. An excess of mercury in the atmosphere and water can cause problems in the future which include breast milk and hence the newborns, brain and kidney damage in adults. In addition to the vaporised mercury, methylated mercury easily accumulates in living organisms and concentrates through the food chain particularly via fish. Methylated mercury causes chronic damage to the brain.

Cadmium in e-waste

Cadmium is present in most components of the computer. It is used as a plastic stabilizer. Mobile phone batteries were originally composed of nickel and cadmium (Ni-Cd batteries). Cadmium is listed as a human carcinogen that causes lung and liver damage. Alternatives contain potentially explosive lithium or toxic lead. Cadmium is absorbed through respiration or through passive ingestion. Due to a long half-life in the body, cadmium can easily be accumulated in amounts that cause symptoms of poisoning. The primary health risks of long term exposure are lung cancer and kidney damage. Cadmium is also believed

to cause pulmonary emphysema and bone disease.

Beryllium in e-waste

Much of the beryllium produced is used in the computer, telecommunications, and automotive electronics industries. Many computer chips contain semiconductors that are made of various poisons such as gallium arsenide, cadmium and beryllium and mercury. Beryllium is present in electronic equipment as copper-beryllium alloy having 2-4% of beryllium and beryllium oxide. Beryllium is released when shredded. Beryllium oxide is released from copper-beryllium alloy when metals are heated. Beryllium is known to cause an acute or chronic disease affecting the lungs. Beryllium has recently been classified as a human carcinogen. The primary health concern is inhalation of beryllium dust, fumes or mist. Workers who are constantly exposed to beryllium, even in small amounts, and who become sensitised to it can develop what is known as chronic beryllium disease (beryllicosis), a disease which primarily affects the lungs. Exposure to beryllium also causes a form of skin disease that is characterised by poor wound healing and wart-like bumps.

Arsenic in e-waste

Arsenic is used in small quantities in the form of gallium arsenide within light emitting diodes. Arsenic is a poisonous metallic element which is present in dust and soluble substances. Chronic exposure to arsenic can lead to various diseases of the skin and a decrease in nerve conduction velocity. Chronic exposure to arsenic can also cause lung cancer and can often be fatal.

Barium in e-waste

Barium is used in spark plugs, fluorescent lamps and "getters" in vacuum tubes. Barium is highly unstable in the pure form and it forms poisonous oxide when in contact with air. Short-term exposure to barium could lead to brain swelling, muscle weakness, damage to the heart, liver and spleen. Animal studies indicate increased blood pressure and changes in heart from ingesting barium over a long period of time.

Polyvinyl chlorides in e-waste

Polyvinyl chloride (PVC) is the most widely-used plastic in everyday electronics and appliances and is hazardous because it contains up to 56% chlorine. The use of PVC in computers is mainly in cabling and computer housings, although most computer moldings are now being made of ABS plastics. PVC cabling is used for its fire retardant properties, but there are concerns that once alight, fumes from PVC cabling can be a major contributor to fatalities, and hence there are pressures to switch to alternatives for safety reasons. Such alternatives are

low-density polyethylene and thermoplastic olefins. When burned, PVC produces large quantities of hydrogen chloride gas, which combines with water to form hydrochloric acid and is dangerous because when inhaled leads to severe respiratory problems. Incineration is used as a common method of disposing of PVC containing materials and plastics, but, incineration leads to formation of hazardous dioxins and furans which is accelerated by the presence of Cu as a catalyst.

Brominated flame retardants in e-waste

The three main types of brominated flame retardants used in electronic and electrical appliances are polybrominated biphenyls, polybrominated diphenyl ethers (PBDEs) and tetrabromobisphenol-A. These flame retardants make plastics materials more flame resistant. In computers, they are used mainly in four applications: in printed circuit boards, in components such as connectors, in plastic covers and in cables. Various scientific observations indicate that PBDEs might act as endocrine disrupters. Research has revealed that levels of PBDEs in human breast milk are doubling every five years and this has prompted concern because of the effect of these chemicals in young animals. Other studies have shown that PBDEs, like many halogenated organics, reduce the levels of the hormone thyroxine in exposed animals and have been shown to cross the blood brain barrier in the developing fetus. Thyroid is an essential hormone needed to regulate the normal development of all animal species, including humans. Major electronics manufacturers have begun to phase out brominated flame retardants because of their toxicity. These flame retardants have been found in indoor dust and air through migration and evaporation from plastics. Combustion of halogenated case material and printed wiring boards at lower temperatures releases toxic emissions including dioxins which can lead to severe hormonal disorders.

Polychlorinated biphenyls in e-waste

Polychlorinated biphenyls (PCBs) are a class of organic compounds used in a variety of applications, including dielectric fluids for capacitors and transformers, heat transfer fluids and as additives in adhesives and plastics. PCBs have been shown to cause cancer in animals. PCBs have also been shown to cause a number of serious non-cancer health effects in animals, including effects on the immune system, reproductive system, nervous system, endocrine system and other health effects. PCBs are persistent contaminants in the environment. Due to the high lipid solubility and slow metabolism rate of these chemicals, PCBs accumulate in the fat-rich tissues of almost all organisms (bioaccumulation). The use of PCBs is prohibited in some countries, however, due to its wide use in the past, it can still be found in waste

electrical and electronic equipment as well as in some other wastes.

Hazardous by-products from burning of e-waste

Dioxins and furans are a family of chemicals comprising 75 different types of dioxin compounds and 135 related compounds known as furans. Dioxins are taken to mean the family of compounds comprising polychlorinated dibenzo-p-dioxins (PCDDs) and furans are polychlorinated dibenzofurans (PCDFs). Dioxins have never been intentionally manufactured, but form as unwanted by-products in the manufacture of substances like some pesticides as well as during combustion. Dioxins are known to be highly toxic to animals and humans because they bio-accumulate in the body and can lead to malformations of the fetus, decreased reproduction and growth rates and cause impairment of the immune system among other things. The best-known and most toxic dioxin is 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8 TCDD).

Handling e-waste

In the US in 2005, 42 million computers were discarded. From which a 4 million were recycled, 13 million of them were used in land filling, a 0.5 million were incinerated while others were shifted out of the country.

In developed countries, electronics recycling takes place in purpose-built recycling plants under controlled conditions. In many European countries for example, plastics from e-waste are not recycled to avoid toxins being released into the atmosphere. Though recycling can be a good way of reusing the raw materials in a product, hazardous chemicals in e-waste can harm workers in the recycling yards, as well as their neighboring communities and the environment. In developing countries, most of the recycling is done by hand in scrap yards, often done by children. In Sri Lanka, small scale recycling is done to recover valuable components of e-waste.

When electronics are thrown out, many end up in landfills. More than 4.6 million tons of e-waste ended up in U.S. landfills in 2000. In many European countries, regulations have been introduced to prevent electronic waste being dumped in landfills. However, the practice still continues in many countries. In Hong Kong, it is estimated that 10-20 percent of discarded computers go to landfill. Land filling is a major threat to the environment because the chemicals can leach into soils and water contaminating them.

Incineration (burning) is a poor practise of handling e-waste. Most electronics contain heavy metals which are toxic when burnt. Highly toxic fumes are released from heavy metals to the air causing respiratory and skin problems. Incineration produces toxins which bioaccumulate in the food chain particularly in fish which is a major route of exposure for the general public.

Electronics are shipped to developing countries for their use. Through reuse, the life span of electronics can be increased but only negligibly. Unfortunately, 25% -75% of electronics that are shipped to developing nations are obsolete. These obsolete products end up in landfills resulting in environmental problems. People in developing nations are exposed to toxic chemicals remaining in the product causing many human health problems.

Final thoughts

We live in a fast-paced world and life is made easier by utilizing a host of technologically based products. Once these electronic and electrical products are discarded they become e-waste or can be considered as hazardous chemical waste products. With the technological development, the number of e-products is increasing and their life is decreasing. Hence, e-waste piles are growing, as is their pollution potential. The only way to minimize e-waste is by applying the three R's in waste management, namely reducing, reusing and recycling. Reduction of e-waste is through the good maintenance of the e-products, optimizing the life span. In the case of computers, upgrading the existing one diminishes the demand for new ones and their commensurate requirement for virgin raw material. However, the temptation of getting a new one or advancing the capabilities through the improved e-system is the biggest obstacle in reducing e-waste. A better option is to reuse the electronics rather than dumping. But reuse is a temporary solution for e-waste. Perhaps the best option for e-waste is recycling which not only reduces the volume of the e-waste but also recovers the valuables. In recycling, electronics are broken down into individual pieces, which need to be done under controlled conditions safeguarding the workers.

Taxing the manufacturers, vendors and the distributors is a common procedure to handle the extra burden of e-waste. This process will be useless unless it is implemented properly. It is unfortunate to note that the customers are taxed and they do not receive the benefits of taxing. Often both the customer and the rest of society have to absorb the environmental burden and pay with their health. Although incineration of hazardous waste is limited in the country, but, the uncontrolled open burning of e-waste must be banned. Authorities must not think about land filling or dumping of e-waste unless proper procedures are followed. Proper collection of e-waste (with minimum or without other types of waste) must be initiated after establishing appropriate safe handling procedures and protocols. Authorities must discourage the importation of the second hand products which end up in landfills with minimum benefits to the country. The country must not accept e-waste from developed nations and monitoring is required to avoid the illegal transfer of e-waste. As a responsible signatory of the

Basel Convention (adopted in 1989 and entered into force in 1995 calling for self sufficiency in waste management and to minimize trans-boundary movement of hazardous waste), accepting or dispatching of e-waste and hazardous materials must be prevented to safeguard the health and the environment.

It is true that one cannot save the world, but one can contribute to help save it by contributing in small ways. In the case of e-waste it is a severe problem which requires immediate attention before it becomes another catastrophe. In order to safeguard our environment it is time to regulate the mechanisms for a safer disposing of e-waste. In parallel, a good understanding is required about the health issues and other implications. Creating a sound public awareness and the commitment of the public and private sectors are two of the vital factors in reducing the damage by e-

waste. Finally, let's not forget that “**Prevention is better than cure**”

References

1. Hicks, C; Dietmar, R.; Eugster, M. (2005) The recycling and disposal of electrical and electronic waste in China -legislative and market responses, *Environ. Impact Assess. Rev.* **25** (5): 459–471.
2. Leung, A.; Cai, Z.W.; Wong, M.H. (2006) *Environmental contamination from electronic waste recycling at Guiyu, Southeast China, J. Mater. Cycles Waste Manage.* **8**:21–33
3. Liu, Q.; Li, K.Q; Zhao, H; Li, G; Fan, F.Y. (2009) *The global challenge of electronic waste management, Environ. Sci. Pollut. Res.* **16**:248–249

Green Chemistry for human well-being

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Introduction

Many of our basic daily needs are based on chemical products and when we move on to a luxurious life, we have to depend more and more on chemical products. During the manufacturing processes of many such chemical products in the past, formation of waste, consumption of non-renewable resources, consumption of energy, life cycle of the product, etc. have not been taken in to consideration. After the occurrence of many environmentally unfriendly incidents and health hazards, scientists came to the conclusion that chemical industries are among the largest sources releasing hazardous waste into air, water and land, which are responsible for many of the present global environmental problems and health issues. As a result, to protect the environment and to ensure a healthy population, environmental legislations have been enforced with a view to develop environmentally friendly chemical manufacturing processes and products. Green chemistry paves the way for chemical industries to find solutions, which enable them to conform to such environmental legislations.

Twelve principles of Green chemistry

There are twelve principles of Green chemistry proposed by Anastas and Warner (1998), which are as follows.

- Prevent waste
- Maximise atom economy
- Design less hazardous synthesis
- Preserve efficacy, while reducing toxicity
- Avoid the use of auxiliary substances wherever possible or use safer solvents
- Increase energy efficiency

- Use renewable feed-stocks
- Avoid/reduce derivatives
- Use catalysts, not stoichiometric reagents
- Design products which will degrade after usage
- Real time analysis for pollution prevention
- Minimize the potential for accidents

The above twelve principles indicate that the major role of green chemistry is an application of a series of reductions as summarized in figure-1.

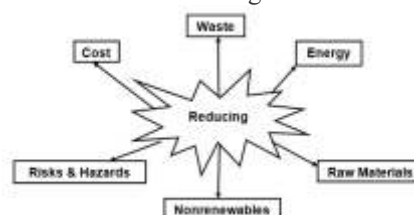


Figure 1: Major reducing roles of Green chemistry

Green chemistry for well-being of humans

Application of green chemistry to chemical industries, ensures the well-being of humans, by providing economic, environmental and social improvements.

Green Chemistry for economic improvements



Figure 2: Application of green chemical concepts for economic improvements

Atom economy, E-factor and/or EMY to improve efficiency of a chemical process

The efficiency of chemical processes in a chemical industry directly affects the economy. Calculation of the % yield is the traditional method of determining the efficiency of a chemical process, which does not take in to consideration the amount of waste formed. Industrialists have to spend large sums of money on treatment of waste. Green chemical concepts such as atom economy, E-factor (environmental factor) and EMY (effective mass yield) determine the most efficient method, while taking steps to minimize waste, which helps to improve the economy.

$$\text{Atom economy} = \frac{\text{FW of the desired product}}{\text{Combined FW of starting materials}} \times 100\%$$

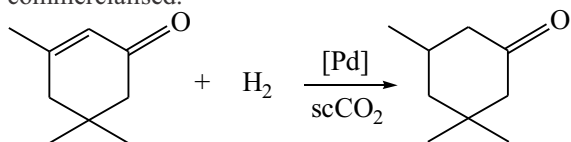
$$\text{E-factor} = \frac{\text{kgs of waste produced}}{\text{kgs of desired product}}$$

$$\text{EMY} = \frac{\text{mass of desired product}}{\text{Mass of non-benign reagents}} \times 100\%$$

Addition reactions and rearrangement reactions give 100% atom economy as all the atoms in the raw materials are incorporated into the product. Elimination and substitution reactions result in low atom economy as certain atoms of the raw materials are not incorporated into the product. Therefore, it is advisable to use addition reactions and rearrangement reactions in the chemical manufacturing process, wherever possible. The EMY suggests that the number of steps should be reduced, which would help to reduce the use of various types of solvents at different steps.

Application of greener solvents to increase the rate of the reaction

Application of greener solvents, instead of conventional solvents can increase the rate of the reaction in some chemical processes, due to their specific properties. For example, super critical CO₂ (scCO₂) is miscible with hydrogen and as a result, when scCO₂ is used instead of conventional solvents, rate of diffusion and therefore the rate of the following reaction increases. This method is now commercialised.



Application of biocatalysts

Biocatalysts such as enzymes produce less waste and therefore cost for waste treatment will be minimised. For example, lactic acid is biocatalytically produced by using renewable raw-material corn and non toxic chemicals and it forms less waste.

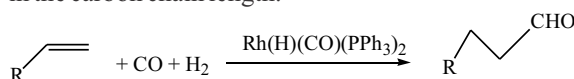
Reduction of consumption of power and energy

It is necessary to take steps to reduce consumption of power and energy in chemical processes in order to improve the economy. Ultrasonic and microwave reactors are possible alternative energy sources. Another possibility is to use biocatalysts, as they are very efficient under mild conditions.

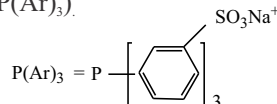
Application of biphasic/multiphase systems

Many catalysts used in fine chemical manufacturing processes are expensive and recovery and reuse of the catalyst are economically and environmentally important. In a biphasic system, the catalyst gets dissolved in one liquid phase and the reactants and the product get dissolved in the second liquid phase. Thus biphasic system would help to reuse expensive catalysts. Different combinations of water, scCO₂, ionic liquids and fluoruous solvents are used as biphasic/multiphase systems.

Hydroformylation of alkenes in traditional way requires Rh(H)(CO)(PPh₃)₂ as the catalyst and separation of the catalyst is difficult with the increase in the carbon chain length.



Above hydroformylation reaction can be carried out by using an organic solvent and water as a biphasic system, where the catalyst is water soluble (e.g. Rh(H)(CO)P(Ar)₃).



The catalyst retained in the aqueous phase can be reused without extracting from water.

Waste minimization

All the above mentioned methods minimise the formation of waste and therefore expenses for waste treatment will be reduced.

Green chemistry for Environmental improvement

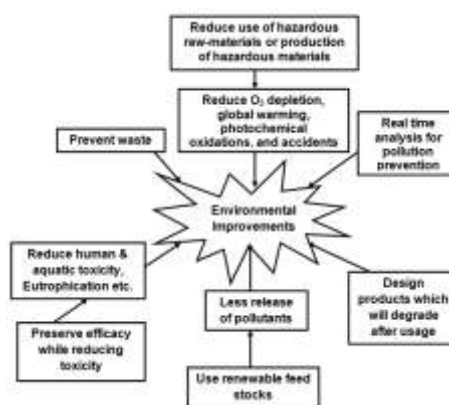


Figure 3: Environmental improvement through

Green Chemistry

Prevention/reduction of amount of waste

E-factor suggests to reduce the number of steps in a chemical synthesis and the number of isolations of intermediates, which minimizes the use of different types of solvents.

Usage of alternative solvents

Volatile organic solvents (VOCs) can cause photochemical smog. Chlorofluorocarbons (CFCs) can accelerate ozone depletion. Certain other organic solvents are carcinogenic (e.g. benzene). In order to overcome such negative environmental and health impacts, it is necessary to use alternative solvents. Possible alternative non-hazardous solvents for such organic solvents are scCO_2 , water, ionic liquids, fluorosolvents and solvent free systems. For example, to avoid possible danger, instead of using classical decaffeinating solvents, scCO_2 is gaining popularity in the process of isolation of caffeine from coffee beans. Ionic liquids are used as additives in paint industry.

Usage of renewable feed stocks

Biofuels release less pollutants and protect the environment from green house effect and certain other negative environmental impacts as described in detail below.

