ENVIRONMENT PROTECTION AGENCY (EPA), PUNJAB

Environment Protection & Climate Change Department (EP&CCD)

PUNJAB AIR QUALITY REPORT

HALF-YEARLY ASSESSMENT

JANUARY – JUNE 2026 (H1)

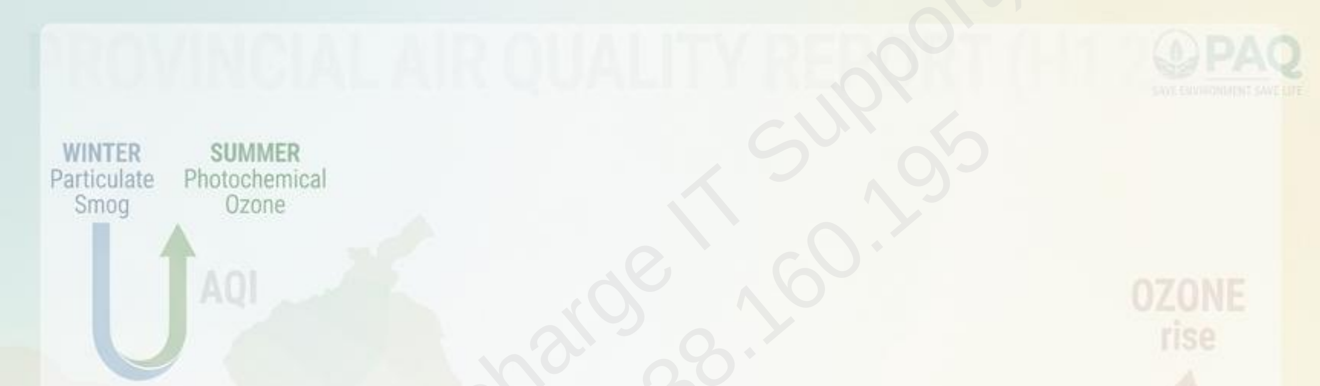
Evidence. Monitoring. Action. Cleaner Air for Punjab.

56 Air Quality Monitoring (AQMS)	**24/7** Continuous Monitoring	$PM_{2.5}$, PM_{10}, O_3, SO_2, NO_2 & CO	**Provincial** Air Quality Assessment	**Data-Driven** Decisions for Cleaner Punjab

Prepared by

Directorate of Environmental Monitoring Center (EMC Directorate), EPA Punjab

Environment Protection & Climate Change Department (EP&CCD)
Government of the Punjab



Executive Summary

This Bi-Annual Report presents a comprehensive assessment of ambient air quality across Punjab for January–June 2026 (H1), prepared by the Environmental Monitoring Centre (EMC), EPA Punjab, based on data from the province's Air Quality Monitoring Station (AQMS) network. The report situates Punjab's air quality within its geographic and climatic context the Indo-Gangetic Plain, seasonal wind circulation, and the annually recurring winter 'fifth season' before presenting a detailed, data-driven analysis of the half-year.

The central finding is a clear seasonal handover in the character of pollution. Winter (January–February) was dominated by hazardous fine particulate matter (PM2.5), which peaked at 176.6 μg/m³ in January five times the Punjab Clean Air Program (PCAP) target of 35 μg/m³ driven by temperature inversions, crop-residue burning, and combustion sources. As the season progressed, PM2.5 fell sharply to 48.4 μg/m³ by June, while ground-level ozone rose from 37.5 to 156.3 μg/m³, exceeding its regulatory limit and becoming the province's leading pollutant by the close of the reporting period. The provincial mean Air Quality Index (AQI) followed a U-shaped trajectory 244 in January, easing to 121 in April, and rising again to 164 in June.

District-level analysis identifies Jhelum and Mandi Bahauddin as the cleanest, with Lahore remaining the province's principal pollution hotspot. City-wise findings highlight the distinct pollution profiles of Lahore, Faisalabad, Multan, and other major urban centers. The AQMS network itself expanded substantially over the period from 17 active stations in January to 56 by June considerably strengthening the reliability and representativeness of provincial air quality data.

The report situates these findings within the province's institutional response, including the Punjab Clean Air Program, the Smog Mitigation Initiative, the 'Air Safe' project, and the World Bank partnership, and concludes with season-differentiated recommendations: particulate-source controls for the winter smog season, and NOx/VOC precursor controls for the summer ozone season, supported by continued network expansion, hotspot enforcement, and public health advisories.

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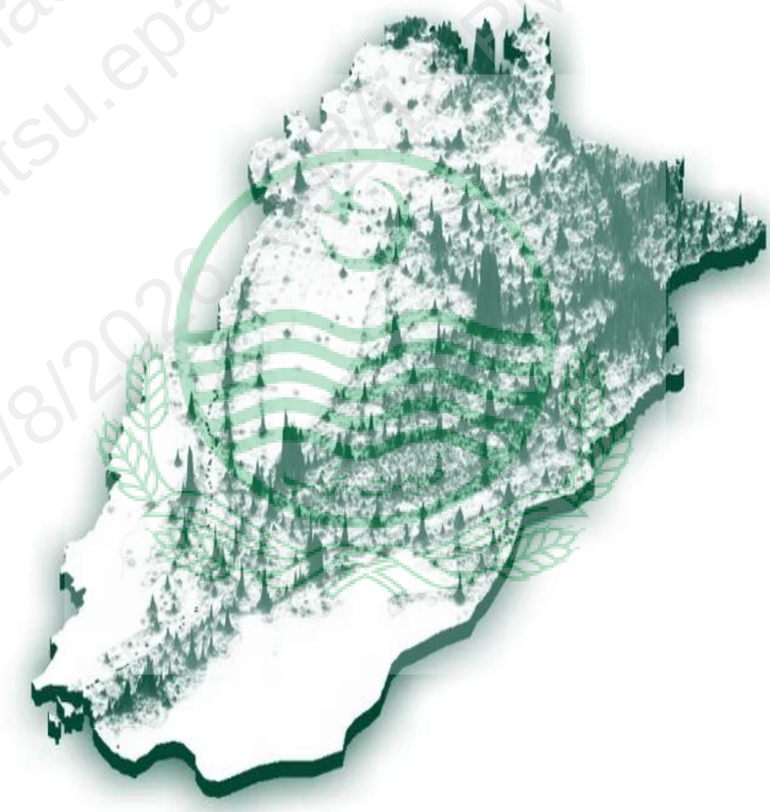
1. Geography of Punjab

Punjab 'the land of five rivers' is Pakistan's most populous and agriculturally productive province, home to over 127 million people (Census 2023) across an area of roughly 205,000 square kilometers. It is administratively organized into 10 divisions and, following the recent creation of several new districts. The province stretches from the foothills of the Himalaya and the Potohar Plateau in the north, across the vast alluvial plains of central Punjab, to the arid Cholistan Desert and the confluence of the great rivers in the south.

The province's settlement pattern (muhalla / mauza-level fabric) is dense and largely agrarian in the rural plains, punctuated by large, rapidly growing urban centers. The Lahore metropolitan district alone houses more than 13 million people, making it one of the largest urban agglomerations in Punjab and, as this report shows, the epicenter of the province's air quality challenge. Other major population and industrial centers include Faisalabad (over 9 million, the textile hub), Rawalpindi (6.1 million, twin city of the federal capital), Gujranwala (5.9 million, an industrial belt), Multan, Sialkot and Bahawalpur. This concentration of population, transport and industry within confined urban footprints intensifies local emissions.



Source: Worldpop (Population Density of Punjab 2020)

POPULATION	AREA	DIVISIONS	DISTRICTS	LARGEST CITY	2nd CITY
127.7 M	**205,345**	**10**	**41**	**Lahore**	**Faisalabad**
Census 2023	*sq. km*	*administrative*	*incl. new districts*	*13.0 M people*	*9.1 M people*

This geographic and demographic backdrop matters directly for air quality, the same plains that make Punjab the nation's breadbasket also trap pollutants, and the dense urban-industrial nodes generate the emissions that, under the erroneous meteorology, accumulate into hazardous smog.

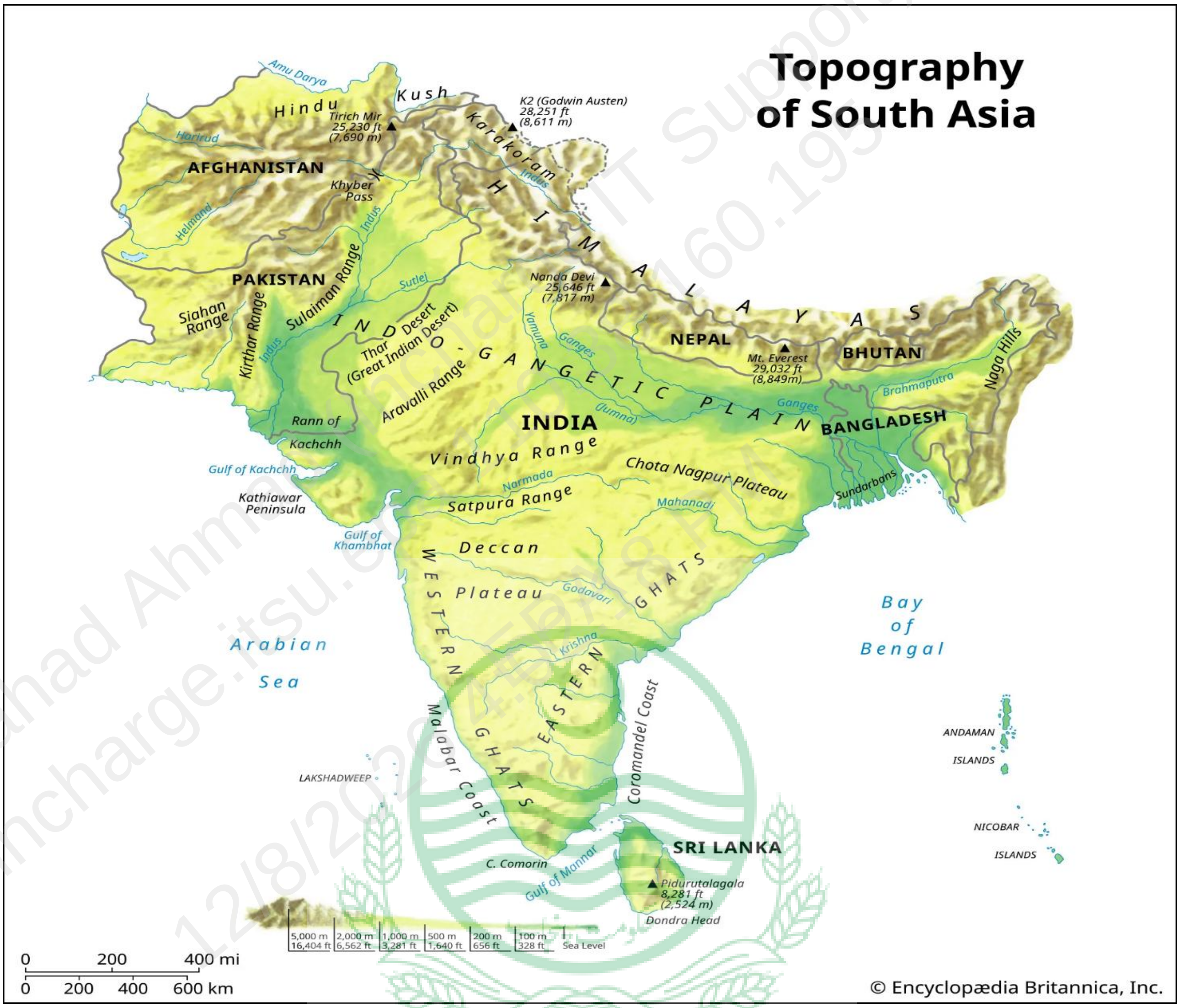
1.1 The Indo-Gangetic Plain (IGP) and the Indus Basin

