occupational environments in particular and other population in general. It is also helpful in the protection of public health against hazards associated with toxic substances in food, air, water and soil. Decidedly, toxicology has played – and will continue to play – a significant role for human health and welfare upon this planet, the earth.

HISTORY OF TOXICOLOGY

- Hippocrates introduced principle of toxicology around 400 B.C.
- Paracelsus (1493-1541) is considered as the *father of toxicology*. He stated : " No substance is a poison by itself " It is the dose that makes a substance poison" and, "The right dose differentiates a poison and a remedy."
- Orfila (1787-1853) is pioneer of **forensic toxicology**. Forensic toxicology is the toxicological knowledge applied to investigate crime. He was appointed as Professor of Jurisprudence at the University of Paris.
- Claude Bernard (1813-1878) used poisons as tools in analysing physiological aspects of organic systems.
- Loomis (1968) recognized three disciplines of Toxicology - Environmental, Economic, and Forensic toxicology. He refers Clinical and Medicolegal aspects of toxicology under the heading "Forensic Toxicology".
- Klaasen (1986) incorporated three more categories of toxicology – Descriptive, Mechanistic and Regulatory toxicology.

DEFINITION OF TOXICOLOGY

Toxicology is that branch of science which deals with poisons with reference to their sources, characters and properties. The symptoms which they produce, the lethal dose, the remedial measures which should be employed to combat their actions, the methods of their detection and estimation, and autopsy findings. It also concerns law regarding their sale and prescription.

DEFINITION OF POISON

Poison may be defined as "a substance which even in small dose, produces **adverse effect in the metabolic activities of an organism and, consequently, may cause death**".

In India both human poisoning and cattle poisoning are prevalent, and it is a sad fact that cases of poisoning of all types are increasing day by day.

Human poisoning may be **suicidal, homicidal, stupefying or accidental** :

- The poisons used for **suicidal** purposes are : potassium cyanide, hydrocyanic acid, opium, barbiturates, organophosphorus compounds,

oxalic acids, and oleander. Suicide by coal gas poisoning, which is common in advanced countries, is not common in India.

- The poisons used for **homicidal** purposes are : arsenic, antimony, aconite, thallium, organophosphorus compounds, oleander, madar, strychnine etc.
- The poisons used for **stupefying** purposes are : dhatura, belladonna, hyoscyamus, *Cannabis indica*, and cigarettes containing arsenic.

SPOT FACT

Dhatura plant is known as thorn apple and commonly grows in waste places in all over India. There are two varieties, viz, *Dhatura alba*, a white flowered plant (safed dhatura) and *Dhatura niger*, a black or purple flowered one (kala dhatura). The flowers are bell shaped. The fruits are spherical and have sharp spines, giving the name thorn apple to the plant. They contain brown seeds resembling chilli seeds. *Dhatura* is poisonous in all its parts but the seeds and fruits are considered to be the most noxious.

Fig. 2. Dhatura plant with fruit and white flower.

- **Accidental** poisoning commonly takes place as a result of the carelessness with which the poisonous and the non-poisonous materials are stored together. On occasions, bites of poisonous animals such as snakes, scorpions and others may be the sole cause of death.

Accidental poisoning in cattle occurs when they eat material obtaining poisonous substance, such as madar, Kadvi juar or linseed. The serum of madar contains a crystalline substance known as gigantin which is a very virulent poison. Kadvi juar contains poisonous glucoside. Parthenium (gazar grass) is also very dangerous poison to cattles.

Above all, anthropogenic activities are adding toxic agents to our food, water, air and land, thus we are compelled to take these toxic agents indirectly.

SPOT FACT

The first research institute of Toxicology in India is ITRC (Industrial Toxicology Research Centre) established in 1969 in Lucknow (U.P.).

4] Toxicology

DEFINITION OF TOXICITY

Toxicity of a substance is defined as the **capacity to cause injury to a living organism.** Toxicity cannot be defined without reference to the quantity of a substance administered or absorbed (dose/concentration), the way in which this quantity is administered (e.g. inhalation, ingestion, injection) and distribution in time (e.g. single dose, repeated doses), the type and the severity of injury and the time needed to produce that injury.

CLASSIFICATION OF TOXICANTS

I. Toxic agents Present in the Air. Ii. Toxic agents Present in the Water. III. Toxic agents Present in the Food. IV. Others.

I. Toxic Agents Present in the Air

There are numerous toxic agents found in polluted air. Common toxicants found in polluted air are as follows :

1. Carbon monoxide (CO) 2. Nitrogen gases viz., NO, NO_2, NH_3 and N_2O. 3. Sulphur gases, viz., SO_2 and H_2S. 4. Hydrocarbons, viz., CH_4. 5. Photochemical oxidants, viz., ozone (O_3) and other photochemical products like benzopyrene, peroxybenzoyl nitrate (PBzN) and peroxyacetyl nitrate (PAN). 6. Lead from automobile emission.

