Chapter II. Toxicology and Environmental Health

I. Toxicology - Health Environment: Concepts and definitions

1. What is environmental health?

The environment can **directly and indirectly** impact on our **health** and **well-being**. Environmental health examines the **interaction** between the **environment** and our **health**.

We use the following definitions:

- Environment broadly includes everything external to ourselves, including the **physical**, **natural**, **social** and **behavioural** environments.

- Health is a state of complete **physical, mental** and **social** well-being, and is **not merely the absence of disease or illness**.

- Environmental health

Environmental Health is the branch of **public health** (quality of life) that focuses on the interrelationships between **people and their environment**, promotes **human health** and **well-being**, and fosters **healthy** and **safe communities**. It also concerns **the policy** and **practices of management**, **control** and **prevention** of environmental **factors** likely to affect **the health** of **current** and **future generations** (**World Health Organisation**).

Environmental health concerns may be divided into two main groups:

a- The standard of risks associated with **poverty** and **underdevelopment**, including a lack of access to **clean water**, **poor sanitation** and **waste management**, **indoor air pollution**, and **vector-borne illnesses** (for example: **Malaria**).

b- Environmentally irresponsible development contributes to **contemporary dangers** including **urban air pollution** and **garbage exposure** from the **agricultural** and **industrial** sectors.

Environmental health is both of science and a practice

Risk = **Danger** x **Exposure**

- **Danger:** Property of a **dangerous agent** to cause a **deleterious effect** (illness).
- **Exposure:** Situation allowing the action of the **dangerous agent** on **the body** (**inhalation**, **ingestion**, **skin contact**)
- **Risk:** Probability of occurrence of a deleterious effect.

2. Why is the environment important for health?

We need safe, healthy and supportive environments for **good health**. The environment in which we live is a major determinant of our **health** and **well-being**. We depend on the environment for **energy** and the materials needed to sustain life, such as: **clean air, safe drinking water, food** and **safe places to live**.

3. Toxicology

It is the science of poisons, identifies and quantifies potentially noxious agents in our environment. The essence of the science of toxicology is defining the fine line distinguishing between tolerable and unacceptable risks to humans and other organisms in the manufacturing, handling, use and disposal of chemical agents. Mechanism-oriented investigative toxicology encompasses the disciplines of anatomy, physiology, biochemistry, chemistry, immunology,

pharmacology, cell and molecular biology as well as pathology and laboratory medicine. The toxicologist must be well versed in not only human and veterinary medicine, but also in the various aspects of agricultural and nutritional sciences. Only through rigorous basic scientific research can responsible regulation of potentially hazardous compounds be achieved.

II. Pollution

1. Definition

An undesirable change in the **physical**, **chemical** and **biological** characteristics of the environment especially air, water and land that may adversely affect human population and the wild life, industrial processes, cultural assets (building and monuments), is **called pollution.** Pollution has **immediate negative consequences on both local** and **global environmental elements**. The agents that pollute the environment or cause pollution are called pollutants.

2. Types of pollution

2.1. Air pollution

2.1.1. Definition

Air pollution is caused by **solid** and **liquid** particles and certain gases that are suspended in the air. These particles and gases regularly originate from vehicle and truck fumes, manufacturing plants, dust, volcanoes and wild fires. **The solid and liquid particles suspended in air are called aerosols.**

Air may get polluted by natural causes such as **volcanoes**, which release ash, dust, sulphur and other gases, or by **forest fires** that are occasionally naturally caused by lightning. However, unlike pollutants from **human activity**, naturally occurring pollutants tend to remain in the atmosphere for a short time and do not lead to permanent atmospheric change.