Punjab lies at the western end of the Indo-Gangetic Plain (IGP) one of the largest and most densely populated alluvial systems on Earth, extending from Pakistan across northern India, Nepal and Bangladesh. The province forms the heart of the Indus Basin, drained historically by the five rivers (Jhelum, Chenab, Ravi, Beas and Sutlej) and the mighty Indus. This setting is central to understanding Punjab's air quality, for three reasons.

Topography of IGP

- **Alluvial surface:** The flat, highly irrigated alluvial plain provides abundant loose sediment and intense anthropogenic activity, supplying both dust and the fine particles and cloud-condensation nuclei around which haze forms.
- **Valley effect:** The IGP is bounded to the north by the Hindukush Karakoram Himalaya mountain ranges, creating a 'valley effect' that blocks the dispersal of pollutants and channels stagnant air along the plain during winter.
- **Shared airshed:** Because the IGP is a single continuous airshed, pollution readily crosses provincial and national borders, meaning Punjab's air quality is shaped not only by local emissions but by transboundary transport from the wider region. *(Kulkarni et al., 2020; Lelieveld et al., 2015).*

It is this combination a rich source of emissions and dust on a flat plain, hemmed in by mountains that makes the western IGP, including Pakistani Punjab and neighboring Indian Punjab, one of the most air-pollution-prone regions in the world.



2. Climate & Weather Across Punjab

Punjab experiences a continental, semi-arid to arid climate with strong seasonal contrasts, and these seasonal weather patterns are the single most important natural control on air quality through the year. Broadly, the province moves through a cool, foggy winter (November–February), a hot, dry pre-monsoon spring/early-summer (March–June), a humid monsoon (July–September), and a short post-monsoon transition (October).

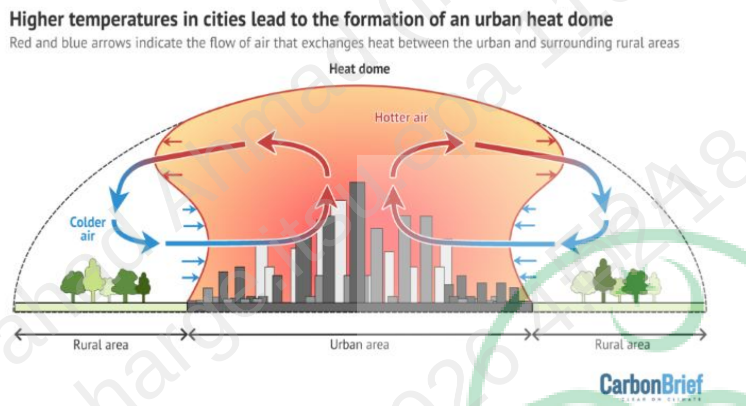
The northern districts (Rawalpindi, Attock, Jhelum, Murree, Chakwal) are cooler and receive more winter rainfall, benefiting from better ventilation off the Potohar Plateau. Central Punjab (Lahore, Faisalabad, Gujranwala, Sheikhupura, Sahiwal) the industrial and agricultural core sees the most intense winter fog and smog. The southern districts (Multan, Bahawalpur, Dera Ghazi Khan, Rahim Yar Khan) are hotter and more arid, prone to dust and in summer, to intense photochemical ozone formation under strong sunlight and high temperatures.

2.1 The Winter Inversion and the 'Fifth Season'

The defining weather-driven air quality phenomenon in Punjab is the winter temperature inversion. From roughly mid-October to mid-February, cold, dense air settles near the surface beneath a layer of warmer air aloft, forming a 'lid' those traps emissions close to the ground. Combined with near-calm winds, low mixing heights and abundant moisture, this produces the thick, persistent haze now widely referred to across South Asia as the 'fifth season' a term that entered common usage as smog episodes became an annual fixture from around 2016 onward. The fifth season brings hazardous pollution, drastically reduced visibility, and large-scale socio-economic disruption across the plains of Punjab, most prominently in Lahore, Faisalabad, Gujranwala and Multan. *(Fatima et al., 2023; Guttikunda & Gurjar, 2012).*

In spring and summer, as the inversion breaks down and temperatures climb, the particulate problem eases but rising heat and sunlight drive a different challenge, photochemical ozone. Pre-monsoon winds also raise wind-blown dust from the arid south and the wider region, producing episodic PM10 spikes. This seasonal rhythm particulate smog in winter, ozone and dust in summer is exactly the pattern captured in the H1 2026 data presented later in this report. A key aggravating factor in this season is the timing of paddy-stubble burning (mid-October to January), which releases fine particulates precisely when the inversion 'lid' is strongest loading the trapped air and intensifying the smog. *(Ahmed et al., 2015; IGC, 2022).*

Punjab's smog does not simply drift away it becomes trapped over cities in a phenomenon known as the pollution or "smog dome." As the winter inversion forms, a layer of warmer air settles above the cooler surface air, acting like a lid. Beneath this lid, emissions from traffic, industry, biomass and crop-residue burning accumulate and cannot rise or disperse, forming a dome-shaped concentration of pollutants over the urban area. The urban heat-island effect reinforces this: warmer city air rising at the center and sinking at the cooler edges sets up a closed circulation that recirculates polluted air back over the city rather than clearing it. Calm winds and the valley effect of the Himalaya–Karakoram barrier to the north further seal this dome in place. The result is that cities such as Lahore, Faisalabad and Multan sit under a persistent cap of hazardous air for days at a time

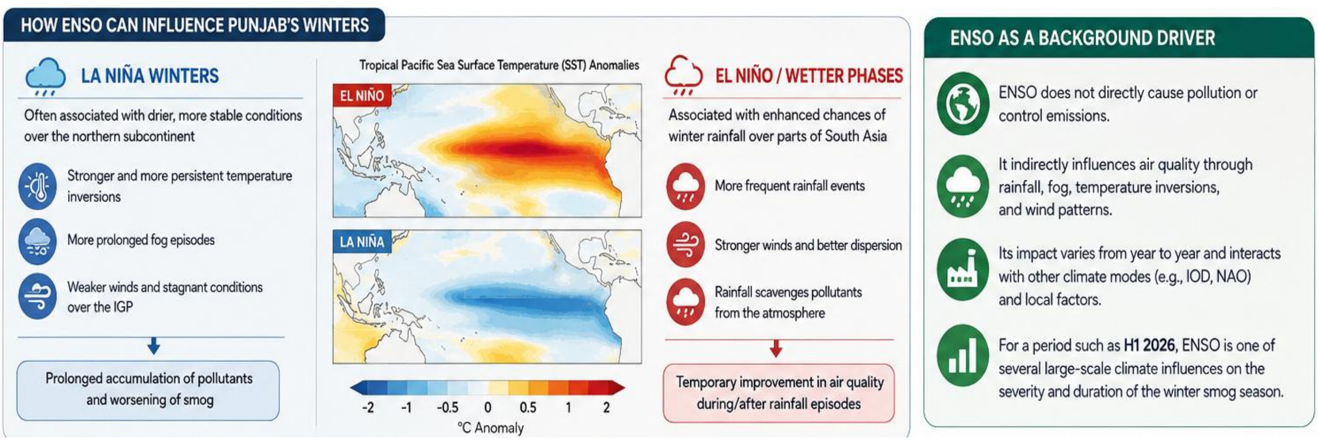


Dome Effect (WISELearn Resources (Environmental Science))

2.2 ENSO El Niño / La Niña Influences

Inter-annual variability in Punjab's winters is modulated in part by the El Niño–Southern Oscillation (ENSO), the periodic warming (El Niño) and cooling (La Niña) of the tropical Pacific that influences weather worldwide. While ENSO's effect on South Asian air quality is indirect and operates through rainfall and circulation rather than directly on emissions, it is a relevant background factor: ENSO phases can shift the timing and strength of winter rainfall, fog persistence, and wind patterns over the IGP. *(Kulkarni et al., 2020).*

La Niña winters, in particular, have often been associated with drier, more stable conditions over the northern subcontinent that can prolong inversion episodes and worsen smog accumulation, whereas wetter phases can bring rainfall that temporarily scavenges pollutants from the air. For a period such as H1 2026, ENSO is therefore best understood as one of several large-scale climate influences on the severity and duration of the winter smog season, layered on top of the dominant local drivers of emissions and inversion meteorology. EPA Punjab's integration of meteorological data through the Punjab Climate Observatory supports tracking of these influences over time. *(Lelieveld et al., 2015).*



2.3 Seasonal Wind Circulation & Pollutant Transport over the Subcontinent

The movement of air over the subcontinent is the master control on how pollutants accumulate, disperse or travel across Punjab, and it changes fundamentally between seasons. Understanding this seasonal wind circulation is essential to interpreting the province's air quality, because the same emissions can produce hazardous smog or relatively clean air depending entirely on the prevailing wind regime and atmospheric stability *(Kulkarni et al., 2020; Guttikunda & Gurjar, 2012).*

