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<u>DISCLAIMER</u>

This "Punjab State of Environment Report, 2024" is based on limited primary data. A significant portion of the information is based on secondary sources. Every effort has been made to ensure accuracy; however, errors and omissions are expected.

Message

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ACKNOWLEDGEMENT

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AARI	Ayub Agricultural Research Institute
ACWA	Agriculture Climate Water
AQGs	Air Quality Guidelines
AQI	Air Quality Index
AQMS	Air Quality Monitoring Stations
BFCs	Business Facilitation Center
BODs	Biological Oxygen Demands
CARSC	Climate Adaptations & Resilience Support Center
CBT	Climate Budget Tagging
CCRC	Climate Change Research Center
CETPs	Combined Effluents Treatment Plants
CNG	Compressed Natural Gas
COD	Chemical Oxygen Demand
COP-29	Conference of Parties
COPD	Chronic Obstructive Pulmonary Disease
CRAES	Chinese Research Academy of Environmental Scientist
CSA	Civil Services Academy
CSCCC	Civil Society Coalition for Climate Change
DACs	District Afforestation Committees
DPSIR	Driver Pressure State Impacts Resource
EAs	Environmental Approvals
ECS	Emission Control System
EIAs	Environmental Impact Assessments
EN	Endangered
EP&CCD	Environment Protection & Climate Change Department
EPA	Environmental Protection Agency
EPC	Environment Policy Center
EPD	Environment Protection Department
EPO	Environment Protection Order
EPR	Extended Producer Responsibility
EVs	Electrical Vehicles
FACE	Food Security And Agriculture Center of Excellence
FIRs	First Information Report
GCF	Green Climate Fund
GCISC	Global Climate Change Impact Studies Center
GHG	Green House Gases
ICE-2024	International Conference on Environment
ICIMOD	International Center for Integrated Mountains Development
IEE	Initial Environmental Examination
LFP	Labor Force Participation
LPG	Liquefied petroleum gas
MAF	Manufacturer's Authorization Form
MICS	Multiple Indicator Cluster Surveys
MPDD	Management & Professional Development Department
MSW	Municipal Solid Waste
MSWN	Municipal Solid Waste Management
MW	Megawatt
NAP	National Adaptation Plan

NARC	National Agriculture Research Center
NDCs	Nationally Determined Contributions
NGOs	Non-Governmental Organization
NOC	No Objection Certificate
ODF	Open Defecation Free
OOSC	Out of School Children
PCRWR	Pakistan Council of Research in Water Resources
PCSIR	Pakistan Council of Scientific and Industrial Research
PDMA	Provincial Disaster Management Authority
PEIMA	Punjab Education Initiative Management Authority
PEPA	Punjab Environmental Protection Act
PET	Punjab Environmental Tribunal
PGDP	Punjab Green Development Programme
PM	Particulate Matter
PMD	Pakistan Meteorological Department
PPC	Pakistan Panel Code
PPP	Public Private Partnership
RECP	Resource Efficient Cleaner Production
RUDA	Ravi Urban Development Authority
SAR	Sodium Adsorption Ratio
SDGs	Sustainable Development Goals
SDPI	Sustainable Development Policy Institute
SMEs	Small Medium Size Enterprises
SOE	State of Environment
SP&IU	Strategic Planning and Implementation Unit
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
UNFCCC	United Nations Framework Convention On Climate Change
VICS	Vehicle Inspection and Certification System
VU	Vulnerable
WDD	Women Development Department
WHO	World Health Organization
WWTPs	Waste Water Treatment Plants

CHAPTER 1   INTRODUCTION

Beneath the sky, on land and sea,
The Earth breathes life for you and me.
Each tree, each stream, each gentle breeze,
A fragile thread that we must seize.

Can you feel it? The Earth's soft plea,
A fragile cry for you and me.
Her environment weeps, her oceans sigh,
Yet still, we turn a blinded eye.

This is not just a distant tale,
It's in our hands, it's ours to hail.
For every child who'll someday roam,
This Earth must be a loving home.

So let us care, let us fight,
For every dawn, for every night.
For in her health, our souls are free—
The Earth's heartbeat is you and me.

            (*By: Ms. Shehr Bano, CLDI Batch III*)

1. Introduction

1.1 Background

The Punjab Environmental Protection Act (PEPA), 1997, mandates the Environmental Protection Agency (EPA) Punjab to publish an annual report on the State of the Environment (SOE) of Punjab. This document represents the third report in the series, following the inaugural report published for the calendar year 2022[1]. The publication of the SOE Report is further supported by the Punjab Green Development Program (PGDP), in addition to the provisions outlined in the Act.

The annual SOE reports serve as a comprehensive repository of environmental quality data and provide detailed insights into initiatives undertaken to mitigate pollution and enhance environmental governance. The incorporation of feedback gathered during public consultations underscores the commitment to transparency and active citizen engagement in the management of environmental issues. This participatory approach reflects the collaborative efforts between the government and the public in fostering sustainable environmental practices.

1.2 State of the Environment Report – 2023

The SOE Report 2023[2] offered a thorough evaluation of the environmental landscape, covering areas such as ambient air quality, industrial emissions, surface and groundwater conditions, soil health, wastewater treatment plants, and solid waste management facilities. Its primary goal was to provide policymakers, stakeholders, and the public with insights into the prevailing environmental conditions in the province, their impact on human health, and to guide the development of an environmental action plan. Alongside detailing the environmental profile of Punjab, the report also underscored several key environmental challenges the province faced in 2023. The major findings of the SOE Report 2023 are summarized in Table 1-1.

1.3 Purpose of the Report 2024

The State of the Environment (SOE) Report 2024 aims to provide an updated assessment of Punjab's environmental quality, covering air, water, soil, climate change, wastewater, innovative pollution control measures, environmental approvals, local and international agreements, redressal of public complaints on environmental issues and environmental action plan. Moreover, it highlights the measures taken by EPCCD Punjab and with relevant departments during 2024 to control pollution and improve environmental sustainability. The significantly higher download count of the 2023 report compared to 2022 highlights its growing importance and relevance. The report serves as a reference framework for policymakers, researchers, and the public, offering insights into Punjab's environmental challenges, regulatory actions, and future strategies.

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[1] epd.punjab.gov.pk/system/files/Report 2022-hi-res %284%29.pdf

[2] SOE Report 20-June low res.pdf

01-1: Findings & Strategic Focus Areas of State of Environment Report-2023

Chapter	Snapshot
Air Quality & Industrial Emissions	PM2.5 exceeded safe limits in all nine divisions, with Lahore worst affected. Lahore had 156 poor to hazardous air days, slightly better than 2022. 68% of vehicles met emission standards. Measures included stricter controls, tree planting, electric buses, and climate-smart farming. Air Quality and Industrial Emissions: The government also initiated anti-smog squads and incentivized the use of low sulfur fuels.
Water Quality (Surface & Groundwater)	Punjab's per capita water availability is projected to fall below 800 m³ by 2025 (5,000 m³ in 1951). EPA rated surface water 'Moderate,' drain water 'Very Poor,' and urban water showed contamination. 58% of groundwater was fit for irrigation. 95.7% of industries failed PEQS for BOD, with major polluters being leather, textiles, sugar, and paper industries. Effluent treatment remains limited, with most industries are either non-complaint or using outdated treatment technologies.
Soil Health & Agricultural Impact	*Neutral to slightly alkaline,* with fertile composition but low phosphorus levels. *Pollution Load Index:* Highest in Multan & Rawalpindi (2.3), indicating moderate contamination. Industrial effluents caused sodic soil conditions in Lahore & Bahawalpur, impacting agriculture.
Climate Change & Environmental Risks	*Temperature rise:* 0.18°C increase, with June peaking at 46.6°C. *Urban flooding (Aug–Sep 2023):* 467 villages, 24,000 homes, and 545,270 acres of farmland affected. GHG emissions unaccounted, as Punjab lacks a comprehensive inventory. Government actions: Resilience-building, renewable energy, and sustainable urban planning.
Wastewater & Solid Waste Management	There are 434 industrial wastewater treatment plants, but limited capacity threatens aquatic ecosystems. Municipal solid waste generation ranges from 115 tons/day (DG Khan) to 5,000 tons/day (Lahore). Incineration facilities perform poorly, with high unburnt carbon, led, and chromium in ash.

	Landfill air monitoring detected hazardous particulate matter exceeding safety limits.
Environmental Protection Measures and Enforcement	Punjab's *first green building,* the EPCCD Green Building, promotes sustainable urban development.
	For 2024–26, 30 Air Quality and 15 Water Quality Monitoring Stations are planned.
	5,970 air-polluting industries were sealed, with fines totaling PKR 467 million.
	908 environmental complaints, mainly on air and noise pollution, led to 83 industrial closures and 42 FIRs.
Environmental Action Plan (2024-26)	Expanded in 2022 to include Air and Climate Change interventions.
	Defines short-term (2024), medium-term (2025), and long-term (2026) strategies for pollution control and governance.
	A real-time monitoring dashboard will track progress.

1.4 Approach and Methodology

The development of the SOE Report is a detailed and multi-step process. The following section outlines the approach and methodology employed for compiling the 2024 report.

1.4.1 Approach

The SOE Report 2024 is a comprehensive document that reflects the state and trends of environmental quality indicators. It is based on the analysis of primary and secondary environmental quality data, as well as extensive consultations and collaborations with multiple stakeholders. The report emphasizes:

1. Providing a thorough assessment of the state of the environment in Punjab.
2. Depicting the impacts of prevailing environmental conditions on human health and well-being, including increased cases of asthma attacks, bronchitis, COPD exacerbations, heart attacks, and strokes
3. Initiatives of department to collaborate with international community
4. Engaging stakeholders, the public, and experts in environmental reporting to support informed decision-making and policy formulation.

The SOE Report 2024 follows the DPSIR (Drivers-Pressures-State-Impacts-Response) framework, maintaining consistency with the approach used in the SOE Report 2023. The DPSIR framework:

1. Identifies key drivers that directly or indirectly influence environmental quality and sustainability.
2. Describes the 'pressures' exerted on the environment, using qualitative and quantitative data to illustrate spatio-temporal changes.

3. Analyzes the 'state' of the environment resulting from these pressures.
4. Evaluates the environmental and health impacts caused by the current state of the environment
5. Outlines policy measures and actions taken in response to environmental changes like green lockdown, and Punjab's Green Sticker Scheme.

1.4.2 DPSIR Framework for Punjab, Pakistan (2024)

This structured approach ensures a holistic understanding of environmental challenges and supports the development of effective strategies for environmental protection and conservation.

Methodology

The methodology adopted for the preparation of the SOE Report 2024 is outlined below:

1. **Developing the Content**

Primary data was mainly obtained from the directorates of the Environmental Protection Agency (EPA) Punjab, while additional information was gathered through coordination with various other departments to support the data compilation process. The content was developed in line with the structure and sequence outlined in the Appraisal Document of the report. External experts were engaged for environmental monitoring, laboratory analyses, and interpretation of data related to soil quality, drinking (tap) water, and the environmental performance of solid waste management facilities. Furthermore, relevant literature and secondary data sources were reviewed to ensure alignment with the primary data collected.

ii. **Review and Recommendations**

A committee consisting of subject matter technical experts was constituted by EPCCD Punjab to periodically review the draft report and provide recommendations to the authors for its improvement.

2. **Inter-Departmental Coordination**

Relevant provincial departments were engaged to establish connections between various sectors and the state and trends of the environment. The stakeholder departments kindly shared sector-specific environmental data for inclusion in the report.

