DP IB Environmental Systems & Societies (ESS): SL

Your notes

Photochemical Smog

Contents

Primary & Secondary Pollutants

Your notes

Primary & Secondary Pollutants

- Air pollution is a significant environmental concern that affects both **human health** and the **environment**
  - It consists of **primary** pollutants **directly emitted** from **sources** and **secondary** pollutants formed through **chemical reactions** in the atmosphere
  - The combustion of fossil fuels is a major source of primary pollutants

Photo by Matt Boitor on Unsplash

Primary pollutants from car exhaust fumes can turn into secondary pollutants

What are Primary Pollutants?

- Primary pollutants from the combustion of fossil fuels include:

- **Carbon monoxide** (CO): a colourless, odourless gas that is harmful to human health and can lead to carbon monoxide poisoning
- **Carbon dioxide** (CO_2): a greenhouse gas responsible for global warming and climate change
- **Black carbon or soot**: fine particulate matter emitted from incomplete combustion, contributing to air pollution and climate change
- **Unburned hydrocarbons**: volatile organic compounds (VOCs) released during combustion
- **Oxides of nitrogen** (NO_x): nitrogen dioxide (NO_2) and nitrogen oxide (NO) are key contributors to air pollution, causing respiratory issues and contributing to the formation of smog
- **Oxides of sulfur** (SO_x): sulfur dioxide (SO_2) and sulfur trioxide (SO_3) are released during fossil fuel combustion, leading to acid rain and respiratory problems

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What are Secondary Pollutants?

- In the presence of sunlight, primary pollutants undergo a variety of reactions with other chemicals already present in the atmosphere, resulting in the formation of secondary pollutants - some notable examples include:
- **Tropospheric ozone** (O_3):
  - This is an example of a secondary pollutant formed through a complex series of reactions
  - Oxygen molecules (O_2) react with oxygen atoms (O) released from nitrogen dioxide (NO_2) in the presence of sunlight
  - Tropospheric ozone is a harmful air pollutant associated with **respiratory issues** and **smog formation**
- Nitrogen oxides (NO_x) contribute to the formation of secondary pollutants such as **nitric acid** (HNO_3) and **nitrate particles**, which contribute to **acid rain** and particulate matter pollution
- Understanding the formation and impacts of both primary and secondary pollutants is essential for effective air pollution control and mitigation strategies
- It highlights the importance of reducing emissions from fossil fuel combustion, promoting cleaner technologies, and implementing measures to mitigate the formation of secondary pollutants

EXAMINER TIP

Regarding primary and secondary pollutants, the use of chemical symbols, formulae or equations is **not** required for your exams - you just need to remember the names of the pollutants and the process by which tropospheric ozone is formed!

Trophospheric Ozone

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Trophospheric Ozone

- Air pollution is a significant environmental issue, and one of the pollutants of concern is tropospheric ozone
- Tropospheric ozone, also referred to as **ground-level ozone**, is formed through a series of chemical reactions involving nitrogen oxides and volatile organic compounds in the presence of sunlight
  - This process occurs **near the Earth's surface**, primarily in the lower part of the atmosphere known as the **troposphere**
  - Nitrogen oxides, mainly released from human activities such as industrial processes, vehicle emissions, and combustion of fossil fuels, react with sunlight and oxygen to produce ozone
- Tropospheric ozone is highly reactive and has several negative impacts

Why is tropospheric ozone harmful?

Plant damage

- High levels of ozone can damage plant tissues, **impair photosynthesis**, reduce crop yields, and cause visible symptoms such as leaf damage
- It affects a wide range of crops, including staple crops like wheat, rice, and soybeans

