University - Industry Interactions in Chemistry

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Chemistry as a science permeates every industrial activity. Its role in development is gaining a new meaning and the need to harness chemical sciences towards solutions of socioeconomic problems is receiving international recognition. The role of a University as an exclusive centre for academic pursuits and high learning is being constantly reviewed. There is a need to recognise the diverse purposes of a University and that of training people for industrial needs in all their variety is particularly important.

It is generally observed that there is little research and development activity in the industrial sector in the developing countries. The local expertise in academic and research institutions have hardly been utilized for building new industries or renewing existing industrial activity. The University is often without experience or even knowledge of the nature and needs of industry. There is much energy often wasted on pointless arguments about 'pure' and 'applied' research. This distinction in Chemistry is becoming more blurred.

In most developing countries, University provides the only opportunity for tertiary education. Increased pressure for University admission results in greater emphasis in the University on teaching and less on research. The lack of the latter ingredient dampens the quality and stimulus for innovative teaching. The finding of the education commission in India portrays the reality of this situation. 'A majority of teachers teach mechanically and listlessly. The subjects in which they lecture do not often involve their intellectual position, even the intellectually ambitious younger members of the staff are soon caught up in the general atmosphere of indifference or cynicism and there is a deadening of the spirit of intellectual curiosity and adventure'.

The picture in the developed world is in sharp contrast. The cooperation between chemical industry and Universities in Germany has always been very close. Since the middle of the 19th century, Universities and chemical industry have based their work on the scientific results and achievement of the chemists. Chemical research was successfully exploited for industrial growth. University research on aniline dyestuffs and plant metabolism laid the foundation for large chemical fertilizers, chemical industry in effect flourished on the efforts of academics at a University. The tradition of close cooperation between industry and the Universities has provided opportunities for the exchange of experience and the promotion of chemistry for chemistry from industry, Universities and government authorities. The industry has profited from the transfer of scientific and technological results provided by the University. The University Chemists in turn hold prominent positions in large industrial companies often as consultants and endowed professorships at Universities. This close interaction between University — Industry has grown and successfully emulated by the developed countries. Science for development has been vital for continued progress of the developed countries.

The relevant statistics emphasise the difficulties of the 'third world' countries and perhaps justify the apt description of most developing countries as 'poor rich' countries - - rich in their resources but their people are poor: only 5% of the world's research and development activity is conducted in developing countries. Over 80% of the world's scientists and technologists work in Europe, USSR and North America, while about 80% of the world's people live elsewhere. A recent study has shown that less than 1% of the total research effort of the developed countries has any significance for the developing world.

The bridging of the widening gap between University and Industry is therefore an urgent priority particularly for the third world. This is not to say that we should plan to transform the University to a vast industrial complex. Many propose increasing the responsiveness of education policies and systems to country needs. A reorientation of the formal and informal education systems to meet national needs through the application of science and technology is often recommended by international conferences. These changes could have the reverse effect. While it should be recognised that curricula should incorporate ingredients to provide awareness and relevance, they should also contain a solid core of fundamental or basic chemistry. Training of University chemists deficient in the fundamental principles of their subject could be equally unbalanced and encourage dependence on assistance of outside 'expertise' to sustain economic growth. How then are we to promote this interaction between University, Chemistry and Industry? To what extent should teaching and research at the University be geared towards the economic growth of the community? The basic philosophy of any developmental process is that you must start from where you are. It would not, for example, be appropriate in a developed country for a University to concern itself with details of village scale soap manufacture, manufacture of good paper glue from manioc starch or be involved in improving methods for rural bricks and tiles. But these are

some of our small scale local industries. Should not our Universities channel some of its energy to develop projects through transfer of laboratory findings and development to industry? No turnkey strategies or institutionalisation is likely to prove successful. Each University should evolve its own mechanism to promote interface activity with industry.

CHEMISTRY AND INDUSTRY IN SRI LANKA.

Sri Lankan industry is largely production oriented. Little evidence is found for research and development for the effective utilisation of the natural resources as raw materials in Industry. The mineral resources of Ceylon range from raw export items as graphite, ilmenite and zircon, materials for local industry as clays, limestone, dolomite, feldspar, etc., to revenue earning items as gemstones. There are those that await exploitation as iron ore, apatite and peat to mention a few, and a host of other minerals as thorianite and fluorspar that are little mined. The utilisation of silica sands for glass is minimal, graphite and mica industries remain to be established. Some of these raw materials find use in the cement and ceramics industry and there is much more that could be achieved.

In the agriculture sector, much effort is required to produce value added products as in the tea, rubber and coconut. Utilisation of agricultural wastes, fractional distillation of essential oils, oil from rubber seed, post harvest preservation of food and many more illustrate the importance of interaction in the chemical expertise of University and industry for development. In all these activities, a multidisciplinary approach is necessary not only among the sciences, but as well in managerial and marketing skills to determine technical priorities and to effect changes in the educational system to ensure that these skills are made available. Industrial chemists and managers could contribute to academic teaching programmes in areas of their competence. University research should direct at least a part of its efforts in the study of some of these resources. Such diversion of the academic community would not provide immediate publication of their efforts and it is here that institutional provision is essential for recognition of such work for academic credits. This then is a challenge for chemistry departments in Universities to reorder their research priorities and perhaps reorient academic programmes to meet some of the needs of industry.

The **private sector** chemical industries in Sri Lanka is not without its development and research programs into new substitutes or product improvement. This activity is isolated and without much cooperation of University chemists. This perhaps stems from the Industry requiring a certain level of confidentiality to be maintained about the technology they would like to develop which must be appreciated by the academic community. A 'person to person' interest and involvement is often necessary for this cooperation to prove a success. Chemists in the Sri Lanka private sector have shown interest in the extraction and isolation of perfumery material from locally grown plant material. Ionone from lemongrass oil is an example of this activity. The use of cashew nut shell liquid as an antioxidant in natural rubber compounding, and extraction of valuable constituents from this source illustrate the potential of study of this natural material. Essences in the food industry, manufacture of activated charcoal, precipitated calcium carbonate and other bases for toileteries are items that interested the private sector in their search for import substitution. These are surely areas where cooperative efforts of University and the private sector chemists could have yielded innovation, development and emphasis on product quality.

University — Industry interaction is a 'two way' process. Just as much as the staff of Universities are without experience and knowledge of the nature and the needs of industry, the industry itself is unaware of the curricula and programs of University Chemistry. There could be several ways of bringing these two groups together to work closely in developing programs which would satisfy the needs of industry. Developing University programs to meet industry requires mutual appreciation of each others efforts. University chemistry courses should clearly bear an intelligent relation to what goes on in a modern chemistry laboratory and so courses must be modified as knowledge expands and the needs of society change. Such changes should be carefully monitored and the system should evolve itself over a period of time.