1.5   Key Updates in Report-2024 The State of Environment (SOE) Report 2024 has been enhanced based on feedback and suggestions from relevant stakeholders, as well as through the identification of gaps in previous editions. The key updates include:

- Updated Profile of Punjab
- Inclusion of Environmental Approvals granted over the years
- Dedicated Chapter on International Agreements and Collaborative Efforts
- New Regulations on Smog Prevention and Abatement

1.6   Stakeholder Consultations

To ensure inclusive participation in the formulation of the SOE Report 2024, the draft report was shared with relevant stakeholders, including provincial and federal government institutions, non-governmental organizations, academia, civil society organizations, chambers of commerce and industry, youth, and the general public. The process was designed to invite comments, suggestions, and reviews from all concerned parties. Feedback received was carefully considered and incorporated into the final version of the report to enhance its quality and relevance.

1.7   Guide for Readers

The SOE Report 2024 maintains the fundamental structure used in previous years. It is organized around seven (05) broad components, as outlined below:

1. **Assessment of water quality** based on available monitoring data.
   - Punjab faces a dual water crisis with scarcity and pollution.
   - Only 1 in 5 industries meet wastewater standards.
   - Groundwater drops 1–2 meters/year, contaminated with arsenic, fluoride, and nitrates.
   - Surface water pollution is rising due to untreated waste and poor enforcement.
   - Treatment facilities are inadequate; many exceed limits for COD, TDS, and heavy metals.
   - Rivers like the Ravi are heavily polluted by untreated industrial effluents.
   - 467 wastewater treatment plants (WWTPs) exist, but only 2% use advanced (tertiary) treatment.
   - Punjab produces about 5500 tons/day of municipal solid waste; open dumping is widespread.
   - Only 46 public and 29 private incinerators exist, insufficient for growing waste volumes.

2. **Severe Air Pollution in cities like Lahore, mainly due to PM2.5, often exceeding safe limits, especially in winter.** Pollution Sources including;

   - Industrial emissions (steel, brick kilns)
   - Vehicle exhaust (especially old/pre-Euro vehicles)
   - Crop burning (notably post-harvest in Oct–Nov)
   - Construction dust and domestic fuel burning
   - Smog Crisis: Peaks in late autumn and winter due to temperature inversions and stagnant air.

   Actions by EPA Punjab
   Emission Control Systems (ECS):
   Installed on 70 steel furnaces → 49% PM reduction
   Installed on 600 boilers → 25% PM reduction
   Brick Kilns:
   40% converted to Zigzag tech → 29% PM and 16% CO_2 reduction

Vehicular Control:

Emission Testing System (Green Stickers) for low-emission vehicles

Roadside checks and promotion of cleaner fuels/EVs

Monitoring Network:

16 AQ stations in Lahore; expanding to other cities

Use of drones and patrolling teams for enforcement

Emergency Measures: "Green Lockdown" in Nov 2024 (limited success)

3. **Measures taken to improve environmental performance and Enforcement**

   Air & Water Monitoring

   30 AQMS installed across 10 districts (including 8 in Lahore)

   15 Water Quality Stations commissioned at major water bodies

   Industrial Enforcement

   27,392 industrial units inspected

   1,620 units sealed, 225 demolished

   677 FIRs lodged, PKR 170.8 million in fines imposed

   Brick Kiln Regulation

   68,569 kilns inspected

   1,375 sealed, 1,219 demolished

   1,967 FIRs lodged, PKR 132 million in fines imposed

   Plastic Pollution Control

   60% reduction in plastic waste (Lahore Waste Management data)

   PKR 5.33 million in fines imposed

   Confiscated plastic repurposed into 300 chairs, 10 hospital benches, 1 play area

   Province-wide Plastic Licensing System launched

   Dust Pollution Reduction

   Covering + wetting of construction materials led to up to 90% dust reduction

   450 vehicles/day regulated for sand/clay transport in Lahore

   Anti-Smog Operations

   24/7 squads deployed in 7 major districts

   Drones, vehicles, and Eco Watch App used for enforcement and monitoring

   Tree Plantation

   300,000+ trees planted, including at brick kilns

   Geotagging via "Plant for Pakistan" app ensured accountability

   Public Complaints & Apps

   Green Punjab App, WhatsApp, and helpline 1373 enabled real-time public reporting of pollution

4. **Environmental approvals and complaints**

   Complaints received, categorized by the nature of the issues and the corresponding actions taken. 585 complaints were filed in tribunals; 632 cases were disposed; and Rs. 23.73 million in fines imposed.

   In 2024, EPA Punjab Headquarters received 386 IEE+316 EIA reports out of which 182 IEE +85 EIA approved, 28 IEE+18 EIA found in violation and 176+213 under process.

   While, EPA field offices processed, 375 IEE reports out of which 214 approved, 42 rejected, 119 under process.

Moreover, at divisional level offices received 943 IEE reports, 531 approved, 141 rejected, and 271 under process.

952 applications were received *via* the Business Facilitation Center (BFC). Rs. 33.6 million in revenue from IEE/EIA processing fees in 2024 was generated.

5. **EPA Punjab's 2024 Global Engagement**

EPA Punjab's participation in COP-29 marked its debut on the international climate stage, highlighting Punjab's air quality initiatives.

Technical Collaboration:

Partnerships with CRAES (China) and ICIMOD enhanced scientific infrastructure for air quality and climate monitoring.

Academic Integration

EPA collaborated with **GCU Lahore** to launch Pakistan's first *Diploma in EIA*, boosting technical capacity.

Policy Partnerships

Engagement with think tanks (e.g., SDPI, GCISC) promoted climate resilience and policy innovation.

Public & Youth Involvement

Initiatives like school councils, *COP in My City*, and public campaigns increased environmental awareness.

Institutional Strengthening

Environmental training introduced in civil service curricula via CSA and MPDD.

Annual environmental action plan outlining future steps for environmental protection and conservation.

1.8 Drivers, Pressures, State, Impacts, and Responses (DPSIR) Framework

The environmental indicators selected for the SOE Report 2024 have been evaluated using the DPSIR (Drivers-Pressures-State-Impacts-Response) framework, as illustrated in Figure 1-1. These indicators primarily focus on the physical (abiotic) components of the environment. The drivers, pressures, state, impacts, and responses associated with specific environmental issues are detailed in the relevant sections of the report.

Drivers: Population growth, urbanization, industrial expansion, and agricultural intensification are major socio-economic trends driving resource consumption and environmental pollution.

Pressures: Increased emissions from vehicles and industry, water abstraction, solid waste generation, untreated wastewater discharge, land use changes, and overuse of agrochemicals.

State: Declining air and water quality, contaminated groundwater, poor solid waste management, loss of biodiversity, rising temperatures, and deteriorating soil health across several districts

Imapacts: Human health risks, reduced agricultural productivity, water scarcity, increased disaster vulnerability (flooding, heatwaves), and ecological stress on forests, wetlands, and rivers.

Responses: Policy reforms (e.g., Environmental Action Plan 2024–2026), environmental monitoring expansion, industrial enforcement actions, climate adaptation initiatives, and public awareness campaigns

Figure 1-1: DPSIR Framework: Illustrates the link between human activities, environmental degradation, and policy responses in the State of Environment Report

1.9 Indicators Ranking

This approach allows for the prioritization of environmental issues based on their relevance, urgency and impacts. Figure 1-2 illustrates the environmental quality assessment rating scale utilized in this report to evaluate air, water, and soil quality, as well as the performance of waste water treatment and solid waste management in Punjab, following the approach adopted in the SOE Report 2022.

Environmental Quality Assessment

Very Good	Good	Moderate	Poor	Very Poor

The environment is in excellent condition, with enhanced provision of environmental services

Good: The environment is in good condition demonstrating stability in the delivery of environmental services

Moderate: The environment is in a moderate state, reflecting inconsistency in the availability of environmental services

Poor: The environment is in poor condition, with noticeable decline in environmental services

Very Poor: The environment is in a severely degraded state. with rapidly worsening environmental services

Figure 1-2 Environmental Quality Assessment Scale

1.10 Limitations in Reporting

Building on the lessons learned from the publication of the SOE Report 2023, data acquisition has been streamlined through improved and timely coordination with stakeholder departments, as well as the development of online portals for the regular submission of environmental data by EPA Punjab. However, to enhance transparency in the reporting process, it is important to explicitly outline the limitations encountered during the preparation of the report. These limitations include:

1. **Heterogeneity of Data**: Like previous reports, the SOE Report 2024 continues to face challenges related to the heterogeneity of data. The data remains scattered and inconsistent both spatially and temporally, making it difficult to provide a comprehensive and quantified representation of the linkages between the state of the environment and its health and economic impacts.
2. **Limited Scope of Monitoring**: A significant gap in reporting persists due to the lack of district-wide monitoring across the entire province. This limitation stems from the constrained availability of resources, which restricts the ability to gather data at a more granular level.

Punjab Population Density (Person/Km²)
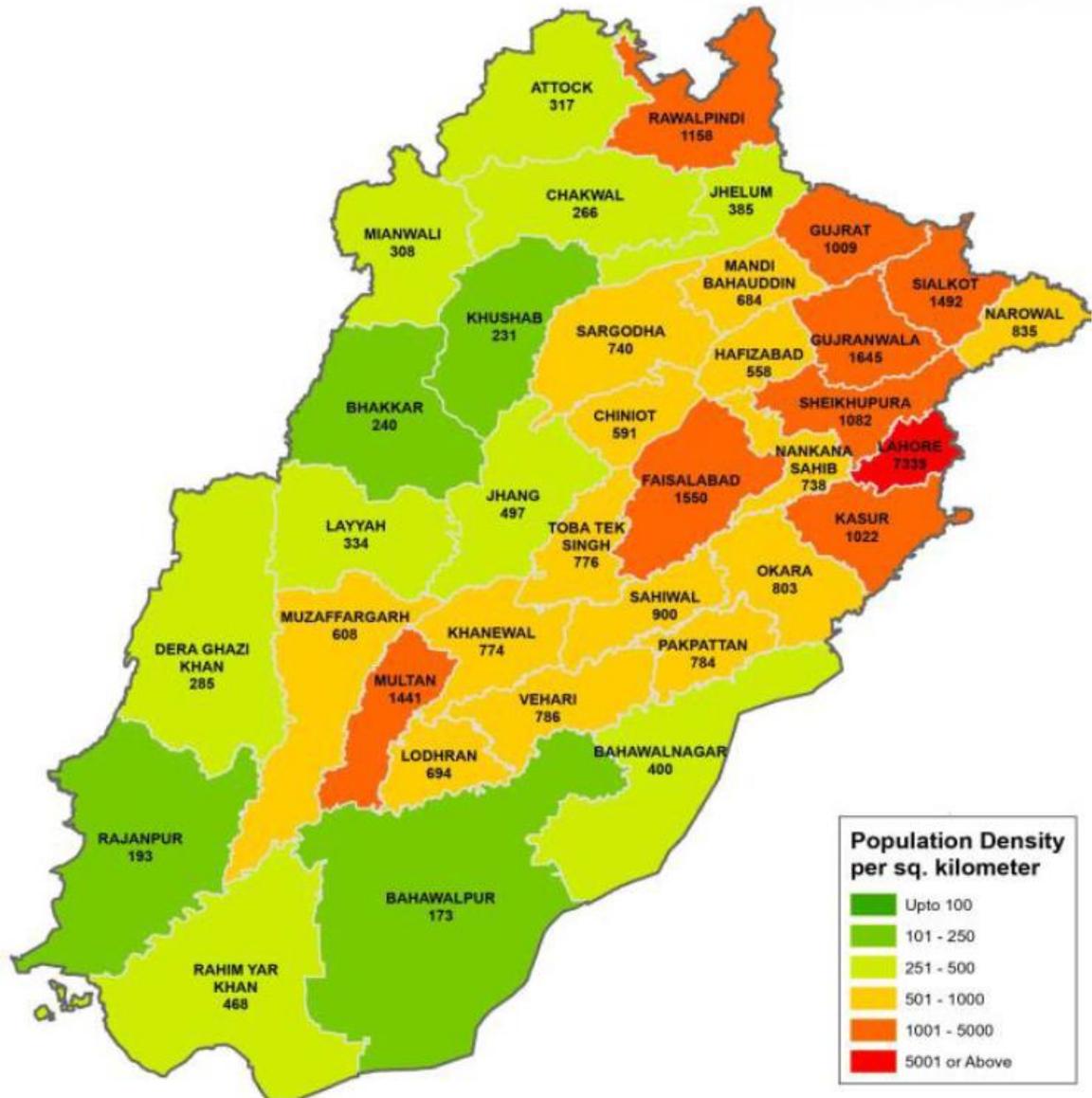
1. Demography