Winter Westerlies and Western Disturbances. During the winter (November–February), the region comes under the influence of the sub-tropical westerly jet and a succession of 'western disturbances' weather systems that travel eastward from the Mediterranean, Iran and Afghanistan. At the surface, however, winds over the plains become weak, cold and dry, and are frequently near-calm. Combined with the strong nocturnal temperature inversion and the blocking 'valley effect' of the Himalaya–Karakoram barrier to the north, this produces highly stable, poorly ventilated conditions. Pollutants including fine particles from crop-residue burning, transport and industry are trapped near the surface under the inversion 'lid', forming the persistent winter smog and the pollution-dome effect described in Section 2.1. The weak westerly surface flow also transports haze eastward along the Indo-Gangetic Plain, reinforcing the transboundary, shared-airshed character of the smog *(Fatima et al., 2023; Lelieveld et al., 2015).*

Summer & Monsoon Moist Easterlies and Mixing. As summer advances, the circulation reverses. Intense surface heating deepens the atmospheric mixing layer, allowing pollutants to disperse vertically rather than remaining trapped. From roughly late June, the South Asian summer monsoon draws moist south-easterly and easterly winds inland from the Arabian Sea and the Bay of Bengal. These moist, unstable air masses together with monsoon rainfall scavenge and wash out particulate matter, making the monsoon months the cleanest of the year for particulates. The pre-monsoon period (April–June), however, brings hot, dry westerly and north-westerly winds that raise wind-blown dust from the arid south and the wider region, driving the episodic PM10 spikes seen in the H1 data, while the same strong sunshine drives the summer ozone season *(Sillman, 1999; Monks et al., 2015).*

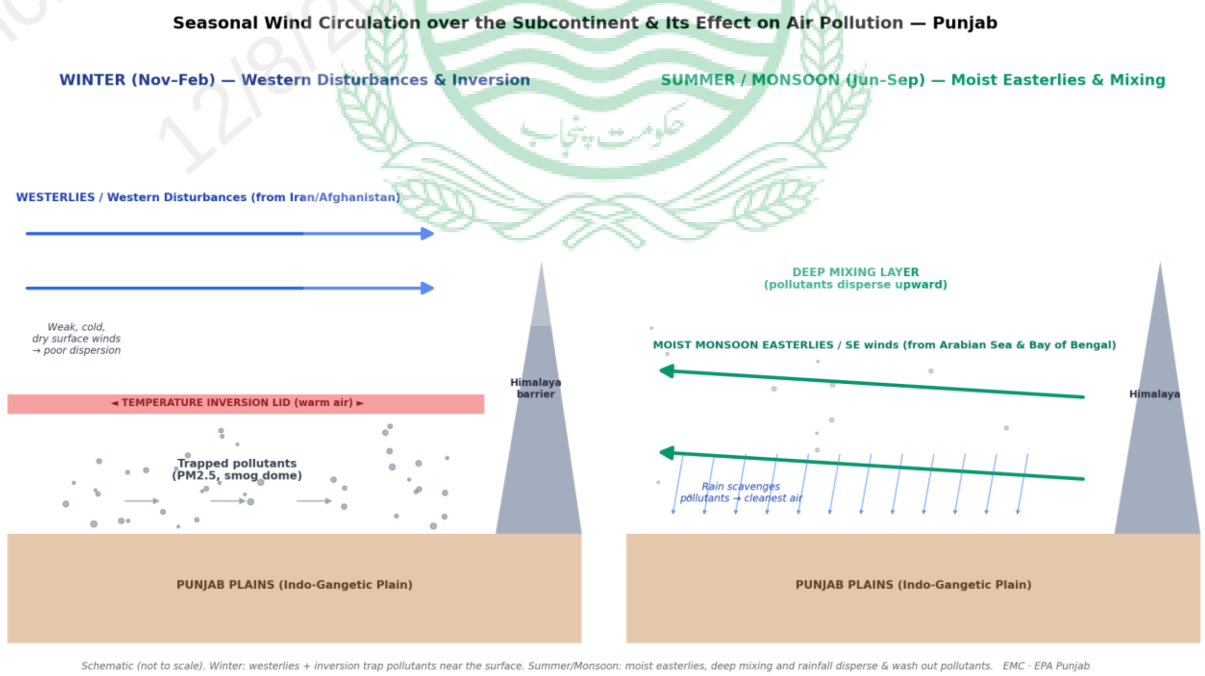


Figure 2.3: Seasonal wind circulation over the subcontinent and its effect on air pollution. Winter westerlies and inversion trap pollutants near the surface (left); summer/monsoon moist easterlies, deep mixing and rainfall disperse and wash them out (right). EMC · EPA Punjab

In summary, Punjab's air quality calendar is written by the winds, stable, trapping westerly-dominated winter conditions concentrate pollutants into hazardous smog, while the deep mixing and moist easterly monsoon flow of summer clears the air of particulates even as it gives way to a photochemical ozone season. This seasonal wind reversal, acting on a shared regional airshed, is the physical backbone of the month-by-month patterns analysed later in this report *(Kulkarni et al., 2020).*

WEATHER–AIR QUALITY LINK (SUMMARY)	Winter (mid-Oct to mid-Feb): temperature inversions + calm winds + moisture → particulate smog (fifth season). Spring/Summer (Mar–Jun): rising heat + strong sunlight → photochemical ozone. pre-monsoon winds → dust (PM10) spikes. Monsoon (Jul–Sep): rainfall scavenges pollutants → cleanest air. ENSO phases modulate winter severity year-to-year.

3. The Pollutants Sources, Science & Evolution

Air quality is assessed against six criteria pollutants, each with distinct sources, atmospheric behavior and seasonal patterns. Understanding how each has evolved and how they interact is essential to interpreting the H1 2026 data and designing effective controls.

3.1 NOx, VOCs, Ozone and Elevated Temperatures

Ground-level ozone (O_3) is not emitted directly. It is a secondary pollutant formed when nitrogen oxides (NOx) and volatile organic compounds (VOCs) react photochemically in the presence of sunlight. NOx originates overwhelmingly from high-temperature combustion diesel and petrol vehicles, power plants, industrial boilers, cement kilns and brick kilns. VOCs come from vehicle exhaust, fuel evaporation, solvents, paints, petrochemical and refining operations, and from biogenic (vegetation) sources that increase under heat stress. *(Sillman, 1999; Monks et al., 2015).*

The critical amplifier is temperature. As spring turns to summer, longer days, stronger solar radiation and rising temperatures accelerate the photochemical reactions, converting the abundant NOx and VOC precursors into ozone. This is precisely why, in the H1 2026 data, ozone climbed from a winter mean of 37.5 µg/m³ in January to 156.3 µg/m³ in June crossing its PEQS limit of 130 µg/m³ and becoming the province's dominant pollutant. The urban heat-island effect in cities like Lahore, Faisalabad and Multan further intensifies local ozone formation. Because ozone is a regional, secondary pollutant, it can only be controlled by reducing its NOx and VOC precursors across a wide area not at any single point source. *(Sillman, 1999; Monks et al., 2015).*

3.2 CO and SO_2 Industrial Zones and Gradual Evolution

Carbon monoxide (CO) and Sulphur dioxide (SO_2) are direct products of combustion. CO arises from incomplete combustion old and poorly maintained vehicles, cold engines, residential heating and certain industrial processes therefore tracks combustion intensity, peaking in the winter smog months and falling to its lowest in summer (0.7 mg/m³ in June 2026) when heating ceases. Throughout H1 2026, CO remained comfortably within its 5 mg/m³ limit.

SO_2 is emitted chiefly from burning Sulphur bearing fuels, coal-fired power generation, industrial boilers, high-Sulphur diesel, brick kilns and shipping fuels, from process industries such as metal smelting and sulphuric-acid production. Its signature is strongly tied to industrial zones, in H1 2026, the highest SO_2 readings clustered around the Faisalabad industrial belt and specific urban-industrial stations. Provincial SO_2 stayed within its 120 µg/m³ limit. Over the years, as fuel quality standards, brick-kiln conversion (zig-zag technology) and industrial inspections have expanded, the province has aimed to bring these combustion-linked gases progressively under control.

3.3 PM10 and PM2.5 Regional and Transboundary Issues

Particulate matter is the pollutant of greatest health concern in Punjab's winter. PM2.5 (fine particles ≤2.5 µm) penetrates deep into the lungs and bloodstream and is driven by combustion (vehicles, biomass, brick kilns), secondary formation from gaseous precursors, and crop-residue burning. PM10 (coarser particles) additionally includes road and construction dust, agricultural tillage and wind-blown desert dust.

Crucially, particulate pollution in Punjab is a regional, not purely local, phenomenon. Because the province sits within the continuous IGP airshed, PM is transported across borders studies of the Lahore smog have linked episodes to transboundary agricultural fires and haze from the wider region, in addition to local emissions. Post-harvest crop-residue burning across the plains (on both sides of the border) coincides with the onset of the inversion season, loading the trapped air with fine particles. This is why PM2.5 reached 176.6 µg/m³ in January 2026, the province's clean-air strategy combines local source control (the Crop Residue Management Program, brick-kiln conversion, vehicle and industrial controls) with recognition of the shared regional airshed. *(Kulkarni et al., 2020; Lelieveld et al., 2015).*

3.4 Crop Residue Burning & the Seasonal Cropping Cycle

Punjab's agriculture is dominated by a rice–wheat double-cropping system, which covers over 80% of the province's cropped area and is a major seasonal driver of particulate pollution. This system produces two distinct crop-residue burning windows each year. The first and more significant occurs from mid-October through January, when farmers clear paddy (rice) stubble after the Kharif harvest to prepare fields for wheat sowing. Roughly 8.5 million tons of rice residue produced annually, an estimated 3.6 to 5 million tons is burnt in open fields releasing large quantities of PM2.5, PM10, carbon monoxide and nitrogen oxides directly into the atmosphere. Critically, this burning window coincides almost exactly with the winter smog season (mid-October to mid-February) and with the onset of thermal inversions, so the fine particles from burning are trapped near the surface rather than dispersed. This combination is a principal reason why provincial PM2.5 reached 176.6 μg/m³ in January 2026 the highest of the half-year. *(Ahmed et al., 2015; IGC, 2022).*

The second, smaller burning window occurs in April–May, when wheat stubble is cleared after the Rabi harvest. While less intense than the rice-burning season, it contributes to the elevated PM10 and particulate loading observed in the pre-monsoon months of the H1 period. Because the Indo-Gangetic Plain functions as a single continuous airshed, residue-burning emissions from both sides of the international border add to Punjab's local particulate burden, reinforcing the transboundary character of the pollution described above. *(Kulkarni et al., 2020; Lelieveld et al., 2015).*

3.5 Greenhouse Gases (GHG) A Brief Note

While this report focuses on ambient air quality (health-relevant pollutants), several of the same combustion sources transport, industry, power generation and agriculture are also major emitters of greenhouse gases (CO_2, methane, nitrous oxide). This overlap is significant, measures that cut air pollution (cleaner vehicles and fuels, efficient industry, reduced crop-residue burning, modal shift to public and electric transport) frequently deliver parallel GHG reductions. Punjab's air quality program therefore contributes to the province's broader climate commitments under the Environment Protection & Climate Change Department, creating co-benefits between clean-air and climate-mitigation goals.