There are still other ways of making University chemistry programs meaningful to the community. Service centres is one such method of approach. Analytical service is a good starting point. Instrumental and other facilities at the University should be made available to industry related largely to small scale and local industry. Such service centres would then grow from undertaking preliminary project investigations to carrying out research projects for industry. This is one way of enlisting the support of industry for University chemistry programmes and vice versa. Organisation of technical workshops for industrialists and conduct of specialist University chemistry courses by specialists from industry is yet another 'two-way' approach where the practical applications of basic and theoretical knowledge would pave for greater involvement of the University and Industry in the study of problems of relevance to the country.

An orientation of University programmes could also consider cooperative curricula between the University and Industry — what is commonly referred to as 'sandwich courses'. This feature could have the added advantage of a higher student intake into Chemistry — a recurring problem of University admissions. This needs to be carefully worked out with a balance between academic requirements and industrial inputs and could best be achieved by direct cooperation between University chemistry departments and industry. This program could even serve as useful opportunities for middle level technicians to obtain

expertise equivalent to their counterparts with the formal University courses of study.

The **University of Colombo** has taken meaningful steps in this direction. Chemistry at Colombo provides for both oriented and academic programs, both of which are built on a firm core of basic fundamental chemistry. Oriented programs at present cover the final year of the general degree course. Courses of an introductory nature are offered in Analytical Chemistry, Industrial Chemistry, Polymer Chemistry, Natural Products Chemistry, Biochemistry and Solid and Surface Chemistry. The course titles provide for optimum staff participation and bring even in a small way scientists from industry to give the specialist flavour so necessary for the vitality of the program.

Each of these courses would provide for postgraduate courses of study and the first of these in Analytical Chemistry has been conducted since 1975. Industrial Chemistry is the obvious choice for the next postgraduate programme planned by the department. Chemical technology, unit operations, process control are some aspects presently covered. There are of course other disciplines as economics, management and chemical engineering so necessary to provide an integrated program to reveal the industrial operations to University students.

The academic programs of a specialised nature are research oriented. These constitute the final two years of the special degree course in Chemistry. Exposure to industry for this course takes the form of visits to industries for a casual interaction. A prolonged attachment to industry is also provided by a work experience program where each student is assigned to an industry or research institute for about 2 months. It is hoped that staff attachments to industry for short periods would also be possible. This would then be a means of bringing back to the laboratory, projects of relevance to industry. There is adequate material from the industries to engage the interests of a group of active and productive chemistry researchers for a considerable time. This University to Industry movement should also have the reverse interaction where specialists from industry would be involved actively in research and teaching programs in the University.

I have attempted to present a general account on this subject. An indepth study is required to evolve strategies for effective University-Industry interaction in Chemistry for national development. Problems in Industry in developing countries often present common features where the experience of one developing country could be of mutual benefit to the other.

The programme activity of UNESCO for 1981 provides for cooperative efforts from different countries to share their experience. Meetings have been held in Canada (1978) and in India (1980) on this subject. The Regional Workshop on University — Industry and the Citizen scheduled for 14 — 16 June 1982 at Colombo would prove a focal point for discussion in our own efforts to harness the chemical sciences towards solutions of socioeconomic problems.

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Chemistry and the Utilization of Local Resources

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Man has depended on the natural resources of this planet from the very beginning and life as we we know it would have been impossible without such basic resources as air, water, sun light, minerals, etc. As man became progressively more civilized, his desire for improvements in living conditions such as better food, shelter and clothing increased. The need for new and more plentiful resources was also felt. In order to obtain these new resources, man had to resort to a wide variety of new techniques and invent or devise new methods of working with raw material such as extracting metal from minerals, making alloys or mixtures of metals and even in the processing of food to make it more palatable and digestible. These improvements and innovations have been going on over the past forty centuries or more until the present day.

Even though primitive man would not have realized it, from very early times, chemistry played a part, small or large as the case may be in those techniques and methods. The development of chemistry and the advancement of technology went hand in hand. To-day technology, chemistry and all other sciences have developed so much that these can benefit man in limitless ways or they can destroy all mankind in more than one way.

We know that resources are all chemical in origin including solar energy. As a result any form of processing or conversion from one product to another involves chemistry to a greater or lesser degree. Simple processing steps such as sun-drying, smoking, boiling, baking and preserving of food materials or industrial materials may involve only very little chemistry. However, a large number of industrial and domestic processes or techniques involve more chemistry. We can safely say the more complex a process is, the greater the involvement of chemistry.

Let us now look at our local resources and see how chemistry and chemical processes are involved closely with them, mainly at the level of industries based on these raw materials.

Resources can be classed as being of

1. Plant origin
2. Animal origin
3. Marine origin
4. Mineral origin
5. Others such as waste material, etc.

We can identify a number of industries based on the different raw materials.

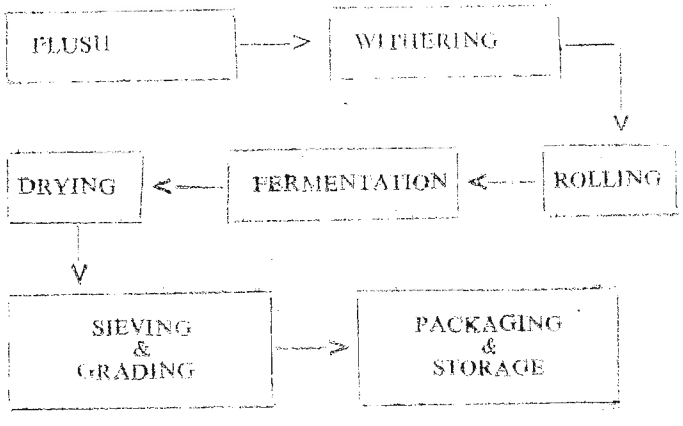
(*a*) Food industry
(*b*) Chemical and Pharmaceutical industries
(*c*) Building industry
(*d*) Energy and Power
(*e*) Manufacturing industries

In the following pages, I shall attempt to show the involvement of chemistry and the application of chemistry in a few of the industries which use local resources.

The food industry is by and large the greatest user of local resources. Crops such as rice, coconut, tea, sugar-cane, coffee other cereals and vegetables are grown in a major portion of the fertile land now under cultivation. Many of these crops require only what is generally called primary processing to give food commodities for the people. A few may require a little more than a first stage of processing, for example rice after harvest is cleaned and dried. Then it is taken for milling and polishing before the consumer can use it. Wheat requires further milling to give flour. All these are purely physical processes requiring energy input only. On the other hand, a commodity such as tea requires more complex processing. The tea industry is a good example of how chemistry is involved in processing one of our most valuable resources.

The tea we usually buy from the market is known as black tea and it is produced by a series of production steps which begins with the plucking of the tender tops of the tea bushes growing in estates. The simple flow diagram shows the main stages of the process of making black tea.

FLOW DIAGRAM OF TEA PROCESSING



Tea pluckers harvest only the topmost parts consisting of two leaves and the bud. The harvested leaf is called the "flush" and this is the only raw material which is required for making tea. Processes using chemistry and technology with the help of various machines turn this leaf into a product of very much higher value called black tea. More than half of our foreign exchange earnings are obtained from this one commodity.