As per Pakistan census data 2023, Punjab remained the most populous Province of Pakistan with total population of 127.68 million in 2023 (and 134.3 million in 2025, based on the current growth rate of 2.53% per year). If same growth rate persists, then the population of our Province will be double by 2051. Lahore, being the most populous city with 13M inhabitant followed by Faisalabad 3.69 M.
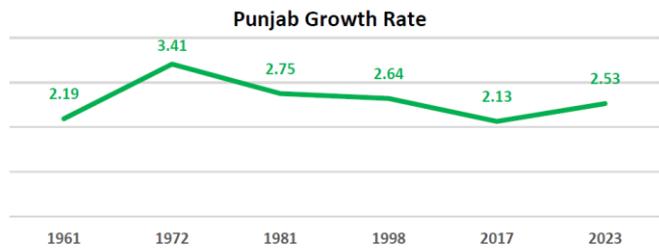
Largest Cities of Punjab in terms of Population

Lahore (13.00 M) Faisalabad (3.69 M) Rawalpindi (3.36 M) Multan (2.67 M) Gujranwala (2.22 M)

Punjab is characterized by a predominantly Punjabi-speaking population, with approximately 67% of residents identifying Punjabi as their mother tongue. Demographically, males make up a slight majority, accounting for 51.26% of the population. The average household size in Punjab is relatively large, at 6.44 members, indicating a strong emphasis on family and extended kinship structures. A significant portion of the population, 44.23%, is under the age of 18, highlighting the Province's youthful demographic profile.
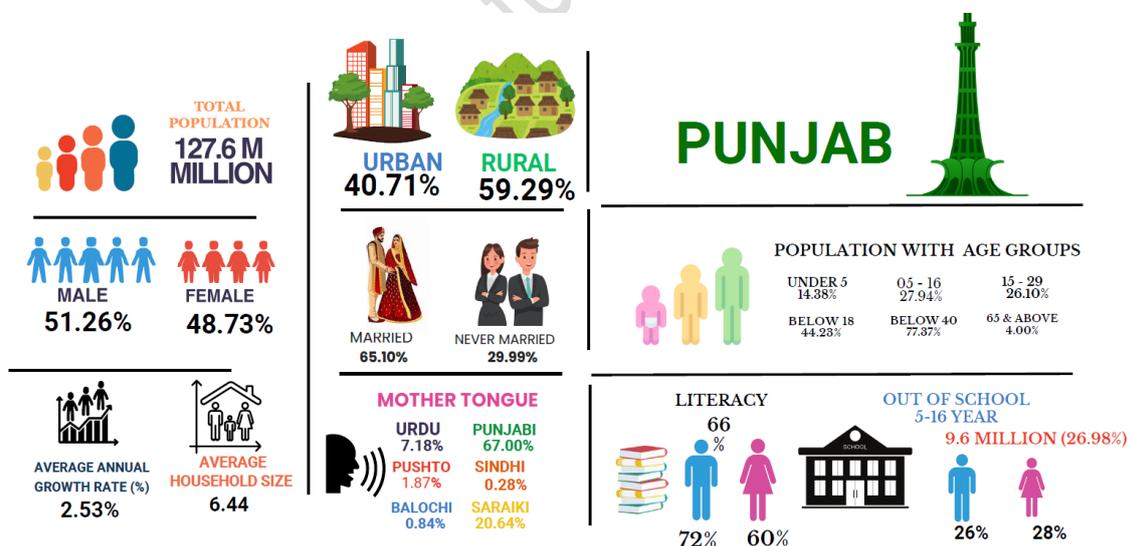
Figure 0-1: Pakistan Census 2023

2. Land Use

Punjab, showcases a land use pattern heavily skewed towards agriculture, with approximately 60% of its total geographical area dedicated to cultivation (excluding forest). This translates to roughly 12.5 million hectares of cultivated land out of the total 20.6 million

hectares of Punjab's area[3]. This agricultural dominance is underpinned by the Indus Basin Irrigation System, one of the largest contiguous irrigation systems globally, which irrigates over 80% of the cultivated land in Punjab.

Major crops occupy this land, with wheat planted on around 9 million hectares, rice on about 3 million hectares, cotton on approximately 2.5 million hectares, and sugarcane on roughly 1.3 million hectares. In contrast, forest cover remains limited, accounting for only about 3% of the land, which is approximately 0.2266 million hectares[2].

Urban areas are expanding, currently occupying around 12% of the land, with major cities like Lahore sprawling over 400,000 hectares[2] alone. Rangelands and barren lands constitute the remaining land use categories, with rangelands estimated at around 10% and barren lands at approximately 5%. These numeric facts underscore the intense agricultural focus of land use in Punjab, highlighting the need for balanced planning that considers urbanization and environmental sustainability alongside agricultural productivity.

Table 2-1: Land Cover area of Punjab

Year	Cultivated Area (Thousand Hectares)	Un-Cultivated Area (Thousand Hectares)	Forest (Thousand Hectares)
2008-09	12567	5114	498
2009-10	12599	5082	490
2010-11	12568	5112	489
2012-13	12689	4897	482
2013-14	12667	5013	489
2014-15	12537	4975	483
2015-16	12561	4951	482
2016-17	12627	4416	476
2017-18	12633	4422	478
2018-19	12600	4456	479
2019-20	12585	4474	476
2020-21	12532	4530	476

Source: - Punjab Bureau of Statistics Land Utilization Statistics[4]

3. Energy

Punjab, as Pakistan's industrial powerhouse and the most populous region, is the largest consumer of electricity, utilizing 68% of the country's generated power[4]. With a thriving economy, rapid urban expansion, and improving living standards, Punjab's energy demand is growing by 6-8% annually, highlighting the need for increased energy production. The

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[3] *Punjab Agriculture Statistics 2024*

[4] *Punjab Bureau of Statistics-Land Utilization*

Province's strategic focus on sustainable development is evident through its Punjab Power Generation Policy, designed to attract private sector investment, and the 2019 Renewable Energy Policy, which promotes green energy solutions.

Notably, the Quaid-e-Azam Solar Power Project, with a capacity of 1,000 MW[5], underscores Punjab's commitment to renewable energy, contributing to the Province's impressive 42% share of Pakistan's total installed capacity. Punjab plays a crucial role as the largest electricity consumer and one of the top contributors to the collection and generation of electricity bills. Importantly, Punjab is actively moving towards major share contribution in the domestic solar production in Pakistan which is expected to rise up to 1500 MW in coming years.

Out of 40606 MW installed capacity at national level, Punjab contributes the highest 17257 MW (42%) to the national grid. Whereas, Sindh has second highest installed capacity of 11,345 MW followed by KP (5951MW), Balochistan (3722MW) and AJK (2331MW). Punjab not only exceeded in production capacity but also succeeded in diversifying the production portfolio. The table shows comparison of energy mix of Punjab with other Provinces in 2021.[6]

Table 2-01: Installed Capacity by Province and Type of Source for the Year 2006-07 and 2020-21 MW

Plant\State	Year	Punjab	Sindh	KP	Balochistan	AJK	Total
Nuclear	2007	325	100	0	0	0	425
	2021	1330	440	0	0	0	1770
	% Growth	309.23	340	0	0	0	316.47
Hydel	2007	1698	0	3746	0	1030	6474
	2021	1802	0	5779	0	2331	9912
	% Growth	6.12	0	54.27	0	126.31	53.1
Thermal	2007	5468	5216	24	2063	0	12771
	2021	13316	9390	172	3722	0	26600
	% Growth	143.53	80.02	616.67	80.42	0	108.28
Bagasse	2007	0	0	0	0	0	0
	2021	373	154	0	0	0	527
	% Growth	100	100	0	0	0	100
Wind	2007	0	0	0	0	0	0
	2021	0	1242	0	0	0	1242
	% Growth	0	100	0	0	0	100
Solar	2007	0	0	0	0	0	0
	2021	436	119	0	0	0	555
	% Growth	100	100	0	0	0	100
Overall	2007	7491	5316	3770	2063	1030	19670
	2021	17257	11345	5951	3722	2331	40606
	% Growth	130.37	113.41	57.85	80.42	126.31	106.43

Source: Trends in Electricity Generation 2006-07 to 2020-21

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[5] PMU Energy Department Punjab
[6] Punjab Power Development Board