II. Toxic Agents Present in the Water

A large number of toxicants enter into aquatic environment through different sources :

1. **Sewage and Domestic Wastes** : The waste from a community discharged into lakes, streams and rivers pollute water. Sewage add lots of toxicants into all important rivers (Ganga, Yamuna, Brahamputra etc. of India) which ultimately drop into the sea.
2. **Industrial Wastes** : The industrial discharges in the aquatic medium are a major contributor of toxicant in water.
3. **Agricultural Discharges** : The injudicious use of fertilizers and biocides in agriculture to raise production also cause aquatic pollution. Fertilizers mainly consist of nitrogen, phosphorus and potassium. Excess quantity of nitrates and phosphates drained into a pond, river or lake from fertilizer factories pollute water bodies.
4. **Wastes from Thermal and Nuclear Power-plants** : Electric Power-Plants and Nuclear Power Stations / Reactors use water as a coolant. This water becomes radioactive due to radioactive matter leaking through the reactor.

Table 1.1 : Toxic trace elements and heavy metals found in natural and waste waters and their effects.

Sl. No.	Name of Toxicants	Symbol	Sources	Effects
1	Arsenic	As	Mining by-products, chemical wastes. Fertilizer factory effluent.	Toxic to higher animals.
2	Beryllium	Be	Coal, Nuclear power - plant.	Acute chronic toxicity to animals.
3	Boron	B	Detergent. Industrial wastes.	Toxic to plants
4	Cadmium	Cd	Industrial discharge, Mining waste, Metal plating, Water pipes.	Replace Zn bio-chemically. Causes high B.P., Kidney damage, deformities in testicular tissue and RBC toxicity to aquatic biota.
5	Copper	Cu	Domestic and Industrial waste, Mining, Metal plating, Mineral leaching.	Essential trace elements, toxic to plants and algae at moderate levels.
6	Chromium	Cr	Metal plating. Cooling tower. Food additive.	Essential trace elements, possibly carcinogenic.
7	Fluorine	F	Natural geological sources. Industrial waste, Water additive.	Causes mottled teeth and bone damage at about 5ppm.
8	Lead	Pb	Industry Mining, Plumbing, Coal, Gasoline.	Causes kidney disease, Anemia, Nervous disorders.
9	Mercury	Hg	Mining, Industrial wastes, Pesticides	Highly toxic.
10	Nickel	Ni	Mining	Carcinogenic.

Table 1.2 : Classification of the Main Chemical Classes of Pesticides

Insecticides	Herbicides	Fungicides
Organochlorines (=chlorinated hydrocarbons)	Criteria often used for classification:	Inorganic fungicides (based on sulphur, copper or mercury).
Organophosphates (=phosphoric acid esters)/Carbamates	In relation to the sowing or planting the crops to be protected	Organic fungicides (e.g. Dithiocarbamates).
Natural and synthetic pyrethroids	In relation to the exposure pathway (e.g. as contact herbicide)	Systemic fungicides (e. g. Benzimidazoles).
Dinitrophenols	In relation to the mode of action (e. g., as contact herbicide, Phenoxyaliphatic acids, substitute, amides, Nitroanilines, substituted ureas.	Antibiotics (produced by microorganisms).
Others	Carbamates and thiocarbamates.	The chemical heterogeneity of fungicides is even larger than that of herbicides.
		In addition to substances applied in the field or greenhouse, a large number of fungicides for seed treatments are of great importance.

6] Toxicology

Toxicants in aquatic medium may, however, be grouped into two principal categories :

(i) **Toxic trace elements and heavy metals** found in natural and waste waters are listed in Table 1.

(ii) **Pesticides in water** : The water contains many pesticides primarily from the drainage of agricultural field. These are listed in Table 2.

III. Toxic Agents Present in the Food

Substances present in food other than a basic food is called food additive. Food additives added knowingly are sodium benzoate, acetic acid, lecithin, monosodium glutamate, saccharin etc. Incidentally added food additives are mixed with food during processing or packaging.

Food additives are used to provide better colour, flavour, texture and as a preservative. Several food additives have been found associated with the toxic hazards and health risks. Many of the additives like cyclomates, safrole, and diethyl stilbestrol (DES) have been banned. Several others like monosodium glutamate, nitrite, nitrate, etc. are under strict investigation and can be banned in future.

IV. Others

There are many invisible toxicants in the form of Heat, Sound, and Radiation. These toxicants are without any apparent weight but are very harmful to living organisms, especially humans.

1.1Toxicology

Toxicology is the study of the effects of poisonous substances on living organisms including the ways in which they gain entry.