Health effects of tropospheric ozone

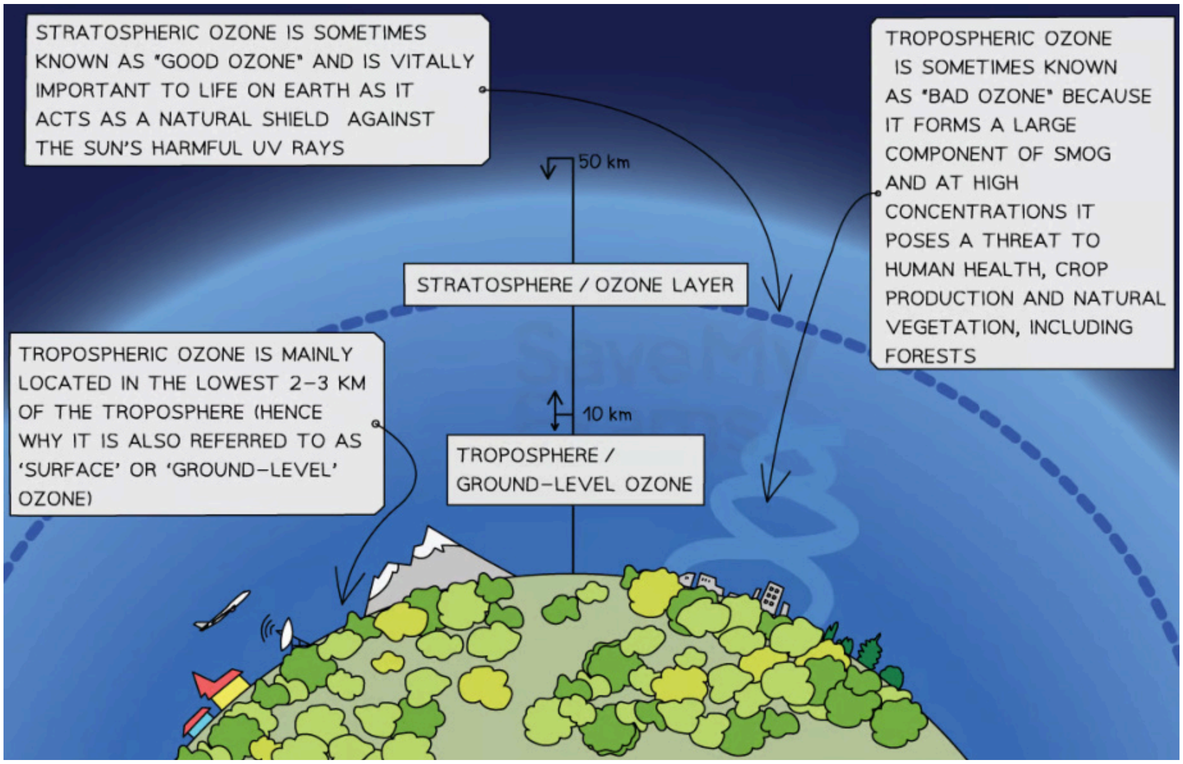
- Tropospheric ozone **irritates** the respiratory system, causing coughing, throat irritation, and contributes to **asthma** and other respiratory conditions
- Prolonged exposure to high ozone levels can lead to chronic respiratory illnesses and **reduced lung function**

Eye irritation

- Exposure to tropospheric ozone can irritate the eyes, leading to redness, tearing, and discomfort

Material degradation

- Tropospheric ozone can damage materials such as rubber, fabrics, and certain plastics
- It accelerates the degradation and ageing of rubber components in vehicles, tires, and industrial equipment
- Ozone exposure can cause cracking, brittleness, and discolouration of materials



Don't get confused between "good" stratospheric ozone, which provides organisms with protection from harmful ultraviolet radiation, and "bad" tropospheric ozone, which can negatively impact life on Earth at high concentrations

- The impacts of tropospheric ozone extend beyond local areas, as it can be **transported** over long distances by **wind**
- This makes it a **global environmental issue** with the potential for widespread damage to vegetation, human health, and materials
- Reducing the emissions of nitrogen oxides and volatile organic compounds, which are precursors to tropospheric ozone formation, is crucial to mitigating its harmful effects
- Implementing **air quality regulations**, promoting **cleaner technologies** (e.g. renewable electricity generation), and adopting **sustainable practices** can help in controlling tropospheric ozone levels and protecting human health, crops, forests, and materials from its damaging impacts

Smog

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Smog

What is Smog?