2.1.2. Sources of air pollution

The sources of air pollution can he divided into two categories:

a- Natural sources

- Ash from burning **volcanoes**, dust from **storm**, **forest fires**;
- **Pollen grains** from flowers in air are natural sources of pollution.

b- Anthropogenic (human-made) sources

- **Combustion of fossil fuels**, like coal and oil for electricity and road transport, producing air pollutants like nitrogen and sulfur dioxide.
- **Emissions from industries and factories**, releasing large amount of carbon monoxide, hydrocarbon, chemicals and organic compounds into the air.
- **Agricultural activities**, due to the use of pesticides, insecticides, and fertilizers that emit harmful chemicals.
- **Waste production**, mostly because of methane generation in landfills

2.1.3. Major air pollutants

Some major air pollutants are discussed here:

a- Carbon dioxide

Carbon dioxide is one of the **major gases** which contributes towards air pollution. It is mainly produced during the **combustion of fuel** in factories, power stations, household etc. The increasing CO_2 in the atmosphere is likely to have the following effects:

- A rise in atmospheric temperature or **global warming** due to **greenhouse** effect. Also causes **climate change**.

- **Reduced productivity of the marine ecosystem**. This is due to the fact that water in the oceans would be more acidic due to increased concentration of CO_2 in the air, which dissolves in the water.

- **Due to Global warming**, the increased surface temperature would cause melting of continental and mountain glaciers and thus would cause flooding of coastal areas of some countries.

b- Sulphur dioxide

It is produced by **the burning of coal in powerhouses** and **automobiles** (car, trucks etc.). It causes **chlorosis** and **necrosis of plants**, **irritation in eyes** and injury to the **respiratory tract** (asthma, bronchitis) in humans responsible for discoloration and **deterioration of buildings**. High concentration of sulphur dioxide in the atmosphere dissolves in **rain drops** to form **sulphuric acid** which **causes acid rain**.

c- Carbon monoxide

Carbon monoxide is produced as a result of incomplete **combustion of fossil fuels** like coal, petroleum and wood charcoal. Automobiles using diesel and **petroleum** are the **major sources** of carbon monoxide which gets added to the atmosphere. **Carbon monoxide is more dangerous than carbon dioxide.** It is a **poisonous gas** which causes **respiratory problems**. When it reaches the **blood stream**, it replaces oxygen due to its high affinity for **haemoglobin**. It also causes **giddiness, headache** and interferes with **normal function of the heart**.

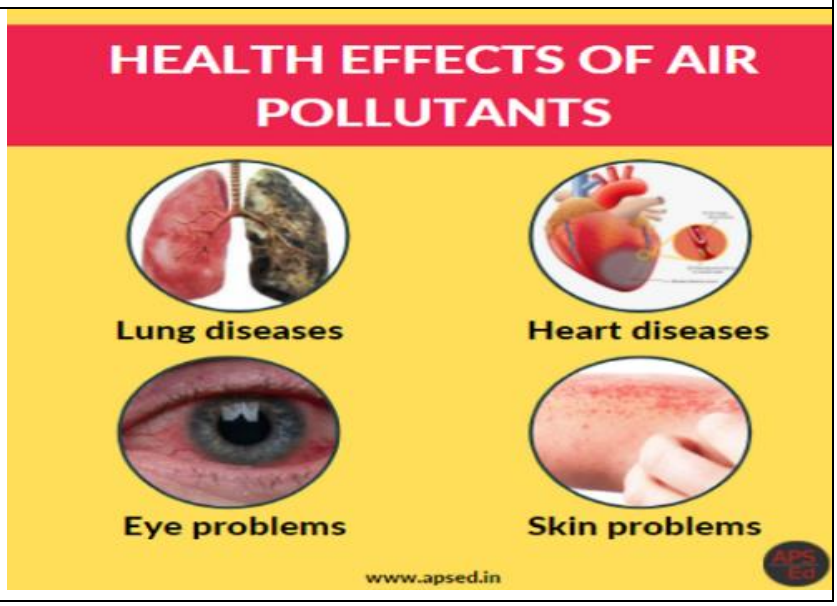
d- Fluorides

Upon **heating**, **rock**s, **soils** and **minerals** that contain **fluorides**, give out hydrogen fluoride gas. This is an extremely **toxic gas**, which causes serious injury to **livestock and cattle**.

e- Oxides of nitrogen

A few oxides of nitrogen, such as **nitric oxide** (NO), **nitrous oxide** (N_2O) and **nitrogen dioxide** (NO_2) are produced by natural processes as well as from thermal.

