

DP IB Environmental Systems & Societies (ESS): SL

8.3 Urban Air Pollution

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Causes of Urban Air Pollution

Causes of Urban Air Pollution

What is urban air pollution?

- Human activities that release harmful substances into the atmosphere cause urban air pollution
 - Pollutants in the air can come from many sources and impact both human health and the environment
- Common pollutants include:
 - Nitrogen oxides (NO_x)**
 - Sulphur dioxide (SO₂)**
 - Carbon monoxide (CO)**
 - Particulate matter (PM)**
 - Particulate matter refers to tiny solid particles or liquid droplets in the air
 - These particles can come from dust, soot, smoke, and vehicle emissions
- Particulate matter can be classified by size:
 - PM_{2.5}**: fine particles with a diameter of 2.5 micrometres or smaller
 - PM₁₀**: larger particles with a diameter of 10 micrometres or smaller

Primary pollutants

- Primary pollutants are harmful substances that are:
 - Directly emitted from a source**
 - Immediately active** in the atmosphere
- They enter the air through various activities like burning fossil fuels, industrial processes, or natural events such as volcanic eruptions

Sources of primary pollutants

- Natural sources:**
 - Some air pollutants come from **natural events** that occur without human involvement
 - Forest fires**: release smoke, ash, and particulate matter into the air

- **Dust storms:** strong winds lift dust from dry areas, which spreads to cities
- **Volcanic eruptions:** these produce large amounts of SO_2 and ash
- **Anthropogenic (human-made) sources:**
 - Many pollutants in urban areas come from **human activities**, especially those involving the burning of fuels
 - **Burning fossil fuels:** emissions from vehicles, power plants, and factories produce NO_x , SO_2 , CO , and PM
 - **Agricultural burning and deforestation:** these release large quantities of smoke, dust, and other pollutants into the atmosphere
 - **Construction sites and roads:** create dust and PM from the movement of machinery and vehicles
 - **Industrial processes:** factories release pollutants like NO_x and PM from smokestacks and chemical processing

Common pollutants from urban activities

- The most common pollutants in urban areas are usually linked to the **combustion of fossil fuels**
 - Particulate matter (**$\text{PM}_{2.5}$ and PM_{10}**): tiny particles from exhaust fumes, industrial activities, and construction dust
 - **CO** : released by cars and industrial processes that burn fuels
 - **NO_x** : produced by vehicle emissions and power plants
 - **SO_2** : released mainly by burning coal and oil

Secondary pollutants

- Secondary pollutants are **not emitted directly** but **form in the atmosphere** when primary pollutants react with other chemicals
 - **Tropospheric ozone (O_3)**: forms when nitrogen oxides (NO_x) react with sunlight
 - It is a major component of urban smog

Examples of urban air pollution

- **Beijing, China:** often experiences high levels of **$\text{PM}_{2.5}$** , mainly due to coal burning for energy and industrial activity
- **Los Angeles, USA:** struggles with **ozone pollution** due to a high number of vehicles and sunny weather, which speeds up the reaction that forms ozone
- The burning of crops, industrial activity, and vehicle emissions frequently cause severe **air pollution** in **New Delhi, India**

Air Pollution Management Strategies

Air Pollution Management Strategies

- Air pollution management strategies are designed to **reduce harmful emissions** and **improve air quality** in urban areas
- These strategies focus on:
 - **Reducing** the sources of pollution
 - **Promoting** cleaner technologies
 - **Encouraging** sustainable urban living

Reducing the use of fossil fuels

- One of the most effective ways to manage urban air pollution is to reduce the **reliance** on fossil fuels
- This includes:
 - Promoting the use of **renewable energy sources** like wind, solar, and hydro to power cities
 - **Improving public transport** systems in cities to reduce car usage, e.g.
 - Electric buses
 - Efficient metro systems
 - Creating infrastructure for **cycling**, e.g.
 - More cycle lanes
 - Cycle-hire schemes
 - Pedestrianising city centres

Emission zones and car restrictions

- Emission zones are areas where only vehicles meeting certain **environmental standards** are allowed to enter
 - **Low Emission Zones** (LEZs) restrict high-polluting vehicles, reducing air pollution in the city centre
 - For example, **London** has an Ultra Low Emission Zone (ULEZ) where only vehicles meeting strict emission standards can drive
- Some cities also restrict car use on certain days or at peak times to decrease congestion and emissions

Catalytic converters

- Catalytic converters are devices fitted to car exhaust systems that **reduce harmful emissions**
 - They contain catalysts that speed up chemical reactions to convert pollutants like nitrogen oxides and carbon monoxide into less harmful gases such as nitrogen and carbon dioxide
 - In many countries, it is **compulsory** for vehicles to have catalytic converters

Growing trees and natural screens

- Trees and green spaces play an important role in **filtering pollutants** from the air
- Trees can reduce air pollution and improve air quality by:
 - Absorbing carbon dioxide
 - Trapping particulate matter
- **Natural screens** such as hedges, tree lines and green walls can also help reduce pollutants near roads and buildings

Green walls and green roofs

- Green walls and green roofs are covered with vegetation and can improve air quality by filtering pollutants
 - They also help regulate temperature, reducing the urban heat island effect

Acid Rain

Acid Rain Formation

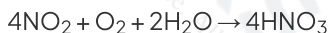
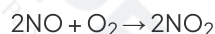
- Acid rain refers rainfall that has a pH lower than normal rainwater
 - Regular rain has a pH between 5 and 5.5, meaning it is naturally slightly acidic
 - Acid rain is more acidic, has a pH lower than 5, and is frequently the result of human activity

