Chapter 4. Importance and ecological effects of the main types of pollution

4.1. Air pollution

Caused by the uncontrolled release of various substances into the atmosphere, air pollution is undoubtedly one of the most obvious forms of environmental degradation. Air pollution results from multiple factors that characterize modern civilization: the increasing consumption of energy, the development of extractive, metallurgical, and chemical industries, road and air traffic, the incineration of household and industrial waste, etc. Air pollution mainly affects urban areas, not only due to the concentration of industries and households, but also because of the circulation of motor vehicles.

4.1.1 Effects of air pollution

Pollutants released into the atmosphere induce multiple harmful effects not only on exposed living species, including humans, but also on entire ecosystems and even at a global scale by disrupting major biogeochemical cycles.

4.1.1.1 Sulfur dioxide (SO_2)

Sources: Volcanism, industrial emissions (especially from sources burning coal or petroleum), and transportation (diesel and gasoline). Sulfur dioxide oxidizes in the air into sulfur trioxide (SO_3), which in turn reacts with water vapor to form highly hygroscopic sulfuric acid (H_2SO_4). This acid plays an essential role in the formation of acidic smogs—typical fogs in urban areas of cold temperate climates affected by severe air pollution.

Effects on vegetation

SO_2 is harmful to plants; some, like lichens, are so sensitive that they are used as biological indicators (no lichen species survives concentrations above 35 ppb).

SO_2 is also very toxic to phanerogams: no higher plant can grow normally in air containing more than 80 ppb continuously, even resistant species.

In very resistant plants, foliar lesions appear after only half a day of exposure to 0.25 ppm. Plants sensitive to SO_2 include: alfalfa, barley, cotton, tobacco, sugar beet, lettuce, tomatoes, wheat, and apple trees.

SO_2 is also responsible for acid rain, which causes large-scale dieback of coniferous forests and acidification of lake waters on crystalline soils.

Effects on animals

Animals and humans also suffer from SO_2 pollution. In mammals, toxicity appears as decreased pulmonary elasticity at concentrations below 1 ppm, and at higher levels causes bronchial hypersecretion.

Effects on materials

It causes the degradation of buildings of all types by conversion into sulfurous and sulfuric acids and by reaction with calcium carbonate (significant damage to famous monuments). SO_2 also contributes to the corrosion of certain metals.

4.1.1.2 Hydrogen Sulfide (H_2S)

Naturally present in the atmosphere. It is produced by various anaerobic fermentations performed by sulfur bacteria in both terrestrial and marine environments. Industrial H_2S production mainly originates from petrochemical facilities. It becomes toxic when it exceeds the permissible concentration in air (15 ppm).

4.1.1.3 Nitric Oxide (NO)

Sources: Nitric oxide is one of the normal constituents of the atmosphere. It is also produced by natural phenomena such as thunderstorms and volcanic eruptions. Large quantities are generated during high-temperature combustion, especially in internal combustion engines.

NO is rapidly converted in the air into nitrogen dioxide (NO_2) and then into very dangerous compounds—Peroxyacetyl Nitrates (PAN)—in polluted, sunny urban atmospheres, favorable to photochemical smog formation. These atmospheres are sites of various reactions leading to ozone formation, which then reacts with other pollutants such as unburned hydrocarbons, oxidizing them into peroxyacyl compounds.

Effects on vegetation

PANs produced from nitrogen oxides are particularly toxic to plants: 15 ppb are enough to cause leaf burn in phanerogams within four hours. Exposure to gaseous air pollutants (SO_2, nitrogen oxides, PAN, ozone) and to acid precipitation leads to serious damage to vegetation, especially in forest ecosystems.

Effects on animals

In mammals, concentrations of just a few ppb cause strong irritation of ocular and bronchial mucous membranes. Levels above 50 ppb are regularly recorded, for example, in several Californian cities. Mixtures of nitrogen oxides dominated by NO_2 form an irritating gas that has toxic effects on the deep respiratory tract, and at high concentrations causes severe effects such as edema, congestion, pneumonia, and death.

4.1.1.4 Fluorides

Sources: Fluorine is ubiquitous in nature: in soil, minerals, water, and volcanic emissions. It is the raw material for many manufacturing industries, especially fertilizer production. Processes such as calcination or sulfuric acid attack release fluorine emissions in various quantities, despite filtering systems (often >99% efficient).