Green chemistry for social improvement

Social improvements can be achieved through sustainable development and good health of the society. Sustainability means meeting the needs of the present generation, while preserving the environment

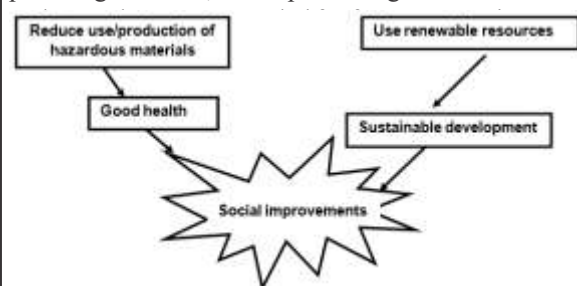
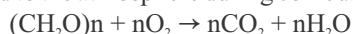


Figure 4: Social improvement through Green Chemistry

Usage of renewable resources

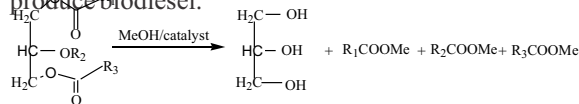
Recently, interest in fuels and petrochemicals from biomass and biofuels has increased tremendously throughout the world. Agricultural residues, wood waste, farm wastes, food processing wastes etc. are considered as biomass. Chemical composition of biomass mainly consists of cellulose, hemicelluloses and lignin. Biomass is carbon neutral because the CO_2 absorbed from the atmosphere during plant growth will be returned to the atmosphere during combustion.



Energy released by combustion of biomass is low and this problem could be overcome by using biofuels. Biofuels (e.g. biodiesel, bioethanol) are fuels derived from biomass.

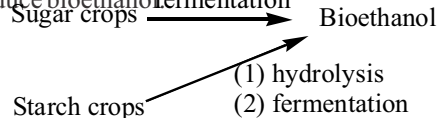
Biodiesel, bioethanol and chemicals from biomass

Biodiesel is a mixture of monoalkyl esters of fatty acids (RCOOMe). Triglycerides in oils (e.g. soy bean oil, peanut oil, *Jatropha* oil) are transesterified to produce Biodiesel.

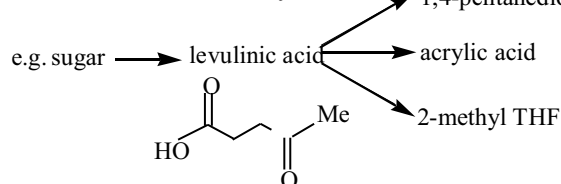


Triglycerides of various plant oils are made up of different fatty acids such as palmitic, oleic, stearic and linoleic in different amounts. Properties of biodiesel mainly depend on the fatty acid profile of the oil. The by-product, glycerol can be used to synthesise many value added chemicals. Fatty acids from plant oils also could be used to synthesise raw materials needed for chemical industries.

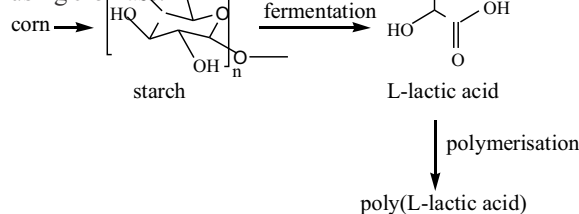
Sugar crops or starch crops could be used to produce bioethanol.



Bioethanol or biodiesel alone or mixed with petrol or petrodiesel respectively can be used as alternative renewable energy sources and they are environmentally friendly. As indicated below sugar and starch can be used to synthesise various chemicals.



Various recyclable polymers also could be synthesized using biomass.

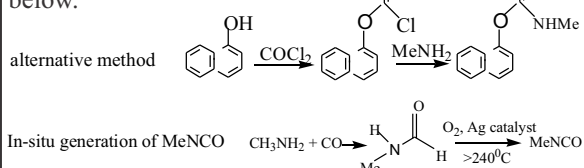


The use of biofuels and synthesis of chemicals from biomass will help to ensure a clean environment, good health and sustainable development of the society.

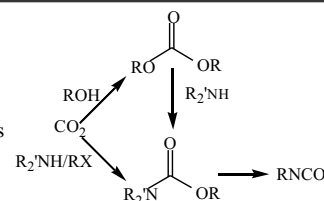
Avoid the use of hazardous materials and hazardous processes

Risk is a function of hazards and exposure. Risks due to usage of hazardous substances could be reduced by on-site generation of dangerous chemicals in low-levels, usage of non-toxic alternatives, regular checking of leakages, checking whether a particular product is extremely necessary and by implementation of taxes or banning of toxic/hazardous reagents.

The Bhopal accident (1984) in India occurred at Union carbide-Bhopal due to an explosion during the manufacturing process of an insecticide called carbaryl, for which the main cause was a leakage of water resulting an exothermic reaction. The product as well as the reactants COCl_2 , MeNH_2 , MeNCO , 1-naphthol are hazardous. In order to prevent the reoccurrence of incidents similar to the Bhopal accident, green chemistry could be applied as indicated below.



use of benign alternatives



Recommendations

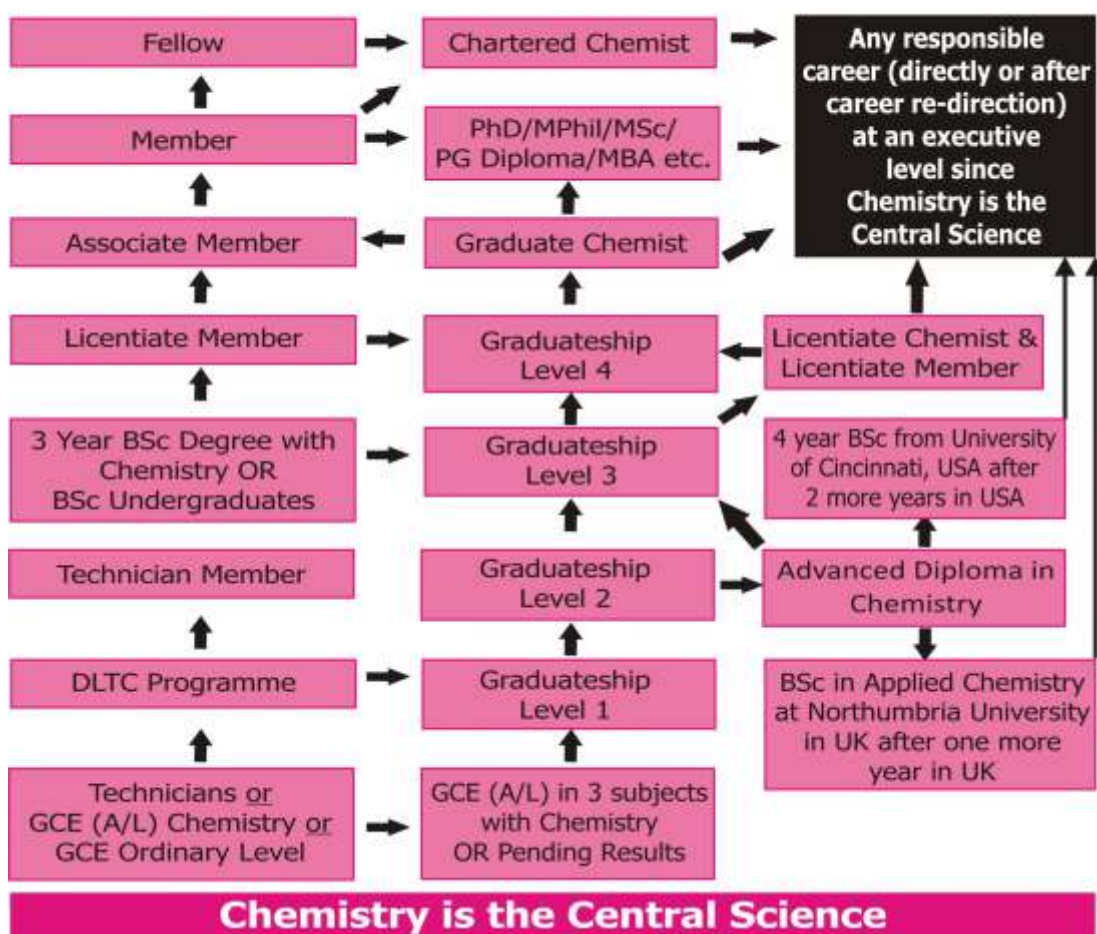
Green chemistry is the most appropriate approach towards a green environment which will help the wellbeing of all organisms living on earth. In order to achieve this, it is necessary to improve awareness, education, research and applications of green chemistry among relevant stake holders.

References

1. Beckman E.J.; J. of Supercritical Fluids. **2004**, 28, 121-191
2. Plechkova N.V. and Seddon K.R.; Chem. Soc. Rev. **2008**, 37, 123-150
3. Clark J.H. and Tavener S.J.; Org. Process Res. Dev. **2007**, 11(1) 149-155
4. Horvth I.T.; Acc. Che. Res.; **1998**, 31(10) 641-650
5. Sheldon R.A.; Green Chem. **2005**, 7, 267-278

Structure of the Graduateship Programme in Chemistry

The present structure of the Graduateship Programme in Chemistry has multiple entry and exit points as indicated below.



Chemistry in the development of polymers for the benefit of man

Mr. Mevan Pieris

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The role of chemist & chemistry in the world of polymers that dominates everyday life, began in early times, when natural rubbers and resins were used in applications such as waterproofing textiles to make raincoats and footwear. **Charles Goodyear's sulphur vulcanization** of natural rubber in **1839**, is the first instance of a chemical reaction being used to improve the properties of polymer based products. Sulphur had cross linked the polymer chains improving strength and elastic properties, imparting greater dimensional stability to products made out of rubber. Soon afterwards, in **1846**, **Dr Frederich Shonbein**, a German chemist **nitrated cellulose** and produced the first artificial polymer (modified natural polymer), which when dissolved in a mixture of ethyl alcohol and ether, gave a varnish that provided new luster to domestic furniture. In **1862**, **Alexander Parkes**, modified the nitrated cellulose by incorporating camphor, and made a new plastic called **celluloid**, which improved the mouldability. This material was able to replace the use of scarce and expensive ivory in the making of billiard balls. It was also possible to lay a thin film of celluloid between sheets of glass and make 'safety glass'. It became clear that other materials could be incorporated to, or used in conjunction with, polymers, to give special properties. A few years later, count **Hilaire deChardonnet**, spun nitrated cellulose and made the **first artificial fibre** which was silk like. However in view of the explosive and inflammable nature of the polymer, such fibres could not make much headway.

The **first ground breaking synthetic polymer** called **Bakelite**, was made by the **Belgian chemist, Leo Baekland**, in **1909**, by reacting phenol with formaldehyde. The polymer when heated formed a hard network, and products showed good dimensional stability with resistance to chemicals and heat, and also was a good electrical insulant. The **German chemist, Hermann Staudinger**, was fascinated with the unique properties of polymers and suggested that polymers consisted of **long chain molecules** based on covalent bonding rather than aggregates of smaller molecules as was the belief then. Although his peers in organic chemistry ridiculed him for such a suggestion, **Meyer & Mark in 1928**, were able to **confirm Staudinger's views**, by carrying out studies using X-rays. By this time the structure of natural rubber (NR) had been identified to be cis-polyisoprene, and such vital information gave direction to the synthesis of new polymers. The next four decades from **1930 to 1970** can be referred to as **the glorious days of synthesis of high polymers**, and all the major high volume polymers of

today, emerged during this time and only what are referred to as **speciality polymers** targeting very specific applications came thereafter.

H.W. Carothers, a brilliant chemist engaged by Dupont, USA, tested the validity of Staudinger's long molecule theory by attempting to build a long chain molecule from small molecules, by **condensation polymerization of aliphatic diamines and dibasic acids**. The research was an outstanding success, and led to the **discovery in 1935**, of linear long chain **polyamides**, which are today an important major polymer known as nylon. Needless to say, that by a choice of different diamines and dibasic acids, and by other techniques as well, a variety of nylons have been synthesized with unique properties. Nylons became the **first synthetic textile fibre** (commercial production in **1938**) and together with the linear saturated polyester- **polyethylene terephthalate**, which was synthesized many years later, has revolutionized the textile industry. Apart from these fibres being used to make good quality cloth, the fibres were used to replace cotton in the manufacture of stronger tyre carcasses. The **first major synthetic elastomer** was also produced in USA during this time, by free radical emulsion polymerization of chloroprene. The new **polychloroprene (CR)** which entered the world as Neoprene, was a **special purpose rubber** (non tyre rubber), with better properties than that of NR in respect of, resistance to ill effects of oxygen, ozone, oils, solvents, and flame. CR was used to make a range of industrial products such as conveyor belting for mining, petrol hoses, matting with flame and oil resistance, etc.

In **1937**, another important special purpose **copolymer was synthesized** in Germany, using **Butadiene and acrylonitrile**. These polymers, have superior resistance to oils in view of the acrylonitrile content and find applications in the manufacture of oil seals and in other special applications.

In **1935**, ICI, UK, had taken a patent to polymerize ethylene, but **polyethylene (PE)** came to the market only in **1939**, on the eve of the second world war. It was manufactured using a **high pressure process, using free radical initiators**, and much branching resulted, giving a low density polymer. The same process continued into the 1950s until better catalyst systems were found to produce more linear high density varieties with greater crystallinity and strength, and with a higher melting point, thereby, increasing the upper limit of their service temperature. Polyethylene was widely used as a packaging material.

When the second world war broke out the

Germans had a capability of **synthesizing a tyre rubber out of butadiene and styrene (SBR)** in the ratio of 77 : 23, and when the Japanese cut off all supplies of plantation rubber from the Far East, an emergency programme was launched in USA, to polymerize Styrene butadiene rubber (**necessity is the mother of inventions**) to feed the war machinery. Chemists and engineers were equal to the challenge, and a large number of polymerization plants sprang all over the country in next to no time. Research on polymer synthesis carried out during the war years in the USA also resulted in another copolymer (**butyl rubber**) based on isobutene, with the use of **Friedel Crafts type of catalysts** (aluminium chloride) and a small amount of a second monomer, isoprene, to introduce a bit of unsaturation into the polymer backbone, so as to permit sulphur vulcanization. The polymer was found to be resistant to air permeability and was highly suited to make air tubes for automobiles. The polymer also had high damping properties and was used to make engine mounts. Research was also being done to make a heat resistant polymer for electrical cables and as an outcome of this research, **silicone polymers**, having a polymer backbone of alternating silicon and oxygen atoms with pendant organic groups, were discovered. The polymer was found to have a wide range of service temperature, from - 120 °C to + 150 °C. Silicone polymers are chemically inert and have found applications in the medical field as well to make catheters, tubing and in view of its high permeability to oxygen, in the manufacture of oxygen permeable diaphragms.

The outstanding work of **Karl Ziegler** (German) and **Giulio Natta** (Italian) around 1953-54, resulted in the discovery of **stereo specific catalyst systems** (such as a combination of triethyl aluminium and titanium tetrachloride). The use of such catalysts enabled the polymerization of linear **isotactic polypropylene**, which was a much stiffer crystalline polymer than polyethylene, although having a lower density. These catalysts also enabled the polymerization of **stereo regular elastomers, such as cis-polybutadiene (BR) and the synthetic counterpart of natural rubber**. The synthesis of BR enhanced the capability of the tyre industry, as by blending BR with NR it was possible to improve the wear properties of the tyres significantly. **Elastomers have played a big role in the transport industry to uplift the standard of life of man**. Tyres have played a key role in enabling people to travel comfortably and safely in motor vehicles, and even planes would not be able to take off and land without them. Trucks travel on tyres to distribute goods to places where people live. Various other vehicle parts are also made out of various kinds of rubber, such as wind screen and door beadings, wiper blades, pedal pads, engine mounts, bushes, seals and tubing. Beyond that, **elastomers are in homes** as floor mats, garden hoses, footwear, foam

rubber mattresses etc.

A copolymer of ethylene and propylene was synthesized by Montecatini, Italy, in 1955, using Ziegler-Natta catalysts. This being a fully saturated polymer had to be cross linked using peroxides by free radical vulcanization. Around 1963 a third monomer (a non conjugated diene) was introduced into this polymer to create a bit of unsaturation in a pendant that enabled sulphur vulcanization, without affecting the high resistance of the polymer towards oxidation and ozonolysis. These polymers came to be known as **EPDM rubbers** and enable products of high ozone resistance to be made. This polymer is the last of the major elastomers to have been made and is excellent for outdoor applications and can be blended with natural rubber to make NR based ozone resistant products.

Fluorinated polymers also came to the market in the **1950s**. Large scale commercial production of **polytetrafluoroethylene (PTFE)** began at Dupont, USA, in 1950. The polymer was a linear highly crystalline polymer with very low surface energy and a very low coefficient of friction. PTFE had **outstanding chemical & thermal resistance** and was **used to line cooking vessels as it gave non stick properties**. Fluoropolymers are suitable for high temperature **applications up to 300°C**.

Polymers which are classified as plastics, generally exist as hard polymers at room temperature, even if they are not cross linked. Polyethylene and polypropylene are examples of polymers which are semi crystalline having a glass transition temperature below the room temperature, but still remain reasonably hard at room temperature in view of the crystallites in them. Other plastics that are amorphous, have a glass transition temperature above room temperature, and as such, are hard at room temperature, as they are in the glassy state. Some examples of synthetic plastics and their applications that have already made a significant contribution towards raising the quality of life of man, are mentioned below.

Polyethylene (PE) is a semi crystalline non polar polymer, considered to be the highest volume plastic in the world. It is mainly available in the form of **low density and high density grades** and is widely used in the packaging industry to make **flexible and semi rigid tubes and bottles, and film for making bags**. **Ultra high molecular weight polyethylene (UHMWPE)** is manufactured using **metallocene catalysts**. The polymer cannot be melt processed but **can be compression moulded into human bones for implants**, as described more fully later in this article. **Polypropylene (PP)** is stiffer and harder than PE, with a higher crystalline melting point of 175 °C. It is used widely to make **rigid bottles, cups, basins and transparent films**. In view of its linearity and stiffness, PP can be used to make fibres that could be

woven into textiles that are suitable to make fertilizer bags. Special yarn is made to produce **woven textiles to support stomach muscles** in hernia operations.

Polyvinylchloride (PVC) is a chlorinated amorphous polar polymer having a glass transition temperature (T_g) of $+80^\circ\text{C}$. Therefore, the polymer is in the glassy state at room temperature. It is used to make rigid water pipes and clear bottles for packaging beverages. PVC can be made more flexible by using plasticizers and such forms are used to make flexible tubing and hoses. It is a flame resistant polymer. **Polyvinylidene chloride**, on the other hand is a highly crystalline polymer with outstanding resistance to gas and moisture permeability. It is one of the very best polymers to make films for packaging food items.

Polystyrene is an amorphous polymer with a T_g of 100°C , and has bulky phenyl groups as pendants that give high rigidity to the polymer. It has good electrical insulation properties and is used to manufacture insides of refrigerators. Expanded polystyrene foam has excellent thermal insulation properties.