The fresh leaf is allowed to wither for a number of hours and become limp by losing some moisture. This material is next passed through rollers which crush and tear the leaf with a rolling motion. Fresh un-withered leaf would have disintergrated in this process so withering is important. The most important effect of rolling is to rupture the cells in tea leaf causing the juices within the cells to mix with others inbetween cells, etc. This is the stage where chemical reactions begin to occur. The rolled leaf is then spread out in warm rooms to expose them to air. The reactions which started in the rolling stage can now go on to create the two most important properties of a good tea. They are: (i) Flavour and (ii) Colour.

All these reactions are catalysed by enzymes and oxygen from air is an important factor. Over a period of seventy five years or more, chemists in many countries including those at the Tea Research Institute in Talawakelle have studied the chemistry of tea. The flavour of good tea is a complex mixture of more than three hundred different compounds and about two hundred (200) have been identified. However no one has up to now been able to produce a good synthetic tea flavour.

The colour is the second most important factor in assessing the quality of tea. The deep golden brown colour of a tea brew is due to two classes of pigments known as Theaflavins which are yellow to orange in colour and Thearubigens which are more reddish. The black colour of the black tea itself is said to be due to the presence of chlorophyll and its break-down products in addition to the other pigments. Very little of the green pigment is water soluble so the brewed tea liquor is reddish instead of being black.

The fermentation stage requires three to five hours and then the leaf goes into a drying oven on a conveyor belt. The driers are at about 85° C and at this temperature the chemical reactions are arrested and the moisture is quickly removed. The product coming out from the driers look very similar to the black tea seen in the market. The other stages are again mechanical such as sieving, packaging, storage, etc.

The two sets of chemical reactions can be illustrated as follows:

FLAVOUR PRODUCING SUBSTANCES OR FLAVOUR PRECURSORS	Oxygen Heat ——> ENZYMES	FLAVOUR COM-POUNDS

COLOUR PRODUCING SUBSTANCES OR PIGMENT PRECURSORS	Oxygen Heat ——> ENZYMES	PIGMENTS OF BLACK TEA

There are other aspects of this industry where chemistry plays very important roles. Any crop that is cultivated has to be fertilized and protected from pests and diseases. Both these aspects involve chemistry in a large way. A very large portion of the fertilisers applied to crops are artificial mixtures of chemical compounds. The application of these have to be carefully controlled and the correct mixtures selected after careful survey of the soil nutrients already present. Crop protection is now an equally important and equally exacting process. The majority of pest control methods used even now are based on complex chemical compounds which are powerful enough to disable or kill weeds, insect pests, fungi and viruses. Everyone knows of the great concern which environment protection agencies (EPA) and governments are showing with regard to pollution caused by these toxins. Unfortunately there are only very few non-chemical methods for pest control at present. Biological methods are being developed rapidly but chemical pest control will be with us for quite sometime.

Spices and essential oils are plant based resources for which Sri Lanka was famous long before such major crops like tea, rubber, coffee, etc. Even today they contribute a small but valuable portion to our economy. It is said that the history of the South Asian Region changed significantly because of spices. Sea-going explorers collected spices such as Pepper, Cloves, Nutmeg, Cardamom, Ginger and Cinnamon from this region and introduced them to the west. All these spices are now available in Sri Lanka, however we are best known for "Ceylon Cinnamon" with 55% of the world production. The cinnamon plant is economically valuable because in addition to the spice from the bark, cinnamon leaf oil is produced from the leaves cut off during harvesting. Essential oils are the volatile aromatic oils found in spices and other plants such as Citronella, Lemon grass, and Eucalyptus. They are obtained by a process called steam distillation and this process leads to a high value product from apparently low cost materials. The chemistry of essential oils have been studied in great detail and many valuable and interesting results have been obtained. Studies on cinnamon by our own chemists enabled the Minor Export Crops Department to select and breed improved varieties of cinnamon and other spices for future crop diversification.

A long standing problem concerning adulteration in citronella oil with kerosene was finally settled only after the author studied the detailed chemical composition of citronella oil from Sri Lanka and and compared it with oils from Java and China.

The results of such studies have been most important in standardising and quality assessment of spices

and oils. Chemists have also been able to produce many new and non-traditional products from spices. Oleoresins and dried green pepper are two such products and these help in increasing the added value component in the marketing of spices.

Sugar is an essential item of diet in man. Sugar is chemically known as sucrose, an organic compound with the formula $C_{12}H_{22}O_{11}$. We import a large portion of our sugar requirements and the rest is obtained from local resources. Sugarcane, of course, takes first place as a source of sugar, but there are many other plants which can give sugar and other sweetening materials. Palm sap from coconut, kitul, palmyrah and talipot contain sugar and the liquid is called sweettoddy. They contain 15—20% sugar and on concentration by evaporation yield sugar, jaggery or treacle. The chemistry involved in the sugar making process is quite interesting. For instance, the sweet-toddy fresh from the palm contains almost pure sucrose, but there are certain enzymes in this sap which breakdown or hydrolyse the sucrose to give two other sugars of smaller molecular weight called glucose and fructose. The enzymes are called **invertases.** The latter sugars are more difficult to crystallize than sucrose. Therefore if the sweet-toddy is not carefully collected and quickly evaporated the chances of getting high yields of crystalline sugar decreases. The final product in making palm sugar depends upon the extent to which sucrose had been hydrolysed. Sugar will result if only little was hydrolysed and treacle will be obtained if enzyme activity had gone ahead. Jaggery could be called an intermediate between these two.

Chemists have found that high pH (basic media) prevents invertase activity

$$\underset{\text{Sucrose}}{C_{12}H_{22}O_{11}} + H_2O \xrightarrow[pH\ 5-6]{\text{Invertase}} \underset{\substack{\text{Glucose}\\ \text{Fructose}}}{2C_6H_{12}O_6}$$

Therefore sweet-toddy is now collected in pots which are coated inside with a thin layer of fresh lime (calcium hydroxide). This helps to keep the medium at pH greater than 7 and prevent invertase activity. Even in sugarcane processing a small amount of sucrose undergoes hydrolysis. This non-crystalline fraction gives the wellknown by-product molasses. It is an important starting material for another chemistry based industry which is the production of ethyl alcohol. Here the sugar solution is fermented with yeast to produce a dilute solution of ethyl alcohol containing traces of other compounds. This product is then carefully distilled to give pure ethyl alcohol. Large amounts of this "Molasses spirits" is used in making blended arrack commonly known as "gal". Rum which is the national beverage in the Carribean region is produced from cane molasses.

I will not discuss the large number of other plant resources we have in Sri Lanka which are used to produce countless numbers of commodities for local markets and users abroad, where chemistry plays some important role. In commercial terms, these are the added-value products of less expensive resources.

Let us now consider a few of our mineral resources where inorganic chemistry plays important roles. The commonest mineral resources we have are rocks and clay. Brick, tile and pottery industries have long histories and the old traditional methods are still being used. The technology is mainly mechanical with very little chemical involvement. Limestone on the other hand is a very important raw material for cement and glass industries. Both these depend on high temperature reactions of substances such as limestone, clay and sand to give the endproduct according to the composition of the mixture.

