Chapter II: Toxicology and Environmental Health

Introduction

Toxicology is the science that examines the effects of chemical substances and pollutants on living organisms, including plants, animals, and humans. It aims to understand how these substances affect biological systems, identify harmful doses, and prevent health risks. Environmental health focuses on the relationship between the environment and the health of living beings, evaluating the effects of pollutants in air, water, soil, and food.

Industrialization, intensive farming, domestic waste, and urban development have increased pollution sources, leading to severe effects on plants, animals, and humans. Understanding these effects is crucial for creating prevention and risk management strategies.

Environmental Health is a branch of public health focused on the interactions between people and their environment to promote human health and well-being. It involves understanding how environmental factors like air, water, soil, food, chemicals, and biological agents impact human health, and developing strategies to prevent or manage ecological hazards.

I. Pollutants and Sources of Contamination

Pollutants can be chemical, physical, or biological and originate from various sources.

I.1. Chemical Pollutants

- **Heavy metals**: lead (Pb), mercury (Hg), cadmium (Cd), arsenic (As) are commonly found in industrial wastewater and contaminated soils.

- **Pesticides and herbicides**: used in agriculture to protect crops, but can contaminate soil, water, and living organisms.

- **Hydrocarbons and volatile organic compounds (VOCs)**: from fuels, chemical industries, and waste.

I.2. Physical Pollutants

- **Fine particles (PM2.5 and PM10)**: emitted by transport, industries, and domestic combustion.

- **Ionizing radiation**: natural or artificial radioactivity, which can damage DNA and cause cancer.

I.3. Biological Pollutants

- **Pathogenic microorganisms**: bacteria, viruses, and parasites present in contaminated water or food.

- **Natural toxins**: mycotoxins produced by certain fungi on cereals and other crops.

II. Effects of Pollutants on Plants

Life plants can show different effects depending on the type and concentration of pollutants (Fig. 1):