Commercial production of **polyvinyl acetate** is believed to have started in Germany in 1920, by emulsion polymerization of vinyl acetate using potassium persulphate initiators. The main application of this polymer is, as a water based adhesive, and in making emulsion paints. The copolymer **ethylene vinyl acetate** (9-40 % vinyl acetate) is widely used as a hot melt adhesive for laminating, book binding and in glue sticks. In the quest of finding alternative sources of energy, solar power is being tapped by photovoltaic cells. This copolymer having excellent light transmission properties and a high resistance to UV degradation, is used to encapsulate such cells.

Polyvinyl Alcohol is a crystalline polymer which could produce films of excellent resistance to air permeability, but dissolves in water in view of its ability to hydrogen bond freely. Hence are suitable to make water soluble sachets to pack chemicals that are added to water without having to handle them (bath salts, bleaching material, disinfectants, and insecticides).

Polymethylmethacrylate: Commercial production began at ICI, UK, in 1934. It is a hard, highly transparent amorphous polymer. It has good outdoor weathering properties and as such find applications as sign boards.

Aliphatic Polyamides(Nylons) and Aromatic polyamides (Aramids): Already mention has been made in this article on how the nylons came to be developed by HW Carothers of Dupont. Several millions of tons of nylon are produced annually and most of it is converted to fibres that are used in textiles, netting, ropes and as bristles for brushes. The rest is moulded into products such as mechanical gears,

bushes, bearings etc., or converted into film. Its toughness, rigidity, abrasion resistance and fair heat resistance, make it a suitable polymer for many applications. Poly paraphenyleneterephthalamide was produced commercially by Dupont as an aramid fibre in early 1970s, and the fibre was highly crystalline and exceptionally strong. The material is used to manufacture bullet and stab proof garments.

Polyesters (polyethylene terephthalate): This polymer was synthesized by Winfield and Dickson in 1941, during the war years; and the rights were sold to Dupont and ICI. Large scale commercial production began only in 1953. It is a linear saturated polymer that forms strong fibres with very low water absorption, and as such, is used to make strong tyre carcasses and fast drying clothing. It is usually blended with cotton for greater comfort.

Polycarbonates (Bis phenol polycarbonate): The polymer has a very low degree of crystallinity, but is **very** stiff due to the high concentration of benzene rings in the chain backbone. The low crystallinity coupled with a high free volume in the polymer, gives very high impact strength, making it a suitable polymer to make helmets, and casings for domestic appliances.

Polyurethanes: Products are manufactured by the catalysed exothermic chemical reactions of polyisocyanates with polyols. It is one of the most versatile polymers and finds applications almost in every area, covering automobiles, furniture, construction, thermal insulation, footwear, foams, adhesives, varnishes, hard tyres, high elastic textile fibres(spandex).

Polymers are indispensable and are to be found everywhere, and occupy a **pivotal position in the world of materials**. The progress in the polymer field has been more rapid compared to any other chemical industry and it would be not wrong to say that, since 1930, man lives in the **age of polymers** which continue to offer solutions to man's unlimited wants. Polymers are being used increasingly in our daily life as plastics, rubbers, fibres and paints as no other material. There are so many polymer based items in our homes as containers, jars, bottles, carrier bags, combs, tooth brushes, furniture, bath tubs, plates and cups, clothes, upholstery, shoes, adhesives, mosquito nets, lamp shades, coverings of electrical items, etc. In fact, far too many items to mention. The applications of polymers are well beyond domestic items, and cover, agriculture, constructions, packaging, automobiles, water transport, furniture for office and homes, industrial applications, fishing, textiles, paints, cosmetics, and now increasingly making a substantial contribution in medical applications.

Physiological needs are concerned with **body**

requirements of food, shelter, and clothing. Polymers have contributed immensely to meet these needs.

Polymers have **uplifted agricultural practices** which generate food. It has simply **made the desert bloom** in improving water retention properties of sandy soil, and providing the tubing for drip irrigation, and pipes to distribute water, not forgetting the host of utensils and other packaging material that enable the collection and proper storage of food items. Different kinds of polymer films having different levels of permeability to gases and moisture are now available to pack various kinds of food, mindful of the deleterious effects oxygen and water could have on the food. Polymers have also provided many kitchen utensils which facilitate cooking, among which are the non stick pans with a lining of PTFE. Fibre forming polymers such as the polyamides and polyesters have **supplied the textile industry with an enormous capability** of producing high quality garments. Without synthetic polymer based fibres, the world would be severely starved of clothes. In the **building construction industry** which provides shelter, polymers provide piping, guttering, conduits, flooring, insulation, wall cladding, roofing sheets etc.

Polymers meet man's security needs as well (prevention of injury to body). Polymers such as the aromatic polyamides (Aramids) and ultra high molecular weight polyethylene (UHMWPE), give ultra strong fibres which are suitable to make bullet proof garments, and protection for high speed travelers on motorcycles. Further, Aramids can withstand temperatures up to 500° C and textiles made of it, can give hand and body protection to factory workers in contact with hot machinery and moulds. Polycarbonates on the other hand have outstanding impact strength and are ideal to make helmets and other products where good impact strength is vital. Dipped latex products such as condoms give protection against sexually transmitted diseases, and rubber gloves protect hands against aggressive chemicals. Footwear protects the feet. There are also speciality polymers, which can **treat water and waste water**, to provide man with clean water and keep the environment clean. There are many liquid/emulsion and dry/powder forms of speciality high performance polymers (such as, poly quarternary ammonium chlorides, polyacrylates, cationic and anionic polyacryl amides), in current use for this purpose.

High polymers are being **used increasingly in medical applications** in three ways. 1 To **construct complete artificial replacements** of human organs. 2. **To repair, sustain or augment** the functioning of organs. 3. To **provide a biochemical function**. Artificial hearts, lungs and kidneys are designed to replace natural organs. Plastics are used in their construction, as they are easy to fabricate, inert chemically and are non toxic. They are available in a

wide range of hardness, flexibility and permeability. Ultra high molecular weight, linear, polyethylene, can be compression moulded to form entire **hip joints**. Greater dimensional stability can be imparted to such mouldings by electron beam irradiation, which cross-links the polymer chains. A homogeneous content of 1000 ppm of vitamin E is added into the product as a stabilizer, as it assists in both irradiation and as an effective antioxidant. **Polymer drug delivery systems**, is yet another interesting development, where the drugs are encapsulated in biodegradable speciality polymers which degrade safely into small, non toxic fragments, releasing the drugs slowly. Drug release could be also influenced by changes in pH, temperature or ionic strength. In almost all areas of medicine, increasingly sophisticated devices require increasingly sophisticated materials. Advanced **plastics have been synthesized for diagnostic & laboratory devices**, blood handling devices, implant & prosthetic devices, organ and tissue replacement, and cardiac pulmonary systems. The use of **polymer scaffolds**, have created an **unlimited potential for tissue growth** oriented health care. The previous view that, medical polymers had to be passive, sterile, mechanical parts, are no longer valid. Advanced medical polymers are now capable of biological processes and are **becoming a part of the living organism**. The more recent class of application of polymers is where the polymer has a definite and specific chemical reaction with the biochemistry of the body so that it is able to play the role of a pharmaceutical. In one such application, the synthetic ion exchange resins are able to absorb the metabolites from the blood, and in another approach the synthetic polyelectrolytes are able to absorb specific viruses.

Speciality polymers are already providing a tremendous new capability in the world of material science. It would suffice to highlight within the scope of this article just a few of the more important examples to give an appreciation of the tremendous potential such polymers have to make the world a better place to live in. **Ceramic precursor polymers** such as the **polysilazanes** are one such example. They can be consolidated at high temperatures to give a ceramic. By this technique a wide range of composites, coatings, fibres, and nano-phase materials can be made. Polysilazanes contain silicon, carbon, and nitrogen and as such it is possible to convert them into silicon nitride or silicon carbide containing ceramics, which have some very important applications in aerospace, automotive and electronic industry. **Polyanilines** is a **conductive polymer** that is easy to manufacture, with applications in microelectronics, membrane technology, lithium-polyaniline batteries, electro chromic devices, in conductive textiles and in sensors. Then there are the polymers used as nanomaterials in the form of nanofibres, whiskers, spheres to give unique properties. Research on

polymer nanofibres is showing rapid growth. **Electrospun nanofibres** have the potential to be mass produced from many polymers. It has a vast potential in many applications, such as biomedical, filtration and separation, sensor technology and in high performance nano-composites. Then there are the **magnetic polymer microspheres** as yet another speciality polymer system. These are nano or micro size particles made by combining magnetic materials such as oxides of iron, nickel and cobalt and a polymer, by physical and chemical methods. They can be used in industrial waste water treatment, clinical detection, targeted drug release, bacterial separation, and in organic synthesis. Their key attributes are the magnetic response and magnetic separation capability in them. The surface of a magnetic microsphere can be functionalized with groups such as hydroxyl, carboxyl and amine, to meet the requirements of specific applications. Some of the other areas in which speciality polymers are making a strong impact are, intrinsically conducting polymers capable of being used for protection of metals against corrosion, inorganic polymers such as polysilanes, polygermanes, and polystannanes for advanced applications, light weight polymer composites in automobile industry, photo converters based on dyed-doped polymers, luminescent polymers etc.

Polymers have offered man a great variety of items to choose from. The advantages of polymers as a material is that it is light, harder to break as it is tough, long lasting, low cost, easy to shape, recyclable, and so many types to choose from that fits any application. By choosing the right polymer the product can be made either soft or hard, flexible or stiff, and at the right strength, which could be much higher than that of steel. All this has been possible by the outstanding contribution made by chemists and the field of

chemistry they represent. Unquestionably the greatest contribution chemists have made is the discovery of such a wide array of polymers, without which the polymer industry would not exist in the way we now know it to be. This would not have been achieved without the experimentation and foresight of chemists that discovered so many methods of polymerization such as condensation, addition, ring opening, free radical, anionic, cationic, bulk, suspension, emulsion, solution, etc, and beyond that the discovery of a range of catalysts of exceptional merit (such as the free radical initiators, Ziegler-Natta types and Metallocenes), without which most of the valuable polymers we have with us would never exist. Additionally, it need be mentioned that, the contribution of chemists has been immense in synthesizing a whole heap of other chemicals which are vital ingredients in polymer based finished product manufacture, but a reference to it is beyond the scope of this article.

References:

1. C.M. Blow and C.Hepburn, Rubber Technology and manufacture, 2nd edition, 1982.
2. J.A. Brydson, Plastics Materials, 7th edition, 2000
3. K,J.Saunders, Organic Polymer Chemistry, 2nd edition, 1988
4. John.H.Briston, Plastics Films, 3rd edition, 1988
5. George Woods, The ICI polyurethane book, 2nd edition, 1990
6. Kathleen O Havelka, speciality polymers: Diverse properties and applications, 2000.
7. Alexander Lukacs , Polysilazane precursors, 2006
8. Faiz Mohammed, speciality polymer materials and applications, 2007

Chamikara Wijesinghe Gradauteship All Round Award

Mr. Chamikara Wijesinghe, Student Association President (2009) who passed out in 2009 and is presently working in Singapore has initiated an All Rounders Award at the Convocation. The Award is intended to be presented to a passing out Graduate Chemist with a GPA of at least 3.25 who has actively involved himself in extra-curricular activities of the College. The Award is intended to encourage involvement in such activities. It is intended to make the first presentation at the Seventh Convocation.

Revised (increased) Benevolent Fund Benefits from Sept. 1st 2010

- 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) provided a paper is being presented
- 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) OR any visiting academic/academic support member who automatically contributes 5% of his honorarium to the Benevolent Fund, are entitled for these benefits. All members are advised to pay the membership fee for life and become beneficiaries. The existing Benevolent Fund scheme has been withdrawn from September 1st.

Impact of nanotechnology on society

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Nanotechnology is no longer merely a topic of social conversation, but is beginning to affect the lives of everyone. Nanotechnology is a field of applied science, focused on the design, synthesis, characterization and application of materials and devices on the nanoscale. Before delving into the depths of nanotechnology and nanoscale science, we should be clear what we mean when we use terms such as 'nanotechnology,' 'nanoscience,' and 'nanoscale.' It is a basic nomenclature, used to describe certain attributes of certain systems, and such nomenclatures are typically designed to eliminate confusion and encourage accurate communication among those discussing the system. The prefix 'nano-' is derived from the Greek word *nannos*, meaning “very short man”. At its root, the prefix 'nano-' refers to a scale of size in the metric system. 'Nano' is used in scientific units to denote one-billionth (0.000 000 001) of the base unit. When we are talking about *nanotechnology*, we are talking about a scale – an order of magnitude – of size, or length. We are making a reference to objects that are sized on a scale that is relevant when we discuss *nanometers* (nm). The nanoscale, then, is the size scale at which nanotechnology operates. A useful and well-accepted convention is that for something to exist on the nanoscale, at least one of its dimensions (height, width, or depth) must be less than about 100 nanometers. In fact, it is these limits to the nanoscale that the National Nanotechnology Initiative (NNI) of USA uses for its definition of nanotechnology: “Nanotechnology is the understanding and control of matter at dimensions of roughly 1 to 100 nm, where unique phenomena enable novel applications.” When the size of particles in the scale of nanometer (1~100nm), they perform some novel properties, such as quantum-size effect, small-size effect, surface effect, and macroscopic-quantum-tunnel effect.

Because of these effects, nanomaterials show excellent and unique optical, electrical, magnetic, catalytic, biological, or mechanical properties. These unique properties of nanoparticles encourage the scientists to seek their possible applications in devices.

Several important events have marked the nanotechnology story. The credit for inspiring nanotechnology usually goes to physicist Richard Phillips Feynman (1918–1988). In his speech, “There's Plenty of Room at the Bottom”, he spoke about the principles of miniaturization and atomic-level precision and how these concepts do not violate any known law of physics. He unveiled the possibilities available in the molecular world. Because ordinary matter is built of so many atoms, he showed that there is a remarkable amount of space within

which to build. The term 'nanotechnology' can be traced back to 1974. It was first used by Norio Taniguchi in a paper entitled “On the Basic Concept of 'Nano-Technology'.” At the beginning of the 1980s, scanning tunneling microscopes (STM) and atomic force microscopes (AFM) were invented (in 1982, IBM Zurich scientists Gerd Binnig and Heinrich Rohrer introduced the scanning tunneling microscope (STM), and they were awarded the 1986 Nobel Prize in Physics for this development) providing methods and approaches required for nanostructure measurement and manipulation. Scanning probe microscopy (SPM) has opened up the new world of nanotechnology for observing and manipulating individual atoms and molecules on solid surfaces. These tools use nanoscale probes that are capable of picking up, dragging or sliding atoms or molecules around resulting in the assembly of more complex structures. One of the most famous examples of this technology in action was demonstrated by D. M. Eigler and E. K. Schweizer. They used STM to produce the now famous image of the letters “IBM,” spelled out of 35 xenon atoms on a nickel surface. This development was a major milestone for nanotechnology, proving it was now possible to manipulate individual atoms as Feynman desired. The discovery of materials on the nanoscale notably began with the Buckminsterfullerene (Richard Smalley along with Robert Curl at Rice university and Sir Harold Kroto at the University of Sussex discovered fullerenes, and was awarded the Nobel Prize in 1996). It consists of an arrangement of 60 carbon atoms and this discovery was made possible due to the facility, high-resolution mass spectrometry. The first scientific paper on nanotechnology was published in 1981 by Eric Drexler and he has been one of the pioneers to focus on emerging technologies and their impact for the future. His publications “Engines of Creation: The Coming Era of Nanotechnology,” “Nanosystems: Molecular Machinery, Manufacturing, and Computation,” and “Unbounding the Future: The Nanotechnology Revolution,” made great impact by introducing the very topic of nanotechnology to many, and exposing an engineering approach to nanotechnology and nanosystems. In 1991, nanoscale materials became the focus of intense research with the discovery of the carbon nanotubes by Sumio Iijima. Since the discovery of carbon nanotubes, a novel nanoscale material after novel nanoscale material has been reported. In 2000, the US government developed the National Nanotechnology Initiative (NNI) in order to administer funding and develop nanotechnology as the major research thrust

of the twenty first century.

Nanotechnology has not only been present in nature, but has also been used unwittingly in human-made technology for centuries. For example, nanoscale carbon black particles, basically high-tech soot, have been used as a reinforcing additive in tires for nearly 100 years. The red paint used on Chinese vases as far back as 15th century is the result of Chinese artisans grinding up gold particles until they are on the order of 25 nm in size. Medieval artisans in Europe discovered that by mixing gold chloride into molten glass they could create a rich ruby color. By varying the amount of gold put in the mixture, different colors were produced. Though the cause was unknown at the time, the tiny gold spheres were being tuned to absorb and reflect the sunlight in slightly different ways, according to the size of these particles. The main difference between the modern push for technology and these previous historical examples of nanoparticle use is that the modern use is intentional and with an understanding of the underlying mechanisms that produce the new properties.

The key to understanding why the properties of nanomaterials differ from those of their macroscopic counterparts is the intermediate location of the nanoscale (1 – 100 nm). Understanding the underlying science of nanoscale interactions is extremely important to the development of nanotechnology. The laws of physics that operate on objects at the nanoscale combine classical (or Newtonian) mechanics, which governs operations of everyday objects, and quantum mechanics, which governs the interactions of very small things. Nanolevel marks the point where quantum mechanics begins to take over from classical mechanics in describing the atom. Though many of the fundamental laws of nature that operate on this level have been discovered, science at this scale is still very difficult. Understanding the forces and theories at play within nanotechnology is just one aspect of nanoscience. The smallest nanoparticles do not behave like free atoms, molecules, or extended solids. Rather, nanomaterials have unusual optical, magnetic, and electronic properties that are size-dependent. This is due to surface and quantum-size effects. At this scale, the proportion of atoms that are on the surface of the particle becomes significant. Atoms respond to their environment differently when they are surrounded by other atoms than when they are on a surface and do not have atoms surrounding them. And the relative amount of atoms on the surface can greatly influence the properties of the material as a whole. With nanoscale materials, many of the atoms reside on the surface of the material and therefore the surface-to-volume ratio is much larger. For example, a 30 nm particle will have 5% of its atoms at the surface, while a 3 nm particle will have 50%. This can change the properties of materials and how it interacts with the

environment.