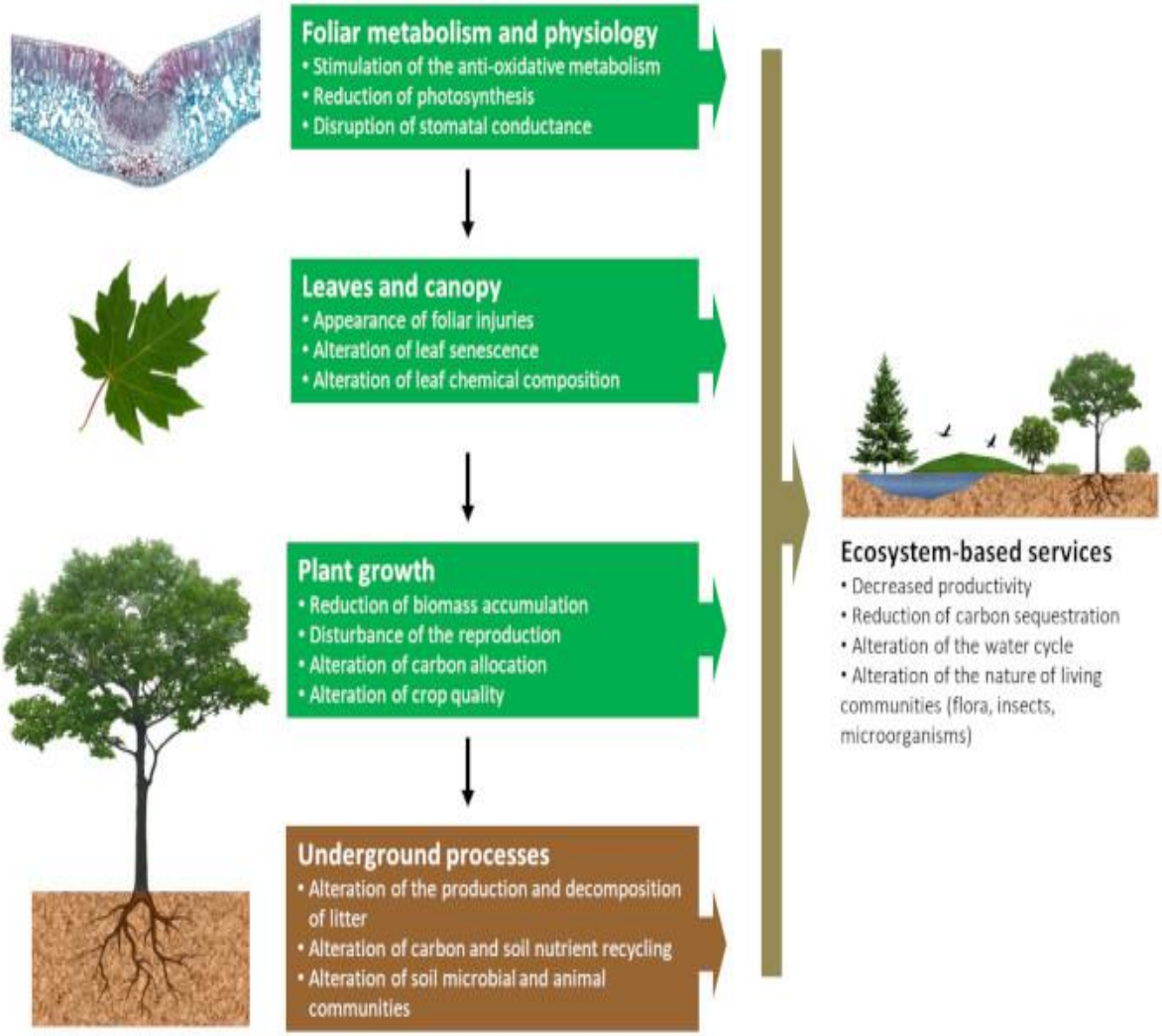
2.1.4. Effects Air pollution

ON HUMAN HEALTH	
Our continual exposure to air pollutants is responsible for the **deterioration of human health.** Air pollution is indeed a significant risk factor for human health conditions, causing **allergies**, **respiratory** and **cardiovascular** diseases as well as **lung damage**.	

ON ANIMAL HEALTH

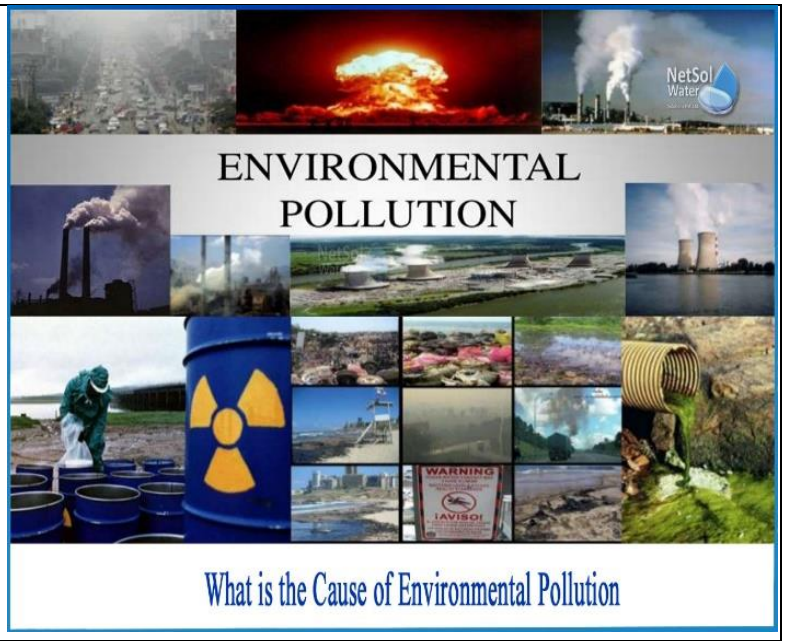
- Formation of **acid rain** in the air damages life **fish** in **lakes** and **streams.**
- **Rays from ozone layer** with excessive ultraviolet radiation coming from Sun may **cause skin cancer in animals.**
- **Ray from ozone** in the lower atmosphere may destroy **lung tissues** of the animals.
- **Toxic chemicals** can force **wildlife species to migrate** to places and change their habitat.