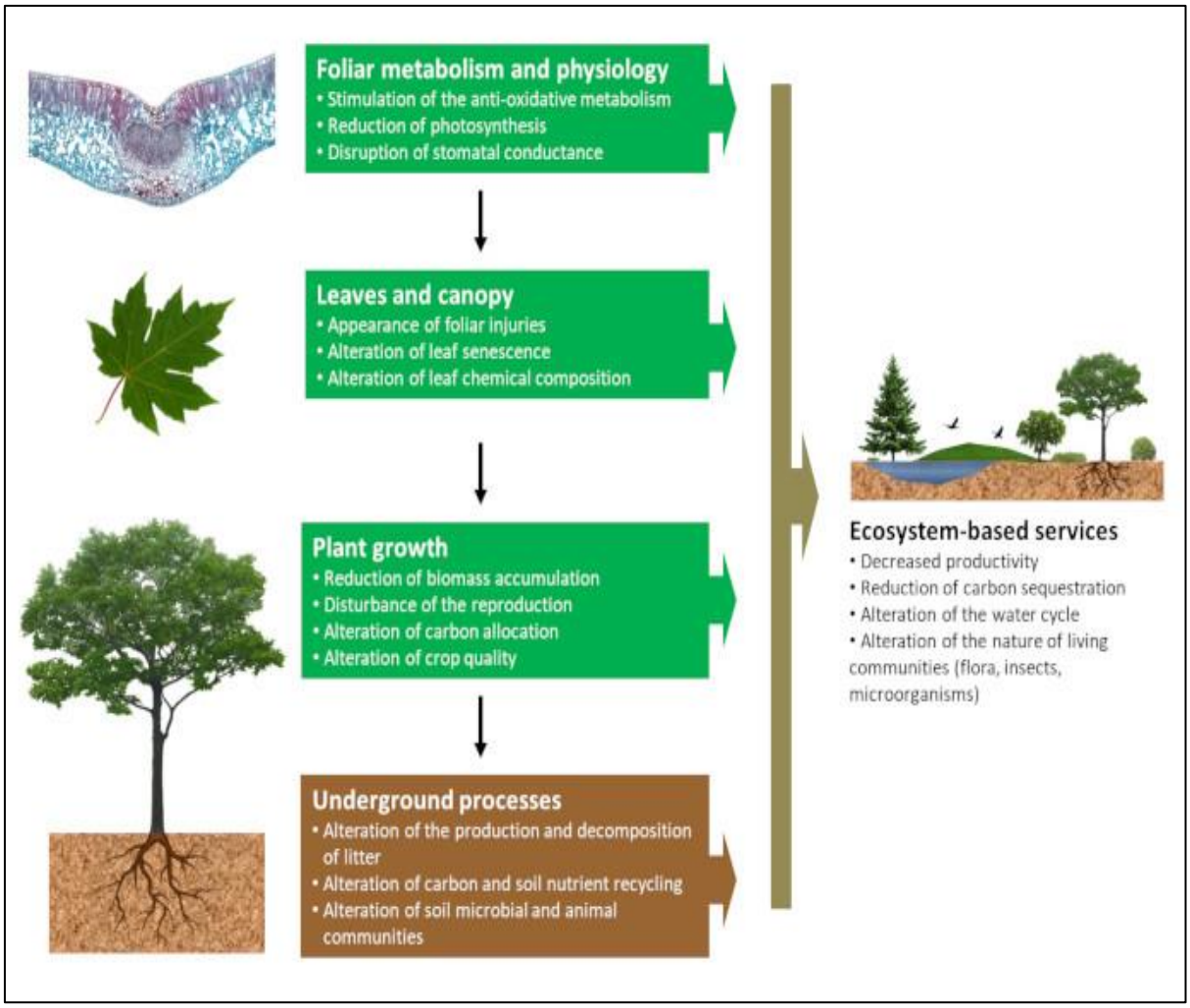

Figure 1: Effects of pollutants on plant.

II.1. Impact of Heavy Metals

Heavy metals like lead, cadmium, and mercury interfere with photosynthesis, slow down root and leaf growth, and can lead to cell death. They also build up in plant tissues, entering the food chain.

II.2. Effects of Pesticides and Herbicides

Pesticides can cause cell damage, decrease seed germination, and harm plant reproduction. Some herbicides interfere with photosynthesis and respiration, resulting in stunted growth and reduced agricultural yield.

II.3. Air Pollution

Pollutant gases like sulfur dioxide (SO_2), nitrogen oxides (NOx), and ozone (O_3) can cause leaf browning and necrosis, decrease photosynthesis, and disrupt mineral nutrition in plants.

III. Effects of Pollutants on Wildlife Animals

Effects of pollutants on wildlife animals can occur through exposure to air, water, soil, and food (Fig. 2):

Figure 2: Acid rain destroys fish life in lakes and streams.

III.1. Bioaccumulation and Biomagnification

Bioaccumulation is the gradual buildup of toxic substances, such as heavy metals (e.g., mercury, cadmium, lead) and persistent organic pollutants (POPs) like polychlorinated biphenyls (PCBs), in the tissues of living organisms. These compounds are difficult to metabolize or excrete, leading to their accumulation over time.

Biomagnification happens when these pollutants increase in concentration as they move up the food chain. Primary producers (e.g., phytoplankton) absorb contaminants from water and soil, which are then eaten by herbivores, small carnivores, and eventually top predators. At each trophic level, pollutant levels rise, making apex predators the most at risk. For example, mercury in fish has been shown to reach levels that cause neurological and behavioural disorders in fish-eating birds and mammals, including impaired hunting abilities, reduced survival rates, and developmental defects in offspring.

III.2. Effects on Reproduction and Growth

Pollutants can seriously affect the reproductive ability and growth of organisms. Endocrine disruptors, such as certain pesticides, pharmaceuticals, and industrial chemicals, interfere with hormonal signalling, leading to reproductive problems. Documented effects include feminization of male fish exposed to estrogenic compounds, reduced sperm quality in mammals, and abnormal egg production in birds. Congenital malformations, lower hatchability, and decreased juvenile survival rates have also been seen in contaminated habitats.

Furthermore, prolonged exposure to air pollutants such as sulfur dioxide, nitrogen oxides, and ozone harm's respiratory function, reduces oxygen intake, and weakens the immune system. This not only decreases growth and reproductive success but also makes organisms more vulnerable to secondary infections and diseases. In plants, pollutants such as ozone can inhibit growth by damaging leaf tissues and reducing photosynthetic efficiency, thereby affecting herbivores and higher levels of the food chain.

III.3. Ecosystem Disruption

Pollution disrupts the natural balance of ecosystems, often leading to biodiversity loss. Sensitive species such as amphibians, corals, and lichens are among the first to decline due to their vulnerability to

chemical stressors. In contrast, more resistant species, including some invasive organisms, may flourish, leading to changes in species composition and disruption of ecological interactions.