1. Forest and Biodiversity
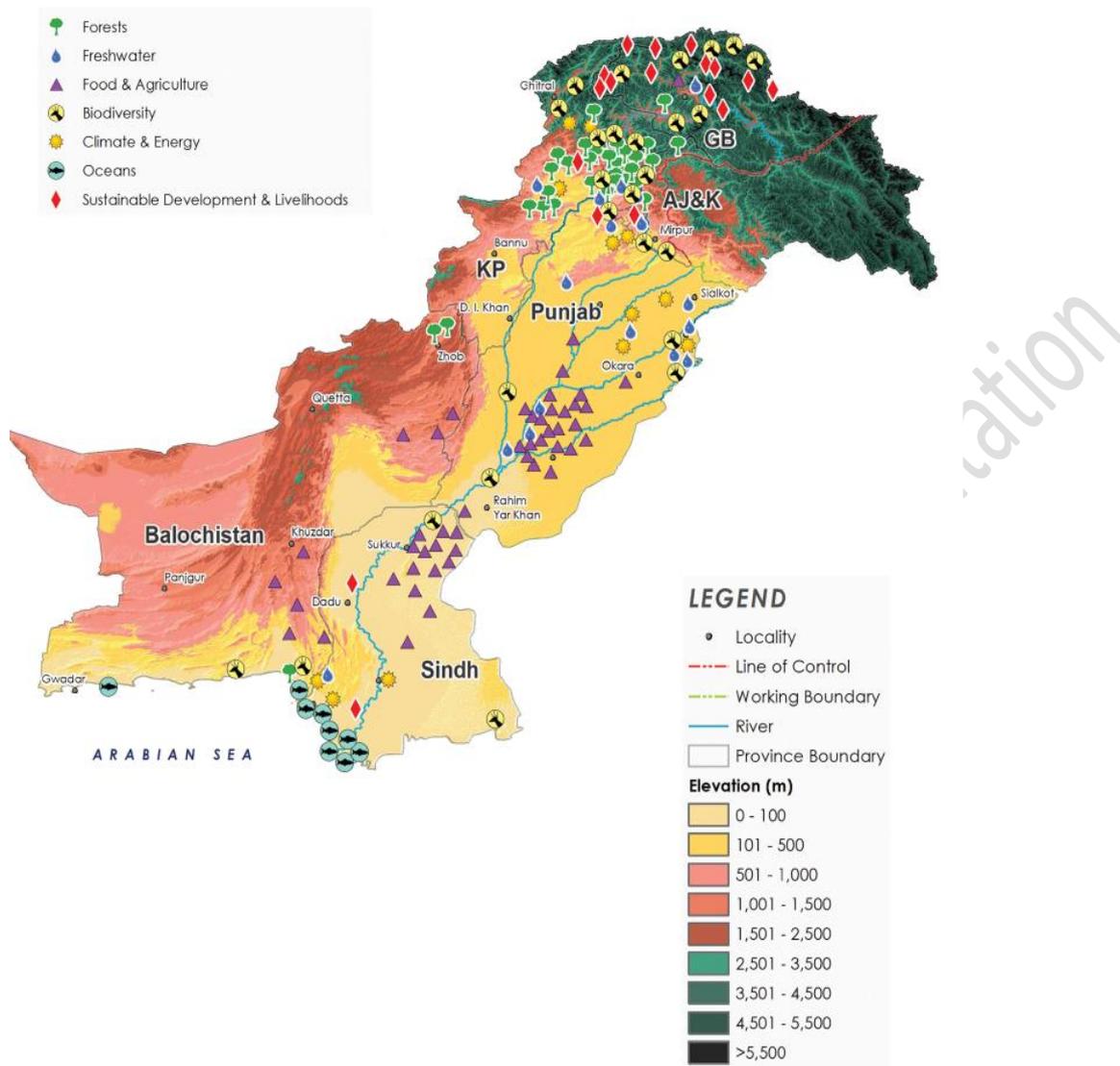
Figure 2-0-2: Forest Areas in the Punjab

4.1 Punjab's Forests and Biodiversity: An Updated Overview

Punjab possesses a diverse range of forest ecosystems, including subtropical dry scrub forests, tropical dry thorn forests, tropical dry broadleaved forests, and subtropical pine forests. These forests are located in the subtropical sub-Himalayan and temperate regions, situated south of the tropical Indus plains. The Punjab Forest Department assesses the status of forests based on various classifications, including the total area planted, plant able blank areas, un-plant able blank areas, total blank areas, and regions requiring revenue verification. Despite ongoing conservation efforts, the loss of forest cover and declining wildlife populations continue to pose threats. This article provides an updated overview of the current state of forests and biodiversity in Punjab, highlighting the latest statistics, conservation initiatives, and challenges.

4.2 Status of Forests in Punjab

Forests in Punjab account for only a small fraction of the state's total land area. Punjab has over 350 protected forests, covering approximately 560,000 acres of land[7]. In Punjab, the total area classified as having high conservation priority is approximately 63,695 km², representing 29.72% of the region's landmass[8]. Furthermore, an estimated 120,788 km² (56.35%) is designated as having moderate conservation value, while 28,870 km² (13.93%) is categorized as low conservation priority. Notably, protected areas constitute only 1.03% of Punjab's total land area[9].

The flora and fauna in Punjab are diversely distributed on the basis of topography and geography of the Province.

The major forest types in Punjab include:

- **Subtropical Dry Scrub Forests** – Found in the foothills of the Shivalik range, these forests consist of thorny bushes and small trees such as *Acacia modesta* and *Olea ferruginea.*
- **Tropical Dry Thorn Forests** – Common in the arid and semi-arid regions, these forests host species like *Prosopis cineraria, Capparis decidua*, and *Salvadora oleoides*.
- **Riverine Forests** – Also known as 'Belas,' these forests grow along the banks of rivers, with dominant species like *Acacia nilotica* (Kikar) and *Dalbergia sissoo* (Shisham).
- **Tropical Dry Deciduous Forests** – Found in parts of Punjab with moderate rainfall, these forests contain species such as *Terminalia arjuna, Syzygium cumini* (Jamun), and *Azadirachta indica* (Neem).

4.3 Flora and Threatened Species:

Punjab's flora has been affected by extensive agricultural expansion and deforestation. Some of the key plant species found in Punjab include *Dalbergia sissoo* (Shisham), *Acacia nilotica* (Kikar), *Morus alba* (White Mulberry), and *Saraca asoca* (Asok). However, several species are now facing threats due to overexploitation, habitat destruction, and environmental changes.

Threatened plant species in Punjab include:

- ***Dalbergia sissoo* (Shisham)** – Once abundant, this tree species is now in decline due to fungal infections and climate stress.
- ***Saraca asoca* (Asok Tree)** – Known for its medicinal properties, this species is now rare in the wild.

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[7] Forests, Wildlife and Fisheries Department, Government of the Punjab
[8] Wildlife and Parks Department, Government of the Punjab
[9] Punjab Spatial Strategy, 2047

- *Azadirachta indica* (**Neem**) – Despite its resilience, increasing pollution and land degradation are impacting its natural growth.

4.4 Fauna and Endangered Species

Punjab supports a variety of wildlife, including mammals, birds, reptiles, and aquatic species. However, habitat loss, pollution, and poaching have led to a decline in animal populations. Several species in Punjab are listed as vulnerable or endangered by the International Union for Conservation of Nature (IUCN).

Notable endangered species in Punjab:

- **Indus River Dolphin (*Platanista gangetica* minor)** – Found in the Beas River and Harike Wetland, this species was once thought to be extinct in India but was rediscovered in 2007. The dolphin is classified as endangered and faces threats from water pollution, habitat fragmentation, and fishing activities.
- **Hog Deer (*Axis porcinus*)** – This species is endangered due to habitat loss and poaching. It is found in riverine forests and wetlands.
- **Indian Pangolin (*Manis crassicaudata*)** – A highly trafficked species due to the demand for its scales in illegal wildlife trade.
- **Blackbuck (*Antilope cervicapra*)** – Once widespread, this species now survives in a few protected areas due to excessive hunting in the past.
- **Great Indian Bustard (*Ardeotis nigriceps*)** – Critically endangered and one of the rarest birds in India, it has suffered from habitat destruction and poaching.

Figure 0-3: List of Threatened Flora and Endangered Fauna in Punjab

Name	IUCN Status	Date Assessed
Asiatic Black Bear	VU	17 March 2016
Black Partridge	VU	11 August 2021
Common Leopard	VU	23 October 2022
Fishing Cat	VU	21 June 2016
Goral	NT	14 January 2020
Great Indian Bustard	CR	17 August 2018
Hog Deer	EN	03 December 2014
Honey Badger	NT	28 February 2015
Houbara Bustard*	VU	05 April 2023
Indian Pangolin	EN	10 May 2019
Indus River Dolphin	EN	01 August 2021
Panther	VU	11 July 2015
Punjab Urial	VU	16 March 2020

Sambar Deer	VU	November 2014
See-see Partridge	VU	October 2016
Smooth Coated Otter	VU	21 January 2020
Striped Hyaena	VU	02 October 2014
White Rumped Vulture	CR	07 July 2021

Source: Migratory, IUNC (International Union for Conservation of Nature)

4.5 Protected Areas and Conservation Efforts

Punjab has several protected areas dedicated to the conservation of its forests and wildlife. These include:

- **National Parks** – Punjab has five national parks, including Harike Wetland and Abohar Wildlife Sanctuary.
- **Wildlife Sanctuaries** – There are 36 wildlife sanctuaries, covering areas such as Bir Bhadson, Bir Gurdialpura, and Takhni-Rehmapur.
- **Game Reserves** – 23 game reserves exist to promote conservation while allowing regulated hunting in some cases.
- **Ramsar Sites** – Important wetland areas such as Chashma Barrage, Taunsa Barrage, and the Beas Conservation Reserve are recognized under the Ramsar Convention.

One of the significant conservation achievements in Punjab is the establishment of the **Beas Conservation Reserve**, which covers a 185-kilometer stretch of the Beas River. Declared a Ramsar site in 2019, this reserve aims to protect the Indus River Dolphin and other aquatic species.

Punjab's forests and biodiversity are critical to maintaining ecological balance and supporting local livelihoods. While conservation efforts have shown positive results, more action is needed to address ongoing challenges. The expansion of tree cover, establishment of new wildlife reserves, and strict enforcement of conservation laws can help ensure the protection of Punjab's natural heritage for future generations. Collective efforts from government authorities, conservation organizations, and local communities are vital to preserving the state's rich biodiversity and forest resources.

2. Transport

Punjab leads the rest of the nation in road density, which currently stands at 0.37 km per square kilometers of land. The existing road network in Punjab comprises a diverse network of roads running 75,958 km in length[8]. Approximately 39,029 km of the road network is essentially farm to market roads. Provincial highways account for 10,519 km of both single

and dual carriageways. The national highways and motorways under the regulatory control of the National Highway Authority (NHA) comprise 2061 km and 443 km respectively[10] .

Figure 2-4 : Road Network in the whole Province

3. Mines and Minerals

The Province of Punjab in Pakistan, while primarily known for its fertile agricultural lands, also possesses a noteworthy array of mineral resources. Although not as richly endowed as some other regions of Pakistan, Punjab still contributes to the nation's mineral wealth. Significant deposits of coal are found in the Salt Range region, particularly in areas like Khewra, Dandot, and Pind Dadan Khan. This coal is primarily lignite and sub-bituminous, utilized mainly for power generation and industrial purposes.

Furthermore, Punjab holds substantial reserves of rock salt, famously mined at the Khewra Salt Mines, one of the world's oldest and largest salt mines. This salt is not only used for culinary purposes but also in various industries. Other minerals present in Punjab include gypsum, silica sand, and limestone. Gypsum finds application in cement production and agriculture, while silica sand is crucial for the glass and ceramics industries. Limestone is a vital component in cement manufacturing and construction. While the mining sector in Punjab is not as extensive as in other Provinces, the existing mineral resources play a significant role in supporting local industries and contributing to the overall economic landscape of the region. Further exploration and sustainable mining practices could potentially unlock more of Punjab's mineral potential in the future.

Besides these, Punjab possesses a variety of non-metallic minerals essential for construction and various industries. Limestone and dolomite are abundantly available and are

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[10] Punjab Road Sector Policy 2020

the primary raw materials for the numerous cement plants in the Province. Other important minerals include gypsum, silica sand, fire clay, bentonite, calcite, celestite, chalk, and china clay, each with diverse industrial applications ranging from to ceramics and chemical manufacturing. The Province is also actively exploring and developing its metallic mineral potential. These mineral resources, coupled with value-added gem and jewelry expertise, position Punjab as a vital hub for mining and mineral-based industries in Pakistan, offering considerable opportunities for economic growth and investment.

In short, minerals are indispensable for a healthy economy, providing raw materials, creating jobs, driving development, and supporting technology. Through responsible mining and a focus on sustainability, we can ensure these vital resources continue to benefit society for generations.

Table 2-2: Mineral Wise Production Data: Mines & Minerals Department Punjab (March 2025)[1]

Sr	Mineral	Production in MT
1.	Arg Clay LSM	364620
2.	Bauxite	4143
3.	Bentonite	1615
4.	Brine LSM	5710
5.	Coal	56710
6.	China Clay	1288
7.	Fireclay	79838
8.	Gypsum	81936
9.	Limestone	2278778
10.	Latrite	6794
11.	Rock Salt	265601
12.	Sand	41180

Source: Mines and Minerals Department Punjab

Moreover, Punjab has estimated receipt of 31 billion rupees, non-tax revenue under Mines & Oil-fields & Mineral Development for the financial year 2024-25[11].