Chemical reactions leading to acid rain

- Nitrogen oxides (NO_x)** and **sulphur dioxide (SO₂)** are the main gases responsible for acid rain
 - These gases react with water and oxygen in the atmosphere to form nitric acid and sulfuric acid

Formation of nitric acid

- Nitrogen oxides are mainly produced from **vehicle exhausts**
- The reactions are as follows:
 - Nitrogen monoxide (NO) reacts with oxygen (O₂) to form nitrogen dioxide (NO₂)
- The nitrogen dioxide then reacts with water (H₂O) and oxygen in the air to produce nitric acid (HNO₃)

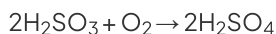


Formation of sulphuric acid

- Sulphur dioxide is produced by **burning fossil fuels** and reacts with water in the atmosphere
- The reactions are as follows:
 - Sulphur dioxide (SO₂) dissolves in rainwater, producing sulphurous acid (H₂SO₃)



- The sulphurous acid is then oxidised by oxygen in the air to produce sulfuric acid (H₂SO₄)



Types of deposition

- Wet deposition** refers to acidic precipitation falling to Earth in the form of **rain, snow, or fog**
- Sulphuric acid and nitric acid can also combine with ash and other particles present in the air, forming **dry particles** (i.e. acidic dust and gases)
 - Dry deposition** occurs when these particles settle on surfaces, including vegetation, buildings, cars and soil

Acid Rain Impacts

Impacts on ecology

Impacts on terrestrial habitats

- Acidic deposition from acid rain accelerates the **leaching** of essential **nutrients** from soil, such as calcium, magnesium and potassium
 - Leaching of these nutrients reduces their availability for plants
 - This leads to **nutrient deficiencies**
 - This reduces plant growth and overall ecosystem **productivity**
- Acidic rain can **increase soil toxicity**
 - This can occur by **mobilising** harmful metals like aluminium
 - This damages plant roots and affects their ability to absorb water and nutrients
- Acid rain causes **direct damage to foliage**
 - This weakens trees, making them more vulnerable to disease and harsh weather
- Coniferous forests, e.g. forests of pine or spruce trees, are sensitive to acid rain
 - This is due to their shallow root systems and thin bark
 - Acid rain also damages their foliage and **inhibits nutrient absorption**

Impacts on freshwater habitats

- Acid rain can make water bodies more acidic
- This is due to a process referred to as **solubilisation of aluminium**
 - Acid rain causes aluminium, which is normally bound in the soil, to dissolve
 - This allows the aluminium to enter nearby water bodies
- This aluminium is **toxic to aquatic life**, such as fish and freshwater invertebrates
 - Fish gills can become coated with aluminium
 - This makes it harder for them to breathe
 - Some invertebrates with **exoskeletons** may have difficulty maintaining their protective shells
 - They rely on calcium to build and maintain their hard outer shells
 - When acid rain increases the acidity of water, it reduces the availability of calcium and other minerals that these organisms need
 - This makes it harder for them to properly develop or maintain their exoskeletons

Impacts on buildings and infrastructure

Corrosion of construction materials

- Acid rain erodes materials like **marble, limestone, steel, and paint** used in buildings and monuments
- Marble and limestone both contain calcium carbonate (CaCO_3)
- The calcium carbonate reacts with sulphuric acid or nitric acid, causing stonework to corrode and weaken
 - For example, the **Taj Mahal** in India, made of marble, has shown signs of erosion and discolouration due to acid rain
 - Acid rain has also had an impact on historical statues and structures, such as those in Rome and Greece

Impacts on human health

Respiratory issues

- Acid rain does not **directly** harm humans
- However, **nitrate** and **sulphate particles** from acid rain can cause **respiratory problems**
 - **PM2.5 particles** (tiny air pollutants) from acid rain can enter the lungs
 - This leads to:
 - Tissue damage
 - Lung inflammation
 - An increased risk of conditions such as asthma and bronchitis
 - As a result, areas with heavy industrial activity, such as parts of China and Eastern Europe, experience greater respiratory health risks

Acid Rain Management Strategies

- There are three main levels of pollution management strategies:
 1. Changing human activity
 2. Regulating and reducing quantities of pollutants released at the point of emission
 3. Cleaning up the pollutants and restoring the ecosystem after pollution has occurred
- These levels can also be applied to acid rain management strategies
 - Acid rain requires effective pollution management strategies to mitigate its harmful effects on the environment and human health

1. Altering human activity

- Reducing the consumption of fossil fuels is a key strategy to minimise acid rain
 - Encourage the use of alternative energy sources, such as **renewable energy**, can significantly reduce emissions of sulphur dioxide and nitrogen oxides
- International agreements and national governments play a vital role in:
 - Promoting sustainable practices
 - Supporting the development of clean technologies
 - Lobbying for emissions reductions

2. Regulating and monitoring pollutant release

- Government regulations and **monitoring systems** are essential to **control** and **reduce** the release of pollutants that contribute to acid rain
 - Coal-burning power plants and vehicles are major sources of sulphur dioxide and nitrogen oxide emissions
 - Installing pollution control devices such as **scrubbers** and **catalytic converters** can effectively remove these pollutants from emissions

3. Clean-up and restoration measures

- In areas heavily affected by acid rain, certain strategies may be used to mitigate the damage caused
 - For example, **spreading ground limestone** or **lime** in acidified lakes and rivers can **neutralise acidity** and restore the water's pH balance
- Restoring damaged ecosystems can also be achieved through re-colonisation efforts, such as **planting acid-tolerant vegetation**
 - This can help restore ecological balance to these damaged ecosystems