Photo by Mikel Letona on Unsplash

Only the highest city buildings protrude above this smog, which has been trapped in the cooler air near ground-level by a layer of warm air above the city

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- Smog is a type of air pollution characterised by a complex **mixture** of primary and secondary pollutants
  - **Tropospheric ozone** is a major component of smog
  - Deforestation and burning of biomass release large amounts of **particulate matter**, volatile organic compounds, and other pollutants into the atmosphere
  - These emissions can contribute to the formation of smog by increasing the concentration of primary pollutants and providing additional reactive substances for secondary pollutant formation
  - To some extent, forested areas can act as natural sinks for air pollutants, so their removal can exacerbate smog formation in surrounding regions

Factors Influencing Smog Occurrence

- The frequency and severity of smog depend on the local topography, climate conditions, population density, and the amount of fossil fuel use in an area
- Areas with geographical features that **inhibit air movement**, such as **valleys** or **basins,** can experience higher levels of smog due to the accumulation of pollutants
- Regions with hot and sunny climates are also more susceptible to smog formation as sunlight contributes to the chemical reactions that produce ozone

Thermal Inversions

- Thermal inversions occur when a layer of **cool**, **dense** air becomes trapped **beneath** a layer of **warmer**, **less dense** air
- Inversion conditions **prevent** the **vertical mixing** of air and hinder the dispersion of pollutants, leading to their accumulation near the ground
- This trapped layer of pollutants can contribute to the formation and persistence of smog, especially in areas with stable atmospheric conditions

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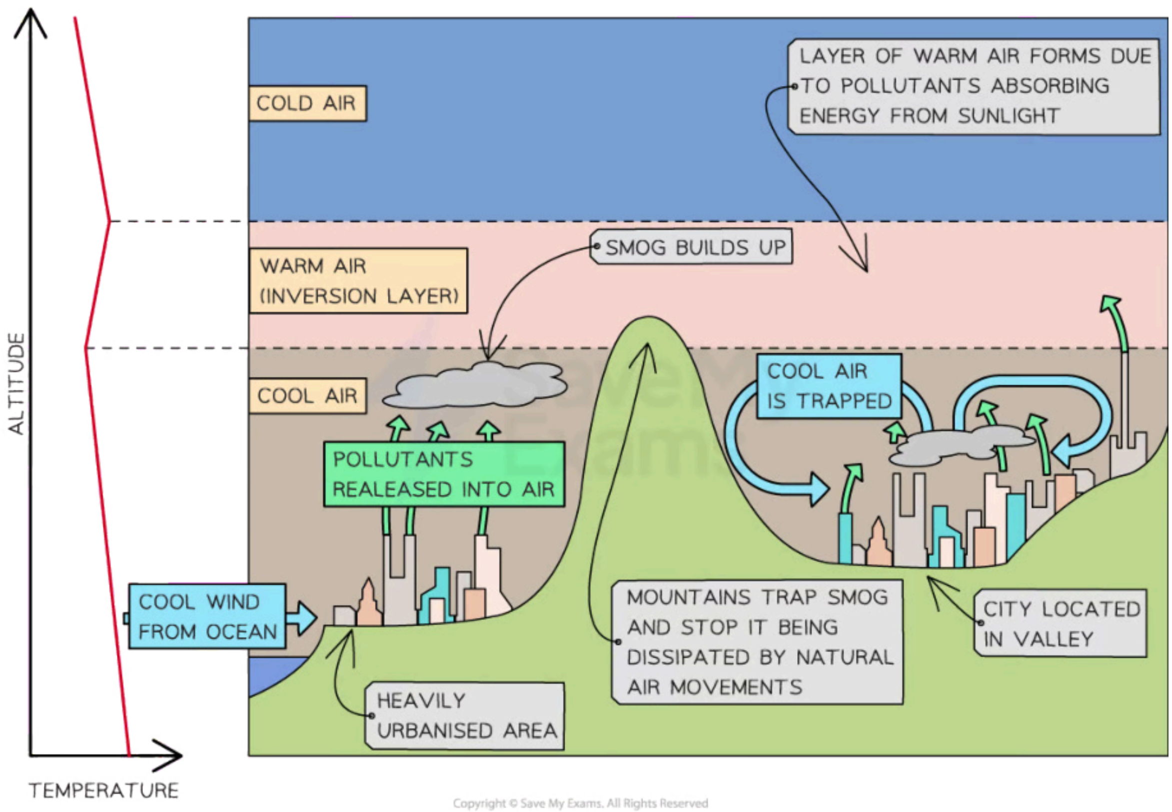