ON PLANTS



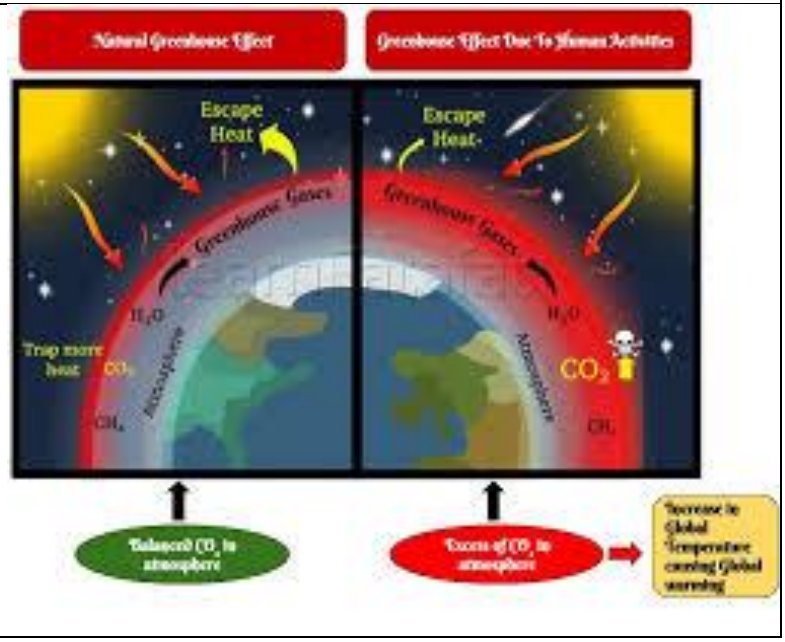
ON THE ENVIRONMENT

Air pollution has a major impact on the process of **plant evolution** by preventing **photosynthesis** in many cases, with serious consequences for the **purification of the air** we breathe. It also contributes to the formation of **acid rain**, atmospheric precipitations in the form of rain, frost, snow or fog, which are released during the combustion of **fossil fuels** and transformed by contact with water steam in the atmosphere.



GLOBAL WARMING

On top of that, air pollution is a major contributor to **global warming and climate change**. In fact, the abundance of carbon dioxide in the air is one of the causes of the **greenhouse effect.** Normally, the presence of greenhouse gases should be beneficial for the planet because they absorb the **infra-red radiation** produced by the surface of the earth. But the excessive **concentration of these gases** in the atmosphere is the cause of the **recent climate change.**



2.2. Water pollution

2.2.1. Definition

Water pollution occurs when **harmful substances-often chemicals or microorganisms-contaminate a stream, river, lake, ocean, aquifer, or other body of water, degrading water quality and rendering it toxic** (dangerous) **to humans or the environment**. Polluted water makes unsafe for drinking cooking, cleaning, swimming, and other activities. Water pollution is caused by industrial effluents, and agricultural effluents are all examples of pollution.

2.2.2. Effects of water pollution on Human health

Water pollution is a severe environmental problem that has an impact on **people's health** and **well-being** all over the world. It can result from various sources, such **urbanization**, **deforestation**, **agricultural runoff**, **industrial discharge**, **detergents** and **fertilizers** and **sewage**. Here are the ten effects of water pollution on human health:

- **Contaminated Drinking Water:** Consuming contaminated drinking water can lead to various health problems, such as gastrointestinal infections, typhoid fever, cholera, and dysentery.

- **Exposure to Toxins:** Exposure to toxic chemicals, such as lead, mercury, and pesticides, can cause serious health problems, including neurological damage, congenital disabilities, and Cancer .

- **Skin Irritation:** Skin contact with contaminated water can cause irritation, itching, and rashes. In severe cases, it can lead to infections and allergic reactions.

- **Respiratory Problems:** Respiratory conditions like asthma and bronchitis can be triggered by breathing in airborne contaminants from polluted water.

- **Reproductive Problems:** Exposure to toxic substances in water can cause reproductive problems, including infertility, congenital disabilities, and low sperm count.

- **Cardiovascular Problems:** Contaminated water can contain heavy metals that can cause cardiovascular problems , such as heart disease and stroke .

- **Liver and Kidney Damage :** Exposure to contaminated water can cause liverand kidney damage, leading to various health problems.

- **Cancer:** Exposure to certain chemicals and pollutants found in contaminated water has been linked to an increased risk of Cancer, including leukaemia and lymphoma.

- **Mental Health Issues :** Exposure to contaminated water can lead to mental health issues, including stress, anxiety, and depression.

2.2.3. Effects of water pollution on Animals

- **The food chain is damaged:** When toxins are in the water, the toxins travel from the water the animals drink to humans when the animals' meat is eaten.

- **Pollutants in the water will alter the overall chemistry of the water**, causing changes in acidity, temperature and conductivity. These factors all have an effect on the marine life.