4. The Rise of Smog in Punjab History & Impact

Punjab's air quality challenge, while rooted in long-standing geography and emissions, has intensified markedly over the past decade. What was once occasional winter fog has evolved into an annual public-health emergency.

4.1 Evolution of Air Quality Monitoring

For much of the past two decades, Punjab lacked a dense, reliable air quality monitoring network. In the early years, the province operated only a very small number of monitoring stations a set of three AQMS units originally provided through Japanese support and operational from around 2007 (two fixed and one mobile), and these were only partially operational for extended periods. Between roughly 2018 and 2022, this minimal capacity meant that during the worst smog years the province had almost no authoritative, real-time ground-truth data of its own, forcing reliance on third-party estimates and fueling public confusion and mistrust over conflicting AQI figures.

This monitoring gap was itself a driver of policy, the absence of EPA-approved stations was explicitly cited as a reason for establishing a modern, province-wide network, so that authentic, localized AQI data could replace exaggerated or inconsistent readings. The transformation from a handful of ageing stations to today's network of 56 AQMS represents one of the most significant advances in the province's environmental governance.

The reality of the fifth season on South Asian roads. Source: Betsy Joles / Getty Images

> *The onset of the fifth season is followed by large-scale socio-economic disruptions, the closure of schools and businesses, traffic accidents, and poor health conditions.*
> Frontiers in Sustainable Cities (2023), on South Asian smog in the Indo-Gangetic Plain

4.3 Sectoral Impact of Smog

The smog emergencies of these years imposed heavy costs across every sector of Punjab's economy and society:

- **Education:** Repeated closures of schools for a week at a time and in the worst episodes, for several weeks disrupted the education of millions of children and forced shifts to remote learning.
- **Business & commerce:** Work-from-home mandates, 'green lockdowns' (bans on rickshaws, halts to construction), and restrictions on markets and outdoor commerce disrupted daily economic activity and hit daily-wage livelihoods hardest.
- **Transport:** Drastically reduced visibility caused motorway closures, flight disruptions and a rise in traffic accidents across the plains.
- **Public health:** Hospitals reported surges in respiratory and cardiac cases, with dedicated 'smog counters' established; long-term exposure raises the risk of chronic lung and heart disease, especially for children and the elderly.

These cascading impacts captured widely in national and international news coverage during the 2023 and 2024 seasons transformed air quality from an environmental concern into a top-tier governance priority for the Government of the Punjab, catalyzing the institutional and programmatic response described in the next section.

A patient in a dedicated respiratory ward during the peak smog emergency. Source: Al Jazeera

Reduced visibility and restricted movement on Punjab's roads during the lockdown phase. Source: AP News

The iconic Badshahi Mosque obscured by hazardous air quality. Source: Al Jazeera

Lahore traffic navigating heavily reduced visibility. Source: Dawn

LAHORE: Smoke billowing from burning garbage on Ring Road causing air pollution.—White Star / M. Arif

'Micro-pollution ravaging China, South Asia'

Lahore second most polluted megacity

New Delhi on top, Dhaka third, says IQAir and Greenpeace study for 2019

PARIS: Nearly 90 per cent of the 200 cities beset by the world's highest levels of deadly micro-pollution are in China and India, with most of the rest in Pakistan and Indonesia, researchers reported on Tuesday.

Taking population into account, Bangladesh emerged as the country with the worst so called PM2.5 pollution, followed by Pakistan, Mongolia, Afghanistan and India, according to the 2019 World Air Quality Report, jointly released by IQAir Group and Greenpeace. China ranks 11th.

Particulate matter of 2.5 microns or less in diameter — roughly 1/30 the width of a human hair — is the most dangerous type of airborne pollution.

Microscopic flecks are small enough to enter the bloodstream via the respiratory system, leading to asthma, lung cancer and heart disease.

Among the world's megacities of 10 million or more people, the most PM2.5-toxic in 2019 was the Indian capital New Delhi, followed by Lahore in Pakistan, Dhaka in Bangladesh, Kolkata in India, Linyi and Tianjin in China, and Jakarta, Indonesia.

Next on the list were Wuhan — epicentre of the new coronavirus outbreak — along with Chengdu and Beijing.

The IQAir report is based on data from nearly 5,000 cities worldwide.

Most of the seven million premature deaths attributed by the World Health Organisation (WHO) to air pollution are caused by PM2.5 particles, which originate in sandstorms, agriculture, industry, wildfires and especially the burning of fossil fuels.

"Air pollution is the world's leading environmental health threat," said IQAir CEO Frank Hammes. "Ninety percent of the global population is breathing unsafe air." China's average urban PM2.5 concentration dropped 20 per cent in 2018 and 2019, but last year it still counted 117 of the 200 most polluted cities in the world.

All but two per cent of China's cities exceeded WHO guidelines for PM2.5 levels, while 53 percent exceeded less stringent national safety limits.

Less data from Africa: The UN says PM2.5 density should not top 25 microgrammes per cubic metre (25 mcg/m3) of air in any 24-hour period. China has set the bar at 35 mcg/m3.

More than a million premature deaths in China each year are caused by air pollution, according to the WHO. Recent calculations put the toll at up to twice that figure.

Across a large swathe of northern India and north central China, meeting WHO standards year round for PM2.5 pollution would increase life expectancy up to six or seven years, according to the Air Quality Life Index, developed by researchers at the Energy Policy Institute of Chicago.

In India, small particle pollution exceeds WHO limits by 500 per cent, even if air pollution in general declined significantly last year, with 98 per cent of cities monitored showing improvements.

Among the club of 36 rich OECD nations, South Korea was the most polluted for PM2.5, counting 105 of the worst 1,000 cities on the index. In Europe, Poland and Italy count 39 and 31 cities, respectively, in this tranche.

Other parts of the world such as Africa and the Middle East lacked data.

"What cannot be measured cannot be managed," Hammes said. "Africa, a continent of 1.3 billion people, currently has less than 100 monitoring stations that make PM2.5 data available to the public in realtime." As of 2018, China alone had more than 1,000 such stations in 200 cities.

Climate change has begun to amplify the health risk of PM2.5 pollution, especially through more intense forest fires and sandstorms made worse by spreading desertification, the report found.

Global warming and PM2.5 also have the same primary driver: the burning of coal, oil and gas.

While the link with lung cancer was well established, a recent study showed that most excess deaths from air pollution are caused by heart attacks, strokes and other types of cardiovascular disease.

Small and larger particulate matter, nitrogen dioxide (NO2), sulphur dioxide (SO2) and ozone (O3) have likewise been linked to drops in cognitive performance, labour productivity and educational outcomes.

Of cities with more than one million people, the least affected by PM2.5 are Adelaide, Helsinki, Stockholm, and San Jose in central California, followed by Perth and Melbourne in Australia, and Calgary in Canada, and New York. —AFP

> *Unprecedented air pollution levels in Lahore prompted authorities to take emergency measures, including work-from-home mandates and closing primary schools; the city topped the real-time list of the world's most polluted cities.* Reported by NBC News / Reuters (November 2024)

Note: The above references are paraphrased from published news and peer-reviewed sources for context. Readers may consult the original coverage (IQAir World Air Quality Report; Frontiers in Sustainable Cities 2023; NBC News / Reuters, Nov 2024; Global Souths Hub 2025) for full detail.

5. Policy & Institutional Response

The escalating smog crisis drove the Government of the Punjab to mount a comprehensive institutional and programmatic response built around dedicated agencies, a modern monitoring network flagship projects and strengthened through partnerships with international institutions.

5.1 Punjab Government _ World Bank Collaboration & the Green Program

A cornerstone of Punjab's environmental transformation has been its collaboration with the World Bank. Recognizing that air quality management requires sustained investment, institutional strengthening and technical capacity, the province advanced a series of programs under this partnership. The earlier Punjab Green Development Program laid the groundwork by strengthening environmental governance, regulatory systems and monitoring capacity across the province.

Building on this foundation, the Punjab Clean Air program (PCAP) was developed as the province's flagship, decade-long clean-air strategy. In March 2025, the World Bank approved a US$300 million concessional loan in support of Punjab's smog mitigation action plan under PCAP. The program aims to reduce PM2.5 by around 35% over the coming decade significantly lowering the burden of respiratory and pollution-related illness for the roughly 13 million residents of Lahore Division alone. PCAP is organized around strengthening air quality management infrastructure, enhancing regulatory and institutional capacity, targeted sectoral abatement, and public awareness.

PCAP KEY INTERVENTIONS (World Bank-supported)	Investment in 5,000 super seeders to curb crop-residue burning (a principal cause of seasonal smog), introduction of 600 electric buses to drive a modal shift to clean public transport; expansion of regulatory grade air quality monitoring across Punjab; and new fuel-quality testing laboratories. The headline target: reduce PM2.5 toward 35 µg/m³ by 2035.

5.2 EP&CCD and EPA Punjab

Institutional responsibility for air quality rests with the Environment Protection & Climate Change Department (EP&CCD) of the Government of the Punjab, and its operational arm, the Environment Protection Agency (EPA) Punjab. Together they are responsible for setting and enforcing environmental standards (including the Punjab Environmental Quality Standards, PEQS), regulating industrial and vehicular emissions, and coordinating the province's cross-sectoral smog response. Successive policy instruments the 2017 Smog Control Policy, the 2022 Health Advisory System for critical air pollution events, the 2023 Clean Air Policy and Action Plan, and the 2024 Smog Mitigation Action Plan reflect the Government's deepening commitment to air quality management.

5.3 The Environmental Monitoring Centre (EMC)

At the heart of EPA Punjab's data-driven approach is the Environmental Monitoring Centre (EMC), which serves as the central hub for collecting, quality-assuring, analyzing and disseminating air quality data from the province's monitoring network. As the network expanded, an initial tranche of around 30 regulatory-grade Air Quality Monitoring Stations was deployed across the province to provide authentic, localized AQI data replacing the earlier reliance on a handful of ageing stations. The EMC aggregates these data centrally and produces the analysis, reporting and advisories on which enforcement and public communication depend.

