ENVIRONMENTAL TOXICOLOGY

Key words: Pollution, Depletion, Risk assessment

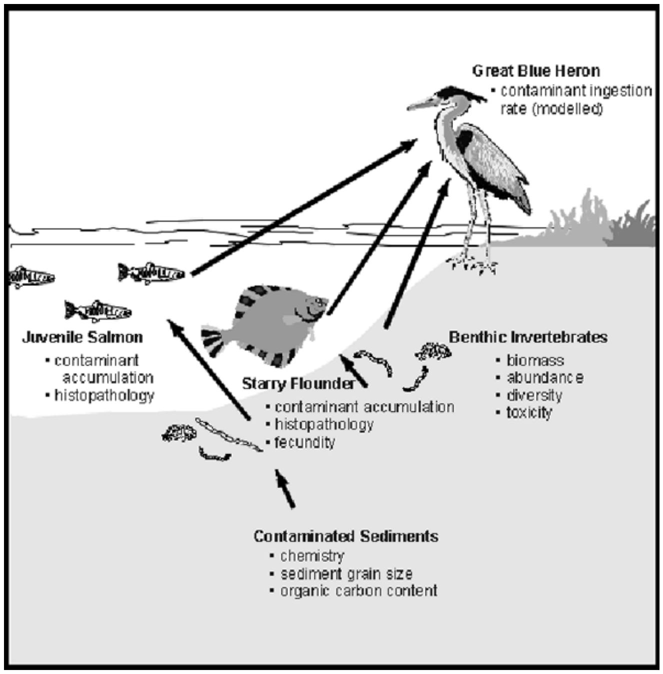


Fig – 21.1

INTRODUCTION

Environmental toxicology deals with the effects of environmental toxicants on health and the environment. Environmental toxicants are agents released into the general environment that can cause adverse effects on health. The word "health" here refers to not only human health but also the health of animals and plants. The study of environmental toxicology stems from the recognition that:

a) Human survival depends upon the well-being of other species and upon the availability of clean air, water and food.
b) Anthropogenic chemicals as well as naturally occurring chemicals can have detrimental effects on living organisms and ecological processes.

Environmental toxicology is thus concerned with how environmental toxicants, through their interaction with humans, animals, and plants, influence the health and welfare of these organisms.

Toxicological Study

Toxicology' traditionally known as the 'science of poisons' began with early cave dwellers who recognized poisonous plants and animals and used their extracts for hunting or warfare. Simultaneously, with time, to determine the effectiveness of a particular compound the concept of toxicology was developed.

Toxicology basically is defined as the study of the effects of chemical agents on biological material with special emphasis on the harmful effects. After gaining relevant information on the harmful effects of a compound the levels for its safe usage or the degree of its safeness is established, which is also known as its (compound) Biosafety level.

Toxicology division of **Institute For Industrial Research & Toxicology**., an autonomous body, was established nearly 27 years ago. Since then it has catered to various industries with a professional outlook and time bound results. It has been involved in generating unbiased preclinical, toxicological and biosafety data. A very large list of satisfied customers over the past 27 years bears eloquent testimony to the scientific culture of the institute

Acute Toxicity

Short-Term Testing

Acute toxicity or acute effects tests are rapid (2 to 4 days) procedures used to measure the concentration that will affect the test organisms, that is, make them sick.
Data from these tests can be used to:

- screen for toxicity (determine if the compound is toxic)
- rank toxicity to identify the best ingredients to continue investigating for use in a product, and,
- assess the potential for effects in the environment.
  In some cases, one group of organisms will be more sensitive to a compound than another group. For example, insecticides are usually more toxic to invertebrates than to fish or algae.
  When we start a toxicity test program, we may not know which group will be most sensitive to the new compound. So we usually test at least one plant, one invertebrate, and one fish species. It is important that all three groups of organisms are tested because all are important in the environment, and effects on a plant may not tell us anything about effects on an animal and vice versa.