- **Chemical contaminants** carried by industrial wastes kill a lot of smaller aquatic organisms, such as frogs, fish, tadpoles, etc. This, in turn, causes a loss of food source for bigger aquatic creatures, leading them to either consume poisoned, dead fish and perish, or leave their natural habitat to go in search of food in other aquatic quarters. Often, this leads to sickness and death of these animals due to the inability to adapt to changed water temperatures, unfavorable tides, as well as exposure to new predators.

- **An excess of nutrients**, such as nitrogen and phosphorus in the water, leads to an increased growth of toxic algae and aquatic plants, that cause poisoning and death in fish and other animals who feed on them.

- **Presence of huge quantities of mercury in water** has led to a lot of undesirable changes in aquatic species. Too much mercury leads to hormonal imbalances and glandular damage, leading to abnormal behavioral shifts. Also, mercury is a toxic metallic chemical that gives a huge blow to the reproductive functions, growth and development of animals, that are continuously exposed to high doses of it.

- **Oil spills** that introduce unhealthy amounts of oil into the marine environment also make marine animals sick and lead to their unnatural deaths.

- **Dumping solid trash** such **as plastic**, **metallic scrap**, **garbage**, etc., may block aquatic channels, and can also cause small animals to get trapped in the debris. Most water-dwelling animals tend to suffocate or drown on being trapped and unable to swim.

- **Polluted water used for irrigation** also contaminates the soil and the agricultural produce. This may lead to health issues in herbivorous animals who feed on agricultural plants and leftovers.

- **These pollutants can radically alter the metabolism of a number of soil-dwelling** bacteria and insects, making them perish or unsuitable for consumption by common predators of the local ecosystem.

2.2.4. Effects of water pollution on plants

The various effects of water pollution on plants are as follows:

- **Phytotoxicity:** It occurs when the plants absorb harmful chemical pollutants dissolved in water through its roots. It can lead to poisoning. It leads to growth retardation in plants.
- Water pollution can lead to increased levels of nutrients including sodium and potassium leading to eutrophication. The process stimulates the growth of algae. And these algae compete with plants for nutrients and can lead to nutrient deficiency in plants.

- **When industries** release heated water into water bodies from thermal power plants, it increases the temperature of the water bodies and disrupts the natural habitat of aquatic plants. It leads to reduced enzymatic functioning in plants.

- **The release of organic wastes** into water products change the pH of the water bodies causing toxicity to the plants absorbing polluted water.

- **The Release of detergents** that contain phosphates into water bodies result in phosphate enrichment. On absorbing phosphate- enriched water by the plants it results in growth retardation, cell destruction, etc.

- **In the agricultural sector**, contaminated water can lead to a poor yield of crops, as well as its low quality and quantity.

2.2.5. Environmental impacts of water pollution

- **Ecosystem disruption:** Water pollution can harm aquatic ecosystems by disrupting the delicate balance of aquatic flora and fauna. Pollutants in water bodies can reduce oxygen levels, alter water temperature, and introduce harmful substances that can negatively impact aquatic life, leading to declines in biodiversity and ecosystem health.

- **Water quality degradation:** Water pollution can degrade the quality of water, making it unsuitable for various uses such as drinking, agriculture, and recreational activities. Pollutants like chemicals, heavy metals, pathogens, and nutrients from agricultural runoff or industrial discharges can accumulate in water bodies, posing risks to both human and environmental health.

- **Habitat destruction:** Water pollution can result in the destruction of aquatic habitats, such as wetlands and coral reefs, which are crucial for supporting diverse ecosystems and providing

critical ecosystem services like flood regulation, water purification, and nursery grounds for marine life.

2.3. Soil pollution

2.3.1. Definition

Soil pollution refers to the contamination of soil with **anomalous concentrations of toxic substances.** When the concentration of one or more such **toxic substances** is high enough to cause **damage to living organisms**, the soil is said to be contaminated.

The root cause of soil pollution is often one of the following:

- **Agriculture** (excessive/improper use of pesticides)
- **Excessive** industrial activity
- **Poor management** or inefficient disposal of waste.