Effects on vegetation

Soil contamination by airborne fluorides is disastrous for many cultivated or wild plants and for coniferous forests. Lesions appear as discoloration progressing to burning. Fruit trees suffer similar damage. Plant sensitivity varies widely from species to species.

Effects on animals

Fluoride-contaminated plants introduce increasing fluoride levels into the food chain of livestock and humans. High intake causes visceral damage leading to death. Lower but chronic exposure (1.5–2 mg/day over long periods) causes chronic intoxication, beginning with dental fluorosis—stains, deformities, and weakened teeth, worsening with longer exposure. Fluorides also accumulate in hooves and hair, causing abnormal appearance.

4.1.1.5 Chlorofluorocarbons (CFCs)

Also called Freons, these are chlorofluorinated derivatives of methane. They were widely used as refrigerants and air-conditioning fluids, solvents in cleaning agents, in electronic boards, as foaming agents (fire extinguishers), and aerosol propellants.

Their atmospheric lifetime ranges from 20 to 100 years. They play a major role in greenhouse gas formation, and their emissions contribute to about 80% of total stratospheric ozone depletion.

CFCs accumulate in the stratosphere, where UV radiation breaks them down, releasing chlorine atoms that react with ozone, splitting it into oxygen.

4.1.1.6 Carbon Monoxide (CO)

Sources : CO is the most widespread atmospheric pollutant. Under natural conditions, it occurs in the air at very low concentrations (0.5–0.2 ppm). Its natural sources include volcanism, anaerobic fermentation (marsh sediments), forest fires, and bush fires. Marine organisms also produce significant amounts—brown algae (Fucus) can generate CO. It is also produced by incomplete combustion of organic substances whenever oxygen is insufficient, and comes from industries, home heating, tobacco smoke, and mainly transportation.

Effects on humans

A highly potent respiratory toxin. It blocks oxygen binding to hemoglobin by forming a stable complex. It also affects various enzymes: phosphatases, mitochondrial respiration, riboflavin, nicotinic acid, and flavin nucleotides.

Even at lower concentrations, symptoms may include abdominal pain, headaches, dizziness, nausea, and vomiting.

Effects on vegetation

CO has toxic effects on plants: leaf loss, bud fall, and premature fruit drop before ripening.

4.1.1.7 Carbon Dioxide (CO_2)

The continually increasing use of fossil fuels over the last century has disrupted the biogeochemical carbon cycle. Human activity has broken the equilibrium between CO_2 released by natural processes (respiration, fermentation, volcanism) and the amount removed through photosynthesis and sedimentation. The rise in atmospheric CO_2 may cause major climatic changes, most notably warming of the lower stratosphere due to the greenhouse effect, as heat-radiating infrared waves are trapped near the Earth's surface.

4.1.1.8 Hydrocarbons

Unburned hydrocarbons are major contaminants in polluted urban atmospheres. They originate from the evaporation of petroleum products in fuel tanks and carburetors, especially after engine shutdown while still hot. The main source, however, is incomplete combustion in engines gasoline engines accounting for 90% of VOC emissions and in fuel-oil heaters.

4.1.1.9 Particles

Particles include a wide variety of substances. The term generally refers to the fraction of liquid or solid components suspended in gas; they originate mainly from solid carbon compounds, unburned hydrocarbons, tire wear, and heavy metals.

Effects on human health

The finest particles, called non-sedimentable (because they cannot settle by gravity), are the most dangerous, as they can penetrate deep into the pulmonary alveoli. They pollute upper atmospheric layers and contribute to global pollution. Two types are especially concerning in urban public health:

- those derived from lead
- those from asbestos fibers, formerly used in industry and construction until banned in many countries.
  Inhaling asbestos fibers causes a severe disease: pulmonary mesothelioma.

4.2 Aquatic pollution

4.2.1 Effects of synthetic organic substances

In surface waters, the stability of pharmaceuticals appears to vary greatly. However, since these substances are discharged more or less continuously, organisms are exposed to pollution constantly over several generations. This pollution does not seem to be acutely toxic because the concentrations that cause immediate effects are relatively high and unlikely to be reached in aquatic environments.