Species typically used in acute toxicity tests
include the following:

- Lethality is the most common endpoint for invertebrates and fish, while growth of a population of cells is used to understand effects on algae. Of course, aquatic ecosystems are composed of hundreds, or even thousands of different species.

- The process we use to protect all these different species is called environmental risk assessment. When acute toxicity data does not provide enough information for us to decide if the compound is safe or not, we conduct chronic toxicity tests.

Sub-Acute Toxicity

Sub-acute toxicity study aim find out toxic effect of drug on repeated exposure and also provide the valuable information i.e. delayed effect which may result due to the cumulative effect of the chemicals on the tissues or other biochemical mechanisms. This study also helps in establishing the level of the safe usage of a compound.
The following routes are commonly used:

- Oral
- Dermal
- Inhalation
- Intravenous
- Intraperitoneal
- Other protocol specified route

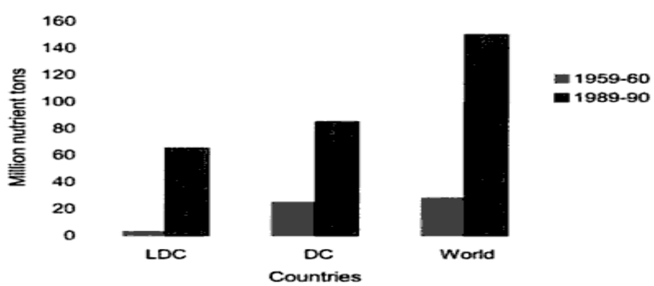
The period of exposure may vary from 14 days to 90 days

Chronic Toxicity Studies

Chronic toxicity aim to characterize the effect of test compound following repeated exposure for prolong period of time in a mammalian species. The route of exposure are most likely the ones to which the human are exposed to that particular compound.

Postwar Development and the Environment:

A rapid growth of chemical industries occurred soon after the World War II, resulting in the manufacture of a large number of chemical products. Worldwide use of many of these products, particularly fertilizers, insecticides, and herbicides occurred. This, together with the development of new high-yield grains, led to a dramatic increase in world food production. Many food-deficient countries, including China and India, became able to produce amounts of grain food sufficient to meet their domestic needs. Furthermore, some traditionally food-importing countries became food exporters. This remarkable achievement is widely known as the Green Revolution.



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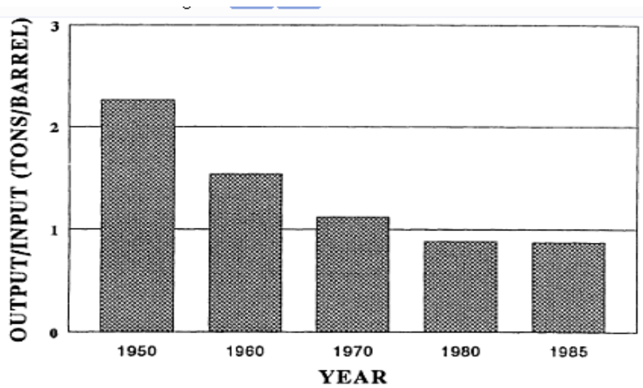
The dramatic increase in food production, coupled with technology advancement and a rise in industrial output, led to an overall global economic expansion. Significant increases in gross national product (GNP) occurred in many countries. These developments, concominant with improved medicine and medical science and technology, helped improve general public health. Worldwide, life expectancy has risen to an average of 65 years and death rates have declined, especially among young children. In the wealthiest developed countries, average life expectancy rose from about 67 years in 1950 to 77 years in 1995; in developing countries, life expectancy jumped from 40 to 64 years.

