

ENVIRONMENTAL TOXICOLOGY (JLS 105)

INTRODUCTION

What is environmental toxicology?

- *Study of poisons/pollutants and their action on the environment*

The Natural Environment

- Man's environment in its widest sense is called the biosphere which consists of the earth's crust, the surrounding atmosphere and the various forms of life that exist.
- The biosphere is very complex and so is usually divided into smaller units or ecosystems

Ecosystem Health

- **Ecosystem** – A system formed by the interaction of community of organisms with their environment.
- Most ecosystems consist of a number of interacting populations of organisms that co-exist in a stable or predictable manner.
- The health of an ecosystem may be determined from the range and variety of species that it contains (a taxonomic or diversity oriented assessment of ecosystem function such as productivity, nutrient cycling, community respiration etc).
- it is generally accepted that a significant environmental impact occurs when the structure and/or function of the ecosystem is permanently displaced from the normal.
- This displacement may be of a short term nature and may be followed by a complete recovery. On the other hand recovery may occur but this may be a different ecosystem, one that is permanently displaced with less diverse or functional norm.

Concept of pollution

Any change in the natural quality of the environment brought about by the following factors:

- chemical
- physical
- biological

Normally, pollution causes by activities of man

Physical factors

- change naturally in short term (flood, fire, storms, etc.)
- longer term change (e.g. climate change)
- man's activities (building, drainage, forest clearance)

Chemical factors

Changes through elevation of concentration of substances, e.g.

- nutrients → eutrophication
- toxic substances → health risk
- Organics → reduce quality of raw water supply

Biological factors

Biological processes like predation or grazing, non-predatory effects like digging and man-induced events like tree felling, hunting etc.

- reduce species niche → ecological imbalance
- cutting trees → reduce oxygen generation capability

Note:

- *Eutrophication: Enrichment of nutrients in water bodies*

- **A pollutant** may be defined as a substance or effect which adversely alters the environment by changing the growth rate of species, interferes with health, comfort, amenities or property values of the people.
- In general pollution causes degradation and/or damage to the natural functioning of the biosphere – the damage caused may involve vegetation, animals and all other species, crops, soil, water and ultimately altering the food chains.

Classification of pollutants:

Naturally occurring pollutants includes poisonous plants, venomous reptiles, insects and toxic minerals.

Man made pollutants: These are related to the production and use of energy, the production and use of industrial chemicals, and increased agricultural activity.

The presence of these compounds in the environment may lead to:

- air pollution
- aquatic pollution
- terrestrial pollution

Terrestrial pollution

Natural – local accumulation of toxic minerals e.g. ferrous salts, radioactive minerals etc.

Man-made – dumped wastes-
municipal/domestic, industrial wastes, etc,

- Agricultural chemicals and pesticides (overuse, drift and persistence)
- Radioactive wastes from nuclear stations and accidental.

Aquatic pollution

Sources:

- **Natural** – Eutrophication by leaching of minerals putrefaction in small ponds due to leaves silting in lakes and rivers. Leaching of toxic ions e.g. Cu and Iron.

Man-made – Domestic sewage

- Industrial effluents
- Heavy metal pollutants from industrial processes
- Eutrophication e.g. nitrates from fertilizers, phosphates from detergents,
- Thermal e.g. cooling water from power stations.
- Radioactive wastes and oil washings from oil tankers, accidents at sea.

SPECIFIC AIR POLLUTANTS

- Five major substances account for about 98% of air pollution: carbon monoxide (about 52%), sulfur oxides (c14%), hydrocarbons (c14%), nitrogen oxides (c14%) and particulate matter (c4%).

The sources of these chemicals include:

- **volcanic eruptions,**
- **dusts and fumes from industries,**

- **technologic development and increased urbanization, transportation – motor vehicle emissions,**

- **municipal waste disposal which includes burning/incineration,**

- **disposal of radioactive wastes from nuclear installation including accidental releases and generation of electric power**

Characteristics of environmental pollutants

- Persistent -poorly degradable and relatively mobile in air & water
- Lipophilic and bioaccumulate in body fat
- highly toxic

How does one predict an environmental impact?

Knowledge of the physical and chemical characteristics of an environmental toxicant.