Nanomaterials are the cornerstones of nanoscience and nanotechnology and are anticipated to play an important role in future economy, technology, and human life in general. The strong interests in nanomaterials stem from their unique physical and chemical properties and functionalities that often differ significantly from their corresponding bulk counterparts. Many of these unique properties are extremely promising for emerging technological applications, including nanoelectronics, nanophotonics, biomedicine, information storage, communication, energy conversion, catalysis, environmental protection, and space exploration. With the current application and advancements soon to come, nanotechnology will have a great impact on the well being of humans. Scientists are blazing a trail for a new technology and looking at every possible avenue to improve upon current methods in every possible field. Nanotechnology is predicted to help solve the world's most burning issues such as environmental pollution, energy crisis, drinking water, world hunger, world security, computing power and cures for diseases such as cancer.

Environmental applications of nanotechnology address the development of solutions to the existing environmental problems, preventive measures for future problems resulting from the interactions of energy and materials with the environment, and any possible risks that may be posed by nanotechnology itself. Nanoscale materials have the potential to improve the environment, both through direct applications of those materials to detect, prevent, and remove pollutants, as well as indirectly by using nanotechnology to design cleaner industrial processes and create environmentally responsible products. Substances of significant concern in remediation of soils, sediment, and groundwater include heavy metals (e.g. mercury, lead, cadmium) and organic compounds (e.g. benzene, chlorinated solvents, cresole, and toluene). Among the many applications of nanotechnology that have environmental implications, remediation of contaminated groundwater using nanoparticles containing zero-valent iron, TiO₂, ZnO, carbon nanotubes (CNTs) and dendrimers are the most prominent examples of a rapidly emerging technology with considerable potential benefits. Carbon nanotube shows the adsorption capability for the removal of organic pollutants like 1, 2-dichlorobenzene, trihalomethanes, n-nonane, and carbon tetra chloride from water. Activated and porous carbons have been traditionally used as filters (e.g., water purification) but the advantage of nanotubes is that the pore sizes are very uniform and small, so that separation of really small molecules becomes possible. Although the pore size is small, the

flow rate is not reduced due to the unique nature of the flow of solvents through the nanotube cavities.

As freshwater sources become increasingly scarce due to overconsumption and contamination, scientists have begun to consider sea water as another source for drinking water. The majority of the world's water supplies have too much salt for human consumption and desalination is an option but expensive method for removing the salt to create new sources of drinking water. Carbon nanotube membranes have the potential to reduce desalination costs. Similarly, nanofilters could be used to remediate or clean up ground water or surface water contaminated with chemicals and hazardous substances. Possible applications of nanoparticles such as cobalt and platinum to remove toxic gases from smokestacks or convert them to non hazardous materials are being in the process of research and development. Finally, nanosensors could be developed to detect waterborne contaminants. Air pollution is another potential area where nanotechnology has great promise. Nanofilters could be applied to automobile tailpipes and factory smokestacks to separate out contaminants and prevent them from entering the atmosphere. Porous Manganese oxide with embedded gold nanoparticles has been used as a room temperature catalyst to breakdown volatile organic compounds from air. Finally, nanosensors could be developed to detect toxic gas leaks at extremely low concentrations. The ability of carbon nanotubes and their derivatives to operate as gas sensors of ammonia and nitrogen at ambient temperature has been demonstrated recently.

Recent increases in demand for oil, associated price increases, and environmental issues are continuing to exert pressure on an already stretched world energy infrastructure. Therefore significant effort has been devoted to develop renewable energy technologies such as solar cells, fuel cells, and bio-fuels. Global energy crisis imperatively requested a revolutionary progress in solar energy conversion. Nanotechnology will cut costs both of the solar cells and the equipment needed to deploy them, making solar power more economical. Major types of nanostructured materials such as semiconducting nanostructured porous materials, nanotubes, nanowires, different types of quantum dots, metal nanoparticles, carbon nanotubes and C_{60} families can be used in nanotechnology based solar cells. All of these nanoscale materials have been found to have quantization size effects and unique optoelectrical properties, and therefore it is feasible to use them in photovoltaics to achieve conversion of light to electricity with more efficiently than the conventional solar cells. Optical properties of nanomaterials, such as CdSe, dye-sensitized TiO_2 and ZnO nanorods, nanowires and nanotubes have been used in the area of solar energy conversion into chemical energy.

Applications of nanotechnology in energy storage clearly reveals that, when moving from bulk materials to the nanoscale can significantly change device performance for energy storage and conversion. Another application of carbon nanotubes in energy production has been the preparation of polymer epoxy with carbon nanotubes to provide strong and light weight materials for long wind mill blades. The resulting longer wind mill blades increase the amount of electricity generated by each wind mill. Researchers at Rice University are developing wires containing carbon nanotubes that would have very low resistance than the wires currently used in electricity transmission grids to reduce the power loss in electricity transmission. One alternative energy/power source under serious consideration is electrochemical energy production, as electrochemical methods have been recognised to be more sustainable and more environmentally benign. Applications of nanotechnology in energy storage are in the stage of research and development. It has been recognized that the potential application of single walled carbon nanotubes as hydrogen storage devices due to the ability of reversible hydrogen storage owing to the presence of large surface and porous structures in hydrogen adsorption. The lithium-ion battery is the representative system of such electrochemical energy storage and conversion. The development of high-performance lithium ion batteries can benefit from the distinct properties of nanomaterials, such as high surface areas, short diffusion paths and a large quantity of active sites. Nanosized ZnO or ZrO_2 coatings on $LiMn_2O_4$ and substituted $LiMn_2O_4$ vanadium oxide offers the essential advantages of low cost, abundance, easy synthesis, and high energy densities for Li-ion intercalation applications, CNTs are also considered to be a candidate for high-performance electrode material of Li-ion batteries again due to their abundant nanosized pore structures.

Let us see how nanotechnology helps when it comes to eliminating world hunger? 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. Nanotechnology can be applied in all phases of the food cycle from how food is grown to how food is packaged. The use of pesticides increased in the second half of the 20th century and many of these pesticides were later found to be highly toxic, affecting human and animal health and as a result whole ecosystems are affected. Using nanotechnology delivery of pesticides can be controlled by means of encapsulation and controlled release methods and this will help to protect the environmental pollution. These chemicals are already in the market. Fertilizers such as Nano-clay capsules

have been formulated for slow release of active nutrients for growing crops minimizing frequent treatment over the life of the crop. Nano formulated herbicides have been developed to attack the seed coating of weeds, destroy soil seed banks and prevent weed germination. A major problem in food science is the developing of effective packaging materials. Silicate nanoparticles have been used to provide barrier to oxygen and moisture in a plastic film used for packaging to avoid possible food spoiling and drying out. Existing chemical UV absorbers in food packaging materials that are used to prevent product deterioration and extend product shelf life are known to migrate out of thin plastic films and in some cases, into the contents of the packaging. It has been observed that replacing the chemical absorbers with dispersed zinc oxide nanoparticles provides the required UV protection and product stability, while remaining transparent, inert and stable within the film. On the other hand, anti-microbial properties of Zinc oxide nanoparticles can be used to kill microorganisms too. The food safety is a major concern for food producers, consumers and food safety authorities. New nanosensors are being developed that can help in detecting e-coli and other pathogens in food within 15 minutes while normal testing can take up to 24 hours they claim. The device offers a way to speed up detection, allowing processors to release products for distribution earlier and to spot contamination problems before goods leave the plant. Food storage bins are being produced with silver nanoparticles embedded in the plastics. This will help to kill any bacteria from any food item which was previously stored in the bins. In addition to packaging, nanotechnology is already making an impact on the development of functional or interactive foods, which respond to the body's requirements and can deliver nutrients more efficiently. Various research groups are also working to develop new "on demand" foods, which will remain dormant in the body and deliver nutrients to cells when needed. A key element in this sector is the development of nanocapsules that can be incorporated into food to deliver nutrients. Other developments in food processing include the addition of nanoparticles to existing food to enable increased absorption of nutrients.

The way to increase computing power to greater rates is to make the features on chips smaller and smaller so that more can be placed onto an area and the costs will be driven down as the speed rises. But there are limitations for this miniaturization for currently used technique which is photolithography. Nanotechnology techniques provide a way out of the entire paradigm. By assembling structures from the ground up, molecule by molecule, or atom by atom, the resolution and depth-of-field limitations can be eliminated entirely. Nanotechnology provides to continue exponential growth in computing through the

properties of the materials. For example, in carbon nanotubes, conduction of electrons occurs without hindrance by defects in the material and therefore at speeds far exceeding carbon on a larger scale. Nanoscale copper has a conductance that exceeds that of bulk copper. Furthermore, Nanotechnology enters into quantum computing, which is an entirely different method of computing, by using quantum properties of nanoscale materials such as quantum dots (QDs). Because quantum dots begin to exhibit and control the quantum properties of materials, they represent nanotechnological boxes that contain a distinct number of electrons. By utilizing the quantum properties of these dots, a powerful quantum computer could be developed. This provides an exponential growth in computing power.

Applications of nanotechnology to medicine are already ongoing and offer tremendous promise, these applications often go under the moniker of 'nanomedicine' or, more generally, 'bionanotechnology'. Disease treatment is reaching a turning point, with the emerging fields of molecular based medicine and personalized medicine. A cellular level control is not possible without nanotechnology as the key enabling technology. Despite the discovery of a large number of active compounds as potential drugs, very few of these research products achieve clinical success mostly due to problems related to their bioavailability. One approach to improve bioavailability is targeted drug delivery, avoiding over dosage-toxicity and consequential inflammatory response. Nano drug delivery vehicles of interest to bionanotechnology include nanocapsules, liposomal vehicles, nanoparticles, microemulsions, metal nanoshells, dendrimers, nanofibers and nanotubes. The breakthroughs of bionanotechnology in the area of drug delivery have been some of the most remarkable applications of nanotechnology in medicine and include immuno-isolated nano porous implants with embedded pancreatic cells delivering insulin for diabetic patients, polarity-based gated nanosieves for selected ion transport, externally controlled nanoshell delivery vehicles for precision targeting, single virus detectors, gene engineered biological robots, artificial red blood cells. The development of hyperthermia nano agents for cancer therapy is underway and could impact patients in the next 2–5 years while transparent sun screens sensing the amount of damage to skin are the next generation products in the sun protection industry. The use of nanoparticles as biomarkers has been applied in diagnostic imaging, targeted delivery and in novel multifunctional approaches. For example quantum dots (QDs) can be used for the study of live cell single-molecule dynamics, monitoring of intracellular protein–protein interactions, disease detection in deeper tissues, detection of cancer/ tumor cells based on selective binding of bioconjugated QDs to known

cancer biomarkers. Ultrasound is currently a well-established technology enabling real-time imaging of the human body. The most interesting advancement in bionanotechnology would be the design of contrast agents in the nano domain. These ultrasound imaging contrast agents causes significant increase in image resolution through enhanced backscattering signal which is observed from the blood flow. A surfactant-stabilized nano bubble with attractive acoustic properties, better yield, higher stability, longevity and higher resolution has been reported. The contribution of magnetic particles in enhancing molecular imaging increases with the wide clinical application of magnetic resonance imaging. Nanosize magnetic particles enable early disease detection, accurate prognosis, and personalized treatment, monitoring efficacy of a prescribed therapy, or study of cellular interaction in a certain biological environment. The super paramagnetic iron oxide nanoparticles are functionalized with site specific biomolecules that render them highly specific and enable to target sites or proteins of interest in the body. This type of active targeting includes cancer, apoptosis, and cardiovascular imaging. Novel pharmaceutical preparations have been developed to fabricate nano vehicles to deliver drugs, proteins and genes, contrast enhancement agents for imaging, and hyperthermia agents to kill cancer cells. Several of these inventions have already transitioned into basic medical research and clinical applications.

The introduction of new technologies to military and defense applications, and how they alter the battlefield, international relations, and society, has a long and rich tradition. By simply making devices smaller and lighter through nanotechnology, the soldier can be made more mobile and have a smaller logistical footprint. The average present-day soldier carries in excess of 100 pounds of equipment while on assignment. Much of this weight is due to the electronic equipment (including communication equipment) and the power supplies (usually batteries) used to power them. Through the use of smaller, lighter equipment, this weight could be reduced dramatically without a sacrifice in functionality; the soldier could therefore move more quickly and/or further (in the same amount of time). Much of this weight reduction can be accomplished by reducing the scale of the power generators that the soldiers have to carry. For example, recently nanoscale power generation has been demonstrated by utilizing an array of piezoelectric nanowires. By converting mechanical, vibrational, or hydraulic energy into electricity, these “nanogenerators” can be used to power the electrical systems carried by the soldiers. Nanotechnology use in defense and protection spans a wide range of applications and applies to entire overall defense and protective systems, not just individuals; it affects societies as a whole. One aspect

of defense is border protection. Border protection includes not only standing guard at borders and regulating which individuals may enter into a particular country, but also controlling ports and scanning cargo to make sure that no harmful chemical or biological species are exposed to the population. It involves quarantining possible contagious diseases, which means effectively testing for them. Nanotechnology can provide some of this capability with environmental, chemical, and biological sensors. Sensing technology is one of the more useful and immediate applications of nanotechnology that is being developed. The smaller size of nanomaterials allow faster response and greater sensitivity to species that they are tuned for.

It is very clear that applications of nanotechnology are many and they affect different aspects of the activity of human beings. Because of its breadth of application, nanotechnology represents a technological revolution that will impact many elements of human life, changing the way things are manufactured and the way we interact with technology. We can highlight that many of these applications are focused on the improvement of human health, whereas others will facilitate a more sustainable economic development allowing for the optimization of resources and diminishing environmental impact. The ability to manipulate the matter on atomic scale opens the possibility of designing and manufacturing new materials and devices of nanometric size. This possibility will alter the methods of manufacturing in factories, allowing for greater process optimization and automation, and therefore contributing to global sustainable development. On the other hand, the nanotechnological revolution will speed up the seemingly unstoppable expansion of the information technologies, and causing the globalization of the economy, the spreading of ideas, the access to the different sources of knowledge, and the improvement of the educational resources. Finally, the bionanotechnology applications will directly affect human beings by substantially improving diagnosis and treatment of diseases, and also our capacities to interact with our surroundings. It is also becoming clear that nanotechnology has the potential to profoundly change the world, even if today's products are uninspired and only incrementally better than previous ones. Therefore, understanding what nanotechnology is and why it matters is the first step toward our future: it is the next generation for industries, financial markets, research labs, headlines, and our everyday lives. The point is that this wide range of disciplines brings interesting opportunities and challenges to researchers. There are opportunities for nearly any scientist to be involved in developing nanoscale science and technology. One of the true revolutionary effects of

developing nanotechnology is that scientists of all different areas are working together on a wide variety of projects.

References:

1. A. N. Goldstein, Handbook of Nanophase Materials, Marcel Dekker, Inc., New York, 1997.
2. B. J. Hinds, N. Chopra, T. Rantell, R. Andrews, V. Gavalas, L. G. Bachas, Science 303, (2004) 62-65
3. A. C. Dillon, K. M. Jones, T. A. Bekkedahl, C. H. Kiang and D. S. Bethune, Nature 386 (1997) 377.
4. G. L. Che, B. B. Lakshmi, E. R. Fisher and C. R. Martin, Nature 393 (1998) 346.
5. E. Radeva, V. Georgiev, L. Spassov, N. Koprinarov, and St. Kanev, Sensors. Actuators B. 42 (1997) 11.
6. J. Kong, N.R. Franklin, C. Zhou, M.G. Chapline, S. Peng, K. Cho and H. Dai, Science 287 (2000) 622.
7. B. J. Hinds, N. Chopra, T. Rantell, R. Andrews, V. Gavalas, L. G. Bachas, Science 303, (2004) 62-65
8. A. Srivastava, O. N. Srivastava, S. Talapatra, R. Vajtai, P. M. Ajayan, Nature Mater. 3, 610-614 (2004) 43
9. E. S. Kawasaki, A. Player, Nanomedicine, 1 (2005), 101-109.

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Promoting safe use of pesticides for maximization of food production

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Introduction

The world population increased dramatically with the development of technology resulting in an increased demand for food production. Through knowledge and technology, humans control diseases, fungi, weeds, nematodes, insects, birds, rodents and other pests, that would otherwise shorten our lives or compete with them for food. The amount of land suitable for agriculture is limited, and most of it is already in use. Therefore, the enormous increase in food production in future will necessitate a significant increase in agricultural productivity. This goal is made even more difficult with the conversion of agricultural lands for urbanization. Due to the lack of suitable lands, expansion of agriculture is done, in many instances, on fragile land which has already caused tremendous environmental problems, including soil erosion and landslides. It has been reported that about 14 % the world's potential food production is lost due to pests. This loss can be overcome to a significant degree by the use of pesticides in agriculture. In fact, the abundance of food and high standard of living in the world would not be possible without pesticides. However, it is of concern that pesticides are unacceptably dangerous to the environment and to mankind. Although pesticides, by nature, are risky, their benefits are real and easily taken for granted in many applications. Fortunately, research, education and government agencies regularly provide recommendations to reduce the risk of using pesticides through various means, such as by producing "safer" chemicals and pest-specific pesticides, introducing better application methods, and implementing tougher pesticide regulations.

Pesticides are defined as chemicals or biological substances that are used to kill pests that cause problems

in food production and human health. Pest problems and their management widely depend on many factors such as climate, type of soil, agricultural system, and pest density. More than two million tons of pesticide products are annually used in the world aiming at a significant increase in crop production.

Before World War II, most pesticides used in agriculture were inorganic compounds such as sulfur, arsenic, lead, copper and lime as well as products made from natural sources such as nicotine and pyrethrum. These pesticides do not persist for long in the environment. This situation was later changed, and development of new synthetic organic pesticides came into effect. New pesticides are more effective and stable, and persist longer in the environment. Most organic pesticides are synthesized from various compounds, but a few are extracted from plant material and are called 'botanicals'. The pathways by which pesticides are dissipated from the target area after application are well known. Some modes of dissipation are volatilization, adsorption, degradation and leaching. The extent of these modes would depend not only on the physical and chemical properties of the pesticide, but also on properties of the medium through which the pesticide is transported, which introduce many uncertainties to the degree of dissipation. Further, when pesticides are degraded in the environment through different means, the degraded products may have different properties. Consequently, quantitative contribution of each pathway to the final outcome is very complex and not clearly known.

Classification of Pesticides

Pesticides can be classified in different ways,

depending on the type of the pest they control, the extent of hazardness, the chemistry of pesticides, and the mode of action. The first type of classification introduces different classes of pesticides such as herbicides, insecticides and fungicides (Table 1). Herbicides are the most frequently used pesticides in agriculture. They are also sub-categorized according to their application and the mode of action. Contact herbicides such as paraquat kills only the plant parts which are exposed to chemicals, while translocated herbicides such as MCPA and propanil move within the plant to destroy roots and other parts that are not exposed. Herbicides can also be subcategorized according to their selectivity. Selective herbicides such as propanil kill the targeted weed without harming the crop. On the other hand, non-selective herbicides, such as paraquat, kill all plants. They are used before a crop is planted or to totally clear an area of vegetation. The most commonly used herbicides in our country include bipyridiniums, glyphosate, chlorophenoxyacid

derivatives, Propanil (figure 1).

