1. Secondary Pollutant- Environment

A third of Delhi's annual PM2.5 load is made up of secondary pollutants. This is how they are formed. Recent analysis reveals that nearly one-third of Delhi's annual PM2.5 load consists of secondary ammonium sulfate, formed chemically in the atmosphere from sulfur dioxide and ammonia rather than being emitted directly. This "invisible" secondary pollution is a major driver of severe smog episodes, particularly during the humid, stagnant conditions of the post-monsoon and winter seasons.

Secondary Aerosols and Delhi's Air Pollution Crisis

1. Context and Overview

Recent Findings- Recent analysis indicates that secondary aerosols account for at least one-third of Delhi's annual PM2.5 pollution load.

Significance- This high contribution helps explain the severe and persistent smog episodes the city faces, even when local primary emission sources seem to be under control.

2. Primary vs. Secondary Pollutants

Feature	Primary Pollutants	Secondary Pollutants
Definition	Pollutants emitted directly from a specific source into the atmosphere.	Pollutants formed in the atmosphere through chemical reactions between primary emissions and other elements.
Formation Factors	Direct combustion or release.	Dependent on sunlight, humidity, and temperature to trigger reactions.
Key Sources	Vehicular emissions, coal-fired power plants, biomass burning, industrial processes.	Precursors come from agriculture (ammonia), power plants (SO_2), and vehicles (NOx).
Examples	Carbon Monoxide (CO) Sulfur Dioxide (SO_2) Ammonia (NH_3) Nitrogen Oxides (NOx) • Hydrocarbons	Particulate Matter (PM) Tropospheric Ozone (O_3) Ammonium Sulphate Ammonium Nitrate Peroxyacetyl Nitrate (PAN) Photochemical Smog Sulfuric & Nitric Acid

3. Understanding Particulate Matter (PM)

Particulate Matter (PM) is a mixture of tiny solid particles and liquid droplets suspended in the air.

Visible vs. Invisible- Some particles like dust, dirt, soot, or smoke are large enough to be seen with the naked eye, while others are microscopic.

Classification by Size

1. PM10- Inhalable particles with a diameter of 10 micrometers or less.
2. PM2.5- Fine inhalable particles with a diameter of 2.5 micrometers or less (posing the greatest health risk).

4. The Role of Ammonium Sulfate

Dominance- Ammonium sulfate is identified as the most dominant secondary inorganic aerosol in Delhi.

Contribution- It accounts for nearly one-third of the city's annual PM2.5 load.

Formation Process- It is created when Sulfur Dioxide (SO_2) reacts with Ammonia (NH_3) in the atmosphere. This reaction is accelerated by moisture and specific temperature conditions.

Sources of Precursors

Sulfur Dioxide (SO_2)- Emitted primarily by coal-based power plants, oil refineries, brick kilns, shipping, and heavy industries.

Ammonia (NH_3)- Released from agriculture (fertilizers, livestock waste), sewage systems, landfills, biomass burning, and specific industrial activities.

5. Seasonal Variation and Meteorology

Meteorological Impact- Factors like high humidity, low winter temperatures, and stagnant air (low wind speed) accelerate the chemical transformation of gases into dangerous particles.

Seasonal Contribution of Ammonium Sulfate

1. Post-Monsoon- Contributes 49% of the PM2.5 load.
2. Winter- Contributes 41% of the PM2.5 load.
3. Summer & Monsoon- Contribution drops to 21% due to rain and lower humidity.

Regional Disparity- High levels of ammonium sulfate are also found in states like Chhattisgarh, Odisha, Jharkhand, and Telangana due to heavy coal-based power generation, which contributes to transboundary pollution affecting Delhi-NCR.

6. Health Impacts of Secondary Pollutants

Respiratory Health- Largely present as PM2.5, these particles penetrate deep into the lungs. They aggravate asthma, bronchitis, and COPD, reduce lung function, and increase susceptibility to respiratory infections (especially in children and the elderly).

Cardiovascular Effects- Fine aerosols enter the bloodstream, triggering systemic inflammation. Increases the risk of heart attacks, strokes, hypertension, and arrhythmias.

Maternal and Child Health- Exposure impairs lung development in children. Associated with adverse birth outcomes like low birth weight, preterm births, and stillbirths. Children are more vulnerable as they inhale more air per unit of body weight than adults.

Neurological Risks- Ultrafine particles can cross the blood–brain barrier. Causes neuroinflammation and cognitive decline, increasing the risk of neurodegenerative disorders.

Long-term Risks- Prolonged exposure weakens immunity. Raises cancer risk (PM2.5 is classified as a carcinogen by the WHO). Contributes to metabolic disorders, increasing the overall public health and economic burden.

7. Global Comparisons and Historical Context

The Donora Smog Incident (1948, USA)- A historic disaster where emissions from industrial plants formed deadly sulfate aerosols under stagnant weather conditions, leading to severe health consequences.

Beijing's Pollution History- Since the late 1990s, sulfate aerosols have been a major contributor to Beijing's pollution. This was driven by a combination of SO_2 emissions from coal burning and high Nitrogen Oxide (NOx) emissions from rapid motorization.

Source- https-//indianexpress.com/article/explained/a-third-of-delhis-annual-pm2-5-load-is-made-up-of-secondary-pollutants-this-is-how-they-are-formed-10446522/