- Effects on different organisms
- Knowledge about its degradability
- Mobility through air, water, soil
- Its transfer and biomagnifications through food chains

Factors affecting food chain magnification in the ecosystem.

Chemical stability

- The mobility that results from biomagnification is dependent on the persistence of a compound in the environment. Compounds which are persistent and not easily degraded in the physical environment or in organisms are most likely to biomagnify if they have the required properties for bioconcentration. This would imply a lack of significant hydrolysis and photolysis in water, as well as lack of significant detoxification in the organisms.

Lipid solubility

- High lipid solubility results in the storage of the substance in fat reserves in organisms. These tissues usually have low turnover rates and any chemical stored in them will be less exposed to degradative enzymes than in other tissues. However, mobilization of fats, which may occur during stress situations, will often result in the release of potentially toxic concentrations of the substance.

Biomagnification of DDT

- The biomagnification of DDT is a good example of the above principle. DDT is too chemically stable and also too lipid soluble. For this reason it accumulates in the fatty tissues and will move up the food chain from one trophic level to another. Example
- **DDT → Lake plankton → small fish → lake trout**
In many cases man is on top of the food chain.

AREAS OF CONCERN- aquatic and terrestrial ecosystems

- Risk to aquatic life – fish and other aquatic animals
- Risk to terrestrial life – wildlife, birds, honey bees, silkworms, earthworms and soil microbial processes

Specific Environmental Pollutants

- pesticides
- organic industrial chemicals
(Persistent Organic Pollutants)
- Leather processing industries

- Most of the chemicals contaminating the environment may penetrate animal organism and be toxic. Manifesting themselves by disease symptoms or causing subclinical effects (e.g.inhibition of growth, drop in milk yield or laying capacity)
- Most of these pollutants are excreted through milk, eggs, or are accumulated in various tissues and organs and eventually transferred to humans.

PESTICIDES

- Depending on their intended use pesticides are classified as herbicides, fungicides & insecticides with minor groups rodenticides, avicides (bird killing agents), acaricides (killing mites), nematocides, piscicides (killing fish), fumigants etc.
- Insecticides are also classified according to their functional groups as:
 - Organochlorines
 - Organophosphorus
 - Carbamates
 - Pyrethrins and related chemicals.

Organochlorine pesticides - persistence in nature, lipophilic and ability to concentrate along food chain reaching higher concentration at high trophic levels. They may reach the human body through the daily diet.

- The way in which a pesticide degrades after application is significant for its potent effects on the environment. The OCs are slowly metabolized and some of the metabolites (e.g. DDE a metabolite of DDT) are extremely resistant to further degradation.
- Furthermore, some metabolites are more toxic than the parent compound (e.g. dieldrin, which is a metabolite of aldrin is more toxic than aldrin)
- Some of the impact the use of OCs have had on the environment in different parts of the world includes – excessive mortality of fish and reduced reproduction in birds, fish and other organisms and also development of pesticide resistance in target and non-target species.

PESTICIDE RESIDUES IN WATER

Surface and ground water may become contaminated with pesticides due to aerial spraying, run off from treated areas, percolation through soil to ground waters, waste discharge by pesticide producers, misuse and other means.

Effects of pesticide residues in water

- Pesticide residues in water may cause harmful effects to various species in the water system as the residues concentrate in the food chain.

PESTICIDE RESIDUES IN THE SOIL

Absorption of pesticide residues by crops grown in contaminated soil leads to residues in harvested products especially those pesticides that are long-lived in soil.

The rate of absorption also depends on type/variety of the crop.

Effects of pesticide residues in the soil

Pesticide residues in the soil may pose several problems in agriculture – injury to crops grown in later years, illegal residues in crops that absorb them, or harmful effects on living organisms in the soil.