5.4 The 'Air Safe' Initiative

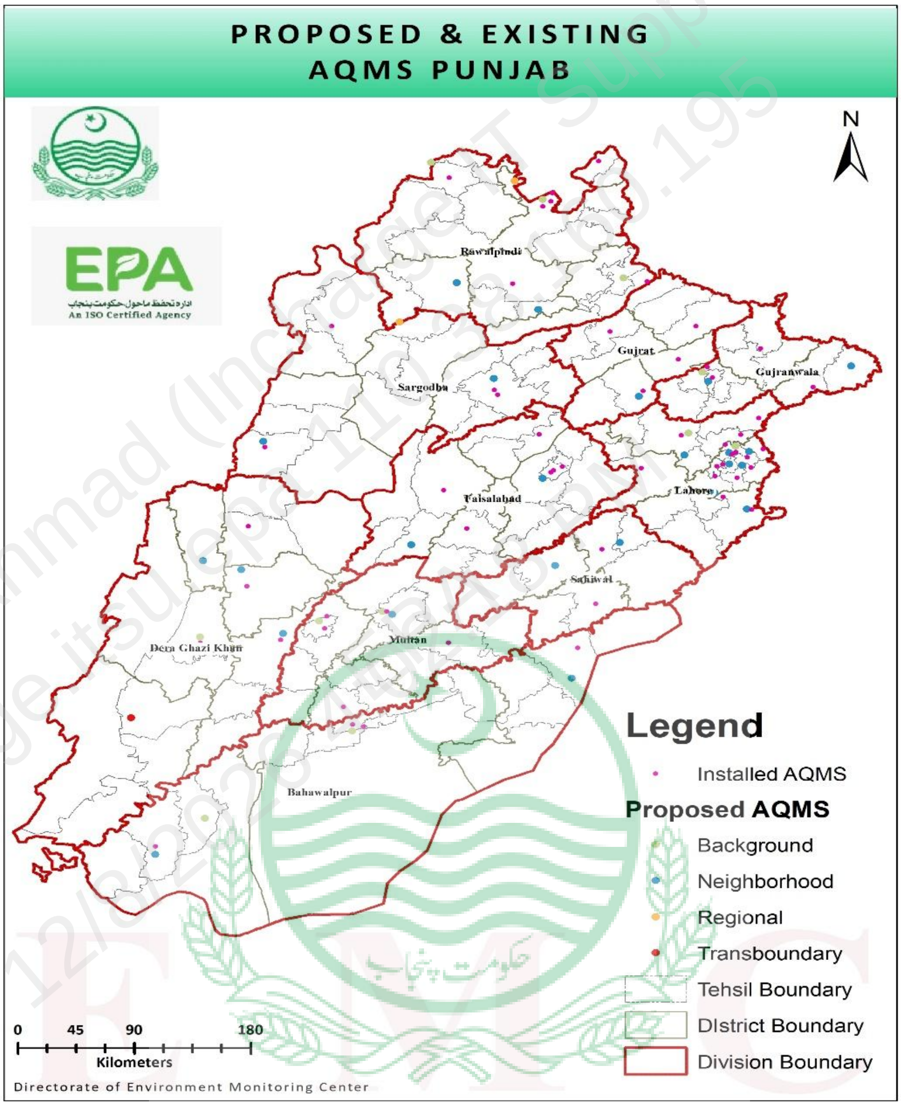
Building further on this monitoring foundation, the Punjab Smog Mitigation & Response Initiative branded 'Air Safe' is a major anti-smog and pollution-control project spearheaded by EP&CCD. Approved by the Provincial Development Working Party (PDWP) with an allocated budget of approximately Rs 5.38 billion, Air Safe substantially expands the province's monitoring and enforcement capability.

Air Safe Component	Details
Fixed AQMS deployment	A tranche of fixed Air Quality Monitoring Stations added across the province (project envisaged 26 additional fixed AQMS)
Mobile fog-cannon units	15 mobile fog-cannon units for localized dust and smog suppression
Fuel-quality testing labs	6 fuel-quality testing laboratories to detect and curb fuel adulteration
Vehicle emission equipment	20 vehicle smoke-opacity / emission-testing units, plus mobile air-quality monitors
Budget (PDWP-approved)	≈ Rs 5.381 billion
Core objective	Real-time, localized AQI data feeding the EPA crisis-management framework to enforce emission standards, penalize polluting vehicles and control fuel adulteration
Public accessibility	Real-time data and hourly AQI updates on the EP&CCD official website; daily indices and localized advisories on the EPA Punjab Facebook page

5.5 Today's Network 56 AQMS and Continuous Monitoring

Through the successive deployment of these projects the initial Japanese era stations, the first 30 AQMS, and the 26 Air Safe expansion Punjab today operates a network of 56 installed Air Quality Monitoring Stations. Each station functions as a compact automated laboratory, using globally approved methods (UV photometry, beta-attenuation and chemiluminescence) alongside meteorological sensors, secure data logging, automated calibration and UPS backed power. The stations operate 24 hours a day, 7 days a week, generating hourly readings without human intervention across all six criteria pollutants (PM2.5, PM10, NO_2, SO_2, O_3 and CO). *(US EPA, 2018; WHO, 2021).*

AQI monitoring is carried out continuously by these AQMS and made available to the public through multiple channels the web portal (https://aqi.punjab.gov.pk), a dedicated mobile application, and a chat-bot following the automated pathway from analyzers to data loggers to central server to the public dashboard, app and Eco-bot. From the EMC, a 24-hour report is issued along with health advisories to all district administrations and the EPA field force. The Director General (DG) EPA Punjab has directed clearly that field-force enforcement activities in each district be engaged and calibrated according to the prevailing AQI level in that district turning real-time data directly into targeted action against polluting kilns, vehicles, industries and open burning.



Proposed and Existing Air Quality Monitoring Stations (AQMS) across Punjab

FROM DATA TO ACTION	Continuous 24/7 AQMS monitoring → EMC central analysis → 24-hour report + health advisory to all district administrations and EPA field force → district-level enforcement calibrated to local AQI, on the DG EPA Punjab's directive. Public access via web portal, mobile app and chat-bot; environmental helpline 1373.

EARLY ERA	1st PHASE	AIR SAFE	TODAY
3 AQMS	**30 AQMS**	**expansion**	**56 AQMS**
Japan-supported (2 fixed + 1 mobile), from ~2007	*First regulatory-grade tranche*	*26 AQMS + fog cannons + fuel labs*	*Installed & operating 24/7 province-wide*

6. Overview of H1 2026 Air Quality Data

Against the geographic, climatic and institutional backdrop set out above, this section summarizes the measured state of Punjab's air quality for January–June 2026, drawing on data from the AQMS network aggregated at the EMC. The half-year captured a complete seasonal cycle, from peak winter smog through the spring transition into the summer ozone season.

Air quality remained a serious public-health concern throughout. The provincial mean AQI ranged from a hazardous 244 in January to a 'Sensitive' 121 in April, before rising again to 164 in June no month reached the

'Good' or fully 'Moderate' provincial category. Over the half-year, fine particulate matter (PM2.5) was the most frequent dominant pollutant (42.9% of station-days), but ground-level ozone rose to dominate on 29.8% of station-days, overtaking PM entirely by June. The single most important finding is the seasonal handover: PM2.5 fell from 176.6 µg/m³ (January) to 48.4 µg/m³ (June), while ozone climbed from 37.5 to 156.3 µg/m³, crossing its PEQS limit.

H1 PEAK AQI	H1 LOW AQI	PM2.5 RANGE	O_3 RANGE	TOP DRIVER	NETWORK
244	**121**	**177→48**	**38→156**	**PM2.5**	**17→56**
January (winter)	*April (spring)*	*µg/m³ Jan→Jun*	*µg/m³ Jan→Jun*	*42.9% station-days*	*Jan→Jun*

7. Regulatory Context, Program & Targets

Punjab's air quality management is framed by a suite of flagship initiatives led by EPA Punjab, described institutionally in Section 5. Their programmatic essentials are:

PUNJAB CLEAN AIR PROGRAMME (PCAP)	The overarching decade-long clean-air strategy (World Bank-supported, US$300M). Targets all major sources with defined milestones; headline goal: reduce PM2.5 toward 35 µg/m³ by 2035.
SMOG MITIGATION INITIATIVE / AIR SAFE	Seasonal anti-smog program (Rs 5.38bn Air Safe) brick-kiln zig-zag conversion, industrial and vehicle enforcement, open-burning crackdowns, monitoring expansion (AQMS, fog cannons, fuel labs) and public advisories.
CM PUNJAB GREEN CREDIT PROGRAM	Incentive-based scheme rewarding tree plantation, cleaner technology and emissions reduction with tradable green credits, mobilizing private and community participation.
CROP RESIDUE MANAGEMENT PROGRAM	Targets stubble burning via ~5,000 super seeders, machinery subsidies and enforcement directly reducing the seasonal particulate load.
PUNJAB CLIMATE OBSERVATORY	Consolidates AQMS, satellite and meteorological data for forecasting, evidence-based decisions and transparent public reporting.

7.1 Targets & Commitments vs H1 2026 Status

Indicator / Milestone	Target	H1 2026 Status
PCAP PM2.5 goal (by 2035)	35 µg/m³	**48–177 well above**
PEQS PM10 (24-hr)	150 µg/m³	**164–284 exceeded**
PEQS O_3 (8-hr)	130 µg/m³	**Crossed in May–Jun**
PEQS SO_2 / NO_2	120 / 40 µg/m³	**Mostly within limits**
Monitoring network	56 AQMS	**Installed; 17→ 56 active in H1**

8. Provincial Scenario Month-wise Analysis

This section presents the province-wide picture across the six months. The central narrative is the seasonal handover from winter particulate smog to summer photochemical ozone the direct data expression of the climate and pollutant dynamics described in Sections 2–3.