The classification based on the extent of hazardousness, which is based on oral and dermal LD₅₀ values, is recommended by the World Health Organization (Table 2). LD₅₀ is a standard measure for expressing and comparing the toxicity of chemicals. It is the dose that kills half (50 %) of the animals tested (LD = "lethal dose"). The animals used for this purpose are usually rats or mice, although rabbits, guinea pigs and hamsters are sometimes used.

The classification based on chemistry includes a complicated list of categories such as organochlorines, organophosphates, carbamates and heterocyclic nitrogen-derivative compounds according to their chemical structure (Table 3). It should be noted that pesticides with similar structures have similar characteristics and usually have a similar mode of action.

Table 1: Type of pesticides according to the pests controlled.*

Type	Mode of action	Examples
Fungicide	to manage fungi	Thiram, Carpropamid, Chloraniformethan
Herbicide	to manage unwanted plants or weeds	Paraquat, Propanil, MCPA, Glyphosate
Insecticide	to manage insects and other related creatures, such as ticks, spiders, and centipedes	Allosamidin, Thuringiensin, Bendiocarb, Carbaryl
Algicides	to manage algae in areas such as swimming pools	Bethoxazin, Copper sulfate, Dichlone, Diuron,, Endothal, Isoproturon
Avicides	to manage birds	4-Aminopyridine, Chloralose, Endrin, Fenthion
Disinfectants	to destroy harmful microorganisms	Ethanol, Sodium Hypochlorite
Microbial insecticides	Naturally occurring insect-disease microorganisms that are lethal to a specific group of insects	<i>Bacillus sphaericus</i> , <i>Beauveria bassiana</i> , <i>Heterorhabditis heliothidis</i>
Molluscicides	to control snails or slugs	Calcium arsenate, Cloethocarb, Copper Acetoarsenite, Metaldhyde
Pheromones	to attract insects	
Repellents	to repel insects or other pests	N,N-diethyl-m-toluidide, Nepetalactone, Permethrin
Rodenticides	to manage rats, mice and other rodents	Scilliroside, Strychnine, Coumatetralyl, Difenacoum

* Source United States Environmental Protection Agency (USEPA).

Table 2.: Classification of pesticides according to hazardousness.*

Class	Hazardousness	LD ₅₀ for the rat (mg/kg body weight)			
		Oral		Dermal	
		Solids	Liquids	Solids	Liquids
Ia	Extremely hazardous	≤ 5	≤ 20	≤ 10	≤ 40
Ib	Highly hazardous	5 - 50	20 - 200	10 - 100	40 - 400
II	Moderately hazardous	50 - 500	200 - 2000	100 - 1000	400 - 4000
III	Slightly hazardous	> 500	> 2000	> 1000	> 4000

* Source: The WHO recommended classification of pesticides by hazardousness (2004).

Table 3: Classification of pesticides based on their chemistry.*

Pesticide class	Example
Carbamates	Baygon(propoxur), Bendiocarb, Oxamyl , Aldicarb, Carbaryl, Methomyl
Chlorinated cyclodienes and camphenes	Oxychlorthane, Aldrin, Chlordane, Endosulfan, Endrin Kepone, Mirex, Nonachlor
Dithiocarbamates	Metam Natrium, Metiram, Nabam, Mancozeb, Maneb, Thiram, Zineb, Ziram
Linuron, diuron, and derivatives/metabolites	1-(3,4-Dichlorophenyl)-3-methylurea, 1-(3,4-Dichlorophenyl)-3-methylurea, Diflubenzuron, Diuron, Ethylene thiourea, Linuron
Organophosphates	Acephate, Chlorfenvinphos, Cyclophosphamide, Fenitrothion, Fenthion, Formothion, Glufosinate, Metalodemeton, Malathion, Ethylmalathion, Phosphamidon, Quinalphos, Ronnel, Trichlorfon, Glyphosate
Pyrethroids	Bifenthrin, Bioallethrin, Cyhalothrin, Cypermethrin, Deltamethrin, Esfenvalerate, Fenothrin, Fluvalinate, , Resmethrin, Allethrin, Karate, Talstar, sumithrin
Pyrimidines and Pyridines	Bromacil, Fenarimol, Picloram
Triazines and triazoles	Biteranol, Cyanazine, Cyproconazole, Difenoconazole, Epiconazol, Epoxiconazole, Etridiazole, Febuconazole, Metribuzin, Penconazole, Propiconazole, Simazine, Tebuconazole, Atrazine

* Source United States Environmental Protection Agency (USEPA).

Global pesticides usage

The use of agricultural chemicals and pesticides has become a great social issue because the effect of such chemicals on the environment is not certain. More than 800 different technical grade pesticides have been introduced, and more than 5000 commercial pesticides have been formulated. A major fraction of agricultural expenses is on the use of pesticides. The world pesticide expenditure was as high as \$ 32 billion in 2001, and it is probably more at present. Among the many different types of pesticides, herbicides accounted for more than 40%, the largest portion of the total expenditure, followed by expenditures on insecticides, fungicides, and other pesticides, respectively. Furthermore, organophosphate insecticides play a major role among other types of insecticides. There are many formulations of pesticides available under different brand names produced by numerous manufacturers.

Impact of pesticides on the environment

Pesticide use in agriculture causes undesirable effects on humans and the natural environment. While agricultural use is restricted to a limited number of compounds among several thousand synthetic chemicals, agriculture is one of few activities where chemicals are intentionally released into the environment to kill the target pest. In areas of regular pesticide use, the environment is regularly deteriorated, resulting in contaminated water supplies, loss of plant diversity, insect resistance and in some instances death of domestic animals.

Agriculture, especially in tropical and subtropical environments, changes the hydrology of the surrounding area, which causes breeding of insects such as mosquitoes which are responsible for a variety of vector-

borne diseases. In addition to pesticides used in the normal course of agriculture, control of vector-borne diseases may require additional application of insecticides. DDT was used in the past for this purpose. It is now banned due to serious and widespread ecological consequences. However, the effects of DDT are still encountered in many countries. DDT has now been replaced by organophosphate or carbamate insecticides (e.g., malathion or bendiocarb), which are effectively used all over the world.

Most pesticides are nonspecific and hence inevitably kill more organisms than the pests against which they are applied. The action of pesticides is largely independent of population density, and therefore pesticides do not necessarily control populations. Usually they kill a proportion of population that would otherwise be destroyed by density dependent factors (e.g., predators). This does not mean that they are ineffective for the purpose for which they are used. Even if pesticides specifically target a single or a group of pest(s), they would produce extremely complex effects. It is not a surprise that the application of a pesticide which affects many species has substantial effects on the ecosystem to which it is applied. Therefore, carefully controlled experiments and accurate use of statistics on experimental results would be essential for environmental studies of pesticides.

It would also be important to investigate the combined effect of many different chemical and non-chemical pest control types. The results of such investigations together with detailed environmental studies can be used to implement integrated pest management (IPM) programs in a systematic way. During the last decade, increased attention has been focused on IPM programs and alternative methods of

pest control to reduce pesticide use in agricultural systems because of food safety issues, ground water contamination, and increased environmental awareness.

Fate of pesticides

It is important to know how and where pesticides enter the environment and what happen to them during both short-term and long-term exposure. This is known as the fate of pesticides in the environment. In recent years, there has been a great deal of concern on the environmental fate of pesticides together with increased attention on environmental pollution issues. The fate of a pesticide is influenced by many different factors associated with both the properties of the pesticide and of the environment. Initial spreading from the application site is determined by the method of application, amount, timing, frequency and placement. Pesticides can move from their initial place to other places by different pathways. To travel longer distances, pesticides move by mass transfer, usually in moving into water or air. Pesticides may adsorb or absorb to soil, vegetation, or other surfaces. The ability of a pesticide's motion is determined by how much it is retained by the surfaces to which it was applied.

Many factors are found to influence the fate of a pesticide. In general, mass transfer includes processes that move the pesticide away from the application site. These processes include adsorption, absorption, volatilization, leaching, runoff and degradation. The most important feature of a pesticide is solubility, which controls the extent of interaction of pesticide molecules with solvent molecules. To some extent, solubility is a relative guide to judge a pesticide's mobility, which in turn provides an indication of how well a pesticide is distributed in the environment. However, the mobility of a pesticide is affected not only by the solubility, but also through sorption to soil particles, which includes adsorption, absorption and leaching.

Adsorption: Adsorption is the binding of pesticides to the surface of soil particles through physical or chemical interactions. Herbicides of ionic nature such as bipyridyl herbicides, for e.g., paraquat, a quaternary salt with high water solubility, shows extensive adsorption properties. Further, pesticides with polar moieties, such as glyphosate and propanil, are strongly adsorbed to soil minerals.

Absorption: Absorption is the uptake of pesticides and other chemicals into plants or microorganisms. Most pesticides breakdown once they are absorbed, or remain inside the plant or animal, and are released back into the environment when the animal dies or as the plant decays. Some pesticides stay in the soil long enough to be absorbed by plants grown in a field years later. They may damage or leave residues in future crops.

Volatilization: Volatilization is the process of solids or liquids converting into a gas, which will move the pesticide away from the initial application site. This

movement is called the vapor drift, which can damage nearby crops. For most pesticides, volatilization is an important mode of dissipation.

Runoff: The presence of detectable concentrations of pesticides in surface water has caused some concerns about possible effects on human health and aquatic biology. Runoff is the movement of pesticides in water over a sloping surface. The pesticides are either mixed in the water or bound to eroding soil. Runoff can also occur when water is added to a field faster than it can be absorbed into the soil. Pesticides may move with runoff as compounds dissolved in water or attached to soil particles.

Leaching: Any pesticide which is weakly adsorbed and persistent is likely to leach to subsoil (the layer of soil above the water table) and reach ground water. **Leaching** is the movement of pesticides in water through the soil. Leaching has no direction, and it occurs downward, upward, or sideways. Factors influencing the extent of leaching into groundwater include characteristics of the soil and the pesticide, and their interaction with water from a rain-event such as irrigation or rainfall. Leaching is significant when the pesticide is water soluble, the soil is sandy, rain occurs shortly after spraying, or the pesticide is not strongly adsorbed to the soil. Further, the pattern of water falling on the soil through irrigation or rainfall should also be taken into account.

Degradation processes: Degradation is the process of pesticide breakdown, after application, into simpler and generally, less toxic compounds. However, in certain instances, degraded products are even more toxic than the parent pesticide. An important aspect of degradation processes is that they reduce the concentrations of pesticides after target pests have been controlled. Consequently, persistence and accumulation of a pesticide are reduced, lowering environmental effects. Degradation processes may take place within any time period from hours or days to years, depending on environmental conditions and the chemical characteristics of the pesticide. Pesticides that break down quickly do not generally persist in the environment or on the crop. However, pesticides that break down too rapidly may only provide short-term control. Pesticides are broken down by microbes, and through chemical reactions and photodegradation.

Investigation of the environmental fate of pesticides through phenomena such as leaching and deposition came into effect in the 1980s in USA where long-term studies were initiated by United States Environmental Protection Agency (USEPA). The active ingredients of pesticides in the soil are subject to specific conditions depending on climatic and soil texture. Therefore, their fate in the environment can be accurately described by long-term monitoring under a given set of conditions. However, it is a very complicated process for quantitative assessment.

Pesticide characteristics, such as solubility in water, tendency to adsorb to the soil and pesticide

persistence in the environment, are also important in determining the fate of these chemicals in the environment. Pesticides with high water solubility, low tendency to adsorb to soil particles and long persistence have the highest potential to move into water bodies. The behavior of a pesticide in the field depends on all the three factors, adsorption, water solubility, and persistence, as they interact with each other. Therefore, the ultimate effect is a complex composite of these factors. As such, properties of a pesticide should be well understood prior to investigation of its behavior in the field.

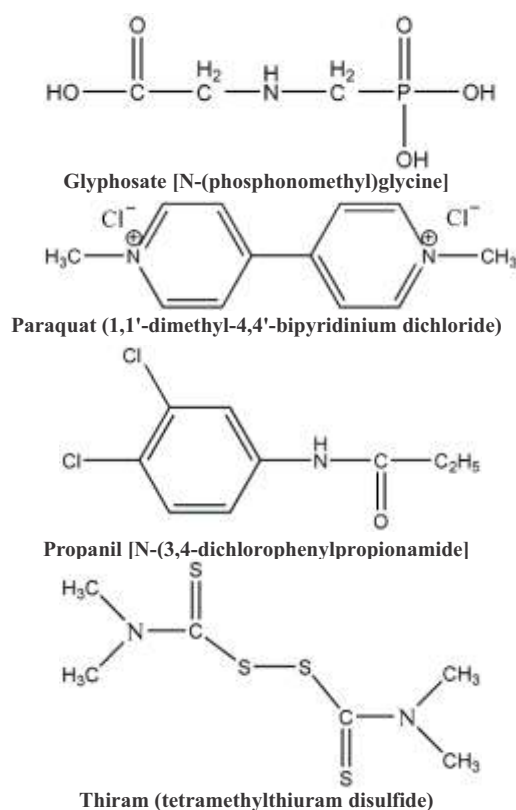


Figure 1: Chemical structures of some commonly used pesticides in Sri Lanka

Current developments in pesticide use, efficacy and environmental pollution

Traditional pesticides, require repeated applications at targeted sites during the growing season to replace losses due to volatilization, leaching and degradation. Repeated pesticide application, however, is undesirable because of high costs and possible environmental pollution.

The modern liquid pesticides and allied formulations, suitable for application as a spray, which dries at the infested site allow the controlled - release of the desired pesticide. In these novel designs, pesticides are released over a predetermined period of time without being affected by prevailing environmental factors. The components of the liquid formulation are selected to be compatible with the application method, such as spraying. In these applications pesticide loaded amphiphilic polymer (film) can release the pesticide in the controlled-release manner (higher pesticide

efficacy). After releasing the pesticide, the polymer degrades with minimum impact on the environment.

Furthermore these controlled-release formulations are further improved by the rate of pesticide release, release period to fit the target site and the extent of pest infestation, and to accommodate many different types of pesticides. The target specific pesticide is the other category of environmental friendly pesticide formulations. This is based on natural chemicals called phytoalexins and their synthetic analogs to control the specific target.

However, it is difficult to offer such improved products in developing countries due to their high cost. Consequently, older pesticide formulations which are cheaper, more persistent in the environment, and more hazardous to the health of the user, are still in use.

Conclusion.

It is very obvious that the use of pesticides is mandatory to meet the demand for food in the world. However, adverse effects of pesticides must be well understood in their usage. The use of controlled-release pesticide formulations, and target specific formulations can play a key role to mitigate the environmental pollution due to pesticides. However, the drawback of these newer formulations is the cost which could be unbearable for developing countries like Sri Lanka.

References

1. Kirk-Othmer's "Concise Encyclopedia of Chemical Technology," John Wiley & Sons publishers; New York, USA, 1985, 652-656
2. A. Navaratne and N. Susantha, An electroanalytical sensor for the detection of Gamexone (paraquat), *Anal. Lett.*, 33: 1491, 2000.
3. Arvinte, A., Rotariu, L., Bala, C., *Chemicals as Intentional and Accidental Global Environmental Threats*, Netherlands: Springer, 2006.
4. Shan, G., Lipton, C., Gee, S.J., Hammock, B.D., *Handbook of Residue Analytical Methods for Agrochemicals*. Chichester: John Wiley and Sons, 2002.
5. N. Priyantha, A. Navaratne, D. Jayawickrama and U.S.K. Welivegamage, Amperometric method for the determination of Propanil in simulated rice field environment, *J. Nat. Sci. Found. Sri Lanka*, 32(3&4):115-125, 2004.
6. A. Navaratne, N. Priyantha and U.I. Rodrigo, Analytical methods for the investigation of reactivity of Propanil *J. Nat. Sci. Found. Sri Lanka*, 36(3), 199-203, 2008.
7. N. Priyantha, A. Navaratne, C.B. Ekanayake, A. Ratnayake, Solvent extraction followed by ultraviolet detection for investigation of tetramethylthiuram disulfide at soil-water interface, *Int. J. Environ. Sci. Tech.* 5(4): 547-554, 2008.
8. B. S. Shasha et al. ((1981) *J. Polymer Science, Polymer Chemistry Edition*, (19), 1891-1899, 1981.
9. D. Trimmell et al. *J. Applied Polymer Science*, (27) 3219-3928, 1982.

are very sensitive to pH changes and processing conditions such as treatment with sulphur dioxide and sulphites results in bleaching. Anthocyanidins form dimers and polymers with certain flavanoids present in fruits such as grapes, especially during the fermentation of wine, where procyanidins are formed. Procyanidins are more stable than anthocyanidins and give a brown red colour to wines. Some sources of anthocyanins used as food colourants are grape skins and red cabbage.

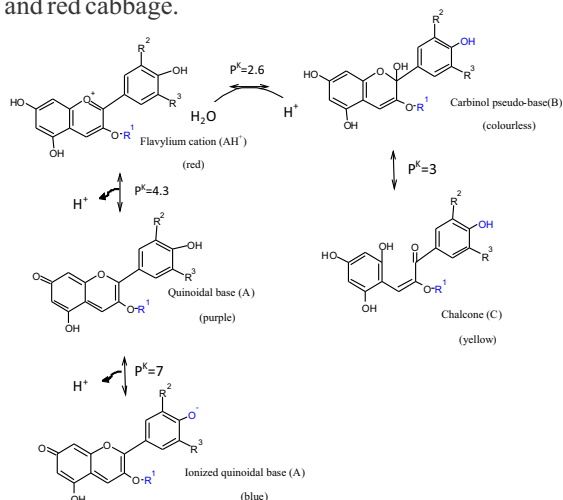


Figure 2: Transitions in the anthocyanin structure

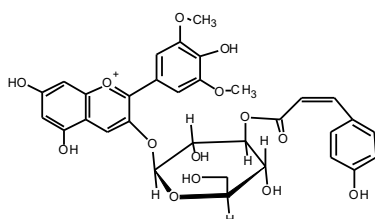


Figure3: Structure of malvidin (3-coumaryl glucoside)

Betalains

Betalains are divided into two groups, the purple red betacyanins and the yellow beta xanthins. Pigments of significance in food are those present in beet root (red beet) *Beta vulgaris*. Ninety percent of beet root betalains are betacyanins. These are quite different from anthocyanins chemically and in their stability, though earlier they were mistakenly named as 'nitrogenous anthocyanins'. Their colour is not affected by pH normally found in food and are more resistant to processing. However, they are unstable to heat at neutral pH.

