AEROSOL: ENVIRONMENT

NEWS: Some cities in the northwestern, northern Indo-Gangetic Plain shielded from long-range aerosol pollution

WHAT'S IN THE NEWS?

A study by IIT Bhubaneswar revealed that cities in the northwestern and northern Indo-Gangetic Plain act as "Urban Aerosol Clean Islands" due to wind-stilling by urban infrastructure, blocking external dust, while southern cities are "Urban Aerosol Pollution Islands" dominated by internal sources. Aerosols, tiny atmospheric particles, have diverse impacts on health, climate, and ecosystems.

Study on Aerosol Levels in Indian Cities (IIT Bhubaneswar)

- **Study Focus:** A recent study, conducted by researchers from the School of Earth, Ocean and Climate Sciences, IIT Bhubaneswar, investigated aerosol levels in 141 Indian cities.
- **Data Source & Period:** The study utilized satellite-retrieved aerosol data collected from these 141 cities across India, spanning a significant period from 2003 to 2020.
- **Key Revelation:** The study surprisingly found that several cities located in the northwestern and northern Indo-Gangetic Plain (IGP) exhibit relatively lower aerosol levels compared to their surrounding areas.

Key Findings of the Study:

- **Urban Aerosol Clean Islands (UACI):**
    - This phenomenon was observed in **43% of cities**, specifically those located in the northwestern and northern Indo-Gangetic Plain.
    - In these areas, the **cities themselves had lower aerosol levels** than the regions immediately surrounding them.
- **Urban Aerosol Pollution Islands (UAPI):**
    - In contrast, **57% of cities**, primarily those in southern and southeastern India, displayed the opposite effect.
    - These cities showed **higher aerosol levels within the urban area** when compared to their surroundings.
- **Wind Stilling Effect (Mechanism for UACI):**
    - The study identifies "wind stilling" as a primary reason for the UACI phenomenon.
    - Urban infrastructure, such as tall buildings and dense construction, effectively **weakens surface winds**.
    - These structures act as "invisible barriers" that partially **block the entry of aerosols from long-range sources**, such as desert dust originating from the Thar Desert.

- **Pre-Monsoon Dominance of UACI:**
    - The UACI effects are most pronounced and visible during the **pre-monsoon period**.
    - This is attributed to the prevailing **dry conditions** and the **high volume of dust transport** that occurs during this time of year, making the "clean island" effect more discernible within cities.
- **Geographical Influence (UAPI in Southern Cities):**
    - Southern cities predominantly exhibit the UAPI phenomenon.
    - This is explained by the **limited external pollution transport** into these regions. As a result, **internal sources of pollution** (such as vehicular emissions, industrial activities within the city) become the dominant contributors to aerosol levels, leading to higher concentrations within the urban areas compared to their less polluted surroundings.

About Aerosols

- **Definition:** Aerosols are defined as **tiny solid or liquid particles** that are suspended in the Earth's atmosphere.
- **Size Range:** They vary significantly in size, ranging from just a **few nanometers to tens of micrometers** (one micrometer is one-millionth of a meter).
- **Concentration:** Due to their mostly surface-based sources (e.g., dust, industrial emissions), aerosols are primarily **concentrated in the lower atmosphere**, typically below 1.5 kilometers (approximately 0.9 miles).

Types of Aerosols:

- **Primary Aerosols:**
    - **Description & Source:** These aerosols are **emitted directly** into the atmosphere from their source.
    - **Examples:** Dust (from land surfaces), sea spray (from oceans), smoke (from burning biomass like wildfires or crop burning).
- **Secondary Aerosols:**
    - **Description & Source:** These are **not emitted directly** but are **formed in the atmosphere** through complex chemical reactions involving gaseous precursors.
    - **Examples:** Sulfates, which are formed from sulfur dioxide (SO_2) emissions (often from industrial processes and fossil fuel burning); nitrates, formed from nitrogen oxides (NO_x).

Long-Term Aerosols:

- **Persistence:** These are aerosols that can **persist in the atmosphere for extended periods**, ranging from weeks to even years.

