Atmospheric Pollution Dynamics: Smog & Its Types

A Strategic Analysis for Management & Environmental Science Aspirants

EXAM STRATEGY SERIES | PAPER 1 FOCUS

Session Agenda & Learning Objectives

The Consultant's Roadmap

01 Conceptual Framework

Deconstructing the Smog Equation (Smoke + Fog).

02 Comparative Analysis

Classical (London) vs. Photochemical (Los Angeles).

03 Chemical Mechanics

Primary vs. Secondary Pollutants (SO2, NOx, Ozone, PAN).

04 Aerosol Dynamics

Differentiating Mist, Fumes, Smoke, and Dust.

05 Historical Context

Case Studies: Bhopal, Chernobyl, Love Canal.

06 Exam Logic

Decoding the NTA/UGC NET Traps (Carbon Monoxide & Concentration).

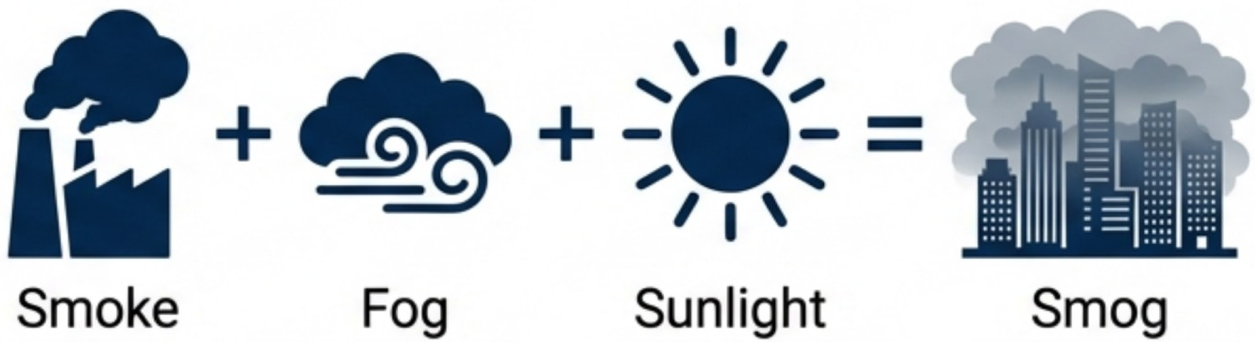
Defining the Phenomenon: The Anatomy of Smog

The Core Equation

Smog = Smoke + Fog + Pollutants

Key Components

- **Precursors**: Interaction of atmospheric moisture (Fog) with suspended pollutants.
- **The Pollutant Mix**: Nitrogen Oxides (NOx), Volatile Organic Compounds (VOCs), Sulfur Dioxide (SO2), and Particulate Matter (PM).
- **The Catalyst**: Sunlight (Solar Radiation) is the critical activation energy source.



Impact Summary

Results in unclear visibility, haze, and high Air Quality Index (AQI) levels.

The Great Divide: Classification of Smog

Smog is categorized into two distinct types based on chemical composition, climatic conditions, and formation era.

Classical Smog

- Aliases: London Smog, Sulfurous Smog, Industrial Smog, Winter Smog.
- Key Era: Industrial Revolution (Coal).

Photochemical Smog

- Aliases: Los Angeles (LA) Smog, Summer Smog.
- Key Era: Modern Urbanization (Vehicles).

DEEP DIVE

WINTER

COAL

REDUCING

Classical Smog (London/Sulfurous)

- **Origin Story:** Rooted in the Industrial Revolution (e.g., 1952 London Event).
- **Primary Source:** Combustion of Fossil Fuels (Coal & Oil).

The Chemistry: The Sulfur Cycle

Burning Coal → Releases → **Sulfur (S)** → Oxidation → **Sulfur Dioxide (SO_2)**

$SO_2 + O_2 + H_2O$ → Reaction → **Sulfuric Acid (H_2SO_4)**

Conditions:

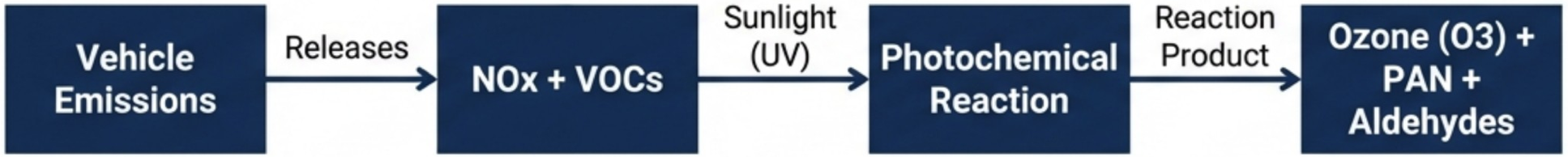
- **Season:** Winter (Cold Weather)
- **Atmosphere:** High Humidity (Damp)
- **Appearance:** Dark Brown / Yellowish-Brown Haze

Academic Corporate

Photochemical Smog (Los Angeles)

- **Origin Story:** Modern Urbanization (First observed LA 1943).
- **Primary Source:** Automobile Emissions (Internal Combustion Engines).