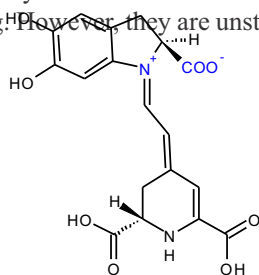


Figure 4: Betanidin

Curcumins

These are derived from turmeric (*Curcuma*

longa) The powdered dried tuber of the plant is used as a spice and a food colourant especially in oriental cookery. Curcumin is obtained by solvent extraction of the powdered turmeric and is a bright yellow pigment. Due to the increasing concern about the potential toxicity of synthetic food dyes, curcumin has become useful in colouring desserts, pickles, icecreams etc. Turmeric also has many medicinal, antioxidant and antiseptic properties.

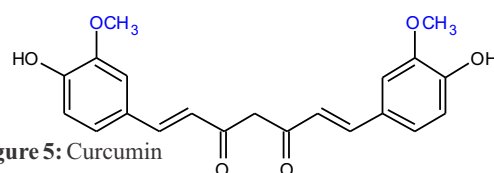


Figure 5: Curcumin

Colours formed during processing and manufacturing

In addition to natural colours of plants and synthetic dyes added to food, colours are formed during food processing and manufacture. Browning due to enzyme activity, sugar caramelisation and Maillard browning (initiated by the reaction between reducing sugars and amino acids) are such examples.

The most important attribute of black tea for which Sri Lanka is famous internationally, is its characteristic colour and flavour. The orange-red compounds in tea, which are the theaflavins are formed during the fermentation stage of tea manufacture. In fact, this is an enzymic oxidation and not a microbial fermentation. The tea catechins form dimers which have a benzotropolone ring system responsible for the colour. Thearubigins are the brown pigments in tea. The ratio of theaflavins to thearubigins determine the final colour of the tea brew. Tea polyphenols cause the astringency of the beverage and are known to have antioxidant properties as well as many beneficial therapeutic effects.

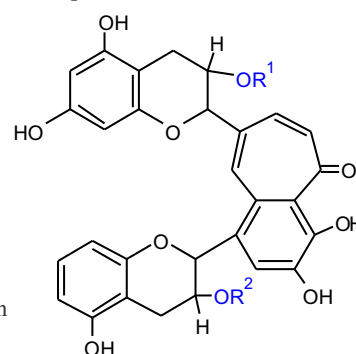


Figure6: Theaflavin
OR = OH or gallate

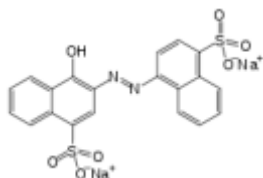
Artificial food colourants

As mentioned previously in this article, artificial colouring of food has given opportunities to the unscrupulous vendor to cheat the consumer. In the past, as far back as 1857, a survey of adulterants detected in food revealed that substances such as lead chromate, mercuric sulphide, red lead, and even copper arsenite were used to colour sweets. Aniline

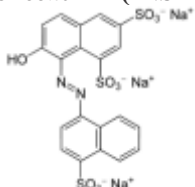
dyes which were subsequently developed eliminated the use of metallic compounds.

Synthetic dyes are cheaper, more stable and brighter with a wide range of shades, than natural colours. Therefore the use of synthetic dye stuffs to colour food steadily increased but at the same time strict legislation removed potentially toxic chemicals from the list of food dyes limiting the permitted dyes to only eight in Sri Lanka.

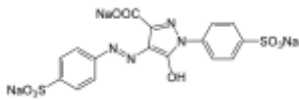
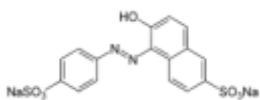
Carmoisine (INS 122)



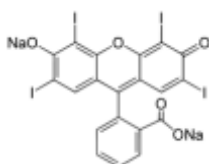
Ponceau 4R (INS 124)



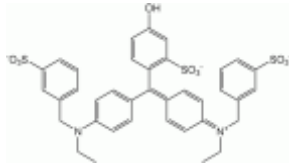
Sunset Yellow FCF (INS 110) **Tartrazine (INS 102)**



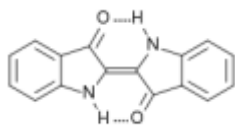
Erythrosine (INS 127)



Fast Green FCF (INS 143)



Indigo carmine (INS 132)



Brilliant Blue (INS 133)

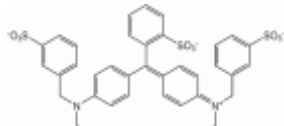


Figure 7: Some of the permitted synthetic dyes.
Food colours are mostly used in flavoured products

such as desserts, confectionery, icecreams etc, and in colouring canned peas. Erythrosine is used to colour canned meats. Addition of colour to raw or unprocessed food (meat, poultry, fish, vegetables, tea, coffee.) is prohibited.

Testing food colourants is often confined to looking at evidence for carcinogenicity. However, food colours such as tartrazine are known to cause intolerance in some individuals, manifesting as allergic reactions such as asthma or eczema.

Despite the growing concern about synthetic dyes, colour remains an important attribute by which the consumer is guided when selecting food. Food chemists and technologists therefore play a vital role in ensuring the safety of consumers, while looking after their culinary preferences.

References:

1. Tom Coultate, Food The chemistry of its components (5th Edition) RSC Publication (2009)
2. S. Carmen Food colorants: Chemical and Functional Properties CRC Press Boca Raton, Florida (2007)

Application and Nominations for Annual Awards

Members of the Institute of Chemistry are invited to submit applications for the following awards to be presented at the Annual Sessions of the Institute of Chemistry Ceylon in June 2011.

Applications for Annual Awards must be submitted on or before 28th February 2011.

Further details and criteria for the awards are available at the Institute office or download from the website www.ichemc.com

Ceremonial Opening of the R.O.B. Wijesekera Hall and the Unveiling of the Portrait of Dr. R.O.B. Wijesekera

Vidya Jyothi Dr. R.O.B. Wijesekera

B.Sc. (Cey); Ph.D. (Sheffield); Honorary D.Sc. (Sheffield, Sabaragamuwa & Peradeniya) FNASSL; FICChemC; FRSC; Chartered Chemist

Born on 17th October 1928, Dr. R.O.B. Wijesekera, had his secondary education at Royal college. He entered the University of Ceylon and graduated with a B.Sc Chemistry Special degree in 1951.

He commenced his research career at Medical Research Institute, Colombo in 1952. He and Dr. L.B. de Silva pioneered systematic chemical research on indigenous drugs and published several papers. Dr. Wijesekera soon joined the University of Sheffield and worked for a Ph.D. under Prof. R.D. Haworth FRS, the Davy medalist on synthesis and biosynthetic aspects of vegetable tannins. On his return to Sri Lanka he once again teamed up with De Silva and commenced a series of investigations on Sri Lankan medicinal plants. They presented their work to an international forum at the UNESCO Symposium on Medicinal Plants held in Kandy in 1964 (later identified as ASOMPS II). Dr. Wijesekera studied the constituents of plants belonging to family Dipterocarpaceae and elucidated their structures in collaboration with Judith Polonsky at CNRS (Gif-sur-yvette) in France. In collaboration with Robert Goutarel he confirmed the structure of mitiphylline from *Holarrhena mitis* in the days when no instruments were available in the country for structure elucidation. By that time Dr. Wijesekera has established research contacts with Finn Sandberg in Sweden, with Lederer, Polonsky and Goutarel in Gif and with Arthur Birch in Canberra and Anders Kjaer and Helmer Kofod in Denmark, beside other reputed Indian colleagues like Sheshadri, Govindachari, Sukh Dev and Nithya Anand. From these links he and his younger colleagues benefited in later years.

In 1967 he joined the Ceylon Institute of Scientific & Industrial Research (CISIR) and commenced the task of developing a Research group on Industrial Natural Products. The group performed outstanding work under his leadership and produced a number of scientists with formidable records. He developed the concept of dual part Ph.D system where his younger colleagues worked in laboratories in Sweden and presented their two part theses to local universities. This Sri Lanka-Swedish science connection derived from this was very beneficial to the country specially during the period when scientific instruments required for research were scarce.

At CISIR Dr. Wijesekera concentrated on flavours such as Cocoa, the Spices and Essential oils of Sri Lankan origin. After a post doctoral stint at the University of California at Davis and a complement of modern instrumentation he pioneered the application of new analytical techniques to studies on Essential oils

and spices.

He next applied himself to the development of new technologies for the field distillation of essential oils. He was selected as an UN expert for a brief survey of the Essential oil industry in Asia, during which he acquired industrial contacts with whom he enriched his research work. The historical land mark at that time was Cisirill Manakoka Still which he designed with Dr. Devanathan for the remote dry regions in drought periods. This research and development work was reported at the International congress of Essential oils in 1974 in San Francisco.

In 1975 Dr. Wijesekera led the Sri Lankan scientific team opposite Carl Djerassi during the US-Sri Lanka Workshop on Natural Products held in Colombo.

The innovative and productive research work performed by Dr. R.O.B. Wijesekera was recognized internationally by the 'Guinness Award for Scientific Achievement' from the Commonwealth Science Council in 1976. He was the first Sri Lankan to win this award for research performed solely in the country. In the same year he was chosen as a specialist consultant expert by UNIDO-ESCAP.

After a distinguished scientific career in Sri Lanka, he went abroad and served the World Health Organization where he was the Task Force Manager of an International research program on 'Plants used in Fertility Regulation'. His leadership of this WHO program where he managed the research of six participating centres (Peradeniya was one of these) towards a common objective was well recognized world wide. After moving to Vienna in 1980, he managed during the next decade the UNIDO program on the Industrial Utilization of Medicinal & Aromatic plants as Specialist Technical Adviser until his retirement from the international scene. Dr Wijesekera was the UNIDO spokesman at international fora in this subject area and was responsible for building up this program as one of the most successful UNIDO ventures covering Asia, Africa & Latin America. He received on his retirement a commendation from UNIDO's Director General for his leadership and innovation in developing this successful program. He has also served as Specialist Adviser to the Government of Guyana.

Back in Sri Lanka in the early nineties, Dr Wijesekera launched into work with enthusiasm and commitment and contributed to national development. At Industrial Technology Institute (formerly CISIR) he was the Chairman from 1995-1998 and simultaneously

served at NARESA as a member of the Board. He was then called upon to shoulder the launching of a new apex organization the National Science & Technology Commission (NASTEC). There he developed the concept of BICOST the biennial conference of S&T and the System of Consultation which attracted several scientists to work for policy development under NASTEC. At present Link Natural Products has successfully acquired his services as a Director / Consultant. He has pioneered their new venture the 'Link Natural Product Digest' an informative magazine on natural products.

Dr. Wijesekera's long string of involvement with professional organizations began in 1970 when he became the President of the Chemical Society of Ceylon. He has been the General President of the Sri

Lanka Association for the Advancement of Sciences in 1995 and is a Fellow of the National Academy of Sciences of Sri Lanka.

Besides his several research publications on scientific themes and on science policy, he has authored several technical books published internationally including, "The Medicinal Plant Industry" and the COSTED-ICSU publication titled, "Pedestrians on the Highways of Global science".

Dr. Wijesekera has been recognized nationally with the national honour of *Vidya Jyothi*. He has been awarded D.Sc. (Honoris Causa) by the Universities of Sheffield, Sabaragamuwa and Peradeniya.

He still participates in the activities of scientific bodies and has been honoured by the bodies he has served.

R.O.B. Wijesekera Felicitation Oration

Good things are not cheap, cheap things are not good

Dr. A. Lakshman Jayewardene

Link Natural Products Pvt. Ltd.

Chief guest Mr. Dhanapala, Dr. and Mrs. Wijesekera, President, Institute of Chemistry, Prof. Nalini Ratnasiri, Dr. Mubarak, colleagues former and present, fellow chemists, friends, ladies and gentlemen.

I am privileged and it is with great pleasure I stand at this podium to-day.

We meet here at Adamantane House this evening to salute one of our own heroes in science and technology on his four score and two year birth anniversary (Abraham Lincoln said 'four score and ten years', at the Gettysburg address).

We also felicitate ROB's half century and more of dedicated service to science and industry both at home and in many countries in the developing world.

Soon after ROB returned from a post-doctoral stay at University of California, Davis campus he initiated a new area of natural products research on the chemistry and technology of spices and aromatic plants, which were labeled as Minor Export Crops in the plantation sector. If one cares to think back to those times 41 years ago, getting foreign exchange from the treasury was almost impossible – *galen watura gannawa wagey*. Furthermore any new hi-tech instruments so essential for scientist to perform any worthwhile R and D were of low priority with the political masters and their permanent servants. The thinking was if some technology was big and highly visible, that's what we need, to show the voters. Foreign aid was spent on such white elephants like the Ambewela powder milk factory, I have been told it has one of the largest spray driers in Asia and the milk from all the cows in country was insufficient to keep it operating at 50% capacity. Another one was the Urea Plant attached to petroleum refinery. The idea was good, but it was a failure from the start and not one kg

of urea was made there. Untold millions down the proverbial drain.

It was under these dire circumstances that ROB and a few of the young grads and some hard working technicians began this new endeavor. How ROB managed to get funds he stated in his SLAAS Presidential address and I quote, 'an enlightened Director and management, gave me the opportunity to build a productive research group performing at the frontiers of the art, in chemistry and technology of essential oils, spices and other natural products'. What arguments and persuasion he used I never found out.

Suddenly our two room NPS (natural products section) laboratory at CISIR was the best equipped analytical lab in all of Ceylon. We had 2 new Varian gas chromatographs in addition to an older Perkin Elmer F11 and a few months later a PE 700 IR spectrometer. Our first study was on citronella oil produced locally, we also analysed oils from lemon grass, cinnamon leaf and bark, which were also being produced commercially. We ran through rolls of recorder chart paper so fast that ROB ordered a whole box of 500 rolls. This was a time when electronic calculators were very rare, and digital integrators unheard of locally, so to calculate percentage composition from chromatograms of the essential oil we had to manually triangulate each peak the old Euclidean way, total the peak areas and then calculate individual percentages. GLC columns were of the packed variety, the now commonly used capillary columns were just curiosities or custom made. Once the columns we used wore out we were able to make our own columns under guidance from ROB. We even prepared our own packing materials, which matched the imported stuff very closely. The first problem we solved for the essential oils industry was to disprove

the so-called kerosene adulteration of Ceylon citronella oil. While the spices from Ceylon had a reputation for high quality, citronella oil was notorious in the trade for adulteration with kerosene. The anecdote about the judge who asked an errant trader, “are you selling citronella or kerosene” is told in books.

The myth that our citronella oil was adulterated was based solely on an ethyl alcohol solubility test known at the time as the Schimmels test. The main rival to our citronella oil was Java citronella oil which was being produced in Indonesia under strict regulations and this oil passed the Schimmels test very easily. The director of agriculture Dr. Walter Joachim personally distilled citronella oil samples from lenabatu grass and did Schimmels test and records show that many of the samples failed. Only after application of gas chromatographic analysis of citronella oil was the picture clearly seen why our oils, even freshly made, failed to pass the test. This is seen in the GLC patterns of Ceylon and Java type citronella oils – because there was already ample amounts of insoluble terpene hydrocarbons simulating kerosene hydrocarbons to cause failure of any solubility test.

Table 1: A Comparison of the Properties of Citronella oils

	Citronella Ceylon	Citronella Java
Botanical name	<i>Cymbopogon nardus</i> , Rendle	<i>Cymbopogon winterianus</i> , Jowitt
Local name	Lenabatu	Maha pangiri
Total alcohols as Geraniol	45 - 55%	70 - 85%
Schimmels Test	Does not pass	Passes easily
Verdict on quality	Adulterated	Good quality
After 1970 following GC analysis		
Monoterpene Hydrocarbons	20 - 35%	<10 %
Oxygenated terpenes	45 - 55 %	70 - 85 %
Other volatile compounds	10 - 20 %	8 - 12 %

Using a simple absorption method which Dru Fonseka devised, we were able to establish that there were no kerosene adulterants in any samples of citronella oil which came into our lab, as follows:

1. Take a small volume of oil and dissolve in 5 mL of pure Hexane and treat this with a few grams of activated Silica gel powder, mix well and keep for 4-6hrs
2. Filter out the hexane solution, evaporate under vacuum and inject 1-2mL onto the gas chromatography column
3. Examine the chromatogram, the peaks of oxy-terpenes are absent
4. When we added 4% kerosene to citronella oil and treated it as above, the glc pattern showed 3 prominent peaks in the blank region where the oxygenated terpene compounds normally appear. Figure 1 is a chromatogram of citronella oil Ceylon to which 4% kerosene was added and then processed as above

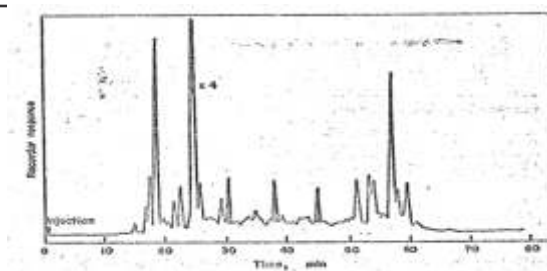


Figure 1

The verdict was very clear after we tested numerous citronella oil samples that **there has been no adulteration of citronella oil for the past 20 years or more**. It was the mistaken identification of high levels of terpene hydrocarbons as kerosene that caused this problem.

This was all possible because of the vision ROB Wijesekera had, that given the modern tools of analytical chemistry we chemists in Ceylon could carry out R and D comparable to what was being done in laboratories of the developed western countries. Accordingly, he made sure our laboratory was equipped with some of the best available instrumentation for the analysis of volatile substances in aromatic plants. When I joined the Natural Products Section of the CISIR, ROB and U M Senanayake had developed methods for the quality assurance of cocoa and chocolate products using TLC to quantify the three purine bases, Caffeine, Theobromine and Theophylline. We extended the application of similar methods to quality control of the oleoresins of spices such as pepper and turmeric.

In early 1972 ROB and I had an opportunity to attend the International Conference on Spices at the Tropical Products Institute in London. At this meeting of R and D scientists and representatives from spice and aromatic trade, ROB argued and explained convincingly that adulteration was a myth without any evidence and why the Schimmels test failed. During the discussion that ensued one trades person complained that the good quality spices were so expensive. ROB replied, I like to use the old Chinese saying, “Good things no cheap, cheap things no good”. This was greeted with much applause and some of the daily papers printed this part of the proceedings.