- **Reasons for Persistence:** Their longevity is usually due to:
    - Their **small particle size**, which allows them to remain suspended longer.
    - Their **presence at high altitudes**, where atmospheric cleansing processes are slower.
- **Examples of Long-Term Aerosols:**
    - **Volcanic Sulfate Aerosols:** Significant amounts of sulfate aerosols released during powerful volcanic eruptions (e.g., Mount Pinatubo in 1991) can spread globally and lead to temporary global cooling lasting for years.
    - **Industrial Sulfates & Nitrates:** Pollutants from industrial activities can travel long distances and linger in the upper atmosphere, particularly over heavily polluted regions like East Asia.
    - **Transported Dust:** Large quantities of mineral dust, such as Saharan dust, can be transported across oceans (e.g., reaching the Americas), or East Asian aerosols can cross the Pacific Ocean, impacting air quality far from their source.

Major Examples of Aerosol Types:

- **Mineral Dust:** Naturally occurring particles lifted from dry regions and deserts, such as the Sahara Desert or the Thar Desert in India.
- **Sea Spray:** Consists of tiny salt particles and organic matter released into the atmosphere from bursting bubbles on the ocean surface.
- **Smoke:** Generated from the combustion of biomass, including wildfires and agricultural crop burning. It is particularly rich in black carbon, a potent climate-forcing agent.
- **Industrial Aerosols:** Primarily composed of sulfates and nitrates, which are byproducts of burning fossil fuels in industries and power plants.
- **Volcanic Aerosols:** Include both ash particles and sulfate aerosols released during volcanic eruptions.
- **Biogenic Aerosols:** Naturally emitted from biological sources, such as pollen, fungal spores, and various organic compounds released by plants.

Positive and Negative Impacts of Aerosols

Positive Impacts:

- **Solar Radiation Reflection & Cooling:** Many aerosols, particularly light-colored ones (like sulfates and some mineral dust), reflect incoming solar radiation back into space. This process helps to **cool Earth's surface**, mitigating some warming effects.
- **Ecosystem Fertilization:** Aerosols, especially dust, can transport vital nutrients (like iron and phosphorus) over vast distances. For instance, Saharan dust fertilizes the Amazon rainforest, providing essential nutrients for its growth.

- **Cloud Formation & Rainfall:** Aerosol particles act as **cloud condensation nuclei (CCN)**. Water vapor condenses around these particles, leading to the formation of cloud droplets and, subsequently, precipitation (rainfall).

- **Temporary Global Cooling (Volcanic):** Major volcanic eruptions inject large amounts of sulfate aerosols into the stratosphere. These aerosols can cause a significant, albeit temporary, **global cooling effect** by blocking sunlight.

Negative Impacts:

- **Health Issues:** Exposure to high concentrations of aerosols, especially fine particulate matter (PM2.5), is a major public health concern. They can penetrate deep into the lungs and even the bloodstream, causing or exacerbating **respiratory illnesses** (e.g., asthma, bronchitis) and **cardiovascular illnesses** (e.g., heart attacks, strokes).

- **Reduced Solar Power Efficiency:** Aerosols scatter and absorb sunlight, which **reduces the amount of solar radiation reaching the Earth's surface**. This can significantly impact the efficiency of solar power generation systems.

- **Visibility Loss:** High aerosol concentrations in the atmosphere scatter light, leading to **reduced visibility** and hazy conditions. This can pose significant hazards for transport, particularly air and road travel.

- **Accelerated Snow/Ice Melting & Warming (Black Carbon):** Black carbon, a component of smoke and industrial aerosols, is highly absorbent of sunlight. When deposited on snow or ice surfaces, it **reduces their albedo (reflectivity)**, causing them to absorb more heat and **accelerate melting**. This contributes to climate warming and sea-level rise.

Source: **https://www.thehindu.com/sci-tech/science/some-cities-in-northwest-northern-indo-gangetic-plain-shielded-from-long-range-aerosol-pollution/article69821691.ece**