Relatively large deposits of kaolin (China clay) are found around Piliyandala, estimated at many millions of tons. This is a valuable raw material in the local ceramic industry which produces plates, dishes, cups and saucers and sanitary ware. The chemistry of ceramic making is again a complex series of high temperature reactions producing complex silicates of calcium, aluminium, sodium and potassium. The coloured glazes on tableware is produced by adding elements such as copper, cobalt, chromium and iron to the glaze mixture.

A natural resource of great value to our increasing crop growing efforts is the apatite deposit at Eppawela. Apatite is crystalline calcium phosphate with additional chlorine and fluorine in it. These minerals are called chlorapatites and fluorapatites. Unfortunately this mineral is highly insoluble and the phosphorous available to plants from this source is very limited. Most fertilizer mixtures contain super phosphate or triple phosphate which are more soluble forms. Chemists at a number of research institutions are trying hard to modify or improve our apatite by chemical methods or heat treatment, etc., so that more of the phosphorous could become available for plants. If such a breakthrough is obtained a large amount of foreign exchange spent in importing phosphates for fertilizer could be saved.

The most important element in a fertilizer mixture is nitrogen and the compound Urea is one of the most widely used sources of nitrogen for crops. Urea (49.7% nitrogen) is a simple organic compound synthesised in very large tonnages for fertilizer. The urea manufacturing plant at Sapugaskanda is expected to produce about 300,000 tons per year.

The chemistry of urea synthesis is rather simple, but the technology for largescale production is very complex.

Only three basic raw materials are required, hydrogen, nitrogen and carbon dioxide. The reactions that take place are:

$$3H_2 + N_2 \xrightarrow{\text{Catalyst}} 2NH_3 \quad (1)$$

$$2NH_3 + CO_2 \xrightarrow[\text{Catalyst}]{} \underset{\text{Ammonium carbamate}}{\overset{\text{ammonia}}{NH_4\ CO_2\ NH_2}} \quad (2)$$

$$NH_4\ CO_2\ NH_2 \xrightarrow[130^\circ C/10\ \text{atmos}]{} NH_2\ CO.\ NH_2 + H_2O \quad (3)$$
urea

The hydrogen for reaction (1) will be obtained from chemical naphtha produced at the petroleum refinery. The nitrogen will be obtained from liquid air and the reaction will be carried out in a large catalyst chamber at high temperature and very high pressure. For reaction (2) liquid ammonia and liquid carbon dioxide will react, again in the presence of a catalyst under pressure to give ammonium carbamate. In the third step, ammonium carbamate on heating under pressure of about 10 atmospheres will get transformed into urea and water.

Finally, let us look at common salt, one of our most valuable marine resources. Anyone who has travelled along the Southern coast or up North in Jaffna would have seen the salterns, where sea water is allowed to evaporate under solar radiation to deposit crystals of salt. In Sri Lanka, we have around 1900 ha (4700 acres) of salterns and they produce about 130,000 tons of salt per year. There are a large number of chemical industries based on sodium chloride. Locally we have only the caustic soda plant at Paranthan and a few others such as soda ash, chlorine, hydrochloric acid and PVC plants. The mother liquor after deposition of salt is called the bitterns. These bitterns contain a large number of other important substances such as magnesium sulphate and chloride, calcium sulphate, potassium and sodium bromide, etc In many countries there are industrial plants extracting all these useful elements and compounds from sea water. Locally about 800 tons of calcium sulphate (Gypsum) is produced for the cement corporation and very recently a plant for producing Epsom salts (magnesium sulphate) was opened in Hambantota.

In my discussion, I have purposely avoided the animal resources which are almost totally consumed by the food industry. I have also avoided the problems that chemicals and industries cause to our environment which is also one of our valuable resources.

What I have attempted to do is to show how chemistry and chemical methods combined with technology have given an enormous range of materials and commodities to us from a limited number of local resources. In most of these instances the value-added factor due to processing is many times the value of the raw material. These industries have also made large contributions towards increasing employment for the abundant human resources available among us.

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Chemistry, Pollution and Industrial Waste

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THE first UN Conference on Human Environment in Stockholm in 1972 proclaimed that:

> "A point has been reached in history when we must shape our actions throughout the world with a more prudent care for their environmental consequences. Through ignorance or indifference we can do massive and irreversible harm to the earthly environment on which our life and well-being depend. Conversely, through fuller knowledge and wiser action, we can achieve for ourselves and our posterity a better life in an environment more in keeping with human needs and hopes. These are broad vistas for the enhancement of environmental quality and creation of a good life. What is needed is an enthusiastic but calm state of mind and intense but orderly work. For the purpose of attaining freedom in the world of nature man must use knowledge to build, in collaboration with nature, a better environment. To defend and improve the human environment for present and future generations has become an imperative goal for mankind — a goal to be pursued together with, and in harmony with the established and fundamental goals of peace and social development".

Today, there are approximately four million formulated chemicals available. The demand and expectation for a better quality of life calls for an increase in the number of chemicals produced as well as increased mobilization of naturally occurring substances. Hence many a thousand new chemicals are produced every year and these are discharged into the environment at least in trace quantities. For many other chemicals, new uses are found which subsequently may increase their levels in the environment. Depending on the production and use of chemicals, there may be a time lag of ten to fifty years or more before they show their environmental significance. Each environmental chemical substance behaves differently in the environment so that there is not one problem, but a series of problems for potential environmental chemicals.

Activities of man in general will always have an impact on the environment. A study of the changes and effects of the natural environment is a major task and involves many a discipline. These studies will include a large amount of data on the chemical characteristics of the environment. Those on the quality of air and quality of water will show the trend of environmental quality changes, related to man's activities.

The effect of chemicals on human health depends on the physical and chemical properties of the pollutants, on the frequency, duration, level and rate of exposure, absorption and transformation (by metabolism in the organism) and on the capacity of the human organism to resist. Pollutants may enter the body by inhalation, ingestion or through the skin and mucous membranes. The mode of entry determines to some extent the degree of retention and absorption in the organism.

The chemical composition and biological availability of pollutants may change in their passage through environmental media; they may be degraded to less toxic substances or may be transformed into more toxic ones; they may accumulate in certain aquatic organisms and build up concentrations which are many thousand times higher than those found in polluted water. They may be eliminated from the water by various physical processes such as sedimentation and adsorption; in the air they may form secondary pollutants, for example, by photochemical reactions between oxides of nitrogen and hydrocarbons emitted from motor vehicle exhausts. An understanding of the environmental transformations of pollutants is of great importance in assessing the hazards to man and in planning control measures. The new discipline, environmental chemistry, is concerned with these problems.

The function of the Environmental Chemist is to detect, estimate and provide guidance to control poisonous, hazardous, and potentially toxic materials which find their way into the environment. Further, he may also have to evaluate the potential hazards of known chemicals with greater utilization and new chemicals for which extensive uses may be found in the future. The importance of the knowledge of chemical science for the purpose of the elimination of environmental hazards has another aspect not readily seen. Often the true hazards are not recognised until complete analysis has been made.

