4. Cloud Seeding – S & T

Delhi Chief Minister has said cloud seeding is essential for the national capital as it could play a key role in controlling rising pollution levels during the winter season

Delhi's Air Quality in Winter - Causes and Dynamics

1. Temperature Inversion

Normally, air near the ground is warmer than the air above, allowing pollutants to rise and disperse.

During winter -

1. The ground cools rapidly after sunset due to low solar heating.
2. Air near the surface becomes cooler than the air above, creating a temperature inversion layer.
3. This inversion traps pollutants close to the ground, preventing vertical dispersion.

Effect - Accumulation of particulate matter (PM2.5, PM10), nitrogen oxides (NOx), and other gaseous pollutants in the breathing zone.

2. Low Wind Speeds

Winter is associated with calm atmospheric conditions, with weak horizontal wind flows. Weak winds reduce the dispersion of pollutants, allowing them to concentrate locally. The combination of inversion and stagnant air leads to prolonged exposure to high pollutant concentrations.

3. Crop Residue Burning in Neighbouring States

Post-harvest stubble burning occurs in Punjab, Haryana, and western Uttar Pradesh between October and November. Burning releases large quantities of smoke, carbon monoxide, and fine particulate matter. Prevailing winds carry this smoke toward Delhi, exacerbating pollution. Studies indicate that up to 30–40% of Delhi's PM2.5 in winter can be attributed to stubble burning.

4. Urban Pollution and Dust Entrapment

Urban dust, vehicular emissions, industrial pollutants, and construction debris remain suspended longer in winter. Lower boundary layer height (the layer of atmosphere where pollutants disperse) traps pollutants near the surface. This compounds pollution from local sources, creating a hazardous mix of smog and particulate matter.

5. Combined Effect

The convergence of stubble burning, urban emissions, low wind speeds, and temperature inversion creates severe air quality episodes in Delhi. Pollution spikes typically occur November to January, coinciding with Diwali fireworks, winter inversion, and crop burning season.

Cloud Seeding - Concept and Principles

1. Definition - Cloud seeding is a weather modification technique to enhance a cloud's precipitation potential. It can increase rainfall or snowfall by introducing specific particles into clouds to facilitate condensation or ice formation.

2. Historical Background - First demonstrated in 1946 by Vincent J. Schaefer, an American meteorologist. Concept has been applied worldwide for drought mitigation, water management, and agriculture.

3. Seeding Agents

Silver iodide (AgI) and **dry ice (solid CO_2) -** Effective for supercooled clouds below 0°C.

Calcium chloride ($CaCl_2$) - Used in warmer clouds above freezing.

Mechanism - These agents act as nuclei for water droplets or ice crystals, facilitating precipitation when the cloud is naturally moist but insufficiently productive.

4. Methods of Delivery

Aircraft spraying - Dispersing seeding agents directly into clouds.

Ground-based generators or rockets - Releasing agents to reach cloud layers.

Targeting - Meteorologists identify moist clouds with precipitation potential but lacking natural triggers for rainfall.

Can Cloud Seeding Help Reduce Air Pollution?

1. Dependence on Natural Clouds - Cloud seeding cannot create clouds; it only enhances existing

clouds. Limitation - If there is no cloud cover, seeding is ineffective.

2. Temporary Pollution Mitigation - Rain can wash away fine particulate matter (PM2.5, PM10) temporarily. However, pollutants like ozone, sulphur dioxide, and nitrogen oxides remain unaffected. Pollution levels typically rebound within 1–2 days if emission sources continue unabated.

3. Efficiency Considerations - Success depends on cloud type, humidity, temperature, and wind patterns. Seeding provides short-term relief, but cannot be a permanent solution for chronic air pollution.

Other Long-Term Measures To Improve Air Quality

1. Addressing Root Causes - Scientific consensus points to vehicle emissions, industrial discharge, coal-based power, construction dust, waste burning, and agricultural fires as the major contributors.

2. Cleaner Transport Systems - Promotion of electric mobility, battery-operated vehicles, and public transport. Enforcement of Bharat Stage (BS) VI emission norms.

3. Sustainable Energy Transition - Gradual phase-out of coal-fired power plants. Adoption of solar, wind, and other renewable energy sources.

4. Urban Planning and Dust Control - Construction dust suppression, green belts, and urban landscape management. Traffic management to minimize congestion and emissions hotspots.

5. Agricultural Interventions - Promotion of alternatives to stubble burning, e.g., Happy Seeder, mulching, or bio-decomposers. Incentives for eco-friendly crop residue management.

6. Waste Management - Efficient solid waste collection, segregation, and incineration to prevent open burning. Expansion of composting and recycling programs.

7. Limitations of Quick Fixes - Reliance on temporary measures like smog towers, artificial rain, or short-term restrictions may provide immediate relief but do not address root causes. Only systemic reforms, policy enforcement, and long-term interventions can ensure sustainable air quality improvements.

Conclusion

Delhi's winter air pollution is a complex interplay of meteorology, regional agricultural practices, and urban emissions. Cloud seeding may offer short-lived relief, but cannot replace long-term structural solutions. Effective air quality management requires evidence-based, multi-sectoral policies, strict enforcement of emission norms, clean energy adoption, sustainable urban planning, and behavioral changes in agriculture and transport practices.

Source - https - //www.thehindu.com/sci-tech/energy-and-environment/why-cloud-seeding-is-not-a-solution-to-delhis-air-crisis-explained/article70194164.ece