4. Agriculture and Livestock

Punjab, often hailed as the 'breadbasket of Pakistan', boasts a robust agricultural and livestock sector that forms the economic backbone of the Province and significantly contributes to the national economy. Agriculture, despite structural shifts in the economy, remains a vital sector, contributing 14% to Punjab's Gross Provincial Product (GPP)[12]. The Province's fertile alluvial plains, coupled with an extensive irrigation system, primarily the Indus Basin Irrigation System, have made it a highly productive agricultural region. Punjab accounts for a dominant

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[11] Finance Department Punjab

[12] Food and Agriculture Organization

share of Pakistan's agricultural output, producing a large percentage of the nation's major crops.

Among the key crops, wheat is paramount, with Punjab contributing approximately 70-75% of Pakistan's total wheat production, making it a staple food crop and a critical component of food security. Rice is another major crop, with Punjab producing around 50-55% of the country's rice, a significant export commodity. Cotton, historically a major cash crop, has seen fluctuating production, but Punjab still remains a key cotton-producing area, contributing about 60-65% of Pakistan's cotton output. Sugarcane is also a significant crop, with Punjab accounting for roughly 65-70% of national production, feeding a large sugar industry[13]. Maize, oilseeds, pulses, and various fruits and vegetables are also cultivated extensively across the province, adding to the diversity of the agricultural sector.

In fiscal year 2023-24, Pakistan witnessed record-breaking harvests in wheat, sugarcane, and rice, with wheat production reaching 28.4 million tons, sugarcane at 87.78 million tons, and rice at 9.92 million tons, a significant portion of which originated from Punjab[14]. The province's well-developed canal network, with around 37,000 Km of canals, plays a crucial role in sustaining this high agricultural productivity.

Alongside agriculture, the livestock sector is equally important in Punjab's rural economy. Livestock contributes around 60% to the overall agricultural value-added and approximately 8% to the national GDP, with Punjab being a major contributor[14]. The province has a large livestock population, including cattle, buffaloes, sheep, goats, and poultry. Buffaloes and cows are prominent for milk production, making Pakistan the 5th largest milk producer globally, with a significant share coming from Punjab. Poultry farming is also well-developed, meeting a substantial portion of domestic meet demand. Punjab's livestock sector not only provides meat, milk, and eggs but also supports various allied industries like dairy processing, leather, and related businesses, significantly boosting rural incomes and employment. The gross value addition of livestock at current basic prices has been showing consistent growth. In FY2023, it was recorded at PKR 5,979,379 million, up from PKR 5,312,744 million in FY2022, highlighting the sector's continuous expansion[15].

Fisheries and forestry, while smaller compared to crops and livestock, also contribute to Punjab's rural economy, adding to the overall agricultural profile of the Province. The integrated agricultural and livestock sectors in Punjab are thus critical for national food security, export earnings, rural livelihoods, and overall economic stability of Pakistan[16].

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[13] Agriculture Department Punjab

[14] Economic Survey of Pakistan 2023-24
[15] Agriculture Department Punjab

[16] Economic Survey of Pakistan 2023-24

Figure 2-05:Mapping of Livestock

5. Industry

Punjab, being the most populous Province of Pakistan, holds a significant industrial profile, contributing substantially to the nation's economy. Accounting for approximately 54.2% of Pakistan's GDP and housing around 68,000 industrial units, Punjab is the industrial heartland of the country. The Province boasts a 58% share in the national manufacturing sector, making it a primary driver of industrial output. The industrial sector in Pakistan, overall, constitutes about 28.11% of the GDP in FY21-22, with manufacturing alone contributing 12.52%. Punjab's dominance in manufacturing is evident, with a large concentration of textile units, which form the backbone of Pakistan's manufacturing base[17].

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[17] Punjab Economic Research Institute

Table 2-3: Production of Major Manufactured Items

Item	Unit of Quantity	Pakistan	Punjab	% Share of Punjab
Cotton Yarn	M.Kg	3446	1007	29.2
Cotton Cloth*	Million Sq. Meters	1051	691	-
Vegetable Ghee	'000' Tons	1401	859	61.3
Sugar^a	-do-	7921	5258	66.4
Fertilizers	-do-	9100	5067	55.7
Cement	-do-	48011	25551	53.2
Paper & Paper Board	-do-	853	731	85.7
Soda Ash	-do-	651	517	79.4
Caustic Soda	-do-	405	252	62.2
Sulphuric Acid	-do-	111	77	69.4
Cigarettes	Million Nos.	59695	18938	31.7

* Production of Cloth in the Punjab is in linear million metres.
ª Includes Sugar produced from Cane, Sugar Beet and Gur.
Source: - i) For Pakistan: Pakistan Economic Survey 2022-23, Islamabad.
ii) For Punjab: CIS Division, Bureau of Statistics, Punjab, Lahore.

The textile industry in Punjab, particularly in Faisalabad, often termed the "Manchester of Pakistan," is the single largest sector, contributing 60% to national exports and 8.5% to the total GDP[17]. Pakistan ranks as the 8th largest textile exporter in Asia and the 4th largest cotton producer globally, heavily reliant on Punjab's textile industry. Beyond textiles, Punjab's industrial landscape is diversifying. Other notable industries include surgical instruments, chemicals, and pharmaceuticals, particularly in areas like Rawalpindi. The manufacturing sector in Punjab is categorized into Large Scale Manufacturing (LSM), Small Scale Manufacturing (SSM), and slaughtering. LSM dominates, accounting for 76.1% of the manufacturing sector's share and 9.73% of the GDP[18].

Recent economic data indicates fluctuating industrial performance. While the Large-Scale Manufacturing (LSM) sector showed a marginal year-on-year growth of 0.02 percent in October 2024, hinting at a gradual recovery, the overall LSM slightly declined by 0.64 percent during July-October FY2025 compared to the previous year. However, certain sectors are showing resilience and growth. For instance, cement dispatches increased by 5.6 percent in November 2024, driven by both domestic demand and a considerable rise in export dispatches by 21.3 percent. This mixed performance reflects ongoing economic challenges and the nascent stages of recovery.

Despite these fluctuations, Punjab's industrial sector remains crucial for employment, with labor Force of Punjab 41.9 million, 58 % of the national (Pakistan's Labor Force is 71.76 million) while the volume of employed persons is 39.1 million, 62.8% of national (Pakistan's volume of employed persons is 67.3 million). 17-20% of the working population engaged in the industrial sector, primarily in manufacturing and construction[19].

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[18] Statistical Pocket Book 2023
[19] Labor Force Survey 2020 – 21

The Punjab government is actively promoting industrial growth through initiatives like Special Economic Zones (SEZs) offering incentives and streamlined services to investors. Key sectors identified for investment and growth include textiles, value-added agriculture, livestock and dairy, and emerging sectors like IT and e-commerce. With its strategic location, robust infrastructure, and a large skilled and young population, Punjab is poised to remain a vital industrial hub in Pakistan, offering considerable opportunities for both local and foreign investment and contributing significantly to the nation's economic progress.

6. Water, Sanitation and Hygiene (WASH)

Punjab, like many developing regions, faces significant challenges in ensuring adequate Water, Sanitation, and Hygiene (WASH) for its population. While progress has been made, access to safe WASH services remains uneven across the Province, particularly between urban and rural areas. Regarding drinking water, while access to improved water sources is relatively high, access to safely managed drinking water is considerably lower. According to a World Bank report, only about 36% of the population in Punjab has access to safely managed drinking water[20].

Figure 2-6: Main Sources of Drinking Water

In terms of sanitation, Punjab fares relatively better compared to drinking water access. Approximately 70.4% of the population has access to improved sanitation facilities[20]. The figure below indicates progress in providing basic sanitation infrastructure. However, improved sanitation doesn't necessarily equate to safely managed sanitation, which includes safe disposal and treatment of wastewater and fecal sludge.

Hygiene practices, especially handwashing with soap at critical times, are crucial in preventing waterborne diseases. While awareness campaigns have been conducted, consistent adoption of proper hygiene behaviors remains a challenge. Socio-economic factors also play a significant role in WASH access. Disparities exist based on household income, education, and location, with marginalized communities often facing greater challenges in accessing WASH services. Efforts are ongoing by the government and various organizations to improve WASH in Punjab through infrastructure development, community awareness programs, and policy interventions. Addressing the challenges of water quality, safe sanitation management, and promoting sustained hygiene behavior change are crucial steps to achieve universal and

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[20] Population and Housing Census 2023

equitable access to WASH in Punjab, ultimately improving public health and well-being across the Province.

TOILET FACILITIES

SEPARATE TOILET 74%   FLUSH 80.%   NO FLUSH 2%   NO TOILET 10 %

Figure 2-7: Toilet Facilities in the Province

7. Social Sector

7.1 Gender

While women make up nearly half of Punjab's population, their representation in the Provincial Assembly is relatively low, 54 female members in the house of 371[21]. This disparity is further highlighted by the fact that only a small fraction of resolutions passed in the Punjab Assembly are initiated by female MPAs. Although women hold a significant percentage of gazetted seats, their underrepresentation extends beyond these sectors. A persistent gender gap also limits their economic participation and opportunities, contributing to widening socio-economic disparities. This is evident in the female Labor Force Participation (LFP) rate in Punjab, which stands at a mere 31%, starkly contrasting with the 84% male LFP rate[22].

7.2 Employment

Employment growth rate is higher in Punjab than the national level. Whereas, employment rate has shown more increase in urban areas as compared to rural areas. With respect to male and female participation in the employment, men far exceed in numbers as compared to women both at national and provincial levels.

Table 2- 4: Economic Survey of Pakistan 2023-24

Area		Employed (Millions)					
		2018-19			2020-21		
		Total	Male	Female	Total	Male	Female
Pakistan	Total	64.03	49.33	14.70	67.25	51.91	15.34
	Rural	42.93	30.59	12.34	45.70	32.79	12.90
	Urban	21.10	18.74	2.36	21.55	19.12	2.44

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[21] *https://www.pap.gov.pk/*

[22] *National Report on the Status of Women 2023*

Punjab	Total	38.21	27.71	10.50	39.07	28.41	10.66
	Rural	26.09	17.29	8.80	40.0	17.91	8.93
	Urban	12.12	10.42	1.70	37.6	10.50	1.74

10.3 Inequality and Poverty

Punjab, while considered Pakistan's most affluent Province, exhibits a multidimensional poverty rate of 30%, according to recent figures, which is notably lower than the national average but still indicates a significant portion of its population experiencing deprivation. When compared to other Provinces, Punjab fares considerably better. Balochistan has the highest multidimensional poverty rate in Pakistan, reaching a staggering 71 percent. Khyber Pakhtunkhwa (KP) follows with 49 percent of its population in multidimensional poverty, and Sindh stands at 43 percent[23]. These figures starkly contrast with Punjab's 30%, underscoring Punjab's relative economic advantage.

While Punjab's poverty rate is the lowest, it's crucial to remember that 30% still represents a large number of individuals facing poverty in health, education, and living standards within the Province. This comparison highlights the uneven distribution of prosperity across Pakistan, with Punjab demonstrating better poverty indicators than other Provinces, yet still requiring sustained efforts to address the needs of its multi dimensionally poor population and ensure more equitable development nationwide[24].

10.4 Child Labor

In Punjab, out of 35.57 M Children (5-16 Years), 9.60 M (27%) are not attending school[24]. Child labor in Punjab, Pakistan, presents a complex and evolving challenge. While commendable strides have been made by the government, in reducing its prevalence within the formal industrial sector of the Province, it remains deeply entrenched in households and agriculture, sectors characterized by informality and weaker regulatory oversight. This disparity highlights the nuanced nature of child labor in Punjab and necessitates targeted strategies to address its persistence in these vulnerable areas. Child labor rates in Punjab are 13.4 and 16.9 per cent for children aged 5-14 and 15-17 respectively[25].