The principal manmade sources of atmospheric pollution are due to the combustion of fuel in stationary sources such as industrial processes and the mobile sources such as motor vehicles. Air pollution is the result of the discharge into the atmosphere of foreign gases, vapours, droplets and particles, or of excessive amounts of normal constituents such as carbon dioxide and suspended particulate matter by the burning of fossil fuels. The concentrations of pollutants at ground level, or rather at lung level,

are what matters in health related studies. The degree of air pollution is often reported in terms of concentration of smoke and sulphur dioxide, two of the commonest pollutants suspected of having ill effects; smoke is produced as a result of incomplete combustion of fuel, and sulphur dioxide from burning sulphur-containing impurities commonly found in heavy fuel oils. Smoke and sulphur dioxide are but indices of pollution which are in fact a highly complex mixture of many different kinds of particles floating in many gases, some of which in high concentrations are irritant and toxic. Dust is of natural or industrial origin and usually formed by disintegration processes. During the time these particles are suspended in air they are known as aerosols. These particles are air pollutants only when in aerosol form. Most of the particulate pollutants are very small, will remain airborne almost indefinitely and can reach the lungs. These particles have an enormous surface area per unit mass; on these surfaces gases may be absorbed and carried into the lung. Some of these particles are acidic and irritant and may even be involved in causing chronic bronchitis. Air pollutants also aggravate the condition of patients with chronic lung diseases.

Major air pollutants emitted into the atmosphere are listed in Table I. Some of these pollutants are directly emitted into the atmosphere as a result of man's activities and are called the primary pollutants. The others, called secondary pollutants, are generated as a result of atmospheric reactions: photo-chemical, catalytic, oxidative or hydrolytic. Particulate pollutants may also participate in the formation of secondary particulate pollutants. Some particles are also formed from gaseous pollutants as a result of chemical reactions.

Table I: **Major Primary and Secondary Air Pollutants**

Gases	Suspended Particulate matter
Inorganic	**Inorganic**
Sulphur Oxide (SO_2, SO_3)	Metal (Pb, Cd, Be, Hg, etc.)
Nitrogen Oxide (NO, NO_2)	Fluorides
Ozone	Nitrates, Sulphates, Phosphates
Carbon Monoxide	Asbestos
Hydrogen Sulphide	Mineral Dusts (Silicates, Silica, etc.)
Ammonium Compounds (NH_3, etc.)	
Carbon Dioxide	
Organic	**Organic**
Hydrocarbons	Polycyclic Organics
Oxygenated Compounds (Aldehydes, Ketones)	Oxygenated Compounds
Sulphur containing compounds	Pesticides
Nitrogen containing compounds, Peroxyacetyl Nitrate (PAN) etc.	
Halogenated Compounds	

Water is considered polluted when it is altered in composition or condition so that it becomes less suitable for any or all of the functions and purposes for which it would be suitable in its natural state. The term contamination denotes impairment of water quality by chemical or bacterial pollution to a degree that creates an actual health hazard to public health through poisoning or spread of disease.

Water pollution is often caused by the indiscriminate disposal of wastes into the water bodies, by deliberate spread of synthetic chemicals on land to increase crop yields and the application of chemical fertilizers, and pesticides for the control of undesirable organisms such as aquatic weeds, insects and molluscs.

In the third world countries, domestic wastes form the major proportion of polluting materials entering receiving waters. This is mainly due to the fact that the wastes municipal or otherwise are largely untreated. Some of these wastes are capable of contaminating water bodies with biological pollutants. Such pollutants associated with contamination of water are: (*a*) Pathogenic Bacteria which include agents causing diseases such as cholera, typhoid, dysentery and enteric infections particularly in citizens of third world communities, (*b*) the enteroviruses, the viruses of of infectious hepatitis, and the viruses supposed to account for the outbreaks of diarrhoeal and upper respiratory diseases, (*c*) Protozoans such as cysts of *Entamoeba histolytica*, the agent of intestinal amoebiasis and *Giardia* and (d) Helminths — eggs of *Ancylostoma duodenale* (hookworm), *Ascaris lumbricoides* (roundworm), *Trichuris trichiura* (whipworm) *Hymeno lepisnana* (dwarf tapeworm) and *Taenia solium* (pig tapeworm).

Domestic and municipal waste contain decomposable organic matter that exerts a demand on the available free dissolved oxygen of the receiving waters. The significance of organic matter is that it can be oxidised biologically during which process more bacteria are produced along with the production of energy. The aerobic bacteria utilize the free oxygen in the water for the biochemical oxidation of polluting organic matter to produce carbon dioxide, nitrates, sulphates, phosphates and water as end products. In the absence of free oxygen, the anaerobic bacteria utilize the oxygen contained in the chemical compounds in water. The end products of this anaerobic process are methane, ammonia, hydrogen sulphide and carbon dioxide. Ions such as sodium, potassium, calcium, manganese, ammonium, chloride, nitrate, nitrite, bicarbonate, sulphate and phosphate are the main inorganic constituents of domestic and municipal waste waters. The effect of oxygen depletion is a form of indirect toxicity. Surface active agents such as synthetic detergents and oil, which interfere with the transfer of oxygen into solution at the air-water interface, and chemical reducing agents which exert an immediate oxygen demand also contribute to oxygen depletion of water bodies.

Treatment plant effluents, will be less polluting than raw sewage, the extent depending on the efficiency or

degree of treatment, however, for large communities it may still be a significant burden on receiving water. Most of the cities in the developed countries have inadequate sewerage and most waste materials will find their way into surface or underground waters.

The discharge of significant quantities of toxic materials into a receiving water make it unfit for water supply and recreational purposes and have a marked effect on the flora and fauna present. Examples of chemicals often involved are: hexavalent chromium from tanning or plating processes; cyanide from metal finishing and pesticides from agriculture and in the use in control of disease vectors. Acids and alkalis are often lethal to plant and animal life in a stream if the pH is too far removed from neutral.

The production of wastes by industry is inevitable. Industry takes raw materials, processes them to yield useful products, and is left with solid and liquid residue for which it has no economic use. The disposal of wastes without causing harm or nuisance is difficult, but the responsibility for the safe disposal should be that of the factory concerned. Disposal of solid waste by tipping must confirm to the pollution requirements for the prevention of pollution of underground water -- even if pollution from a tip is only feared, one must be fully informed of the constituents and characteristics of the waste and of any changes that may occur.

Industrial wastes can be divided into categories according to the type of industry involved, for example:

1. Effluents from the food industries, such as canning, brewing, dairy and agricultural products, meat preparation and processing, etc.