Warning Signs:

Life appeared to be better for everyone. Then the negative aspects of this progress manifested by general deterioration of air and water quality began to surface. Three cases of widespread fatalities due to urban smog were reported (Meuse Valley, Belgium, in 1930; Donora, Pennesylvania, in 1948; and London, England, in 1952). In each of these cases, temperature inversion (the settling of a layer of warm air on top of colder air) contributed to the air pollution by keeping the pollutants near the ground. The number of fatalities was 65, 20 and 4000 for Meuse Valley, Donora and London respectively. These events brought worldwide attention to the danger from the emission of toxic substances (sulphur dioxide, nitrogen oxides, etc.) as by-products of fossil-fuel combustion, especially coal combustion. It became obvious that neither water nor air is a bottomless sink allowing indefinite disposal of toxins.

Thus the use of toxic chemicals, whether applied purposefully or generated as by-products of industrial processes, had to be restricted. It was also realized that normal human activities threatened the environment. For example, runoff from fields being fertilized with phosphates or nitrogen containing chemicals caused eutrophication of streams and lakes. Runoff from cattle feedlots had a similar effect. Irrigation of poorly drained fields in a hot climate led to salinization of land, making it irreversibly lost to agriculture.



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Present State of the World:

Environmental problems have assumed dimensions of a global magnitude. What happens in a remote corner of the world concerns all of us, the best example being the nuclear plant accident in Chernobyl. The burning of tropical forests in Brazil will affect not only the climate in Brazil, but our climate as well. Overpopulation in developing countries may affect our climate, economy and political stability.

Environmental Toxicology:

Environmental Toxicology is a young (1965) and interdisciplinary science that uses both basic and applied scientific knowledge to understand natural and anthropogenic pollutants life cycle and their impacts upon structure and functions of biological and ecological systems. Research in Environmental Toxicology includes both laboratory experiments and field studies. Environmental Toxicology wants to answer two main questions.

(1) How the release pollutant causes harmful effects?
(2) What can we do to prevent or minimize risk to biological and ecological system?

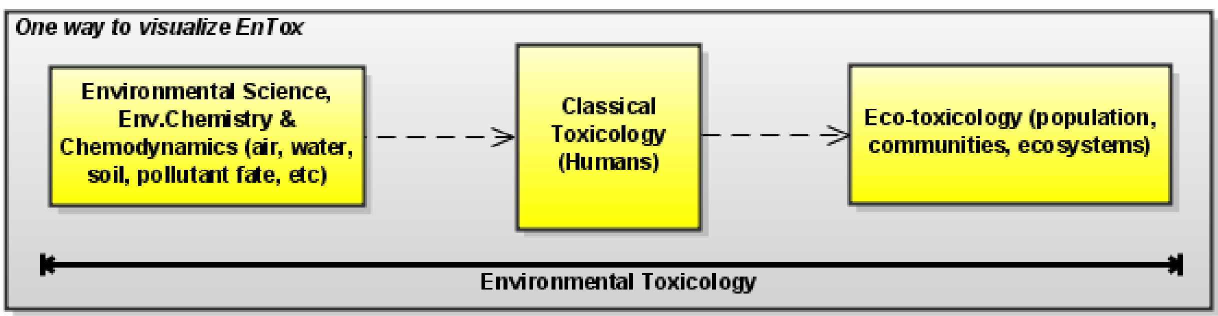

Fig – 21.4

Environmental Toxicology objective is broken down into a 5-steps understanding process useful for research/regulation:

- Release of pollutant into the environment
- Transport and fate into biota (with/out chemical transformation)
- Exposure to biological and ecological system
- Understanding responses and/or effects (molecular to ecological systems)
- Design remediation, minimization, conservation, and risk assessment plans to eliminate, prevent or predict environmental and human health pollutions situations.
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People misunderstand Environmental Toxicology as a scientific discipline that only focus on chemicals into the environment. Not true. It represents environmental chemistry and chemodynamics. The rich fabric of ideas, core concepts, literature body, technology and ideologies that merge together to develop Environmental Toxicology is rather a dissimilar process through most educational institutions. This may be the point in case that Environmental Toxicology is a young interdisciplinary science and controversy regarding what to include in a curriculum is an ongoing matter of discussion.