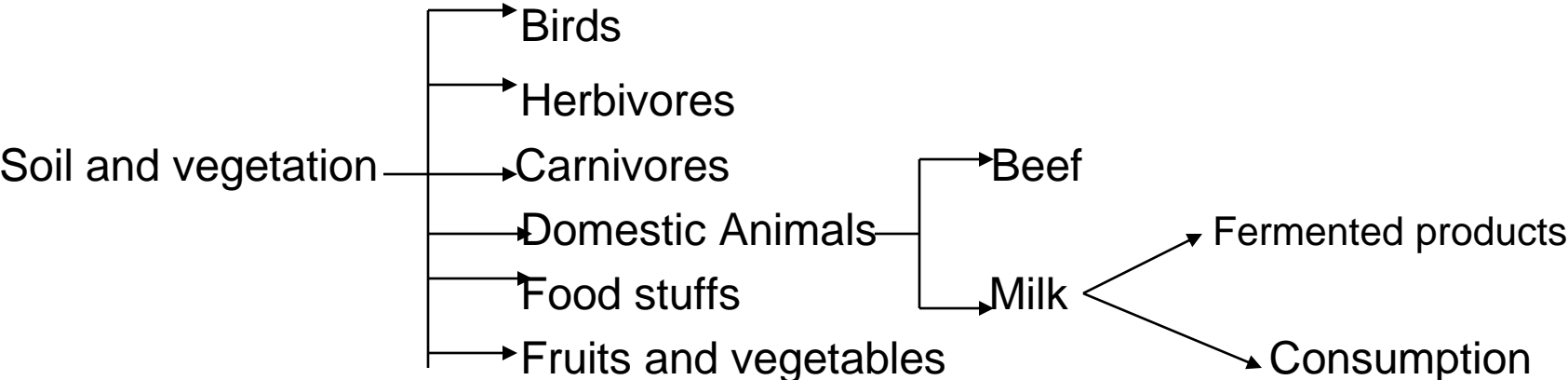
Significance of residues in air

Pesticides by definition are toxic to target and non-target organisms / species

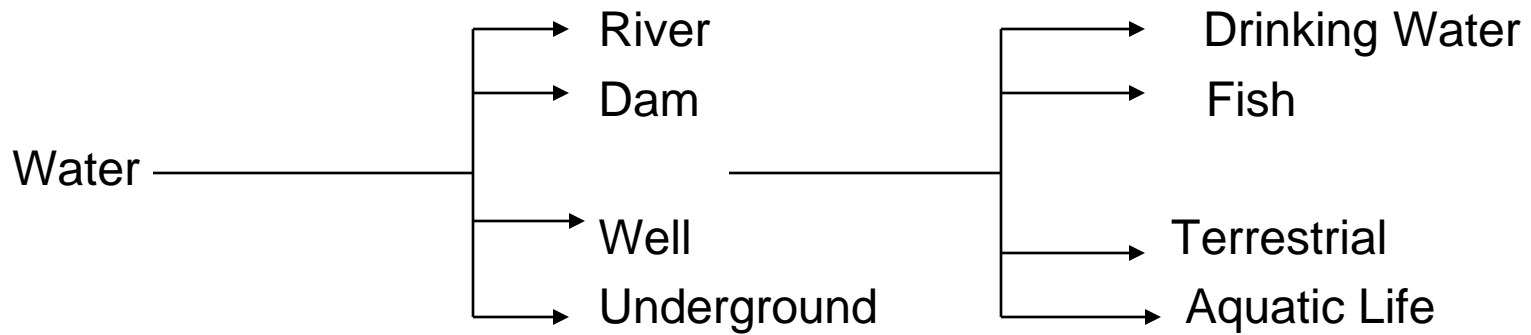
- The hazard to non-target organisms usually depends on type of exposure such as inhalation, ingestion or contact with skin.
- The hazard to mammals is greater if the pesticide is inhaled - absorbed from the lungs more quickly and completely than from the digestive tract or through intact skin. Thus they are potential respiratory hazards.
- Highest concentrations of airborne pesticides are expected near the point of application- people working near that point are more likely to be exposed. Protective measures should be taken by the applicators.

Effects of pesticides on food production

Non-target sector of Ecosystem



Cont/ non target.....