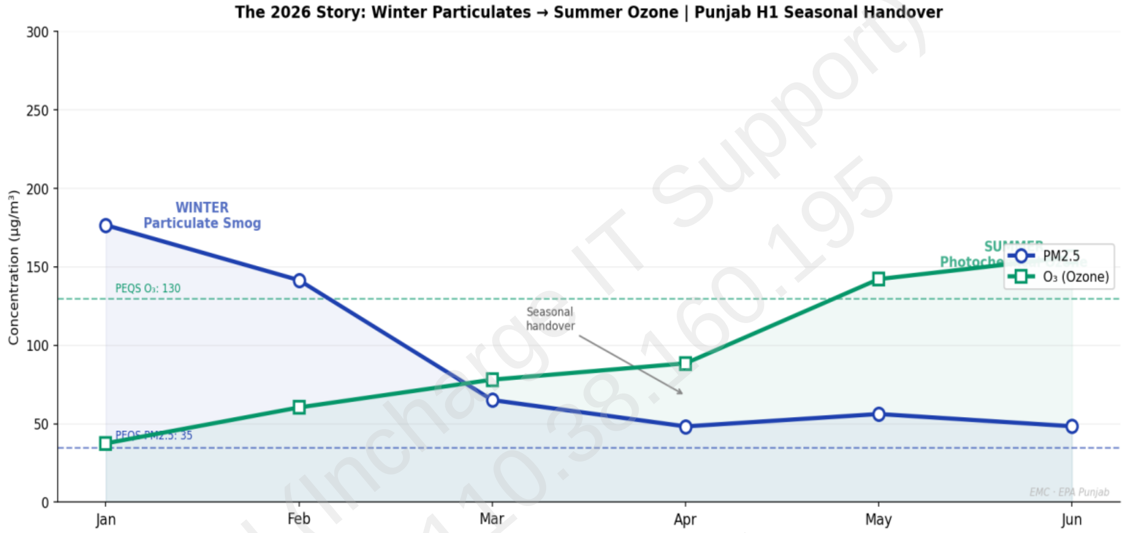


Figure 8.1: The 2026 seasonal handover. PM2.5 (blue) fell as O_3 (green) rose, crossing over in late spring winter belongs to particulates, summer to ozone.   EMC · EPA Punjab

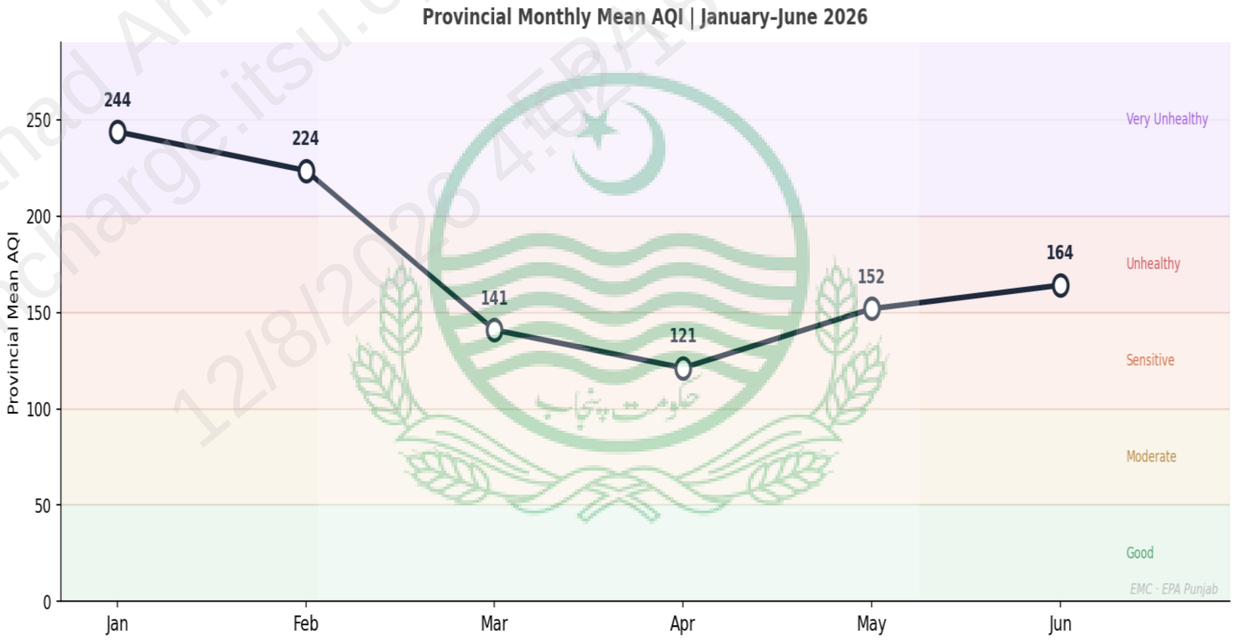


Figure 8.2: Provincial monthly mean AQI, Jan–Jun 2026. The U-shaped trajectory reflects the winter-particulate to summer-ozone transition, with April the cleanest month.   EMC · EPA Punjab

8.1 Month-by-Month Summary Table

Month	AQI	PM2.5	PM10	O_3	Narrative
January	**244**	176.6	283.8	37.5	Peak winter smog PM2.5 5× PEQS; hazardous episodes
February	**224**	141.5	258.4	60.4	Smog easing; NO_2 above limit, ozone beginning to rise
March	**141**	65.1	167	78.1	Spring transition; network recovers; PM halves
April	**121**	48.3	164.4	88.5	Cleanest month; ozone climbing steadily
May	**152**	56.2	208	142.2	Ozone crosses PEQS; PM10 dust rising
June	**164**	48.4	198.4	156.3	Ozone the #1 pollutant; PM2.5 lowest of year

AQI categories: Jan–Feb 'Very Unhealthy'; Mar–May 'Unhealthy/Sensitive'; Jun 'Unhealthy'. PM2.5/PM10/O_3 in µg/m³; red = above PEQS.

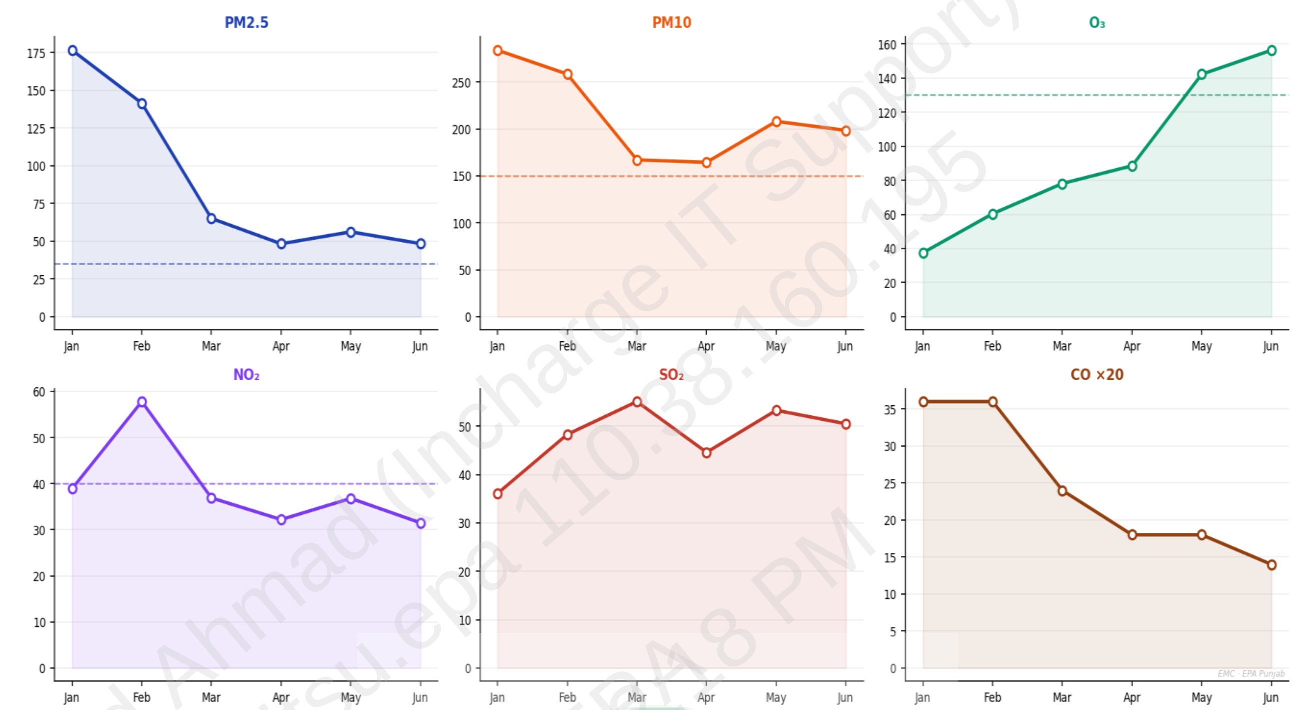


Figure 8.3: All six criteria pollutants monthly provincial means, H1 2026 (dashed = PEQS). Diverging PM2.5 and O_3 trajectories are the central signal.   EMC · EPA Punjab

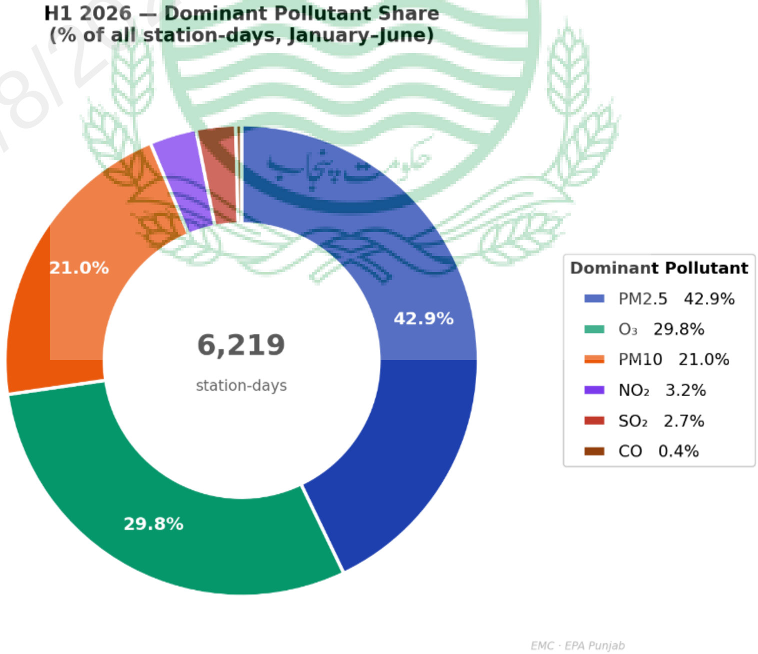


Figure 8.4: Dominant pollutant shares across all station-days, H1 2026. PM2.5 led overall; ozone's 29.8% share (later months) signals the seasonal shift.   EMC · EPA Punjab

9. District-wise Analysis

This section examines air quality separately for each monitored district (H1 2026 mean across that district's active station(s)). Coverage varies Lahore has twelve stations; many districts one so single-station districts indicate their monitored location. Districts are grouped by administrative division and ranked by mean AQI.