Reading the objectives for each discipline that merge into Environmental Toxicology should decrease the confusion:

- Classical toxicology protects human (subcellular to individual) from toxic substances at concentration that are harmful.
- Ecotoxicology (ecology + toxicology) want to protect many individuals, populations, communities and ecosystems from exposure to toxic substance at concentration that are harmful.
- Environmental science is an interdisciplinary science that studies the earth, air, water, living environments and social components.
- Environmental chemistry and chemodynamics is the study of chemical sources, reactions, transports, effects and fate in the environment.

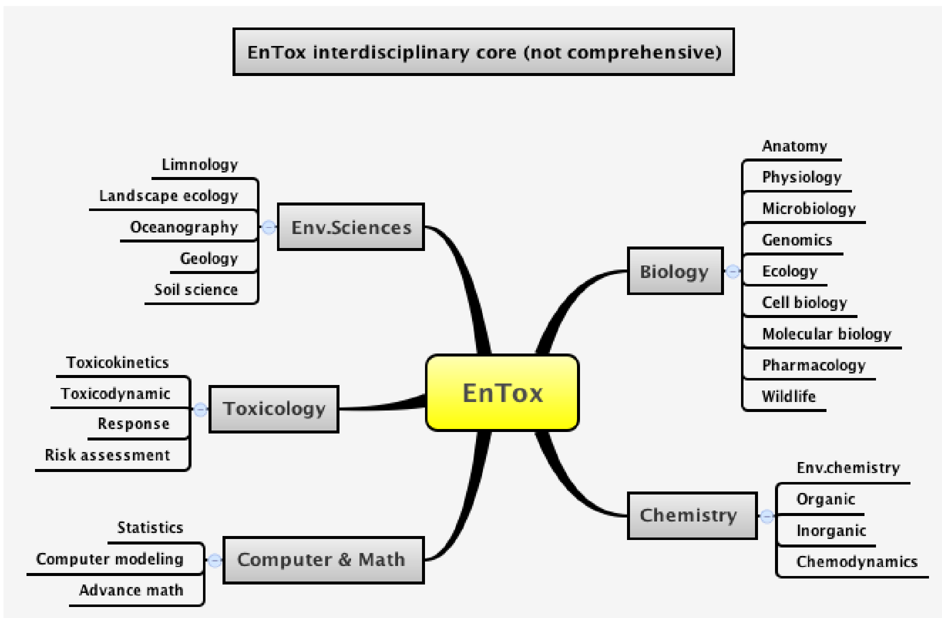
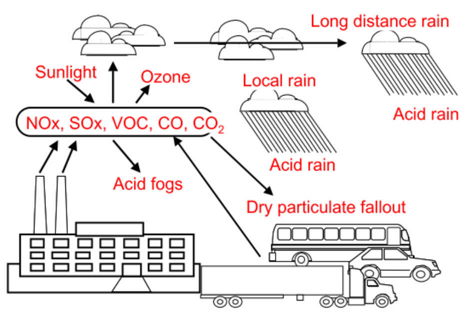


Fig – 21.5

Therefore, although these terms do not mean the same, they are related through a linear logical progression (Pollutant Release-Exposure-Dose-Response Paradigm). Environmental Toxicology embraces both disciplines: classical toxicology and ecotoxicology. Further, it includes other sciences to make a more logical approach to understanding and solving real and complex pollution problems that society faces today or will encounter in the future. The interdisciplinary core of Environmental Toxicology borrows heavily from a range of disciplines such as: environmental science, environmental chemistry and chemodynamics, analytical chemistry, organic chemistry, biochemistry, molecular genetics, cell biology, genomics, pharmacology, pharmaco-and toxico-kinetics, physiology, mathematics and statistics, computer modeling, risk assessment, soil science, geology, ecology, meteorology, marine biology and oceanography, limnology, and wildlife biology.