2. Effluents from textile, leather and paper industries, including synthetic raw material processing.

3. Effluents from the fuel processing industries, including oil refining and coal carbonization, gas reforming, etc.

4. Effluents from chemical industries such as the production of fertilizers, pesticides, pharmaceuticals, etc.

5. Effluents from engineering works including electronics manufacture, metal finishing, transport maintenance, etc.

Food industry wastes are similar in nature to domestic sewage, consisting mainly of organic matter in suspended, colloidal and dissolved forms, but often of much greater concentration. Typical examples of this type of waste causing problems in various countries are processing of sugar cane, tapioca and palm oil; from dairies or milk reconstitution plants; from breweries, distilleries and soft drinks bottling plants; from fruit and vegetables canning and fish freezing plants. These wastes are amenable to treatment using the same processes commonly applied to domestic sewage and can be treated in admixture with sewage in municipal plants.

The effluents from the textile, leather and paper industries are also often comprised mainly of degradable organic matter and can be treated like domestic sewage. However, chemical treatment processes are sometimes necessary to remove particular constituents before discharge or further treatment for instance, dyes and pigments may have to be removed from textile finishing wastes or chromium for tanning effluents.

Wastes from the remaining categories of industries make up the bulk of difficult-to-treat and toxic effluents. The simplest and cheapest way of disposing of them is usually in admixture with sewage if sufficient dilution exists. Sometimes it is necessary to have considerable pretreatment even before discharge to a sewer. In developing countries, the position is made worse by the fact that smallscale industries are far more common than large industrial works and that these industries are not always located in the same area to take advantage of communal treatment facilities.

Chemistry and Alternative Energy Sources

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In relatively simple terms, energy is the ability to do work. Though probably not widely understood as such, mankind's interest in energy arose from the dawn of civilisation when we first looked for food, clothing and shelter. Muscle power of humans as well as animals was derived from the energy contained in the food that they ate. The energy locked in fossil fuels and in certain physical states of matter, e.g. the potential energy of water at high elevations, the thermal energy contained in naturally occurring geysers, etc, provided the sources of power so very necessary to drive the machinery and provide us the many conveniences of modern living.

According to the laws of thermodynamics and conservation of energy that energy can neither be created nor destroyed and that work, energy and heat bear a fundamental relationship. Under certain conditions, energy is transformed into work with the release of heat. Similarly, chemical reactions could be utilised to transform the energy contained in elements and compounds to provide heat (thermal energy) which in turn could transform the state of a medium, to make it do "work". The motive power of both steam and oil engines as well as the jet engine is basically derived from these fundamental principles and sources.

However, we were not so aware of the economic and social implications of the relationship between chemistry and energy and the impact it has on our daily lives until the energy crisis of the seventies. For us, in the developing "Third World", this is all the more important, for while the developed world is trying to maintain its affluent and high consumption life style, our very survival amidst degrading poverty and deprivation depends upon understanding and using this knowledge.

The natural desire of civilised humans to improve their lot has set us on a course where our progress is dependant on the quantity of fuel available. It is unfortunate that the areas which are short of fuel or cannot afford it are the very areas that need it most. They also have the biggest populations. We therefore have the paradoxical situation where
(*a*) development is proportional to energy resources and
(*b*) development is inversely proportional to Population Growth. Beggar nations must learn to distinguish between their "wants" and "needs" and carefully husband their resources to initially provide basic needs. The welfare and prosperity of future generations will depend upon the choices we make and the strategies we adopt.

Having made this general preamble to bring into focus our present situation, let us now examine how the relationship between chemistry and energy could be usefully developed to steer us through these difficult times with reasonably acceptable standards of living whilst maintaining and improving the quality of life for future generations. It is by accepting the reality of certain fundamental limitations and making some sacrifices that we shall survive until we reach the next major turning point in our civilization, i.e., the economic and universal harnessing of Solar Energy and its derivatives possibly in the 1990s or more hopefully by the turn of the century.

A little bit of chemistry may not seem out of place here. Most of us are aware that there are chemical reactions between elements and compounds which either require the introduction of heat or yield heat. The former reactions are known as endothermic and the latter exothermic. For example, the combination of carbon and carbonaceous compounds with oxygen yields carbon dioxide, monoxide, other volatiles and incombustibles and a certain quantity of heat is liberated.

Since I have chosen to limit this topic to traditional energy sources, let us consider the common carbonaceous fuels — for example, Coal and Wood Charcoal, Fossil fuel oils, Natural Gas and Biomass, abundantly available in the tropics. To make a proper exposition and have an appreciation of our present predicament of trying to balance energy supply and demand, we should also consider the conventional energy sources we are familiar with in Sri Lanka, viz: hydropower and wind energy as well as the interesting but as yet impractical systems such as OTEC, wave energy and even more questionable nuclear energy.

The Government has at last begun to realise that there are limits to growth and unrestricted use of subsidised power and energy cannot be matched by supplies which are limited by technology, time scales and above all finance. Even with the support of foreign funds and technology some of the alternatives will need deep and serious thought when considered from a point of of integrity of supply, safety of our population, waste disposal, etc. The one single energy resource we have in abundant supply is sunlight. It can outlast all our requirements and is non-polluting. What therefore prevents us from using it? The short answers are technology and finance. There are encouraging signs however that just as in the field of computers, a breakthrough is round the corner. Meanwhile, use of the sun can be made via the photosynthesis/chemical conversion route i.e., use of biomass.

It is quite noticeable that in the past 2 to 3 years an increasing number of knowledgeable and influential persons in our country have begun to realise the benefits of energy plantations, and conversion of agricultural waste materials to provide heat and power. For example, roughly 75% of our total energy requirements are yet met by firewood. This is both wasteful and ecologically harmful, particularly in view of the fact that the reforestation program does not appear to match the required replenishment. What are the other alternatives? There are as yet abundant supplies of agricultural byproducts much of which is going waste. The materials which are very commonly available in our country in large quantities are from the coconut industry, rice husk and straw. Though one may argue that these are used in rural areas, such use is limited and to a large extent wasteful. The problems of transportation, storage, handling and ash disposal and the difficulties and discomfort experienced in burning these materials preclude its general usage.

One such waste material available in large quantities is coir fibre dust. The coconut plantations in Sri Lanka cover about 450,000 hectares and the annual nut yield is about 2500 million nuts. Whilst the fibre industry produces about 150,000 MT of 'Kohubath' annually, there are the existing mounds estimated at about 5 million MT from over 500 fibre mills.

The major problems which have prevented the large scale use of coir dust as a fuel have been its very high moisture content, basically due to the method adopted locally in processing for fibre, i.e. "retting" and its low density. At the moment, work is underway to overcome both these disadvantages, i.e. a means of economically drying large quantities of kohubath and compacting the mass into fuel logs. Thus a convenient form of firewood will be available for domestic and industrial use.

The composition of kohubath found in literature is as follows:

Table 1. **Composition of Kohubath**

Proximate Analysis (Dry)		**Ultimate Analysis (Dry Ash free)**	
Fixed Carbon	26%	Carbon	46%
Volatiles	62%	Hydrogen	7%
Ash	12%	Oxygen	46%
		Nitrogen	1%

Chemical Analysis

Holo Cellulose	30%
Lignin	60%
Ash	10%

High Calorific value on ash free basis about 20,000 KJ/Kg.