Toxicology studies unwanted effects of chemical or physical agents, including drugs and pollutants on living organisms. There are many branches of toxicology including those that focus on the toxicity to a specific organ system or on issues associated with food safety, metal toxicity, reproductive and developmental toxicology, regulatory toxicology, occupational health, forensic toxicology, epidemiology (the study of populations to determine the frequency and distribution of disease and measure risks), and cancer development. At present toxicology is an expanding field and can be divided into the following branches:

1.2 Applications or branches of toxicology

(a) **Medical Toxicology/Clinical Toxicology/human toxicology**: deals with diagnosis and treatment of human diseases caused by poisons and pollution

(b) **Veterinary Toxicology**: deals with diagnosis and treatment of diseases of domesticated and wildlife caused by poisons and pollution

(c) **Forensic Toxicology**: The branch of toxicology that deals with toxicity associated with criminal activity is forensic toxicology. A post-mortem analysis may include determination of the presence of drugs, volatile substances such as carbon monoxide, and other toxic chemicals in body fluids and tissues, and evaluates their potential role as a factor in the cause of death.

The presence of drugs or toxins that can modify the behaviour or performance may also be evaluated by the forensic toxicologist, by analyzing blood, breath or other specimens. The urine is commonly tested

for the presence of drugs and their metabolites as an indicator of prior use or abuse.

(d) **Analytical Toxicology**: deals with measurement of poisons in tissues, water, food, air, etc.

(e) **Environmental Toxicology**: deals with effects of pollutants on the environment and wildlife.

(f) **Ecotoxicology**: a more specialized area of environmental toxicology dealing with effects of pollutants on population dynamics in an ecosystem.

(g) **Genotoxicology**: deals with the effect of toxic substances on the genetic material of cells. Genotoxicity results when the toxin interacts with DNA, resulting in gene mutations or cancer formation. Although the toxic effect of most substances occurs shortly after their ingestion, genotoxic effects often manifest years later. Certain drugs including some cancer chemotherapeutic agents or environmental toxins may also impair sperm formation.

(h) **Regulatory toxicology**: deals with enforcing laws designed to protect people, wildlife and environment from poisons or pollutants. There are several national and state agencies that play this regulatory role. Some agencies like Food and Drug Administration (FDA) enforce laws, which protect people, and animals from food contaminants or unsafe drugs, while others like the Environmental Protection Agency (EPA) protect the environment from pollution. The concept of Regulatory Toxicology is made up from a combination of the words "regulation" and "toxicology". The purpose of regulatory activities is to make regulatory decisions on the basis of current knowledge, with the objective to protect health, including environmental health.

Regulatory toxicology studies the junction of toxicology (including epidemiology) and regulatory activities. The objective of regulatory toxicology is to improve the performance of regulatory decisions. This can be done by combining the sciences of toxicology, epidemiology and decision theory and therefore, it draws upon methodology both from toxicology and the decision sciences.

(i) **Mechanistic Toxicology**: deals with understanding mechanisms of how poisons or pollutants cause disease in people, animals, plants, wildlife, etc.

(j) **Occupational Toxicology/Industrial Toxicology**: deals with the science of work-related chemicals or gases on human health.

(k) **Toxicologic Pathology**: This is a branch of pathology specializing in interpreting histologic lesions in tissues of people or animals caused by poisons.

(l) **Food additives**: This is an area of toxicology, which is currently receiving much attention. Poisons, bacteria or products of bacteria, viruses, etc. can

endanger human health if they are present in food in sufficient amount. Food safety toxicology deals with understanding how food-borne poisons or pathogens affect human health. Our concern here is with the biological effects of pollution and, most especially, the relationship between the scale of an impact and the concentration of the pollutant in the environment.

A toxic pollutant can induce one of the two responses in a living organism: it may have some sublethal effect, perhaps causing an impairment of growth, reproduction or metabolism. Alternatively it may, sooner or later, cause the death of the individual. Both the sublethal and lethal effects can be quantified and are the most direct methods of judging the biological impact of a pollutant. The death of a single organism can tell us relatively little about the ecological significance of a pollutant. Instead we need to measure the response of a large number of individuals to establish the dose likely to produce that response in the majority of the population. Different individuals will respond at different doses, so we measure both the average response and its associated variation. The toxicity test is one obvious way of establishing the dose response relationship. Ideally, the dose is applied in a form and at levels that the organism is likely to encounter in the environment.

1.3 Routes of entry of toxic substances into biological systems

From the environment the pollutants enter the biosphere. There are four main routes by which hazardous chemicals enter the body:

1. Inhalation: occurs by absorption through the respiratory tract, and is most important in terms of severity.
2. Skin absorption: or absorption through the mucous membranes.
3. Ingestion: here absorption occurs through the digestive tract, and occurs through eating or smoking with contaminated hands or in contaminated work areas.
4. Injection: introduction of toxin into bloodstream, which occurs by accidental needle stick or puncture of skin with a sharp object.

Pollutants can enter the biological system from any of the three media. In lower organisms the plasma membrane serves as the main barrier between the external and internal environment. Higher organisms generally have a protective cover, and pollutants thus take other routes. In plants the pollutants enter through the root system or the stomata, while in animals it enters via the gastrointestinal, respiratory tract, or the skin. From here the pollutants gain entry into the circulatory system and may gain access into various organ systems. In any case