The Chemistry: The Nitrogen Cycle



Conditions:

- **Season:** Summer (Hot, Dry, Clear Skies)
- **Catalyst:** Strong Sunlight is a strict prerequisite.
- **Appearance:** Brown Haze (due to NO2)

DEEP DIVE

SUMMER

VEHICLES

OXIDIZING

DEEP DIVE

SUNLIGHT

VEHICLES

OXIDIZING

The Solar Catalyst & Secondary Pollutants

Tropospheric Ozone (O3)

Ground-level "Bad" Ozone.
Greenhouse Gas & Health Hazard.

PAN (Peroxyacetyl Nitrate)

Secondary pollutant causing eye irritation.

Nitrogen Dioxide (NO2)

Contributes to the brown haze color.

Professor's Note: Stratospheric Ozone is 'Good' (Protective). Tropospheric Ozone formed here is 'Bad' (Pollutant).

Classical vs. Photochemical: A Strategic Comparison

Feature	Classical Smog	Photochemical Smog
Alias	London / Sulfurous / Industrial	Los Angeles / Summer / LA
Primary Season	Winter (Cold)	Summer (Hot & Sunny)
Humidity	High (Damp/Foggy)	Low (Dry)
Main Pollutants	SO2, Particulate Matter	NOx, Ozone, PAN, VOCs
Chemical Nature	Reducing	Oxidizing
Primary Source	Coal / Oil (Industrial)	Vehicles (Urban / Transport)

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SUMMER

VEHICLES

OXIDIZING

Understanding Aerosols: Suspended Particulate Matter (SPM)

MIST

Liquid droplets suspended in air (e.g., herbicide spray, ocean spray).

SMOKE

Solid particles from combustion (e.g., burning wood, cigarettes). Visible to the eye.

FUMES

Formed by Condensation. Hot vapors contact cool air turning into solid/liquid particles (e.g., metal vapors).

DUST

Fine solid particles (approx 1µm). Formed by mechanical disruption (Sawdust, Sand, Fly Ash).

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SUMMER

VEHICLES

OXIDIZING

Chronology of Major Environmental Disasters

1943
Los Angeles
First major Photochemical Smog recorded.

1952
London
The Great Smog (Classical benchmark).

1978-82
Love Canal (USA)
Toxic Waste dumping tragedy.

1984
Bhopal (India)
Gas Tragedy (MIC Leak).

1986
Chernobyl (Ukraine)
Nuclear Reactor Explosion.

2011
Fukushima (Japan)
Nuclear Disaster (Tsunami).

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SUMMER

VEHICLES

OXIDIZING

Case Study: Bhopal Gas Tragedy (1984)

DEEP DIVE

Date: December 2-3, 1984

Location: Bhopal, Madhya Pradesh, India

Facility: Union Carbide India Limited (Pesticide Plant)

Critical Exam Details:

- The Gas: **Methyl Isocyanate (MIC)**
- The Source: **Storage Tank E610**
- Plant Output: Manufacturing Plastics and Pesticides (Carbaryl)

Case Studies: Nuclear & Chemical Catastrophes

Chernobyl (1986)

- **Location:** Ukraine (USSR)
- **Event:** Nuclear Reactor Explosion
- **Impact:** Immediate deaths (31) & long-term radioactive contamination.

Love Canal (1978-82)

- **Location:** New York, USA
- **Event:** Hazardous chemical waste dumped into water streams/soil.
- **Impact:** >700 deaths/illnesses due to contaminated water consumption.

Fukushima (2011)

- **Location:** Japan
- **Event:** Nuclear accident following a Tsunami.
- **Impact:** Reactor meltdown and radiation release.

DEEP DIVE

SUMMER

VEHICLES

OXIDIZING

Exam Strategy: The Carbon Monoxide (CO) Trap

The Dilemma: Is CO a component of Photochemical Smog?

The Logic:

1. Photochemical smog is caused by vehicles.
2. Vehicles emit high levels of Carbon Monoxide (CO) as a Primary Pollutant.
3. Therefore, Exam Bodies (NTA) link CO to Photochemical Smog questions.

Strategic Takeaway: If a question asks for 'Other Primary Pollutants' associated with smog, CO is a correct inference, even if not part of the secondary reaction chain.

Composition Nuances & Health Impacts

Component Analysis:

✅ **Hydrocarbons (VOCs):** Essential precursor. Often listed as 'Least Concentration' but mandatory for formation.

✅ **Formaldehyde:** Present in Photochemical Smog (Aldehyde group).

❌ **Dioxins & Furans:** NOT smog components. Produced by burning solid/medical waste.

Health Impact Hierarchy:

- **Eyes:** Severe irritation & watering (Lachrymatory effect).
- **Respiratory:** Asthma aggravation, throat dryness, lung infections.
- **Note:** Smog is primarily a respiratory/irritant hazard, not a direct carcinogen like Dioxins.

Final Revision Checklist: The Strategic Takeaways

- ✓ **London** = Winter + Sulfur + Reducing + Coal
- ✓ **Los Angeles** = Summer + Sunlight + NOx + Oxidizing + Vehicles
- ✓ Bhopal (1984) = Methyl Isocyanate (Tank E610)
- ✓ Sunlight is the non-negotiable factor for Photochemical Smog
- ✓ Tropospheric Ozone = Bad (Pollutant)
- ✓ CO = Primary Pollutant linked to Vehicle/Smog source

Master the Logic. Ace the Exam.