(Ref. J. D. Mannapperuma—paper presented at SLAAS 15.12.81)

It will therefore be seen that densely compacted dry briquette logs of density approximately 1000 Kg/m^3 offer good heating value and economical short haul transport together with easy storage and handling.

It will be useful here to consider the comparative costs of these coir dust briquettes with other traditional fuels (1981 prices).

Table 2. **Comparative costs of coir dust briquettes**

	Firewood	*Coir Dust Briquettes*	*Furnace Oil*	*Heavy Diesel*
Unit	Kg.	Kg.	Kg.	Kg.
Price (Rs.)	-/40	1/50	4/60	6/60
Ash %	2.0	5.0	0.2	0.02
Moisture %	35.0	10.0	1.0	----
Heat Value KJ	11,700	19,200	42,500	44 000
Combustion Efficiency %	72	79	81	81
Useful Heat	8,400	15,200	34,400	35,000
Cost of Useful Heat Rs/GJ	47/60	98/70	133/70	185/40

Thus in actual use, whilst coir fibre dust briquettes are about twice as expensive as firewood they are about half the cost of fuel oil used for heating purposes. In integrated systems using combined heat and power there will be several advantages of introducing solid fuel firing direct in furnaces or via the gasification route. The technology for conversion of solid fuels in block form or as particulate matter using boilers, steam turbines coupled to generators and exhaust heat exchangers, condensing open or closed loop feed systems is very sound and well known. Gasification gas engines coupled generators using waste heat recovery systems, are technically reliable and a viable source of power for us, even though gasification did fall out of favour after the World War II mainly due to low fuel oil prices. Both systems are currently returning to the European and Japanese markets, economic units for steam/turbo generation being in the 2 — 50 MW range and gasification 1/2 — 2 MW range. Therefore, a programme for using kohubath as an alternative fuel to replace imported fuel oil and to an extent as a substitute for firewood, is very feasible. It is estimated that if suitable incentives are provided for the necessary conversions about 25% of our fuel oil import for heating purposes could be replaced with these briquettes. However, as long as it is possible to obtain firewood by illicit means without much risk or grave consequences, it will not replace the use of firewood on any significant scale.

On an islandwide scale and considering major usage only about 70% of our total energy requirements are for cooking purposes. The balance 30% is roughly divided equally between transport and power generation. Of course this is in quantitative terms but it is very necessary that we view this in terms of rising costs

of imported fuel and the saturation levels being reached in adding to our hydropower generation within acceptable cost/time targets. From this aspect alone, "fuel farming" seems to be a very appropriate answer to our needs.

If we could only overcome our conservative fears and be more open minded about the changes being wrought around us we should see the obvious advantages and the opportunities before us to convert solar energy to useful power and energy using fuel farms.

1. Viable, self-renewing energy plantations can be grown very advantageously in small allotments.

2. Plantation requirements for 10 MW power plants would be about 1000 hectares.

3. It is the most compact form of naturally available biomass.

4. Use of biomass will have the least interference with the ecological balance.

5. The exhaust emissions are almost sulphur free and the ash is re-usable for plant growth.

6. No serious environmental dangers.

7. An economic means of converting solar energy to produce electricity.

8. Storage, transportation and handling are manageable and within the means of a production unit.

9. The growth of wood fuel reserves has many additional benefits in soil and water conservation, foliage, shade plants and wind breaks, etc.

The village reawakening movement and the rural electrification programmes have brought in their wake increased demand for supply and distribution of electrical power in widely separated areas albeit in limited quantities. Central generation and distribution of electrical energy is both uneconomic and wasteful particularly considering that most of the demand will be for household lighting. Biogas generation using animal dung and agricultural waste can be considered for small localised units.

The conversion of Solar Energy to heat and electricity can be through several paths but as yet these require expensive and sophisticated technologies for wide usage. On the other hand biomass is essentially stored chemical energy produced by photosynthesis. The biomass itself can be converted into energy by several methods, the commonest of course being by burning. Though other energy sources such as wind, mini-hydro and solar are being considered, it is abundantly clear that in our own situation the greatest potential for alternative energy lies in the use of energy from biomass.

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Chemistry and the Transfer of Technology

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Industrial development has become increasingly important to the economy of Sri Lanka over the last few decades. Chemistry is used in almost every facet of industry ranging from the extraction and utilisation of heavy metals to such diverse industries as foods, polymers, synthetic fibres, drugs and microelectronics. As a result, chemists and those trained in related disciplines such as chemical engineers, food technologists and biochemists are employed in nearly every industrial organisation.

A considerable number of highly skilled persons graduate in chemistry from the universities in Sri Lanka and it is relevant to examine the programmes available for the effective utilisation of this national resource of knowledge and information. A prerequisite to the effective utilisation of the available know-how is an inflow of information on available technology and related industrial information, a process that can be broadly classified as one aspect of technology transfer.

The discussion will be relevant if ongoing industries and projects are used as a guide to understanding how much technological knowledge has been accumulated in the country over the many years of industrial progress that has gone on in Sri Lanka. Such an analysis will further be helpful in considering methods by which the net inflow of technology can be increased.

Classes of industry using Chemistry

The chemistry based industries in Sri Lanka can be very broadly divided into the categories of private and public sector enterprises and the following subdivisions may be recognised within each category.

(*a*) Heavy industry eg. steel, tyres, petroleum processing;
(*b*) Light industry, eg. batteries, toilet preparations;
(*c*) Food process industry - - jams, cordials, soft drinks;
(*d*) Cottage industry — handlooms, handicraft.

It is quite evident that chemical knowledge is certainly applied at some stage in (*a*), (*b*) and (*c*).

The heavy industry in the country is almost entirely state owned and the required technology has been obtained generally by intergovernmental agreements. This type of technology acquisition represents the extreme case where packaged complete process technology has been purchased or obtained by long-term financial agreement. The role of chemists in this type of industry is mainly in quality control work governed by standards laid down in the original process and related to product standardisation.

The fast growing facet of industry in Sri Lanka is however, mainly in the class of light industry and food processing industry and it is of interest to briefly consider the usefulness of chemical knowledge in this area and to also discuss means by which the national store of knowledge can be increased; an important aspect of effective technology transfer.

Modes of Technology transfer

The setting up of any manufacturing industry will require information on the best process technology available as well as information on the type of equipment to be utilised. This is, of course, in addition to the investment of capital and market prospects for the product. The framework available for the acquisition of technological knowledge can be classified as:

(*a*) The setting up of subsidiaries of international organisations;

(*b*) The manufacture of branded products under franchise agreement;

(*c*) Setting up of joint ventures;

(*d*) The development of technology through research and development.

The setting up of subsidiary companies or the manufacture of branded products under franchise agreement is the type of industry that can be set up most conveniently, but the long-term usefulness of such enterprises is questionable. Generally, such industries come into the country with well established processes and all research and innovative changes are effected in the laboratories of the principals and only the results are transmitted. The national personnel are employed to keep the quality standards and may not even have the full details of processes. In a sense, their jobs are routine and the sum total gain of technological know-how is limited.