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[23] *Punjab Growth Strategy 2023*

[24] *Punjab Education Sector Plan 2019/20-2023/2024*

[25] *Punjab Education Statistics 2021-22*
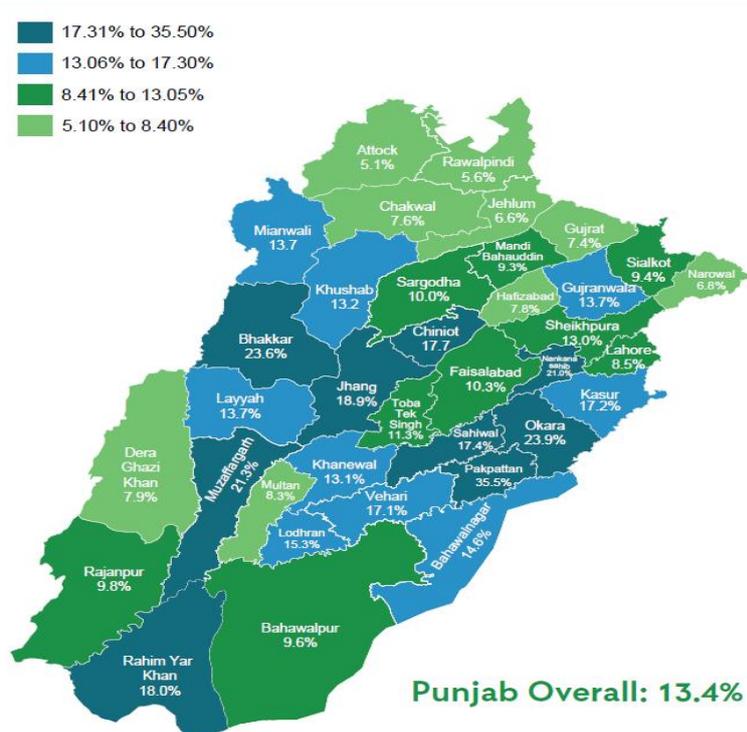
Figure 2-8: Punjab Child Labour Incidence (age 5-14)

In Punjab's industrial zones, particularly in sectors like textiles and manufacturing that face strict government scrutiny, child labor has seen a sharp decline. This progress is also partly attributable to increased awareness among businesses, stricter labor inspections, and the influence of global supply chain ethics. Factories registered under social security programs in Punjab are also mandated to provide benefits like free schooling for workers' children, indirectly reducing child labor in the formal sector.[26]

The consequences for children engaged in labor in Punjab's households and agriculture are dire. They are deprived of their right to education, limiting their future opportunities. They face significant health risks, including injuries, respiratory problems from dust and pesticides in agriculture and brick kilns, and psychological trauma in exploitative domestic work situations[27]. Addressing this deeply rooted issue in Punjab necessitates a multi-faceted approach. This includes strengthening labor inspections in agriculture and informal sectors, expanding access to quality and affordable education, particularly in rural areas, and implementing social safety nets to alleviate poverty-driven child labor. Raising awareness within communities about the harmful impacts of child labor and promoting alternative livelihood options for families are also crucial steps to protect the future of Punjab's children and eradicate this practice from the Province[28].

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[26] Economic Survey of Pakistan 2023-24

[27] Punjab Child Labor Survey 2020

[28] Pakistan Census 2023

8. Education

While Punjab has made strides in school participation over the past five years, significant disparities based on gender, location, and socioeconomic status remain, hindering children's progression beyond primary school. A considerable portion of Punjab's school-age population, approximately 27%, remains out of school. This equates to roughly 9.6 million children aged 5-16 who are not receiving formal education, despite the expansion of both public and private schools[29]. Many of these children live in remote and difficult-to-access areas, requiring targeted interventions to provide them with learning opportunities. Recent data on literacy rates (2018-19 to 2022-23) reveals a slight increase in Pakistan's overall literacy rate (from 62.4% to 62.8%) and a similarly small rise in Punjab (from 66.1% to 66.3%). While rural literacy rates for both males and females in Punjab have seen marginal improvements, female literacy in urban areas has remained stagnant at 74.3% during this period[30].

9. Health & Nutrition

Covering an area of 205,344 square kilometers, Punjab boasts an estimated population exceeding 127 million, with 60% residing in rural areas. The Province's healthcare has an extensive infrastructure comprised of 151 hospitals, 194 dispensaries, 293 Rural Health Centers (RHCs), 2,461 Basic Health Units (BHUs), and 188 Maternal and Child Health Centers (MCHCs), totaling 37,272 beds across various facilities. The Punjab government has earmarked Rs 539.1 billion for the health sector for the financial year 2024-25 with a 24% increase compared to the last budget. Although the health sector faces numerous challenges, yet the overall trends are encouraging.

9.1 Key Health Indicators
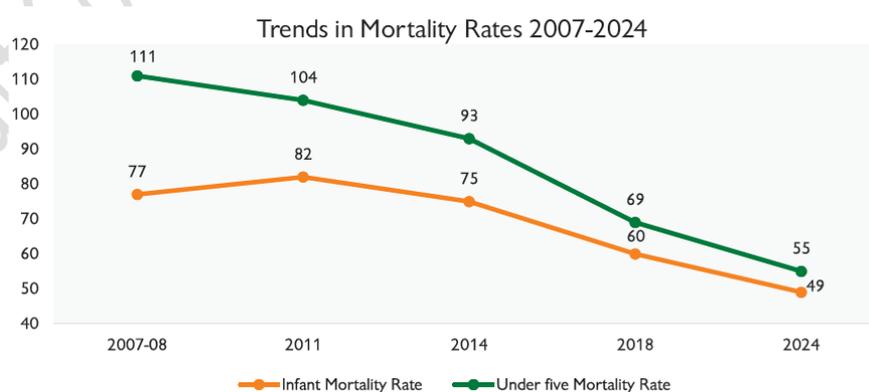
Figure 2- 9: Punjab Multiple Indicator Cluster Survey (MICS) 2024

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[29] Population and Housing Census 2023

[30] Punjab Education Sector Plan 2019/20 – 2023/2024

- **Infant Mortality Rate (IMR):** 55 per 1,000 live births.
- **Under-Five Mortality Rate:** 49 per 1,000 live births.
- **Maternal Mortality Ratio (MMR):** 300 per 100,000 live births, slightly below the national figure of 350.
- **Total Fertility Rate:** 4.7 children per woman.
- **Life Expectancy at Birth:** 64 years[31].

9.2 Access to Essential Services
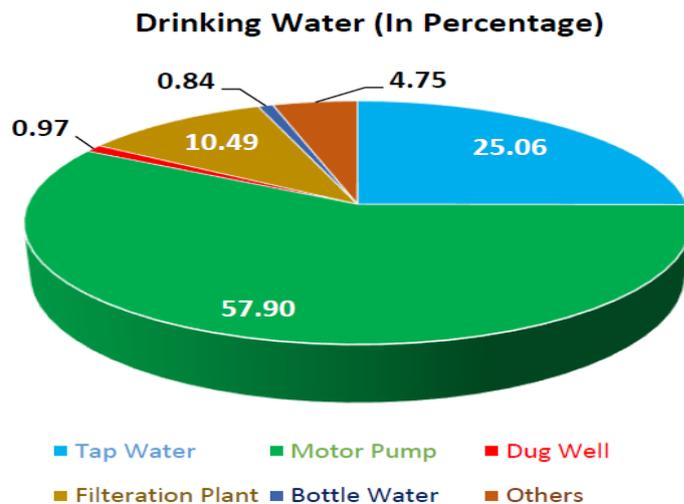
Figure 2-10: Population and Housing Census 2023

Access to improved drinking water sources is available to 92% of the population, while 58% have access to adequate sanitation facilities[26]. However, malnutrition remains a pressing concern, with approximately four million children affected. Over 34% of children under five are stunted, more than 10% are underweight, and over half are anemic. While Punjab has made significant progress in healthcare infrastructure and service delivery, substantial challenges remain. Addressing these issues requires continued investment in healthcare, education, and infrastructure to improve health outcomes for all residents.

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[31]Specialized Healthcare & Medical Education Department

CHAPTER 3   **AIR QUALITY AT PUNJAB**

1. Introduction

Natural air, in its pristine state, is a complex mixture of gases that sustains life on Earth. Approximately 78% of this mixture is nitrogen, 21% is oxygen, and the remaining 1% consists of trace gases like argon, carbon dioxide, and others[1]. However, human activities have significantly altered the composition of natural air, leading to the phenomenon of air pollution. Air pollution is defined as the presence of substances in the atmosphere at concentrations that can harm human health, other living organisms, or the environment[2]. These substances, known as air pollutants, can be in the form of gases, particulate matter, or biological molecules. The primary sources of air pollutants include industrial emissions, vehicular exhaust, agricultural activities, and domestic fuel combustion.

Ambient air quality refers to the condition of the air in the outdoor environment, accessible to the general public. It's a crucial metric for assessing the health risks associated with air pollution exposure. Ambient air quality is often monitored and regulated by government agencies to ensure that pollutant concentrations remain within acceptable limits. The World Health Organization (WHO) has established air quality guidelines (AQGs) that provide recommendations for maximum permissible levels of various pollutants[2]. These guidelines are based on scientific evidence linking air pollution exposure to adverse health effects, including respiratory diseases, cardiovascular problems, and even premature mortality[3].

In regions like Lahore, Pakistan, the ambient air quality is often severely compromised due to rapid urbanization, industrial growth, and agricultural practices like crop burning (Guttikunda et al., 2019). The data presented in the image, showing high PM 2.5 levels, particularly during the winter months, illustrates the severity of the situation. High PM 2.5 concentrations in ambient air are a major health concern, as these fine particles can penetrate deep into the lungs and even enter the bloodstream, causing a range of health problems[4]. Effective air quality management strategies are essential to mitigate air pollution and protect public health. These strategies often involve a combination of regulatory measures, technological solutions, and public awareness campaigns.

Air pollution poses a significant threat to human health, contributing to a wide range of adverse health outcomes. The fine particulate matter (PM2.5), which is prominently featured in the provided data for Lahore and other Pakistani cities, is particularly concerning. These particles, due to their small size, can penetrate deep into the lungs and even enter the bloodstream,

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[1] Seinfeld, J. H., & Pandis, S. N. (2016). *Atmospheric chemistry and physics: from air pollution to climate change*. John Wiley & Sons.

[2] WHO. (2021). *WHO global air quality guidelines: particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide*

[3] Pope, C. A., & Dockery, D. W. (2006). Health effects of fine particulate air pollution: lines that connect. *Journal of the Air & Waste Management Association*, *56*(6), 709-742.

[4] Kelly, F. J., & Fussell, J. C. (2019). Air pollution and public health: emerging hazards and improved understanding of risk. *Environmental geochemistry and health*, *41*(3), 631-643.

causing both respiratory and cardiovascular problems[5]. Exposure to PM2.5 has been linked to increased risk of asthma exacerbations, chronic obstructive pulmonary disease (COPD), lung cancer, and heart attacks[6]. In Lahore, with its alarmingly high PM2.5 levels, the population is particularly vulnerable to these health hazards.

Beyond particulate matter, other air pollutants like nitrogen dioxide (NO2) and ozone (O3) also contribute to respiratory illnesses. NO2, primarily emitted from vehicular exhaust, can irritate the airways and trigger asthma attacks[7]. Ozone, a secondary pollutant formed from the interaction of sunlight with other pollutants, can cause chest pain, coughing, and throat irritation. Long-term exposure to these pollutants can lead to the development of chronic respiratory diseases and reduce lung function. Furthermore, air pollution has been associated with adverse effects on cognitive development, particularly in children, and an increased risk of neurological disorders[8].