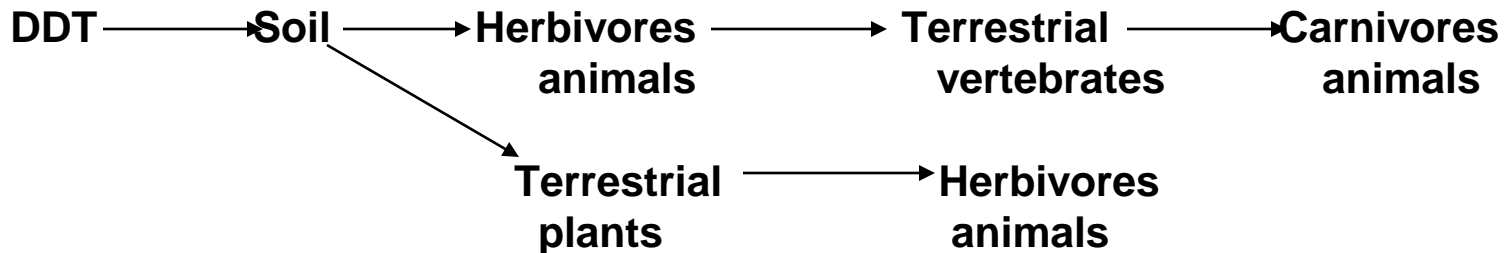
- Food chain facilitates transfer of residue from one trophic level to the other.

(Producers, consumers, decomposers)

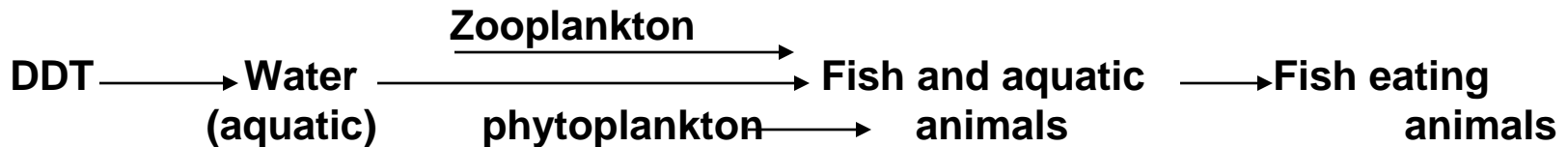
- The presence of toxic chemical wastes and pesticides can reduce or completely eliminate the population of link species and severely disrupt the food web.
- If the pollution is of short duration and not continuous, then the ecosystem will recover and a balance of food web is re-established.
- **NB** Pesticide residues pose a greater hazard in the aquatic ecosystem than in the terrestrial systems because of the longer distance they are carried through water and also because of the larger number of organisms that are likely to be exposed and the closer contact that is possible within the aquatic ecosystem.

MOBILITY OF PESTICIDES IN THE ENVIRONMENT

➤ Mobility of DDT in the terrestrial ecosystem



➤ Mobility of DDT in aquatic ecosystem



Concentration of DDT magnified in the food chain

Ways of poisoning by food chain

- i) Secondary poisoning – eating poisoned food
- ii) Through food chain magnification

Risks Associated With The Use Of Pesticides

- Acute toxicity
- Chronic toxicity (long term effects)- leads to biomagnification - harmful effects on fish, wildlife etc
 - ▶ These compounds are known to be carcinogenic, teratogenic, mutagenic in a number of species including man.'
 - ▶ Hazardous to beneficial insects e.g. bees, silk worms; wildlife and other microorganisms.

- Environmental pollution – marine and fresh water pollution leading to fish mortality and other aquatic life. Soil pollution leading to food residues.
- Development of resistance in target and non-target species.
- Birds mortality, reproductive failure of birds thru' egg shell thinning-eggs breaking before hatching
- Residues especially of pesticides reported in foods of animal origin – daily products- milk, meat canned foods etc., poultry, eggs, fish etc.
- Disturbance of ecological balance or ecosystem health – interfere with nutrient cycle- nitrogen and carbon cycle by killing microorganisms.

Measures one would take to control pesticide residues in foods

- Use alternate methods of pest control e.g.
 - Biological methods
 - Sterilization technique – e.g. sterile male release
 - Use of cultural techniques
 - Use of traps e.g. fly traps in slaughter house or meat processing plant.
- Use of short – acting easily biodegradable pesticides e.g. Organophosphorus pesticides – for crops
- Observation of withdrawal periods post harvest
- Breed resistant animals and plants etc.
- Avoid contaminated feeds e.g sprayed foliage stovers until suitable time interval

Reduction measures cont/

- Storage of chemicals/drugs away from food substances – avoid migration into foods or accidental contamination.
- Use the right dose of chemicals at the recommended rates
- Educate farmers and other users, community on proper use of pesticides and the associated risks
- Proper disposal of pesticide containers – storage of foods from pesticides. Stop misuse of pesticides eg carry over from coffee to vegetables
- It is important to emphasize that pesticide residues can be most effectively controlled through good agricultural practice good animal husbandry, and good manufacturing practice.