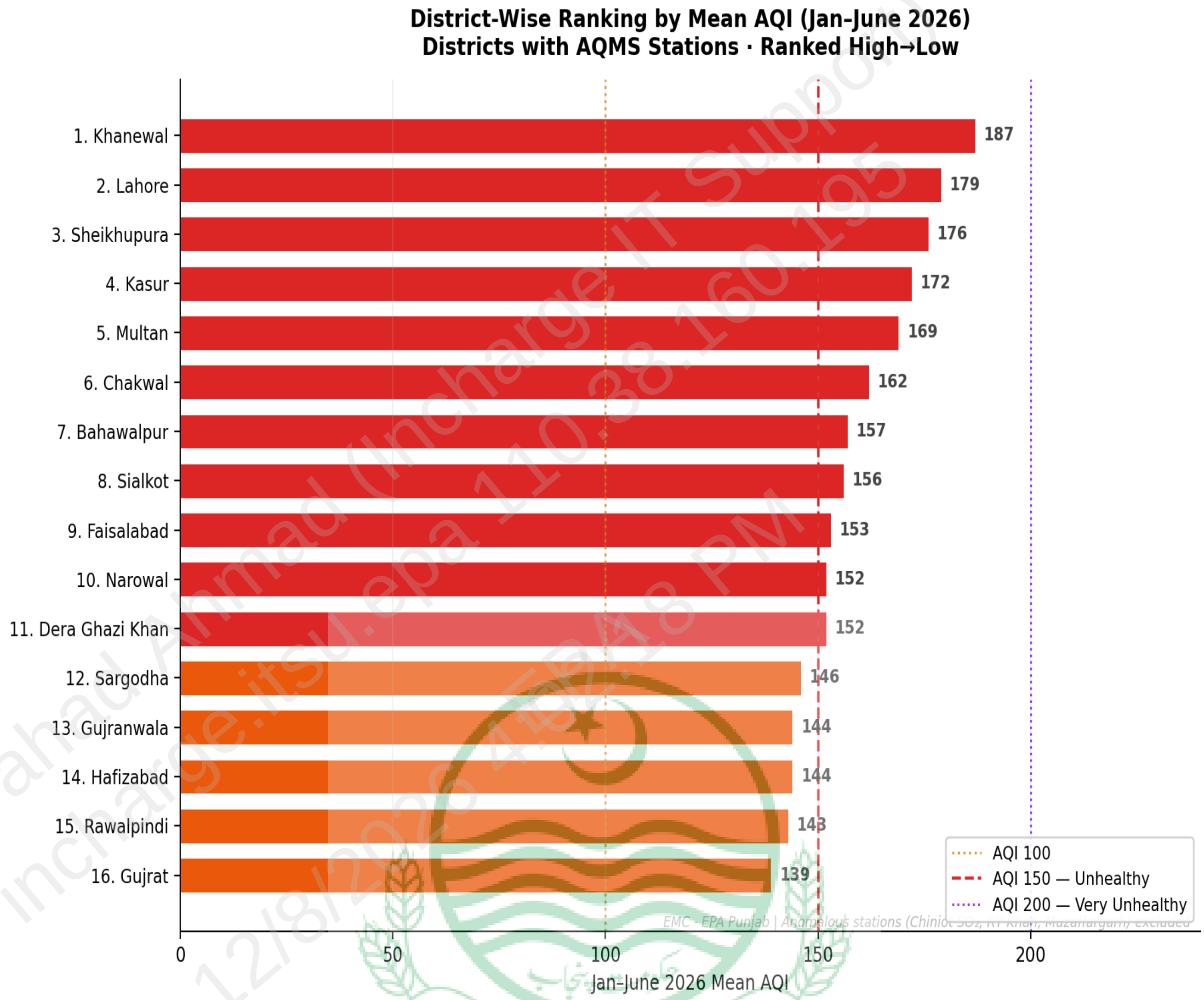


Figure 9.1: District-wise ranking by H1 2026 mean AQI. Red=Unhealthy; orange=Sensitive, EMC · EPA Punjab

DISTRICT-WISE AIR QUALITY ALL POLLUTANTS (Jan–June 2026) 10 Divisions

District	Mean AQI	Category	PM2.5	PM10	O_3	SO_2	NO_2	CO
PEQS Limit →			*35*	*150*	*130*	*120*	*40*	*5*
Lahore Division								
Lahore	179	Unhealthy	88.7	223.6	94.6	56.7	48.2	1.2
Sheikhupura	176	Unhealthy	97.9	239.6	71.2	83.4	54.6	1.1
Kasur	172	Unhealthy	80.2	210.3	121	55.8	27.8	1
Nankana Sahib	112	Sensitive	62	227.8	71	7.2	11.5	0.6
Bahawalpur Division								
Bahawalpur	157	Unhealthy	47.9	218.7	131.4	63.8	31.2	0.8
Faisalabad Division								
Faisalabad	153	Unhealthy	50.3	188.2	148.4	100.2	42.4	1
Jhang	96	Moderate	61	205.5	65	5.5	15.6	0.7
Multan Division								
Khanewal	187	Unhealthy	90.8	184.5	153.4	15.9	15.6	2.6

Multan	169	Unhealthy	54.9	204.9	157	96.4	35.6	1
Vehari	130	Sensitive	62	270	96	3	18.2	0.6
Dera Ghazi Khan Division								
Kot Addu	168	Unhealthy	89.6	236.8	86.5	1.5	10	0.4
Dera Ghazi Khan	152	Unhealthy	36.4	184.3	164.5	24	31.1	1
Rajanpur	108	Sensitive	57	219.1	66	6.1	10.7	0.5
Gujranwala Division								
Sialkot	156	Unhealthy	37.3	166.2	166.8	14.8	28.3	1.2
Narowal	152	Unhealthy	80	163.2	83.4	34.5	11.9	0.5
Gujranwala	144	Sensitive	41.4	177.2	136.9	59	50.3	1
Sargodha Division								
Bhakkar	168	Unhealthy	56.9	258.1	98.9	1.7	13.4	0.4
Sargodha	146	Sensitive	36	174.6	144.6	34.1	29	0.8
Khushab	122	Sensitive	40	165.6	110	2.1	15.8	0.4
Mianwali	104	Sensitive	42	155.4	92	3.3	22.7	0.5
Rawalpindi Division								
Chakwal	162	Unhealthy	41	83.1	127.5	29.2	67.9	0.6
Rawalpindi	143	Sensitive	37	145.7	156.1	33.2	52.2	1.1
Attock	101	Sensitive	28	94.3	118	—	14.5	0.5
Talagang	99	Moderate	23	102.2	123	2.3	8.5	0.4
Jhelum	70	Moderate	35	96.4	78	5.1	15	0.5
Gujrat Division								
Hafizabad	144	Sensitive	77.9	149.3	63.4	29.7	16.8	0.7
Gujrat	139	Sensitive	72.2	147.8	66.9	23	39.5	0.7
Wazirabad	91	Moderate	53	166	93	5.5	12	0.5
Mandi Bahauddin	74	Moderate	46	128.3	49	1.7	13	0.7
Sahiwal Division								
Sahiwal	120	Sensitive	63	234.3	52	9	5.8	0.5
Pakpattan	95	Moderate	58	222.5	36	9.9	11.9	0.5
Okara	90	Moderate	60	228.6	59	7.2	9.6	0.5

Across 10 divisions. All µg/m³ (CO mg/m³, H1 mean). Red=above PEQS · Green=within. Source: AQMS Network · EMC · EPA Punjab

9.1 Divisional Observations

Lahore Division recorded the highest sustained pollution, led by Lahore district (H1 mean AQI 179 across all stations) the epicenter of winter smog with Sheikhupura (176) and Kasur (172) reinforcing the picture. Faisalabad district averaged 153 with strong summer ozone. Rawalpindi Division showed moderate particulates but very high ozone (Rawalpindi 156 O_3), reflecting the Potohar plateau's summer photochemistry, while Jhelum (70) and Attock (101) were among the cleanest in the province.

The southern divisions Multan, Bahawalpur and Dera Ghazi Khan combined high summer ozone with episodic dust, Multan district posted some of the highest ozone (157 µg/m³). Gujranwala, Gujrat, Sargodha and Sahiwal divisions were generally 'Sensitive' to 'Unhealthy', with the cleanest readings at Mandi Bahauddin (74), Okara (90) and Wazirabad (91).

10. City-wise Snapshot Major Urban Centers

Beyond the district averages, the major cities warrant focused attention as the province's principal population, transport and industrial hubs and thus its main emission sources. The following snapshot draws on the key urban stations in each city.

City	H1 AQI	Category	Profile
Lahore	**179**	Very Unhealthy	The provincial epicenter. Twelve stations averaged 179; winter PM2.5 extreme (UET, Shahdara, Kahna Nau, FMDRC all 'Very Unhealthy'). LWMC-Lahore is a persistent particulate outlier (flagged). Dense traffic, industry and population under shared inversions.
Faisalabad	**153**	Unhealthy	The textile-industrial hub. Three stations averaged 153, with strong industrial SO_2 signals (NTU, DC Faisalabad, GCU) and high summer ozone. Industrial-zone emissions are the defining feature.
Rawalpindi	**143**	Sensitive	Twin city of the capital. Moderate particulates but very high summer ozone (156 µg/m³ mean) across ARID, DC Office and Drug Testing Lab stations a photochemical, traffic-precursor profile.
Multan	**169**	Unhealthy	Southern hub. Two stations (BZU, MNS-UET) averaged 169 with some of the province's highest ozone (157 µg/m³) intense southern photochemistry plus dust.
Gujranwala	**144**	Sensitive	Industrial belt. Two stations averaged 144; elevated ozone and localized SO_2. Industrial and vehicular emissions dominate.
Bahawalpur	**157**	Unhealthy	Southern city; two IUB-campus stations averaged 157 with high ozone (131 µg/m³) and summer dust (PM10).
Sialkot	**156**	Unhealthy	Export-industry city; single station 156, driven strongly by summer ozone (167 µg/m³).
Sargodha	**146**	Sensitive	Central Punjab; two stations averaged 146 with very high ozone (145 µg/m³ mean).

11. Source Analysis by Pollutant

Effective control requires understanding each pollutant's sources. The following summarizes the root causes behind elevated levels of each criteria pollutant, grouped by category (combustion/transport, industrial, mechanical/dust, natural, and regulatory/local factors). These inform the sectoral priorities in Section 13.