What did this pioneering and hard work get us from the trade and government of Ceylon? **Absolutely nothing**, no words of appreciation nor a ‘well done’.

There is a saying at the American Chemical Society to the question, ‘why do chemists practice their profession so diligently? Because they pay us to do what we love to do’.

ROB and his team did not stop at this point, but continued to develop new technology and generate new knowledge about aromatic plants and spices and

after ten years of selfless service it needed a foreign organization to recognize these efforts. The Guinness Foundation awarded ROB Wijesekera the coveted Guinness Award for sustained R&D efforts in developing country. On perusing the old correspondence I noticed more than fifty messages congratulating ROB from well wishers, fellow scientists and friends, but the only message from any government department was the note from the treasury saying, "Please arrange to have the one thousand pounds sterling transferred to the treasury, you may retain two hundred pounds for your own expenses."

The successive governments' endless lamentation is brain drain and one need not look further for reasons. ROB left Ceylon soon after, but he did not give up on the people of Sri Lanka. Many opportunities were found for young scientists to be funded to start projects or opportunities to work as consultants in other developing countries, while he worked for the different branches of the United Nations Organization.

About six years ago ROB wrote me a note indicating his final retirement from full time work and that he and Marina will be returning to Sri Lanka. As it happened it was not to idle away the well earned rest, but to work in a consultant position with over fifty years R&D experience. Link Natural Products (Pvt) Ltd, gladly took him on as a member of the board of management. On my retirement from the University of California, San Francisco Campus I too was invited to join the company. I am happy to mention that over 25 years ago the Chairman and MD of Link Natural Products asked me for help in setting up the small essential oil producing facility. It is with great pleasure that I rejoined that small venture which has now grown to be an industry leader in spices and essential oils and scientifically formulated herbal health products which have international recognition. I can say with confidence that my theme is very much in force at this industry that good things are not cheap and cheap things are not good. Link Natural Products has a well equipped quality control and R&D laboratory and a

team of qualified scientists working all the time assuring the quality of raw materials, intermediate and final products manufactured at this facility. The raw materials are the key to running a profitable and well regarded industry and I personally know the great effort needed to maintain the high standards for which this company is recognized.

The list below is the Wijesekera R&D team and many others who helped us in many ways. I would also like to pay my personal tribute to Prof. Tuley de Silva who was in the Department of Applied Science at the University of Sri Jayewardenapura whose vision of in post graduate education enabled me to register for my Ph.D. degree at USJP. I was the first candidate from there.

Wijesekera R & D Team 1969 - 1977

Upali M. Senanayake, Ph.D.
B. Drupadha Fonseka, B Sc
A. Lakshman Jayewardene, Ph.D.
Lakshmi S. Rajapakse-Arambewela, Ph.D.
Kanthi Fonseka-Hettiarachchi, Ph.D.
Roshantha C.Chandraratne, Ph.D.
P. Anura Senaratne, Ph.D.
Donald Wijekoon, Ph.D.
V.U. Ratnayaka, Ph.D.
Azeez M. Mubarak, Ph.D.
K Ratnasingham
Philo Ambrose
Lakdas N. Fernando
Nissanka deSilva
Kamalita Fernando
K.R. Dayananda
C.L.M Nethsingha
Arthur Bamunuarchchi
Shiranee Samaranayake

I would like to thank the Institute of Chemistry Ceylon for giving me this opportunity to deliver this oration and everyone for your kind attention.

Remarks by Mr. Jayantha Dhanapala

Mr. President, Distinguished members at the High Table, Ladies & Gentlemen,

Let me first thank the President and members of the Institute of Chemistry for the honour of this invitation and allowing me the opportunity to participate in felicitating Dr. R.O.B. Wijesekera. My first and most pleasant task is to greet him on his birthday which was yesterday and to wish him many happy returns in the service of the cause of science and of his country.

We are here to honour a man who matters, and matters greatly, in a science devoted to the study of matter. As many of you know, I am not myself a man of

the sciences having devoted myself to a lifetime in diplomacy and international affairs. But I have had frequent encounters with Dr. Wijesekera in the Rotunda of the Vienna International Centre and elsewhere, and have been an admirer of his contribution to science in Sri Lanka and to the application of science for international development and peace through his work in the WHO and in UNIDO. I am also the eleventh President of the Nobel Peace Prize-winning Pugwash Conferences on Science & World Affairs established by Lord Bertrand Russell in 1957 and my distinguished predecessors have included famous chemists like Dorothy

Hodgkin. I am therefore very aware of the importance of science in world affairs and of the international significance of Dr. Wijesekera's work.

I would like to divide my presentation this evening into two parts. First, I will address what to me are the significant features of this felicitation ceremony. Second, I will discuss the role of Science in the multilateral global order today.

This felicitation ceremony has a special importance because, contrary to the self-denigratory image that Sri Lankans have of themselves as a society riven by jealousy, the Institute of Chemistry, as a peer group of Dr. Wijesekera, is giving honour where honour is due. That is a noble tradition. Next there is a focus in the ceremony on the legacy of a pioneer in the field. I recall the words of that famous seventeenth century British scientist, Sir Isaac Newton, who once said, "If I have seen a little further, it is by standing on the shoulders of giants." Future chemists in Sri Lanka will stand on the shoulders of Dr. Wijesekera and build on the foundations of his work in the first decades after Independence. It is the Asian tradition to give respect to the *guru* and the Institute of Chemistry which honoured Professor P.P.G.L. Siriwardena sometime ago, is now bestowing its honours on Dr. Wijesekera who has been part of the critical mass of scientists of his era.

This ceremony also highlights the role of science in society especially in a developing country like Sri Lanka. "ROB" devoted his life to the application of science for development. His major work on medicinal plants for the WHO and his research on the industrial applications of local resources in UNIDO have a special relevance for our country and for all of the developing Global South. At a time when our country has emerged from the trauma of three decades of terrorism and is poised for an economic take-off, the role of the scientist is especially important. Finally this ceremony has given due regard to the gender dimension and I am happy to see a lady at the head table and others prominent on the Institute's committee. I must also acknowledge the presence of Mrs. Wijesekera - herself a scientist of great distinction and the daughter of the first Sri Lankan Director of Agriculture.

Let me move on to the role of science in the multilateral world order of today. There has been a spate of criticism of the United Nations and we have recently witnessed the ridiculous spectacle of demagoguery in front of the UN office in Colombo. Whenever I am faced with such criticism of the UN, I recall the words of the UN's finest Secretary-General, Dag Hammarskjöld, who once said, "The UN was not established to take humanity to heaven but to save it from hell." If any credit must be given for saving humanity from hell, it must go to the specialized agencies in the UN system. Among them are the WHO, which helped to eradicate small pox from the world and organized an effective strategy to combat the SARS pandemic, and UNIDO which has devoted its energies to the use of local

resources in developing countries for industrial development and raising their standard of living. Dr. Wijesekera worked for both these specialized agencies. His reports are there as a legacy of his work.

There has also been some misguided xenophobia and attacks against countries who have been critical of our conduct of our battle with terrorism. Albert Einstein once wrote, "Concern for man himself and his fate must always be the chief interest of all technical endeavours... in order that the creations of our minds shall be a blessing and not a curse to mankind. Never forget this in the midst of your diagrams and equations." It is the essential humanist approach to role of science that must prevail at all times. We are a part of an international community. Anton Chekhov, the Russian playwright, said something on the same theme when he wrote, "Science cannot be national, in the same way that a multiplication table cannot be national. If science becomes national it ceases to be a science". Through science we keep our windows open to the world. An inward looking society risks becoming a stagnant autarchy.

The global trend is to celebrate diversity and to recognize its political, economic and cultural strength. In a lecture in 2004 Dr. Wijesekera said, "Peace lies in nurturing diversity" and, further, that "Democracy is the power of the people to shape their destiny". These are very pertinent comments today. In this post-conflict period of our history we have a unique opportunity to build an inclusive society with economic growth, human development and social progress as a foundation for a durable peace and for equitable development.

We are faced with challenges nationally and internationally. In the span of human history it is only in the nineteenth century that Asia lagged far behind as the West, spurred by the Industrial Revolution, surged ahead. Today we see a resurgence of Asia with the growth of the Chinese and Indian economies. Sri Lanka can enjoy the benefits of this resurgence in this phase of our nation building forging unity and repairing our internal differences. The world faces a host of problems – poverty which the Millennium Development Goals hope to mitigate; weapons of mass destruction; international terrorism and climate change are some of them. We cannot continue to spend \$ 1531 billion on military expenditure per year or \$224 per person, while one billion of our fellow human beings, the "Bottom Billion", exist on less than a dollar a day – the benchmark of absolute poverty. The world we live in must be a world we can live with.

Science has a vital role to play in facing these challenges both in Sri Lanka and in the world. And it is scientists like Dr. R.O.B. Wijesekera who can make a difference and set an example to inspire future generations of scientists.

I thank you for your attention.

Response by Dr. R.O.B. Wijesekera

President Professor De Costa, Chief Guest Jayantha Dhanapala, Other Members of the Head Table, Distinguished invitees, Fellows & Members of the Institute, Ladies and gentlemen.

I have a hard task before me, in attempting to give expression to my deep and heartfelt gratitude to the Institute of Chemistry for the honour bestowed on me. Today I am forcibly reminded of several things, Landmarks if I may so refer to them, in the annals of the Institute.

I am reminded of the voluntary labours of those who formed the CHEMICAL SOCIETY OF CEYLON in 1941, from which our present Institute is derived. Then in 1954 as a young researcher, I was thrown into the deep end as it were, and elected a joint secretary of the Society. At the time I worked alongside some of the giants of the past who nursed the Chemical Society. To us all, their successors, they are now honored names as they are, without any doubt, to the present generation who have chosen to honour me.

Then it was in 1970 that I was elected President of the Chemical Society. In that year, together with Dr. M.A.V. Devanathan, then Vice President, we restructured the Chemical Society, to become the Institute of Chemistry – according to the trend of the time. Very soon an incorporation bill had to be presented in parliament and the task fell to a youthful MP for Beliatta, by the name of Mahinda Rajapakse. Thus our Institute came to be the formal organ it is today.

From that time onwards the members of the present generation have made the Institute today into a formidable instrument of social, educational, and scientific change in the country. While I salute those who made this possible, I am deeply conscious of being felicitated today by this new generation – a generation who by their hard work and dedicated endeavour has proved their mettle.

I have been a research chemist for the first twenty five years of my long career and it was my chosen pathway. I have known what it is to do research ranging from the very fundamental to the most applied. To me what matters most of all is the quality of one's research, and the scientific discipline underlying it. Publishing one's work in peer reviewed journals is part of that discipline – a measure of quality assurance by peers. Today we witness the phenomenon of scientists publishing work, mostly half-baked if at all, in the daily press. The results which are not of the quality expected of true science spell danger. To me this is quite unacceptable.

Dr. Lakshman Jayewardene recalled a while ago my quip at the International Conference of Spices in London in 1972, where in response to a question as to why Sri Lanka spices were expensive I had stated: "As

the Chinese are reputed to say: Good Things No Cheap; Cheap Things No Good." May I in the context of what I said a while ago, remind you of another such Chinese slogan which I came to know in Beijing in 1982: "Good Science, can no easy do; Easy Science can no good do."

I believe that in science we must have one standard. Whether it is good or bad in science is based on peer judgment. Doing bad science sans the scientific discipline is a waste of resources, time and energy. It may fool the public for a time. It is unacceptable. Institutes such as ours, professional bodies, must outlaw bogus scientific work, and ensure that discipline in scientific work is maintained. In the ideal situation, aligned with scientific institutions such as ours we have a group of individuals with kindred interests supporting each other worldwide. We are able to draw on each other's expertise, and that is the strength of science worldwide.

In the latter half of my career, internationally I served the WHO as a Manager of a Special Research Program. It was a goal oriented effort to derive from plants an ideal contraceptive agent, according to goals and philosophies spelled out by a WHO expert Steering Committee to which I reported. My Research Team was situated in six different chosen Centers, spread out far and wide: in Seoul, Hong Kong, Peradeniya, Recife, Chicago and London-Leeds. I had to technically direct the program and ensure, that the goals and methodology mapped out by the steering committee were observed in the research. After my two year stint as manager, the technical parameters of the program were in-tailed as was the capacity of each centre to follow them.

There were eight distinct leads resulting from our efforts in two years when I transferred to UNIDO. I took over at UNIDO the world renowned Professor Finn Sandberg, as a Special Technical Adviser. My task was to develop within UNIDO a program of technical assistance to developing countries to enhance their capability in the area: that is Essential Oils and Industrial Utilization of Medicinal Plants. It was essentially building research capabilities and strengthening of local institutions.

I must say that all the time I enjoyed my work immensely. I relished the new challenges and the fellowship with scientists in three continents, both with those who had high reputations and those who were modestly gifted. I enjoyed interaction with the great scientists who assisted me in these international programmes. We were all like a common community, understanding each other with both sympathy and empathy. I also experienced the interaction with bureaucrats and even politicians of different countries and this too was new to me as a challenge.

But still for me there is nothing more rewarding than actual research. Our own search for truth even in a small way, and to understand why things behave in the manner they do.

On returning to Sri Lanka in 1991 I was to re-linked with Link Natural Products. I had been in touch with them whenever I was intermittently at home; as it had been once my daydream to develop a herbal products based industry in Sri Lanka.. It had been made into a reality by the skill, vision and contrivance of mainly two people: Devapriya Nugawela, and Wimuw Jayewardene. In spite of my spells as Chairman CISIR and then Chairman NASTEC, both very demanding roles as they were, I maintained my interest with Link Natural.

Not surprisingly, therefore, I am still there today; more as a Science writer and Editor than as an actual adviser in research although I sometimes find myself useful in such a role.

It now remains for me to renew my appreciation of the Institute of Chemistry and my thanks for the honour I accept with very deep humility. I have many to thank too. I thank Ambassador Jayantha Dhanapala, the absorbing speech he has just made; it was wonderful to listen to him. I must thank Lakshman Jayawardena, who revived for me the memories of days of goodness spent. I thank Azeez Mubarak and Nalini Ratnasiri for the recollection of pleasant memories and rewarding times. I owe a deep debt of gratitude to Lakshmi Arambawela, who shouldered the organization of this event. She came as a young

dedicated scientist and joined my group in the 1960's and I am proud of her own achievements in natural product research. She is a past-President of our Institute of Chemistry in whose term of office this very building: Adamantane House was opened. And I must not fail to thank JNO the Honorary Dean, who is the dynamo that runs affairs here and my niece, Professor Ramanee, who assisted in the organization of this event.

Permit me to also mention my gratitude to my wife Marina, who jettisoned her own career and took on the task of bringing up a family of five, while I was destined to do what I had to do. As a result we have today five good professionals who are at the same time good and decent human beings. That is her triumph. Her compensation was the great work she did in the United Nations Women's Guild, finally, becoming its President, and the best such during the time.

And then permit me to thank all of you distinguished people, Friends, Family, and Well wishers who are present today. Let me end by borrowing some words from that adorable actress Julie Andrews:

When the Joints ache, when the hips break, when the eyes grow dim

Then I remember the great life I've had, and then I don't feel so bad.

THANK YOU.

Chief Guest's Address

Professor T. David Westmoreland

Department of Chemistry, Wesleyan University, Connecticut, USA

I wish to express my sincere thanks to Prof. S.P. Deraniyagala and the Institute of Chemistry Ceylon for inviting me to attend the 69th Anniversary celebrations of the Institute. It is a great honor for me to be the Chief Guest at this session. I am also grateful for the opportunity to make a few remarks to this distinguished assembly.

2010 marks the beginning of a new era for Sri Lanka. A long and costly conflict has ended and the country may now devote itself more fully to national advancement. It is hard for us in the United States to understand how disruptive the war has been to Sri Lankan society, but we do know that the importance of peace cannot be overemphasized. It is the hope of all that peace will lead to prosperity of all kinds for Sri Lanka for many years to come.

Many of the challenges that Sri Lanka now faces are the same that other nations face and I predict that Sri Lanka will become a significant contributor to their solutions. For example, we all realize that our use of petroleum and other fossil fuels must change dramatically. We must develop new sources of the energy our societies require and more efficient methods for transforming chemical feedstocks into the products we need. The development of biofuels and other renewable energy sources is a field to which Sri Lankan chemistry has already made contributions and will continue to be a fruitful research area for Sri Lankan chemical and biological sciences. The people of Sri Lanka will also look to the chemists for solutions to the problems of providing adequate nutrition, clean drinking water, and treatments for common diseases. These are, of course, only a few of the challenges for Sri Lankan chemistry in the next decades.

It is especially appropriate that this session is devoted to the Graduate Chemists. They represent the next generation of scientists that will need to take on these new challenges. What they achieve will change Sri Lanka and perhaps the world. I have reviewed the curriculum that the Graduates must successfully complete. I admire the hard work they have done and the level of expertise they have achieved. They certainly need no advice from me, but I may be able to offer some perspectives on the possibilities that await them. I especially want to emphasize to the Graduate Chemists that Sri Lanka is the type of place where discoveries can be made that can change Sri Lanka and the world.

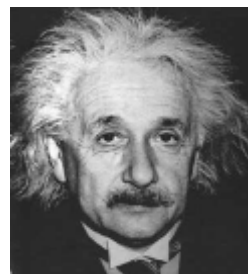
Chemistry in Sri Lanka may not enjoy the material resources available at some of the large research centers in the world, but it does have the most important

resource: A well educated and scientifically sophisticated group of young chemists who have the skills and the ambition to do important work. In his fascinating book "Discovering", Robert Root-Bernstein sets out to investigate whether there are habits of thinking and working that make some scientists more likely than others to make important discoveries. He suggests that the work that changes a field in science comes from creative thinkers who are well trained in their disciplines, but are willing to reject the standard accepted theories if their research requires it.

I have always remembered a map he gave that shows the great centers of chemistry and physics in 18th century Europe. These were at universities located in cities like Paris, Berlin, Zürich, and Leipzig. The map also indicates where the major discoveries in physical chemistry were made. The list of locations is very different and includes Aberdeen, Uppsala, Utrecht, Riga, and New Haven (near my home institution). These are places largely on the periphery of 19th century science and were far removed from the large, well-equipped academic centers. They represent places where scientists like van't Hoff, Gibbs, and Arrhenius were free to follow risky lines of research and to think independently beyond the scientific dogmas of their time. Their creativity was more important than the material resources available in Berlin or Paris.