Air Pollution:

Acid precipitation (acid rain, snow, particulates etc) is a result of air pollution caused by burning of fossil fuels such as coal and oil and other compounds containing sulphur and nitrogen. Acid precipitation results from the solution of nitrogen and sulphur oxides to give a mixture of nitrous, nitric, sulfurous and suphuric acids. Acid precipitation may reduce the pH of lakes below 6, releasing aluminium ions which kill the fish. (Note – above pH 6, aluminium in water is increasingly in the form of hydroxides which are not bio-available). The products of burning fossil fuels are nitrogen oxides (NO_x), sulphur oxides (SO_x), volatile organic compounds (VOC), carbon oxides (carbon monoxide and carbon dioxide), and particulates. Environmental damage may result from carbon monoxide (CO) and carbon dioxide (CO_2) contributing to the "greenhouse effect". The greenhouse effect is heating of the environment because heat loss from the surface of the earth through the atmosphere is reduced by reflection of infrared radiation from gases and vapours such as CO_2 and water vapour.

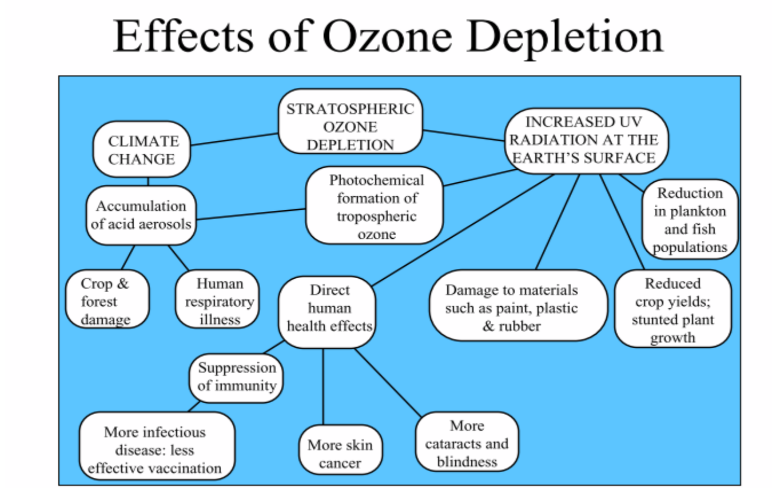


The formation and distribution of acid precipitation
- acid rain, acid fog and acid particulates

Fig – 21.6

Stratosphere Ozone Depletion:

Ozone depletion in the upper stratosphere is a worldwide problem that has required co-operation by world leaders. Ozone in the stratosphere protects us from the harmful effects of excess ultraviolet radiation from the sun which, among other things, causes skin cancer. CFCs – chlorofluorocarbons (formerly used extensively as refrigerants and solvents) have entered the stratosphere and catalytically reacted with the ozone there, reducing the amount so much that holes have appeared in the ozone layer. The Montreal Protocol of 1987 is an international treaty signed by many countries agreeing to reduce the release of CFCs.



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According to the traditional definition of toxicology, it is the science of the study of qualitative and, more importantly, quantitative aspects of injurious effects of chemicals and physical agents in a subject or in a population of subjects. Paracelsus had already recognized nearly five hundred years ago that there is no such thing as non-poisonous and that the dose alone makes a poison not to be poisonous. Even endogenous body constituents and food stuffs can be deleterious to an organism if present in excessive quantities over prolonged periods of time. Thus, in addition to the dose, time is the second important variable that the science of toxicology deals with.