Thermal inversions can cause a serious build up of smog in urban areas that are located in basins and valleys

Economic Losses

- Economic losses caused by urban air pollution can be significant due to various reasons:

Healthcare Costs

- Poor air quality in urban areas leads to an increase in respiratory and cardiovascular diseases among the population
- This results in higher healthcare costs for individuals, businesses, and governments
- The treatment of pollution-related illnesses, including hospitalisations, medications, and long-term care, can put a strain on healthcare systems and result in substantial economic burdens

Reduction in Productivity

- Air pollution can have a detrimental effect on worker productivity

- Exposure to polluted air can lead to respiratory issues, allergies, and fatigue, all of which can impair work performance
- Reduced productivity levels translate into economic losses for businesses and the overall economy

Loss of Workdays

- Severe air pollution episodes often trigger health warnings, prompting people to stay indoors or limit outdoor activities
- This can result in missed workdays or reduced working hours, impacting businesses and individuals' incomes
- Additionally, when pollution-related health issues force workers to take sick leave, it affects productivity and leads to economic losses

Environmental Damage

- Urban air pollution not only affects human health but also causes environmental damage
- Contaminated air can harm vegetation, crops, and ecosystems, leading to reduced agricultural yields, damage to natural resources, and disruption in the ecological balance
- These impacts can result in economic losses for industries reliant on agriculture, forestry, and tourism

Decreased Property Values

- Areas with high levels of air pollution often experience a decline in property values
- Potential buyers and investors are deterred by the health risks associated with living or operating businesses in polluted areas
- This reduction in property values can have negative economic consequences for homeowners, real estate developers, and local governments

Increased Environmental Regulations

- To combat air pollution, governments may impose stricter environmental regulations on industries, businesses, and vehicles
- Compliance with these regulations often requires investments in pollution control technologies, infrastructure upgrades, and cleaner energy sources
- These expenses can place a financial burden on businesses and potentially impact their profitability
- Tackling air pollution not only **improves** public **health** but also brings **economic benefits** by reducing these losses and creating a healthier and more sustainable environment for communities

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Air Pollution Management Strategies

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Air Pollution Management Strategies

- Air pollution, particularly urban smog, poses significant challenges that require effective management strategies
- Various approaches can be adopted to mitigate and reduce air pollution

Photo by Bhawin Jagad on Unsplash

There is a clear need to alter human activity to consume less fossil fuels

Altering Human Activity

- This can be done by encouraging the use of energy-efficient technologies in homes, industries, and transportation
- Another approach is to promote the use of public or shared transit systems to reduce the number of individual vehicles on the road

- Encouraging walking or cycling for shorter distances also reduces reliance on motor vehicles

Regulating and Reducing Pollutants at Point of Emission

- Government regulations and policies can be implemented to set emission limits and standards for industries, vehicles, and power plants
- Taxes or fees on high-polluting activities can be imposed to discourage their usage and incentivise cleaner alternatives
- The transition to cleaner and renewable energy sources, such as solar, wind, and hydroelectric power should be promoted (e.g. by providing financial incentives for early adopters)

Catalytic Converters

- Catalytic converters are devices installed in vehicles' exhaust systems to reduce emissions of primary pollutants, such as nitrogen oxides and carbon monoxide
- These devices facilitate chemical reactions that convert harmful pollutants into less harmful substances before they are released into the atmosphere

Regulating Fuel Quality

- Governments can establish regulations and standards for fuel quality, ensuring that it contains fewer pollutants
- For example, this can be achieved by implementing stricter controls on sulfur content in fuels, therefore reducing emissions of sulfur dioxide and related pollutants

Adopting Clean-up Measures

- Reforestation efforts can help absorb carbon dioxide from the atmosphere, reducing its concentration and mitigating the greenhouse effect
- Re-greening initiatives involve creating green spaces within urban areas, improving air quality and providing additional benefits such as shade and cooling effects
- Conservation of natural areas and preservation of ecosystems (e.g. salt marshes, peat bogs, tropical rainforests) can contribute to carbon sequestration and the reduction of air pollution
- These management strategies, when implemented collectively, aim to reduce air pollution, improve air quality, and protect human health and the environment
- By addressing pollution at its sources and promoting sustainable practices, we can work towards a cleaner and healthier future

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