I urge all of you to develop and pursue new ideas in chemistry like these earlier scientific explorers did. My experience tells me that some of your ideas will be correct and occasionally one of them will be important.

I would also like each of the Graduate Chemists who are early in their careers to consider the portrait below. This picture represents one of the great icons of 20th century physics. Everyone, including non-scientists, knows whose picture this is.



But it is very important to remember that this is *not* the Albert Einstein who invented special relativity, who explained Brownian motion and the photoelectric effect, and who changed the way we perceive the universe. The portrait below is the Einstein who



transformed the physics of time and space. He was in his early twenties, working at an obscure entry level position in a patent office. Although it is true that experience can count for a great deal, in science great discoveries can come from anywhere and anyone, including anyone sitting in attendance today.

Let me again offer my congratulations to the Institute of Chemistry Ceylon on the 39th Annual Session and the 69th Anniversary Celebrations and to the Graduate Chemists on their impressive achievement. Thank you once more for the honor of addressing this session and I offer my best wishes for a successful meeting.

Guest of Honour's Address

Professor Paul R. Sharp

Department of Chemistry, University of Missouri, Columbia, USA

Good morning. May I begin by saying how honored I am to be asked to take part in this inauguration and celebration. A celebration of the founding of IChemC and the accomplishments and the successes of you, the former and students of the Institute of Chemistry, Ceylon.

For you students, I am also honored to share in the pride felt by your families and all of your teachers. Each of them, even the teachers from your earliest days at school have contributed to your lives, to bring you to where you are today and to wherever life leads you next. You sit today looking at a future full of promise. Your path may take you to further studies here in Sri Lanka, or further afield to other countries, perhaps even the United States of America. Your future may lead you into careers as technicians, entrepreneurs, and researchers or perhaps even on to become teachers to impact the next generation of young scientists.

This is my first visit to your beautiful country. And having just completed ten days touring here I can honestly say that your country offers so much that is truly remarkable. While this is my first visit it is not my first meeting with young Sri Lankan students. We have had several Sri Lankan graduate students come to the University of Missouri in Columbia where I teach. In fact, I have a Sri Lankan doctoral candidate working in my labs at this moment finishing her thesis with me. Three years ago she came to my labs and proved herself to be every bit as prepared for doctoral work as I could have wished. My colleagues have found the same with other students from your country who have progressed through our doctoral program. What does this tell you about your preparation for work in chemistry? It says clearly to your faculty and the faculty around the world that you have received not just a world-class education but that you have been well trained and prepared for success in your future endeavors. Personally I can tell you that my Sri Lankan student, Malathi Welinge is one of the best I have had the privilege to teach, train and work with in my nearly 30 years of preparing PhD students.

In preparing to come here I stopped to think exactly what it is that has made this one student so

special? Certainly her knowledge and grasp of Chemistry is a strong point in her favor. But is this all? No. I have to say that it is more her passion for her field, her need to look deeply into the wonders scientific study offers, her determination and tenacity in that investigation, and her willingness to work and work hard.

A friend of mine reminded me lately of an old saying; "Genius is 10% inspiration and 90% perspiration."

I am sure my Sri Lankan colleagues are all sagely nodding their heads in agreement. But I am also sure they would agree that it takes a bit more as well.

My Sri Lankan student's work ethic was obvious from the first day. She well understood the need to put long hours into her lab work as well as with her textbooks if she was to achieve her goals. Yes, long hours. I am sure there are a few of your heads down there before me nodding in agreement.

Her willingness to work hard was obvious but what slowly became apparent was her determination and sheer tenacity of spirit. This solid base, the refusal to give up, first became apparent when the research project I had given her was not going well. She had made some advances but had reached a point where no further progress seemed possible. That 'do we put this one back on the shelf or do we scrap the whole thing' stage. I myself was discouraged and, after all, this was a student in the early stages of her degree work, so I offered to change her to another, perhaps less trying project. Her response was a real surprise. She, very politely, but point blank told me, "No thank you, I want to finish this project."

After I recovered from the shock of her refusal, we began a long discussion of different approaches one could take to attack this impasse. Armed with new ideas, her poor teacher still amazed at the tenacity of this young woman, she went back to the lab. Did she succeed? Absolutely. The results were far and away better than we had dared to hope, all because of determination, because this young scientist would not give up.

She has grown immensely since those early days,

finding not just self-confidence but real joy in the work, the fun of discovery and the sense of accomplishment in seeing her work shared with the scientific community. Her thesis work is all but complete and she will go on to great things, I have no doubt.

So what do you need to be a really good scientist? Labs? Yes. It is hard to do bench chemistry without a bench to work on. Libraries? The Internet has certainly made those far more accessible. Colleagues? Definitely. My colleagues and students have certainly been my greatest assets over the years. But what is important to be really successful?

My undergraduate training was at the University of California, Berkeley and then for my PhD I trained at the Massachusetts Institute of Technology. The facilities at both of these institutions are among the best in the world. We had the latest NMR and mass spectrometers, the fastest computers in the world. The bench tops and sinks gleamed and each lab was outfitted with large and efficient hoods. We had several inert atmosphere boxes. The latest of everything. I thought this is what you needed to really do chemistry.

My postdoctoral fellowship was with Professor Allen Bard at the University of Texas at Austin. Dr. Bard is a highly regarded electrochemist and has been editor of the prestigious Journal of the American Chemical Society. He was famous. So, what a shock when I arrived in the chemistry department in Texas and was shown down into a dark and dingy basement laboratory and office. The equipment was functional but old and well worn; the benches were corroded and stained. Nothing was the latest model. This was not what I expected at all. I feel a bit ashamed now to admit that I could be so bold and well, rude, but during one of my early meetings with Dr. Bard I asked him why the facilities were not as I had expected them to be. He did not get upset or angry; he simply looked at me and calmly said that he preferred to invest in people not facilities. With good people the facilities don't need to be the best and the newest. It is ideas, creativity, intelligence and hard work that make a thriving enterprise.

And he was absolutely correct. The students and postdoctoral fellow that I worked with there in the two short years of my fellowship in Bard's labs turned out top quality work, excellent results on those worn out old benches. Chemists graduated from his labs to go on to top academic and industrial positions.

It was a hard lesson for me to learn but one that has stood me in good stead for a lifetime of research and study and is a lesson I offer to you today. Facilities are important. We need a workplace, but it is ideas, creativity, passion for learning and research, and resourceful minds that are the best equipment. It is all of you that will make the difference; it is your talents that make the contribution to your future employers and to your country.

And we need your contributions. Never doubt that. Not just your own country but also the world needs you. Think about where innovations in chemistry are needed; health and medicine, electronics, material manufacture, energy.

Let us focus on one area of research open to us as chemists. We have all of us become dependent of the burning of fossil fuels with the resulting release of CO₂ into the atmosphere. Combustion, what could be more chemical than that? Now we have the worldwide problem of the effect of CO₂ on our planet. Who is better to address this than us, chemists? All of the potential solutions to keep us moving, our lights on and our computers running, short term and long term require chemistry. One possible solution, short term at best, is the continued use of fossil fuels but to include carbon sequestration, the capture and storage of CO₂. For this to be done it must be done efficiently and inexpensively and this calls for an understanding all aspects of CO₂ chemistry. Beyond this, is the development of alternative fuels, biofuels, and of chemical feedstocks from biomass. This all involves the breaking and forming of bonds: Chemistry.

Ultimately, as my friend Nate Lewis at CalTech eloquently outlines, we will need to harness solar energy. Dramatic advances in light to electricity conversion and light to stored chemical energy will be essential for this process. Some of my students are already working in this area. Our entry into this research was accidental based on the keen observations of a past student, now Dr. Lee then just Han Baek. He had prepared some new platinum compounds and left one of these compounds on his desk. When he went to retrieve it he noticed that it had changed from red to yellow. We were all intrigued but little did we know that this simple observation would launch a whole new area of research for my group. The color change was a photochemical reaction, but neither Han Baek nor I had much experience or knowledge in photochemistry. But we did have the same basic understanding of chemistry as a field that all of you have and this allowed us to know what had caused the reaction and where to direct our reading and library work. From the books and journal articles on photochemistry we gained the insight to understand that light absorbed by the compound was causing the elimination of bromine, a thermodynamically uphill reaction; in other words, the conversion of light into the stored energy of chemical bonds. Think of what that could mean for solar energy? Best of all for us, Han Baek's compound is unusually efficient and is easily modified, excellent features for experimentation. There are now 3 students working on this project and we have reached a basic understanding of how the photochemistry works and what steps we might take to optimize the system for energy conversion. And all this from one student's simple observation. Professor Bard was

right. Invest in your people.

Inspiration comes in the most unexpected ways. The history of science is full of theories and inventions arrived at seemingly by accident. Be open to new ideas and knowledge because you can suddenly find yourselves working in unanticipated areas. Through hard work and study you have gained a basic knowledge in one area of science but it is an area that touches on so many fields. Never stop building on that knowledge, learn new material, teach yourselves and learn from your colleagues and for those of you destined for academics, be ready to learn from your students as well. You have an exciting world ahead of you. So much work to be done, so much to learn, so

much to discover. You will make contributions to society and the world wherever your path leads you because it is you who will be in the forefront of new learning.

As you leave today you have new endeavors, challenges and opportunities awaiting you. But whatever heights you reach don't forget how you got there. Always remember the support, learning, and encouragement of your families, your teachers and your home, Sri Lanka. They set you on this road to success and applaud you as you walk along it.

My congratulations and best wishes to each and every one of you.

Thank you.

Seventh Convocation Awards & Prizes 2010

Overall Examination Awards -2010

- | | | |
|-----------------------|--|---|
| 1st | Shireen Jayasuriya Memorial Gold Medal | Mr R Loorthuraja |
| 2nd | Graduateship Silver Jubilee Award | Ms. D L Basnayake |
| 3rd | Graduate Chemist (25th Batch Passing out) Silver Jubilee Award | Mr. Y M D Y Bandara & Ms. B I Karawdeniya |

First Class Honours (15)

Mr. R Loothuraja, Ms. D L Basnayake, Mr. Y M N D Y Bandara, Ms. B I Karawdeniya, Ms. C H Narangoda, Ms. M L Coorey, Mr. J V A Dahanayake, Ms. K M Rajapaksha, Mr. W S de Silva, Ms. S Nilushni, Ms. H S M Fernando, Mr. S Loganathan, Mr. SCD Fernando, Ms. W M U D Bandaranayake, Mr. H A G S Perera

Second Class Honours (Upper Division) (28)

Ms. L R S Jayasinghe, Ms. S A K Amarasinghe, Ms. W A C V Warsapperuma, Ms. K A N Manathunga, Ms. N C Abeysinghe, Ms. G U Chandrasiri, Ms. N P W Rathuwadu, Ms. K K D P M Dhanapali, Ms. H M D T Herath, Ms. H L T Udayakanthi, Mr. U P M Shavinka, Ms. N K B S S K Narasinghe, Ms. A S K Kankanamge, Ms. K M Nagawatte, Ms. A G M J Gunaratna, Ms. F Z Z Mohamad, Ms. F N Ashan, Ms. R A D U Ranawaka, Mr. W H A K A A Buddhapriya, Ms. D Sriselvam, Ms. M C N Fernando, Mr. S Senthil Maaran, Ms. A U Wijesekara, Ms. N Sivanantha, Ms. W B M L Fernando, Ms. S L O Erandika, Ms. P A I C Silva, Mr. S D J Fernando

Second Class Honours (Lower Division) (12)

Mr. G J V Dabera, Mr. K B W M R A I Wathupola, Ms. S M R W S Silva, Ms. R D P M Weeraratna, Ms. C B Thanganayagam, Ms. P A N K P Jayawardhana, Ms. M S K Wanigasekara, Ms. T V M Sriyanjani, Mr. W B A Wijayarathna, Ms. K I P M Ahugammana, Ms. H H S Y H Hewawasam, Ms. J M D K Karunaratne

Third Class Honours (10)

Ms. D M T P Alwis, Ms. D N Dasanayake, Mr. S Mithurshan, Ms. P G D Kaushalya, Ms. K A D M S Sarathchandara, Mr. B M D Senevirathne, Mr. S S Gajaweera, Mr. V D Suaris, Ms. D S D W Madanayake, Ms. A S S Mendis

Pass (10)

Mr. K H P R de Silva, Mr. W A M Harinda, Ms. H D Hansamali, Ms. E D C P De Silva, Mr. R A S D Jayawardhana, Ms. L R Gurusinghe, Ms. W C I Cooray, Ms. H M U Hippola, Ms. G A W Silva, Mr. W M K I Weerasinghe

15 First Classes



Levels 3 & 4 Overall (Theory) Prizes

First RSC (SL Section) Award Ms. D L Basnayake

Second Mr R Loorthuraja

Third Ms B I Karawdeniya

Overall Best Performer Awards for Practical

Professor RS Ramakrishna Memorial Award

Ms. H M D T Herath

Mr. & Mrs. K Sivarajah and Family Award

Mr. R Loorthuraja

B A Jayasinghe Memorial Award & CCS Award

Mr. W S De Silva & Ms. B I Karawdeniya

Convocation Prize List 2010

P Rohan K Fernando Prize for Special Topics in Chemistry

Mr H A G S Perera

W R O Fernando Memorial Prize for Energetics & Kinetics

Ms. N Sivapragasam &
Ms. D L Basnayake

Dr Sudath Kumarasinghe Memorial Prize for Selected Topics in

Physical Chemistry

Mr. R Loorthuraja

Dr. Lakshman Ponnampuruma Memorial Prize for Special Topics in

Inorganic Chemistry

Ms. W M U B Bandaranayake

Mr. & Mrs. N I N S Nadarasa Prize for Special Topics in Organic Chemistry

Mr. R Loorthuraja

Denzil and Christabel Fernando Commemoration Prize for Agro Industries

Ms. N Sivapragasam

MicroChem Laboratories Pvt (Ltd.) Prize for Environmental Chemistry

Mr. J V A Dahanayake

Prof. Paul & Rune Sharp Prize for Fundamentals of Chemical and

Process Engineering

Ms. B I Karawdeniya

A P De Silva Prize for Chemical Sensors

Ms. K A N K Manathunga

Prize for Computational Chemistry

Mr. R Loorthuraja &
Mr. H A G S Perera

Dharmachandra and Thamarasa Gunawardhana Memorial Prize for

Selected Topics in Analytical Chemistry

Mr. Y M N D Y Bandara

N M S Hettigedara Family Prize for Pharmaceutical and Medicinal Chemistry

Ms. B I Karawdeniya

Batch 2005 Prize for Information Technology

Ms. M L C Cooray

Vasanthan & Menaka Prize for Further Management,

Economics & Marketing (Course provided by Unilever)

Ms. H S M Fernando &

Ms. P A N K P Jayawardena

Not Awarded for passing out students at this year's Convocation

Professor P. P. G. L. Siriwardane Memorial Prize for Further Topics in Inorganic Chemistry, Prof. Eugene de Silva Prize for Industrial Chemistry & Technology, Mevan Pieris Prize for Polymer Chemistry & Technology, Egodawatta G Somapala Prize for Food Chemistry and Technology, Pincock Prize for Photochemistry, Careen Manel Abeywardene Memorial Prize for Natural Product Chemistry, Susila Jayaweera Memorial Prize for Biochemistry II, Marina and ROB Wijsekera Prize for Molecular Biology and Biotechnology.

Overall Excellence Awards covering all levels

Prof. Leslie Gunatilake Award for Organic Chemistry

Mr R Loorthuraja

Prof. J K P Ariyaratne Award for Inorganic Chemistry

Mr R Loorthuraja

Haniffa Award for Physical Chemistry

Ms. D L Basnayake

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/-
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21	*Silicones	Prof Sudantha Liyanage	Rs.65/-
22	Pericyclic Reactions: Theory and Applications	Dr M D P De Costa	Rs.65/-
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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/-

* - 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		Prof S Sotheeswaran	

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	Abbreviation	Number
Fellow Life Member.	F E L	05
Fellow C Chem.	F C C	09
Member	M E M	26
Associate Member	A M E	12
Affiliate Member	A F F	01
Affiliate /Under Graduate. A F U		02
Total Membership as at March 2010		55

2. Committee of Management

The following were elected to the Committee at the 49th Annual General Meeting held on 23rd July 2010.

Chairman	- Mr. R M G B Rajanayake
Vice Chairman	- Dr. M P Deeyamulla
Chairman Elect	- Prof. Sudantha Liyanage
Hony. Secretary	- Mr. I M S Herath
Hony. Treasurer	- Prof. W S Fernando
Committee Members	- Dr. Positha Premaratne Mr. W A P Silva Mr. S Perasiriyan Mr. W J P D Jayalath
Hony. Auditor	- Prof. L G Chandrasena

3. Committee Meetings

There were 11 Committee Meetings held during the period, June 2009 to July 2010. The venue of these meetings was the office of the Royal Society of Chemistry SL Section at the S L A A S Headquarters. These meetings were held to discuss the R S C SL Section's, new plans and strategies with regard to organizing the activities for the year 2008/2009 and thereafter.

4. Activities

4.1 Contributions to Activities of the Institute of Chemistry, Ceylon

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

(b) Annual Dinner

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

(d) Annual Sessions

4.2 Inter - University Chemistry Competition, 2010/2011

4.3 All - Island Inter School Chemistry Essay Competition 2010/2011

4.4 Book donation at North Central Province.

4.5 Teacher training workshop.

4.6 Popular lectures.

4.7 Donation of teaching and learning resources for chemical society of selected University.

4.8 Newton A. Dias Weerasinha Memorial Scholarship

4.9 Book donation programme

4.10 Writing monographs by few committee members

4.11 Industrial visit

4.12 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/Sri Lanka/index.asp.

I M S Herath
Hony Secretary

Ceremonial Opening of the R.O.B. Wijesekera Hall and the Unveiling of the Portrait of Dr. R.O.B. Wijesekera



Dr. Wijesekera's portrait had been painted by Mr. Weera Wickrama, then Head of the Haywood School of Arts, Horton Place, Colombo 7



Head table of the felicitation



Dr. Lakshman Jayewardene delivering the ROB Wijesekera Felicitation Oration.



Remarks by Mr. Jayantha Dhanapala, Chief Guest.



Response by Vidya Jyothi Dr R O B Wijesekera



part of the invitees



Ceremonial Opening of the R O B Wijesekera Hall & Unveiling of the Portrait by Mr Jayantha Dhanapala



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