Thus, toxicology can be collectively defined as the accumulation of injury over short or long periods of time, which renders an organism incapable of functioning within the limits of adaptation. Therefore, a more appropriate definition of the scope of toxicology would be that it is the science that elucidates the causality chain of interactions and their time course (exposure) between biological entities (subjects) of different intrinsic susceptibility and chemical and physical agents of different intrinsic potency. Thus, modern toxicology determines in a broader sense exposure-responses consisting of dose-and time-responses thereby establishing practical thresholds which define the safety of chemicals.

Exposure:

There is a qualitative notion, which in itself has no toxicological connotation. As a luminal condition, entry of a single molecule into an organism represents exposure. The major portals of entry into higher organisms pre per os, via the lungs and through the skin. However, any surface area is a potential site of exposure, e.g. the eyes. Artificial portals of entry can be created, e.g. by intravenous, intramuscular or subcutaneous injections. The duration and/or frequency of exposure to chemicals is one critical, quantitative aspect of toxicology. It deals with the time course of absorption, distribution, biotransformation and excretion of chemicals. Its quantitative treatment is termed pharmacokinetics or more properly toxicokinetics. The above mentioned factors are critical determinants of the residency time of a toxic agent in an organism, which in turn represents one of the two time scales of toxicology to be discussed.

Effects:

Similar to the notion of exposure, effect is a qualitative designation. It follows from the definition of toxicity that any biological manifestation beyond the limits of adaptation for a sufficiently long period of time is an adverse effect. The manifestation of an adverse or toxic effect is the second time-dependent function of toxicology because it is determined by the reversibility/irreversibility of the injury. For example, the high affinity binding of carbon monoxide to haemoglobin leads to rapid asphyxiation once a critical carrier capacity reduction for oxygen has been reached. However, moderately elevated blood pressure will not result in frank injury until after years of its persistence. It needs to be pointed out that this second time scale (pharmacodynamic or more correctly toxicodynamic time scale) is seldom, if ever, identical with the toxicokinetic time scale. This would be the case only if a toxic interaction in an organism would be instantaneously and entirely reversible with the disappearance of the causative agent.

The field of environmental toxicology is consequently drawn in two synchronous directions. Regulations entreat standardized testing that is fast and economical, with results that may be applied in a general fashion. This has resulted in an emphasis on simplified scenarios, such as the traditional mortality test using only one test species and one test compound. Toxicological research, however, increasingly reveals the importance of complex interactions between physiological processes, species, individual organisms, myriad environmental factors, and multiple anthropogenic compounds.

A comprehensive approach is emerging in the form of "risk assessment". This approach incorporates scientifically derived information with social and economic concerns to appraise the potential consequences of particular human-induced stressors on the environment.

Risk Assessment for Environmental Exposure:

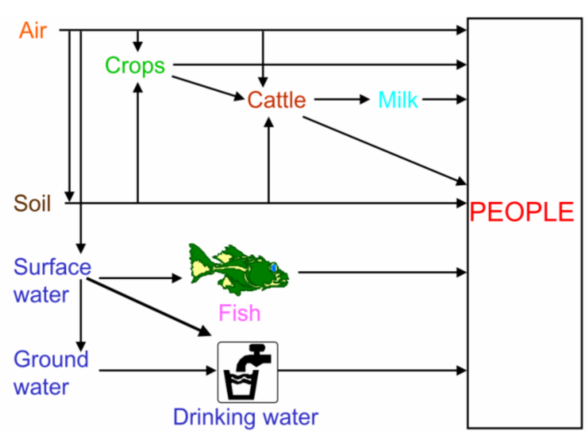

Fig – 21.8

Risk assessment for the possible effects of any substance entering the environment which may harm people must sum up the exposures through all routes in order to determine the total exposure and then the possible effect.

Risk assessment often culminates in the development of a model to predict toxicant effects using environmental and long-term data. In addition, models may not be transferable from one site to another, because no two sites have identical characteristics. The challenge of environmental toxicology now is to identify the common principles that might allow extrapolation and prediction of toxicant effects on the environment.

Source:
http://nptel.ac.in/courses/120108002/21