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

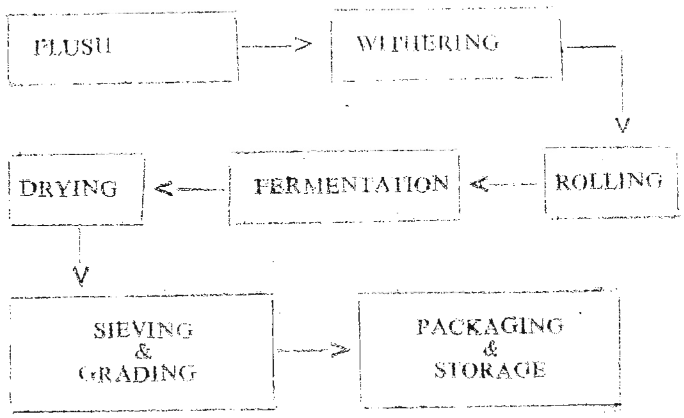
(*a*) Food industry
(*b*) Chemical and Pharmaceutical industries
(*c*) Building industry
(*d*) Energy and Power
(*e*) Manufacturing industries

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 COMPOUNDS

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 $C_{12}H_{22}O_{11}$. Weimport 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

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

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:

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

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

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

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.