Currently, it is therefore not possible to exclude the possibility that pharmaceuticals may have long-term effects on aquatic ecosystems. For instance, **17 α-ethinylestradiol**, a synthetic hormone used in contraceptive pills, is suspected to affect fish communities at concentrations detected in the environment—around a few ng/L.

4.2.2 Effects of acid rain

Acid rain alters the chemical balance of receiving environments, particularly when these are already naturally acidic (lacking buffering capacity). This results in damage to aquatic flora and fauna, nutrient deficiencies leading to reduced yields, visible lesions on plants, yellowing, and defoliation of trees. The most significant consequence of strong declines in pH in natural waters is the dissolution of aluminum. Below a pH of 6, the solubility of aluminum in aquatic habitats increases considerably, leading to rapid collapse of entire communities.
The acidification of lakes and rivers causes the disappearance of fish.

4.2.3 Mercury

Pollution of freshwater and marine environments by mercury has provided a dramatic illustration of the severe ecotoxicological consequences associated with this contaminant.

4.2.4 Lead

Saturnism (lead poisoning), caused by contamination of freshwater ecosystems by hunting ammunition, threatens many species especially waterbirds, including rare and endangered species. Just **three lead pellets** are enough to kill a swan.

4.2.5 Hydrocarbons

Pollution from oil spills and other hydrocarbon discharges into the marine environment is a major cause of disturbance to ocean ecosystems.

- **Petroleum is highly toxic to marine autotrophs**, reducing phytoplankton primary production by inhibiting photosynthesis.
- It causes **shortening of marine food chains** due to disappearance of large zooplankton and young salmon that feed on them.
  At the base of the trophic network, microphytoplankton is replaced by nanoplankton, and crustaceans by jellyfish.
- **Coastal benthic flora and fauna** are severely affected by oil spills and sometimes by chronic pollution: destruction of coral reefs and seagrass beds, mortality of benthic invertebrates, crustaceans, and bivalves.
- Oil spills and chronic contamination **kill coastal and migratory aquatic birds**, and even numerous species of marine mammals.

4.2.6 Effects of organic pollutants in lentic environments: Eutrophication

Eutrophication results from excessive input of nutrients and biodegradable organic matter from human activities. It mainly occurs in aquatic environments with low water renewal, stimulated by continuous inflows of phosphorus and nitrogen.
This may result from excessive releases of nitrogen or phosphorus compounds through sewage, or from changes in natural water currents (dams, river diversion). Phytoplankton and some aquatic plants grow and multiply excessively. When they decompose, they increase the amount of biodegradable organic matter in the ecosystem. Bacteria that degrade this matter proliferate in turn, consuming increasing amounts of dissolved oxygen in the water.

4.2.7 Ecological Effects of Thermal Pollution of Water

- A typical fossil-fuel power plant raises river temperature by about **5°C**.
- Higher water temperature **reduces dissolved oxygen levels**.
- Thermal pollution also decreases the concentration of nitrogen and carbon dioxide in water.
- Warming reduces the concentration of **calcium ions**, essential for fish bone formation, mollusk shells, and marine invertebrate exoskeletons.
- Water heating decreases the diversity of phytoplankton and algal flora.
- Planktonic and benthic invertebrates are directly affected: *cladocerans, copepods, insect larvae, mollusks, fish*, etc.

4.3 Soil Pollution

Unlike air pollution, which occurs in both urban and rural industrial areas, soil pollution is often caused by certain modern agricultural techniques aiming to produce increasing quantities of food, while the available arable land per person decreases due to population growth.

Soils are often an obligatory intermediary between the atmosphere and hydrosphere for part of the pollutants released into the air by humans.

Soil pollutants include:

- Agricultural chemicals
- Mineral substances
- Synthetic organic compounds
- Large quantities of solid waste
- Atmospheric fallout of toxic gases

Effects of Pesticides on Human Health

Pesticides cause various health issues in humans, such as:

- Loss of appetite
- Fatigue
- Headaches
- Vomiting
- Digestive disorders
- Frequent skin irritations (40% of cases)
- Respiratory problems
- Neurological disorders, allergies, asthma, and cancers (leukemia, brain, lung, kidney cancer…)
- Reproductive behavior disorders
- Immune system and hormonal disruption