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.