2.3.2. What are the Pollutants that Contaminate Soil?

- Heavy Metals

The presence of heavy metals (such as **lead** and **mercury,** in abnormally high concentrations) in soils can cause it to become highly **toxic to human beings**. These metals can originate from several sources such as **mining activities**, **agricultural activities**, and **electronic waste** (e-waste), and **medical waste**.

- Polycyclic Aromatic Hydrocarbons

Common examples of **PAHs** include naphthalene, anthracene, and phenalene. Exposure to polycyclic aromatic hydrocarbons has been linked to several forms of **cancer**. These organic compounds can also cause **cardiovascular diseases in humans**.

Soil pollution due to PAHs can be sourced to **coke** (**coal**) processing, **vehicle emissions**, **cigarette smok**e, and the **extraction of shale oil**.

- Industrial Waste

The discharge of industrial waste into soils can result in soil pollution. Some common soil pollutants that can be sourced from industrial waste are listed below.

- **Chlorinated industrial solvents**
- **Dioxins** are produced from the manufacture of pesticides and the incineration of waste.
- **Plasticizers**/dispersants
- **Polychlorinated biphenyls (PCBs)**

The petroleum industry creates many petroleum hydrocarbon waste products. Some of these wastes, such as **benzene** and **methylbenzene**, are known to be **carcinogenic in nature**.

- Pesticides

Pesticides are substances (or mixtures of substances) that are used to kill or inhibit the **growth of pests**. Common types of pesticides used in agriculture include

- Herbicides - used to kill/control weeds and other unwanted plants.
- Insecticides - used to kill insects.
- Fungicides - used to kill parasitic fungi or inhibit their growth.

2.3.3. Effects on Human Beings

Soil contaminants can exist in all three phases (**solid**, **liquid**, and **gaseous**). Therefore, these contaminants can find their way into the **human body** via several channels such as **direct contact with the skin** or through the **inhalation of contaminated soil dust**.

The **short-term effects of human** exposure to polluted soil include:

- Headaches, nausea, and vomiting.
- Coughing, pain in the chest, and wheezing.
- Irritation of the skin and the eyes.
- Fatigue and weakness.

A variety **of long-term ailments** have been linked to soil pollution. Some such diseases are listed below.

- Exposure to high levels of lead can result in permanent damage to the nervous system. Children are particularly vulnerable to lead.
- Depression of the CNS (Central Nervous System).
- Damage to vital organs such as the kidney and the liver.
- Higher risk of developing cancer.

2.3.4. Effects on Plants and Animals

Since soil pollution is often accompanied by a decrease in **the availability of nutrients**, **plant life** ceases to thrive in such soils. Soils contaminated with **inorganic aluminium** can prove **toxic to plants**. Also, this type of pollution often increases **the salinity of the soil**, making it inhospitable for the **growth of plant life.**

Plants that are grown in polluted soil may accumulate **high concentrations of soil pollutants** through a process known as **bioaccumulation**. When these plants are consumed **by herbivores**, all the accumulated pollutants are **passed up the food chain**. This can result in the **loss/extinction of many desirable animal species**. Also, these pollutants can eventually make their way to the top of the **food chain and manifest as diseases in human beings**.

2.3.5. Effects on the Ecosystem

- Since the **volatile contaminants** in the soil can be carried away into the atmosphere by **winds** or can seep into underground **water reserves**, soil pollution can be **a direct contributor to air and water pollution.**
- It can also contribute to **acid rain** (by releasing huge quantities of **ammonia** into the atmosphere).
- Acidic soils are **inhospitable** to several **microorganisms** that improve soil texture and help in the **decomposition of organic matter**. Thus, the negative effects of soil pollution also impact soil **quality and texture**.
- Crop yield is greatly affected by this form of pollution. In China, over **12 million tons of grain** (worth approximately **2.6 billion USD)** is found to be unfit **for human consumption due to contamination with heavy metals** (as per studies conducted by the China Dialogue).