11.1 Fine Particulate Matter (PM2.5)

PM2.5 drove the winter crisis (dominant on 42.9% of H1 station-days). Sources direct combustion (diesel/petrol exhaust with black carbon and Nox, residential wood and biomass burning, brick kilns, shipping/marine fuels), secondary precursors (ammonia from agriculture, SO_2 from power plants, NOx from transport/industry, and VOCs transforming into particles), industrial processes (cement, metal smelting, chemical manufacturing, refining), mechanical resuspension (construction and demolition dust, road-dust resuspension, brake and tyre wear), natural sources (wildfires, biomass burning, wind-blown dust, sea salt), and environmental trapping factors (temperature inversions, low wind speed, high photochemical activity, long-range transboundary transport).

11.2 Coarse Particulate Matter (PM10)

PM10 stayed elevated all period, spiking in summer from dust. Beyond the combustion sources shared with PM2.5 (diesel exhaust, crude-oil combustion, agricultural/crop-residue burning, heavy off-road equipment), PM10 is dominated by mechanical and dust processes: land clearing and excavation, agricultural tillage and soil disturbance, road sanding, re-entrainment of deposited dust, mining and quarrying, brick kilns and bulk-materials handling; plus natural sources wildfires, wind-blown desert dust, massive dust storms (haboobs) amplified by drought conditions and high winds during the pre-monsoon season.

11.3 Ground-level Ozone (O_3)

Ozone the summer dominant pollutant is secondary, formed from NOx and VOC precursors in sunlight. Precursor sources: transport (old/idling vehicles, cold-start emissions, evaporative VOC losses, heavy-duty diesel NOx), primary industry (refining and petrochemicals, power plants, cement kilns, waste incineration, natural-gas processing), chemical/process VOCs (solvent evaporation, printing and coating, dry-cleaning fluids, painting), residential/commercial (home heating, landscaping equipment, cleaning and personal-care products) and biogenic VOCs (isoprene/terpene from vegetation under heat stress). Amplifiers strong sunlight, elevated temperatures, urban heat-island effect and transboundary ozone transport.

11.4 Nitrogen Oxides (NO / NOx)

NO and NOx are direct products of high-temperature combustion the key ozone precursors. Sources transport (unmaintained engines, heavy-duty diesel trucks, off-road and non-road diesel, cold-engine operation), primary industry (coal/gas power plants, industrial boilers, cement kilns, petroleum refining, pulp and paper), chemical processes (nitric-acid production, ammonia oxidation, metal pickling, glass manufacturing, explosives/dyes), residential/commercial (home heating, large boilers, water heaters, small combustion engines), natural sources (lightning, wildfires, soil emissions, sea spray) and regulatory/local factors (weak standards, enforcement gaps, temperature-inversion trapping, long-range NOx transport).

11.5 Sulphur Dioxide (SO_2)

SO_2 comes chiefly from sulphur-bearing fuels and process industries, and clusters around industrial zones. Sources: coal and solid-fuel combustion (coal-fired power, industrial boilers, residential coal heating, high-sulphur coal sourcing); liquid fuel and transport (heavy fuel oil for shipping, high-sulphur diesel, refinery off-gases), process (non-combustion) emissions (metal smelting of copper/lead, sulphuric-acid production, oil-and-gas H_2S removal, chemical manufacturing); operational practices (inadequate fuel switching, scrubber/FGD malfunction, process upsets); natural sources (volcanic, geothermal, organic-matter decomposition, dimethyl sulphide from oceans); and regulatory/external factors (weak standards, enforcement failures, transboundary transport).

11.6 Carbon Monoxide (CO)

CO least significant in H1 2026, always within limits marks incomplete combustion and tracks winter combustion intensity. Sources: residential/commercial combustion (woodstoves, inefficient furnaces, space heaters, indoor charcoal grilling, malfunctioning gas appliances); transport (old/unmaintained vehicles, cold engines, stop-and-go 'rich mix' traffic, off-road engines); industrial processes (steel blast furnaces, petroleum refining/FCCU, chemical production, brick-kiln smelting); operational/behavioral factors (idling, poor burner maintenance, ventilation blockage, improper fuel use); natural sources (wildfires, biogenic oxidation of methane) and regulatory/local factors (weak standards, enforcement failures, long-range transport, local topography trapping).

12. Health Advisories

The following category-specific guidance corresponds to the AQI bands recorded across Punjab in H1 2026. Because ozone (summer) and particulates (winter) affect the body differently and peak at different times, seasonal guidance is included. Advisories are issued daily from the EMC to all district administrations alongside the 24-hour AQI report.

GOOD (0–50)	Satisfactory air. No restrictions ideal for outdoor activity for all.
MODERATE (51–100)	Acceptable for most. Unusually sensitive individuals should consider limiting prolonged intense outdoor exertion.
SENSITIVE (101–150)	Sensitive groups (children, elderly, heart/lung patients) should reduce prolonged outdoor exertion. Punjab's spring baseline (Mar–Apr).
UNHEALTHY (151–200)	Everyone may be affected; sensitive groups more seriously. Limit prolonged outdoor exertion; sensitive groups avoid it. Typical summer-ozone level (May–Jun).
VERY UNHEALTHY (201–300)	Health alert all groups should avoid outdoor exertion; sensitive groups remain indoors. Punjab's winter-smog level (Jan–Feb).
HAZARDOUS (300+)	Emergency — everyone indoors with windows closed; use air purification. Reached in peak January smog episodes.

12.1 Seasonal Guidance

- **Winter smog (mid-Oct to mid-Feb):** Main threat is fine particulate matter. Wear well-fitted N95 masks outdoors, use indoor air purifiers, keep windows closed during peak episodes, and minimize outdoor exercise in early morning/evening when inversions are strongest.
- **Summer (May–Aug):** Main threat is ground-level ozone, peaking in the afternoon. Schedule outdoor activity for early morning, avoid strenuous exertion on hot sunny afternoons, and stay hydrated. Masks are less effective against ozone (a gas) than against particulates.
- **All seasons:** Watch for coughing, throat/eye irritation, breathlessness or chest tightness; seek medical advice if persistent. Asthma/COPD patients should keep rescue medication accessible during high-AQI periods.

13. Sectoral Highlights Emission Controls

The source analysis points to four priority sectors. EPA Punjab's controls, aligned with PCAP and the Smog Mitigation / Air Safe initiative, are summarized below.

TRANSPORT / VEHICLES	Largest urban source of NOx (key ozone precursor), primary PM and CO. Measures: vehicle emission inspection/certification, phasing out high-emitting diesels, cleaner fuels and e-mobility (600 electric buses under PCAP), congestion reduction, and Air Safe's 20 smoke-opacity testing units. Benefits both winter (PM/CO) and summer (ozone).
INDUSTRY	Major source of SO_2, NOx, PM and VOCs. Measures: brick-kiln conversion to zig-zag technology, emissions inspection and enforcement, CCTV/stack monitoring, fuel-sulphur control (6 fuel-testing labs under Air Safe), and targeted action at SO_2 hotspots (Faisalabad belt; Chiniot verification).
CONSTRUCTION & FUGITIVE DUST	Dominant PM10 contributor, worsened by summer dust. Measures: dust-suppression at sites (15 mobile fog cannons under Air Safe), covering transported materials, road paving/cleaning, and greening critical during the pre-monsoon dust season.
AGRICULTURAL BURNING	Significant seasonal PM source. Measures under the Crop Residue Management Program: ~5,000 super seeders, machinery subsidies, and enforcement against open field burning during the post-harvest window directly targeting the winter particulate peak.

14. Monitoring Framework & Data Accessibility

EPA Punjab operates 56 installed AQMS province-wide, each measuring the six criteria pollutants (PM2.5, PM10, O_3, SO_2, NO_2, CO/NOx) plus meteorology, using globally approved methods (UV photometry, beta-attenuation, chemiluminescence). Stations run 24/7 with hourly updates, feeding the EMC via the automated chain: analysers → data loggers → central server → public dashboard / app / EcoBot. The AQI condenses pollutant concentrations into a single health-based index (0–500+), driven by the dominant pollutant, and directly informs advisories and enforcement. *(US EPA, 2018; WHO, 2021).*

AQI monitoring is continuous and publicly accessible. From the EMC, a 24-hour report with health advisories is issued to all district administrations and the EPA field force. On the DG EPA Punjab's directive, district field-force enforcement is engaged and calibrated to the prevailing local AQI converting real-time data into targeted action.

Channel	Access
Live AQI Portal (24/7)	https://aqi.punjab.gov.pk/
EP&CCD / EPA Punjab	https://epd.punjab.gov.pk/
Mobile Application	'Punjab AQI' real-time station AQI, 7-day hourly trends, advisories

EcoBot Chat-bot	Conversational AQI & guidance based on official EPA Punjab data
EPA Facebook Page	Daily indices & localized advisories
Environmental Helpline	1373 report pollution & emergencies (24/7)

14.1 How Citizens Can Participate

- Maintain vehicles, avoid idling, share rides, use public/non-motorized transport.
- Avoid open burning of waste and crop residue; adopt residue-management alternatives.
- Reduce household emissions; avoid indoor biomass/charcoal burning.
- Report visible polluters (smoky vehicles, illegal burning, industrial smoke) to helpline 1373.
- Check the AQI daily via the app, portal or EcoBot and follow the category-specific guidance.

15. Conclusions & Priority Recommendations

H1 2026 revealed an air quality challenge that is severe, seasonal and shifting in character. Winter delivered hazardous particulate smog rooted in the IGP's inversion meteorology and regional emissions; summer brought province-wide ozone above its limit, driven by NOx/VOC precursors and heat. Meeting the PCAP target of 35 µg/m³ PM2.5 by 2035 will require sustained, source-targeted action across all seasons, underpinned by the now-expanded 56-station monitoring network. Priority recommendations:

1. Adopt a season-differentiated strategy particulate-source controls (biomass, brick kilns, dust, vehicles, crop-residue) for winter smog; NOx/VOC precursor controls for the summer ozone season.
2. Priorities NOx reduction for its double benefit lower direct NO_2 and reduced summer ozone. Transport and industry are the key levers.
3. Sustain and complete network operation (56 installed keep all active year-round) and expand to unmonitored districts, building on the Air Safe expansion.
4. Target hotspots the Lahore metropolitan cluster, the southern high-ozone belt (Multan, Bahawalpur, DG Khan, RY Khan) and industrial SO_2 zones (Faisalabad) with AQI-calibrated field enforcement.
5. Strengthen public communication with season-specific advisories via the app, portal, EcoBot and helpline 1373, and expand school and community awareness programs.

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The following peer-reviewed studies, agency reports and data sources inform the scientific basis, methods and contextual facts presented in this report. In-text citations appear in parentheses throughout.

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