Environmental Toxicity of Mercury

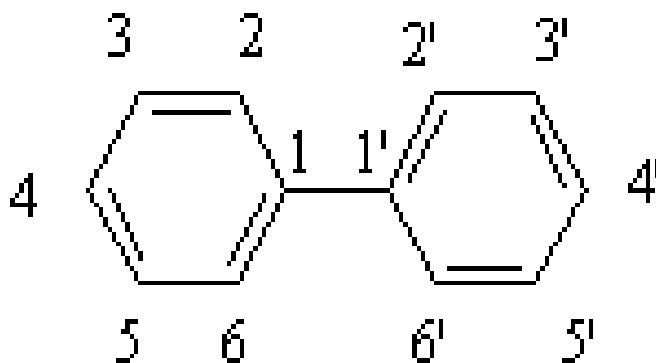
Methyl mercury is lipid soluble and tends to bioaccumulate in organisms as well as through food chain.

Mercury poisoning has been reported in many parts of the world e.g. Japan, Iraq etc. from mercury released from chlorine production facilities and as a result of mistaken consumption of organo-mercury treated grain intended for use as a pesticide.

Consumption of contaminated fish and marine mammals is the most important source of human exposure to methyl mercury. The highest concentration found in large predatory species.

Polychlorinated Biphenyls (PCBs)

The general chemical structure of chlorinated biphenyls is shown below in Figure 1.



These are mixtures in which chlorine substituents can occur at ten sites in a biphenyl molecule. Up to 210 isomers are assumed possible to form.

Uses

- ▶ These compounds are used in industry as plastizers, insulators, lubricants, heat exchange fluids, in electric transformers and capacitors, as additives in paint, copy paper and printing inks.

Properties

- ▶ Chemically stable, lipophilic and persistent in the environment (same as organochlorines).

Many countries have severely restricted or banned the production of PCBs.

- PCBs accumulate in the food-chain.
- They are rapidly absorbed from the gastrointestinal tract and distribute to and accumulate in the liver and adipose tissue.
- They also cross the placenta, are excreted in milk, and accumulate in the fetus/infant.
- Animals may be exposed to PCBs by inhaling contaminated air and ingesting contaminated water and food.
- PCBs were first detected in fish and wildlife by Jensen (1966). Since then their residues have been reported in human milk, fat and in foods especially of animal origin but mainly from industrialized countries.

PCBs build up in living organisms

- **In aquatic environment**

plankton < shell fish < large predatory fish or mammals

- **On land**

Soil or plant leaves < worms or insects < birds and mammals

PCB found also in the eggs of contaminated birds

- **Humans** can also accumulate PCBs from food. The concentrations in fatty tissues is over a hundred times greater than in the food they eat.

Toxic effects of PCBs

PCBs are harmful to human hormonal and immune systems even in very low concentrations. People who have been in regular contact with high concentrations of PCBs suffer from chloracne, liver disorders, breathing problems, and other physical problems.

- Other effects include- enzyme induction leading to reduced rate of reproduction especially in predatory birds.
- -accumulation in tissues occurs in proportional to amount fed.
- -egg shell thinning (causing breakage before hatching)
- -teratogenic effects have been demonstrated
- -PCB excreted in milk unaltered or hydroxylated metabolites
- -effects on new born- small infants
- -effects on reproduction-abortions.

- **Other** unintentional chemical by-products:
polychlorinated dioxins and furans which result from combustion and industrial processes such as the production of pesticides, polyvinylchloride and other chlorinated substances.
- Dioxins and furans are the most potent cancer-causing chemicals known.

Major sources of unintended persistent organic pollutants (UPOPs) in Kenya:-

- municipal and hospital waste incineration
- cement kilns
- production of pulp and paper using chlorine or chemicals generating elemental chlorine for bleaching.
- open burning of wastes.
- residential combustion
- destruction of animal carcasses
- crematoria
- waste oil refineries.

Psalm 119:130.

- “The unfolding of your words gives light, it gives understanding to the simple.”