Joint ventures, on the other hand offer a greater promise. Many joint ventures are in operation in Sri Lanka at present, mainly in the Free Trade Zone. Most of these ventures are located in the country to take advantage of cheap labour and special concessions but some positive technological gain can be ensured by carefully planning such joint ventures. An important consideration should be training of local

personnel. If the agreement can incorporate some element of training particularly in the process plants of the principals, a useful step can be considered accomplished. Joint ventures in chemistry based industries are not common in Sri Lanka but could be very useful in areas such as polymers (including manufacture of synthetic textiles), food processing and canning and beverage manufacture. The advances in these fields are very far reaching and it is certainly in the interest of the country to have some access to this technology.

The most complex category for a developing country and yet most important is the evolution of an industry through Research and Development from the basic beginnings. The final results can be very beneficial but in the case of chemistry based industry, in particular, the cost of research and development can be so high that an organisation with high R & D expenditure may not be able to recover these costs from its own operations. Yet, Sri Lanka produces its own pool of young chemists and chemical engineers and we also have a number of raw materials. An important question is how the globally available knowledge can be transferred effectively to the country to be utilised in the setting up of industries based on our own raw materials.

The State Sector in Sri Lanka is perhaps the main source of new processes and products. Engineering or light industry related processes have originated from the Ceylon Institute for Scientific and Industrial Research and the National Engineering Research and Development Centre. More chemically based processes have been formulated by the CISIR and also the Crop Research Institutes for tea (TRI) rubber (RRI) and coconut (CRI).

Development of Processes

A large number of processes have been patented by research organisations in Sri Lanka and sometimes even developed up to the largescale laboratory or pilot plant stage. Licencing of patents for chemical processes or food and beverage production processes has been very slow to take effect in Sri Lanka. Investors are generally interested in ventures which promise a rapid and sure return of capital. They will not normally want to tie up capital in R & D even if the final product has a promise of a good market.

Thus, it is of interest to consider the alternatives available in commercially exploiting chemistry based processes developed in Sri Lankan laboratories.

The possible alternatives are:

1. The formation of a joint venture with a private sector organisation with or without foreign collaboration is the first alternative. In this case, all the process know-how or at least most of it, will generally originate from the laboratory that has formulated a process. Information on equipment designs and their adaptation will originate through the purchase of machinery, particularly if the equipment manufacturers are requested to provide a turnkey process.

2. The second alternative is for the originator of the process to go a step further and scale up the process to a point where economic evaluation and costing can be carried out and samples provided for market tests. The principal question here is the manner in which technology can be acquired at moderate costs.

Technological information is available through organisations such as UNIDO for some of the processes. In other cases the main process know-how has to be developed indigenously.

In the context of the discussion so far, it is relevant to note that the technology developed must also be relevant to the country. The principal consideration being whether the plant or process line developed can be maintained and run with locally available resources and manpower.

Trained personnel are certainly available in the country but chemical technology is nearly always owned by large companies abroad. Such organisations will not give away know-how without assurance of some return, mainly because they would have already invested in R & D to build up their knowledge.

In overview, developing countries have to build up their own technological information banks and continued research toward new processes and scaling up of such processes is absolutely necessary, in spite of the high cost.

Co-operation between lesser developed countries including technology exchange programmes can be a mutually useful route in addition to each one developing its own technology. The development of commercially exploitable processes need not always be considered as the only successful end of a project. It is well to bear in mind that spin-off benefits from the net contribution to knowledge should also be considered important to any developing economy.

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The Institute of Chemistry, Ceylon

The Institute of Chemistry, Ceylon, established in 1971 is the professional body representing the interests of Chemists in Sri Lanka. As successor to the Chemical Society of Ceylon founded in 1941 the Institute is the oldest professional body in any field of pure sciences in Sri Lanka.

The main objectives of the Institute are :

(1) to promote and advance the science of chemistry and its application in Sri Lanka.

(2) to advise the Government and give counsel to Public Corporations, local bodies and other institutions on all matters connected with the application of chemistry to the progress and development of the country,

(3) to promote education in chemistry at all levels and promote, encourage and foster original research in chemistry.

(4) to conduct or provide for the conduct of examinations for the award of diplomas, certificates and other distinctions in chemistry and to prescribe, approve or provide courses of study for such examinations.

(5) to establish and enhance the status of the profession of chemistry in Sri Lanka.

MEMBERSHIP

In the institute, there are two grades of corporate membership — Fellow and Associate and three grades of non corporate membership — Graduate, Licentiate and Student.

EDUCATION

The institute is actively engaged in an education programme organised by an education committee comprising chemists with wide experience in teaching. At present two courses are being conducted.

The graduateship course in chemistry is conducted using the laboratory facilities of St. Thomas' College, Mount Lavinia. The examination of this course is held in two parts every December.

The institute also conducts a course of one and a half years duration leading to the laboratory technician's certificate. This course is open to those employed as laboratory technicians as well as to others who have the necessary minimum attainment at the GCE (Ord/Adv level).

AWARDS AND MEDALS

Two Kandiah memorial awards for research in chemistry are awarded every year in commemoration of the first Professor of Chemistry at the University of Ceylon, the late Professor A. Kandiah, DSc.

Each award in the form of a medal and a book voucher is intended to be given for the best piece of current research in chemistry carried out by a postgraduate student working in Sri Lanka in (*a*) any higher educational institution (as defined in the Universities act,) in the case of one award and (*b*) any other institution in the case of the other award.

The 'Institute of Chemistry Medal' donated by Mascons, Ltd., is awarded for the most outstanding contribution in the use of any branch of chemical sciences for the development, application or innovation in industry and/or National Development in Sri Lanka.

All awards are made at the Annual Sessions of the Institute.

ACTIVITIES

The Annual Session of the Institute is held in June every year. The institute also organises lectures, seminars, workshops and symposia on topics of current interest. "Strategies, priorities and problems of applied research", "Quality control of consumer products and consumer protection", "Facilities for postgraduate training of chemistry graduates in Sri Lanka" were some of the topics selected for the year 1981/82.

A newsletter, the 'Orbital', is released quarterly to the members of the institute.

REGIONAL WORKSHOP

The Institute also fosters links with foreign chemical societies and other bodies with interest in chemistry. A regional workshop on 'Chemistry, industry and the citizen' is scheduled for June 1982. It is the first time the institute has launched on a venture of such magnitude. The workshop will bring together participants from India, Sri Lanka, Bangladesh, Thailand, Malaysia, Singapore, Australia, Philippines, Indonesia, Japan and Korea for interchange of experiences in the areas of (1) relationships between universities and chemical industry, (2) use of the chemical sciences in utilisation of local resources, (3) environmental studies and industrial waste, (4) chemistry and alternative energy sources and (5) chemistry and transfer of technology.

The articles in this issue of 'Vidurava' centres around the objectives of the Workshop and have been contributed by eminent scientists all of whom are actively involved in the relevant fields.
The release of this issue will coincide with the opening of the Regional Workshop in June 1982.