Aquatic ecosystems, for example, undergo eutrophication when excess nutrients from agricultural runoff promote algal blooms. These blooms consume oxygen during decomposition, forming "dead zones" where most aquatic life cannot survive. Terrestrial ecosystems may also be affected by soil contamination, which reduces fertility and alters microbial communities vital to nutrient cycling. Overall, pollution-related ecosystem disruption weakens services like pollination, water purification, and climate regulation, directly affecting both wildlife and human well-being.

IV. Effects of Pollutants on Human Health

Exposure to pollutants has various effects on human health (Fig. 3), depending on dose, duration, and route of exposure (respiratory, digestive, or skin contact):

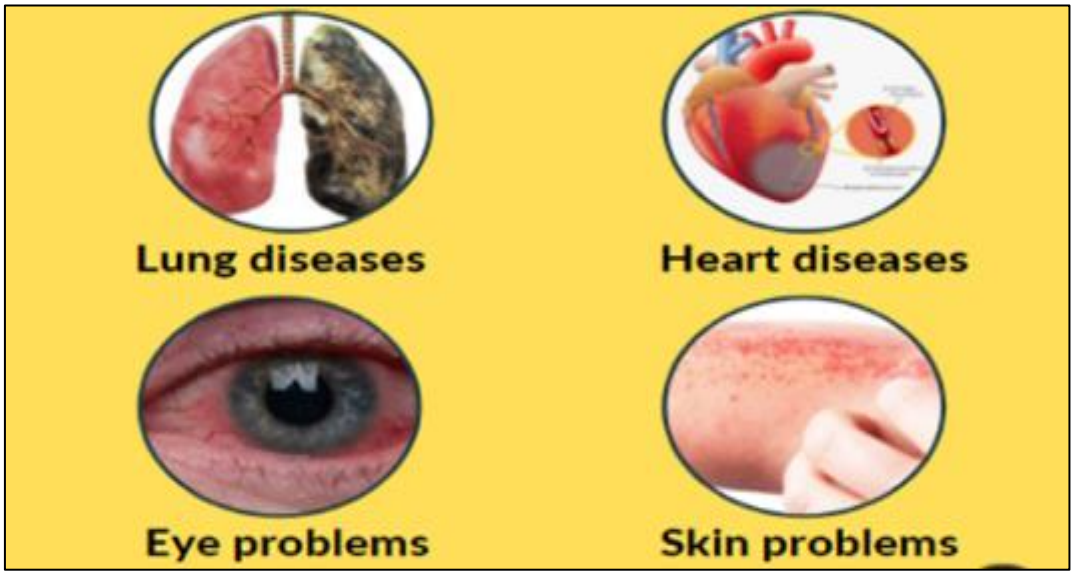

Figure 3: Health effects of air Pollutants.

IV.1. Acute Effects

- **Food poisoning**: ingestion of pesticides or bacterial toxins (e.g., Salmonella, E. coli).
- **Irritations**: eyes, skin, and respiratory tract due to chemical or particulate exposure.

IV.2. Chronic Effects

- **Respiratory diseases**: asthma, chronic bronchitis, and lung diseases caused by fine particles and VOCs.

- **Cancers**: some heavy metals, polycyclic aromatic hydrocarbons (PAHs), and radiation may cause cancer over time.

- **Neurological** and hormonal disorders: mercury, lead, and endocrine disruptors affect the nervous and hormonal systems.

IV.3. Developmental Impacts

Prenatal exposure to certain pollutants can lead to congenital malformations, cognitive delays, and developmental disorders in children.

V. Prevention and Risk Management

To minimize the effects of pollutants on human health and the environment, several measures are necessary.

- Monitoring and control: overseeing air, water, and soil quality.
- Regulations: restricting pesticide use and industrial emissions.
- Pollution remediation: phytoremediation, water treatment, and waste recycling.
- Education and awareness: educating the public about risks and safe practices.

Conclusion

Toxicology and environmental health emphasize the connection between pollution, ecosystems, and human health. Chemical, physical, and biological pollutants impact plants, animals, and humans both directly and indirectly. Knowing these effects is vital to protecting biodiversity, ensuring food safety, and guarding public health. Prevention, regulation, and sustainable resource management are essential for reducing risks and maintaining a healthy environment for everyone.