The health impacts of air pollution are not limited to respiratory and cardiovascular systems. Studies have also linked air pollution to increased risk of diabetes, reproductive problems, and even premature death[9]. The economic burden associated with these health impacts is substantial, including increased healthcare costs, lost productivity, and reduced quality of life. In a city like Lahore, where air pollution levels are consistently high, the health and economic consequences are likely to be significant. Therefore, effective air pollution control measures are essential to protect public health and mitigate the long-term health hazards associated with air pollution exposure.

2. Factors Contributing to Air Pollution

The major air pollutant in the district of Lahore is particulate matter. The ambient air quality data indicated that PM10 and PM2.5 are major pollutants leading to increase the air pollution in the region. Various factors contribute to increasing the PM, include the following:

a. Industrial Emissions:
Lahore, being the capital of Punjab, is the largest industrial hub of the province. The two majors industrial Estate include Quaid-e-Azam Industrial Estate and Sundar Industrial Estate. Many other Industrial clusters mostly in northern Lahore comprises of industries like steel mills, resource recovery units, textile, pyrolysis plants, food, pharmaceutical, paper, chemical etc. release substantial quantum of particulate matter, sulfur dioxide (SO2), nitrogen oxides (NOx), and other pollutants in the form of stack gaseous emissions into the atmosphere. Due to

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[5] Kelly, F. J., & Fussell, J. C. (2019). Air pollution and public health: emerging hazards and improved understanding of risk. *Environmental geochemistry and health*, *41*(3), 631-643.

[6] Pope, C. A., & Dockery, D. W. (2006). Health effects of fine particulate air pollution: lines that connect. *Journal of the Air & Waste Management Association*, *56*(6), 709-742.

[7] WHO. (2021). *WHO global air quality guidelines: particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide*

[8] Block, M. L., Elder, A., Auten, R. L., Bilbo, S. D., Chen, H., Chen, J. C., ... & Wright, R. J. (2012). The outdoor air pollution and brain health workshop. *Neurotoxicology*, *33*(5), 972-984.

[9] Apte, J. S., Brauer, M., Cohen, A. J., Ezzati, M., & Pope III, C. A. (2018). Ambient PM2. 5 reduces global and regional life expectancy. *Environmental Science & Technology Letters*, *5*(9), 546-551.

outdated technologies and inefficient emission control devices, air pollution is the biggest challenge in Lahore.

b. Vehicular Emissions:

Rapid urbanization and increasing vehicle ownership have led to a surge in traffic congestion in Lahore. Older vehicles with inefficient engines and poor maintenance contribute significantly to air pollution. Adulterated fuel is another major factor responsible for air pollution in the province.

c. Agricultural Practices:

Punjab referred as the "breadbasket of Pakistan," and a major agricultural region, in which variety of crops cultivated across different seasons. The two primary cropping seasons are Rabi (winter) and Kharif (summer). During the Rabi season, the major crops include wheat, which is the staple food crop, along with barley, gram (chickpeas), and oilseeds like mustard and rapeseed. The harvesting of Rabi crops typically occurs from April to May. The Kharif season sees the cultivation of key crops such as rice (paddy), which is a water-intensive crop widely grown, maize (corn), cotton, and sugarcane. The harvesting period for Kharif crops generally extends from September to November. Crop residue burning, a significant contributor to air pollution, is particularly prominent during two periods. After the Rabi harvest in April-May, wheat straw is often burned to clear the fields quickly for the subsequent Kharif sowing. However, the most intense period of crop residue burning and its consequent impact on air quality, especially leading to the severe smog in Lahore and surrounding areas, occurs after the Kharif harvest in October and November, when large volumes of rice straw are burned. This practice coincides with stable atmospheric conditions, trapping pollutants and exacerbating air pollution levels across Punjab.

d. Meteorological Conditions:

Punjab, Pakistan experiences a distinct annual pattern of meteorological conditions characterized by four main seasons. The **winter season**, typically spanning from November to February, is marked by cool to cold temperatures, with average lows ranging from 4-10°C and highs from 16-22°C. Fog is a common occurrence, particularly in the plains, and occasional rainfall can occur due to western disturbances. The transition to **spring**, from March to mid-April, brings a gradual increase in temperatures, with pleasant days and cooler nights. This period often sees blooming vegetation and relatively dry conditions. The **summer season**, extending from mid-April to September, is characterized by intense heat, with temperatures frequently exceeding 40°C and sometimes reaching extreme highs. Dry and hot winds, known as "loo," are common during the day. The monsoon season, usually from July to September, brings significant rainfall, high humidity, and a slight respite from the extreme heat. During the winter months, temperature inversions trap pollutants near the ground, preventing their dispersion. Low wind speeds further contribute to the accumulation of pollutants, leading to the formation of thick smog. This meteorological phenomenon, combined with the emission sources mentioned above, results in the extremely high PM2.5 levels observed in the data.

e. Urbanization and Construction Activities:

Rapid urban expansion and ongoing construction activities generate fugitive dust and particulate matter. The proper dust control measures on construction sites is now a days focus to control pollution.

f. Domestic and Commercial Fuel Combustion:

For domestic and commercial heating and cooking purposes the use of biomass like wood, coal, cardboard, LPG, kerosene oil etc. as fuel contributes to indoor and outdoor air pollution.

3. Smog in Punjab:

Smog in Punjab, particularly during the late autumn and winter months, has become a severe and recurring environmental and public health crisis. This dense, hazardous haze blankets the plains of the province, including major urban centers like Lahore, Faisalabad, and Multan, significantly reducing visibility and drastically degrading air quality. The formation of smog is a complex interplay of meteorological conditions and a multitude of anthropogenic emissions. As the monsoon recedes and temperatures drop, stable atmospheric conditions with low wind speeds and frequent temperature inversions trap pollutants close to the ground, preventing their dispersal. This meteorological setup coincides with peak emissions from various sources, most notably the widespread burning of rice straw after the Kharif harvest in October and November. Smoke from these agricultural fires, laden with particulate matter, travel across the landscape, engulfing cities. Additionally, industrial emissions from numerous factories, including steel mills and brick kilns often operating with outdated technologies, and the ever-increasing vehicular exhaust in urban areas further contribute to the smog's intensity and persistence. The resulting cocktail of pollutants, dominated by fine particulate matter (PM2.5), poses significant health risks to the population, leading to a surge in respiratory illnesses, cardiovascular problems, and other adverse health outcomes, severely impacting daily life and the overall well-being of the residents of Punjab

a. Air Pollution

Major urban and industrial center in the agricultural heartland of Punjab faces a severe air pollution crisis, particularly during the winter months. The data consistently highlights alarmingly high levels of particulate matter, especially PM2.5, exceeding national and international safety standards. This pollution is a complex issue stemming from a confluence of sources, including substantial industrial emissions from sectors like steel and numerous brick kilns operating often with outdated technologies. The burgeoning vehicle fleet, comprising both old and new vehicles, contributes significantly through exhaust emissions, exacerbated by traffic congestion. Furthermore, the widespread practice of agricultural residue burning in the surrounding regions, particularly the burning of rice straw after the Kharif harvest, sends plumes of smoke and particulate matter into the city. Meteorological conditions, especially the prevalence of temperature inversions and low wind speeds during winter, trap these pollutants, leading to the formation of dense and hazardous smog. This cocktail of emissions poses a significant threat to public health and the overall environment of Lahore.

b. Smog in Lahore and Central Punjab:

Smog in Lahore and central Punjab is a recurring and severe environmental phenomenon, primarily occurring from late autumn to winter. **From a health perspective**, this dense haze of pollutants, rich in PM2.5, poses significant risks to the respiratory and cardiovascular systems. Residents experience increased incidence of asthma attacks, bronchitis, COPD exacerbations, and even higher rates of heart attacks and strokes. Children and the elderly are particularly vulnerable. Long-term exposure to such high levels of air pollution is linked to chronic respiratory diseases, lung cancer, and reduced life expectancy. The reduced visibility caused by smog also leads to traffic accidents, further impacting public safety. **Meteorologically**, smog formation in Lahore is heavily influenced by the region's annual

weather pattern. The transition from the monsoon to the dry winter sees stable atmospheric conditions, characterized by low wind speeds that hinder the dispersion of pollutants. Crucially, frequent temperature inversions, where a layer of warm air sits above cooler surface air, act as a lid, trapping pollutants emitted at ground level. The lack of rainfall during this period further exacerbates the accumulation of particulate matter and gaseous pollutants, creating the dense, persistent smog that blankets the city.
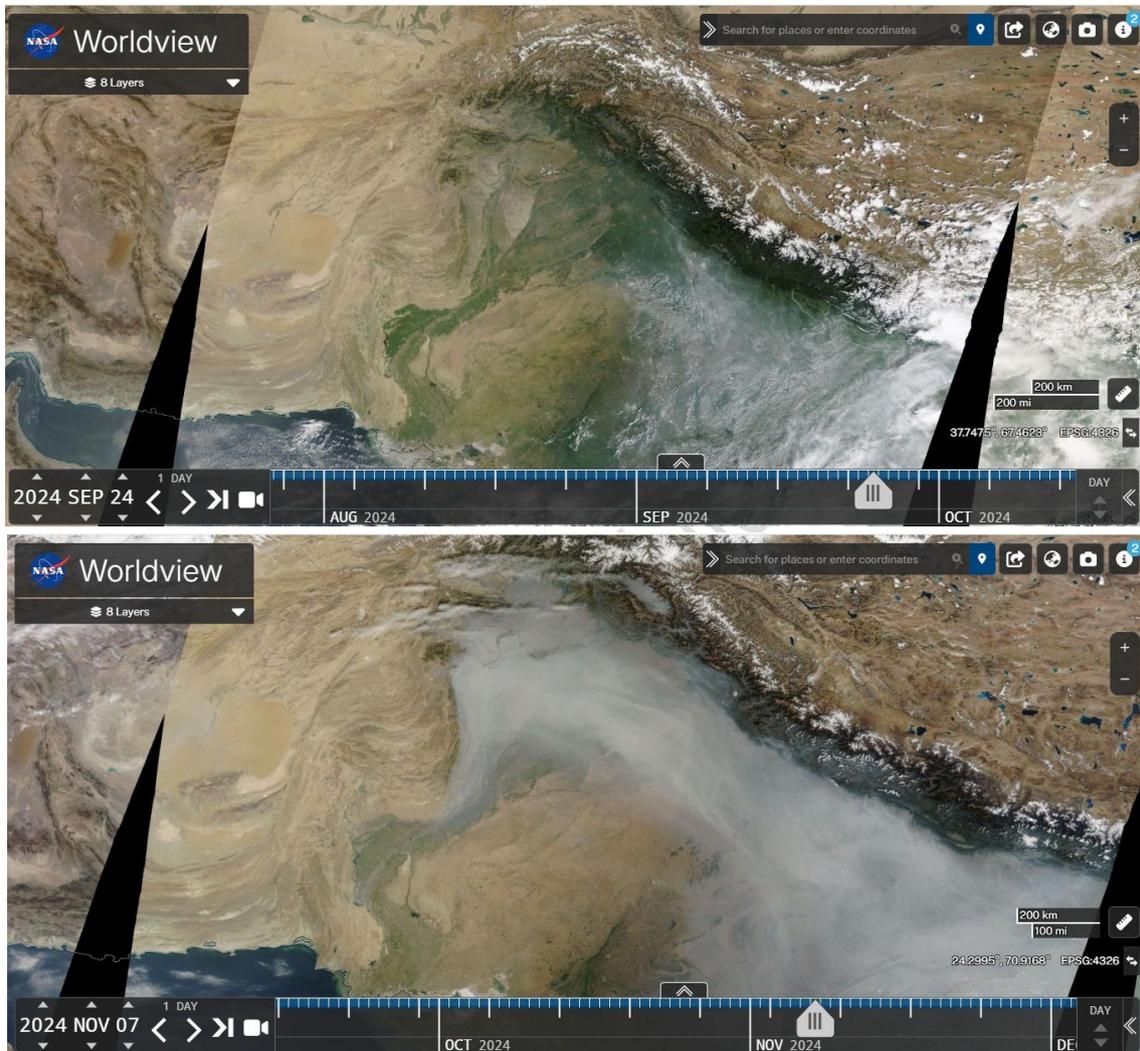
Figure 0-1: NASA satellite image of Lahore and New Delhi before and during Smog season (Source: NASA website earthdata.nasa.gov)

c. Mitigation Measures:

Addressing the complex air pollution crisis in Lahore requires a multi-pronged approach encompassing various mitigation measures. On the industrial front, the EPA's enforcement of emission control technologies in steel industries and on industrial boilers is crucial, mandating the adoption of cleaner technologies like baghouse filters and scrubbers. To tackle vehicular emissions, stricter enforcement of vehicle inspection and certification systems, promotion of cleaner fuels like CNG and potentially electric vehicles, and improvements in public transportation infrastructure are necessary to reduce the number of polluting vehicles on the road. Combating agricultural pollution requires strict enforcement of bans on crop residue

burning, coupled with the provision of viable and economically feasible alternatives for farmers to manage crop waste. For fugitive dust, particularly from construction activities and the transportation of materials, the EPA's directive to cover trolleys carrying sand and construction material is a positive step, and its rigorous implementation is essential. Furthermore, exploring and evaluating innovative solutions like smog towers, while acknowledging their limitations, can contribute to localized air purification efforts. Finally, sustained public awareness campaigns are vital to educate citizens about the sources and health impacts of air pollution and encourage behavioral changes.

d. Enforcement Activities by EPA Punjab

The EPA Punjab plays a critical role in enforcing environmental regulations to control air pollution in Lahore across various sectors. For industry, enforcement activities include regular inspections of industrial units to ensure compliance with the Pakistan Environmental Quality Standards (PEQS) for emissions. This involves verifying the installation and proper functioning of pollution control technologies and taking action against non-compliant facilities through fines, legal notices, and potential shutdowns. Brick kilns, a significant source of particulate matter, are subject to specific regulations regarding their design and emissions. The EPA conducts inspections to ensure kilns are operating with mandated technologies and are not contributing excessively to smog. In the vehicle sector, the Vehicle Inspection and Certification System (VICS) is a key enforcement tool, identifying and penalizing vehicles that fail to meet emission standards. Roadside checks are also conducted to monitor visible smoke and enforce compliance. Regarding ambient air quality, the EPA operates a network of monitoring stations across Lahore to track pollutant levels. This data is used to assess compliance with PEQS, identify pollution hotspots, and inform enforcement strategies targeting specific sources contributing to poor ambient air quality. The EPA also responds to public complaints and conducts investigations into potential violations of environmental regulations, aiming to hold polluters accountable and improve the overall air quality in Lahore

4. Role of Meteorology

The data provided, especially when considering the Lahore context, highlights the significant role meteorological parameters play in influencing air pollution levels. Here's a breakdown of how meteorological conditions interact with air pollutants:

a. Temperature Inversions:
- During winter months, particularly in cities like Lahore, temperature inversions are common. Normally, the air temperature decreases with altitude. However, during an inversion, a layer of warm air traps cooler air near the ground.
- This creates a stable atmospheric condition that prevents the vertical dispersion of pollutants. As a result, pollutants like PM2.5, emitted from vehicles, industries, and agricultural burning accumulate near the surface, leading to high concentrations.
- The data shows a dramatic increase in PM2.5 during the winter months (November and December) across all cities, which is a direct consequence of temperature inversions.

b. Wind Speed and Direction:

- Wind speed plays a crucial role in dispersing pollutants. Stronger winds can dilute and carry pollutants away from their sources, improving air quality.
- Conversely, low wind speeds, as observed during the winter months, allow pollutants to accumulate. Lahore, being an inland city, is particularly susceptible to this.
- Wind direction also influences the transport of pollutants. For example, smoke from agricultural burning in surrounding areas can be carried by wind towards Lahore, contributing to its air pollution.

c. Humidity:
- Humidity can affect the formation and behavior of certain pollutants. High humidity can promote the formation of secondary pollutants, such as particulate matter and ozone.
- It can also affect the size and composition of particulate matter, influencing its ability to penetrate deep into the lungs.

d. Precipitation:
- Rainfall can effectively remove pollutants from the atmosphere through a process called wet deposition. Rain droplets can scavenge particulate matter and gaseous pollutants, bringing them to the ground.
- The lack of rainfall during the dry winter months in Lahore contributes to the accumulation of pollutants.

e. Sunlight:
- Sunlight plays a crucial role in the formation of ground-level ozone, a secondary pollutant.
- Photochemical reactions driven by sunlight can transform primary pollutants, such as NOx and VOCs, into ozone.

f. Impact on Lahore:
- Lahore's geographic location and meteorological conditions make it particularly vulnerable to air pollution. The city's location in the Indo-Gangetic Plain, combined with low wind speeds and frequent temperature inversions during winter, results in severe smog episodes.
- The data clearly shows that the highest PM2.5 values are shown during the winter months.
- The high population density of Lahore, combined with the other factors, creates a severe pollution problem

5. Role of EPA to control air pollution

The Environmental Protection Agency (EPA) plays a crucial role in controlling air pollution and implementing mitigation measures, particularly in regions like Lahore where air quality is a significant concern. Here's a breakdown of the EPA's responsibilities and actions, with a focus on regulatory frameworks:

a. Regulatory Framework:
- **Development and Enforcement of Standards:**
  - The EPA is responsible for establishing and enforcing ambient air quality standards, often referred to as Pakistan Environmental Quality Standards (PEQS). These standards set permissible limits for various air pollutants,

including PM2.5, which is a major concern in Lahore, as shown in the provided data.

o The EPA develops and implements regulations to control emissions from various sources, including industries, vehicles, and agricultural activities.

- **Smog Policy and Action Plans:**
  o The EPA formulates and implements smog policies and action plans, particularly during the winter months when air pollution levels are at their peak.
  o These policies often include measures such as restrictions on industrial activities, traffic management, and control of agricultural burning.

- **Environmental Impact Assessments (EIAs):**
  o The EPA conducts environmental impact assessments of proposed development projects to ensure that they comply with air quality regulations.
  o This helps prevent the establishment of new pollution sources and mitigates the environmental impact of existing ones.

- **Monitoring and Enforcement:**
  o The EPA monitors air quality through a network of monitoring stations.
  o It enforces environmental regulations through inspections, fines, and legal actions against violators.

- **Coordination and Collaboration:**
  o The EPA coordinates with other government agencies, industries, and civil society organizations to address air pollution issues.
  o It also collaborates with international organizations to exchange knowledge and best practices.

b. Mitigation Measures:

In addition to regulatory frameworks, the EPA also implements various mitigation measures to control air pollution:

- **Promoting Cleaner Technologies:** Encouraging industries to adopt cleaner technologies and processes to reduce emissions.
- **Promoting Cleaner Fuels:** Promoting the use of cleaner fuels, such as CNG and LPG, in vehicles and industries.
- **Controlling Vehicular Emissions:** Implementing vehicle inspection and maintenance programs and promoting the use of electric vehicles.
- **Controlling Agricultural Burning:** Enforcing bans on crop residue burning and promoting alternative agricultural practices.
- **Increasing Green Cover:** Promoting tree planting and urban greening to absorb pollutants and improve air quality.
- **Public Awareness Campaigns:** Educating the public about the health impacts of air pollution and encouraging them to adopt sustainable practices.

- Enforcing regulations in a rapidly urbanizing and industrializing city like Lahore can be challenging.
- The large number of vehicles and industries makes monitoring and enforcement difficult.
- Public awareness and behavior change are essential for long-term success.

6. EPA Enforcement: Installation of emission control system on Steel Induction Furnaces

Figure 3-02: Stack Emission Monitoring at Meezan Incinerator Lahore

Table 3-1 shows a significant decrease in total PM emissions from steel induction furnaces from 2021 to 2024, calculated based on zinc ash generation[10]. Here's a breakdown of the contributing factors:

- Zinc ash is a byproduct of the steelmaking process in induction furnaces, and it's used as a basis for estimating PM emissions. The variation in zinc ash production from year to year (2218.32 tons in 2021, peaking at 2972.26 in 2022, then decreasing) indicates changes in overall steel production volume.
- Decreasing Number of Units Without ECS: The most significant factor is the dramatic reduction in the number of steel induction furnace units operating without Emission Control Systems (ECS). In 2021, 69 units operated without ECS, contributing 2155.83 tons of PM. By 2024, this number has dropped to just 1 unit, contributing only 25.842 tons of PM. This demonstrates the successful implementation of ECS across the steel industry.
- No. of Units With ECS: This shows the number of units equipped with ECS. The number increases from 2 in 2021 to 70 in 2023 and remains stable in 2024.
- Respective Emissions (25-79%) ave. 60% collection efficiency due to ECS installation) (Tons per Year): This row calculates the total PM emitted by the units with ECS. It's calculated as follows:
- First, the PM emissions *without* ECS for these units are calculated (just like in row 4, but for the units *with* ECS).
- Then, this value is multiplied by (1 - collection efficiency). Since the collection efficiency is (25-79%) ave. 60%, the multiplication factor is (1 - 0.60) = 0.40. This means that only 40% of the potential emissions are actually released because 60% are captured by the ECS.
- Increasing Number of Units With ECS: Correspondingly, the number of units *with* ECS has increased significantly. In 2021, only 2 units had ECS installed. By 2024, this number has risen to 70 units.

The combined effect of these factors resulted in a substantial decrease in total PM emissions from all steel induction furnace units. From 2193.33 tons in 2021, total emissions decreased to 1111.21 tons in 2024, representing a 49.34% reduction.

Table 3-1: Comparison of PM emissions from Steel Furnaces in Lahore from 2021 to 2024

		2021	2022	2023	2024	Improvement (2024 Vs 2021)
1.	Zick Ash Per Year in tons	2218.32	2972.26	1753.13	1834.78	
2.	Average PM emission Per Unit Per Year (Tons) if all units have working without ECS	31.2439	41.8629	24.692	25.842	
3.	No. of units without ECS	69	6	1	1	
	Respective emissions without ECS (Tons per year)	2155.83	251.177	24.692	25.842	
4.	No. of units with ECS	2	65	70	70	

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[10] Economic Survey of Pakistan, 2023-24

	Respective emissions (25-79%) ave. 60% collection efficiency due to ECS installation) (Tons per Year)			37.4927	1632.65	1037.06	1085.36	
5.	Total PM emissions from all Steel induction units per year ECS (Tons) (with ECS + without ECS)			2193.33	1883.83	1061.76	1111.21	49.34%

(Source: Based on Economic Survey of Pakistan, 2023-24)

7. Installation of Emission Control System on Boilers

Table 3-2 presents data on particulate matter (PM) emissions from 600 boilers between 2020-21 and 2023-24. In 2020-21, with an average PM concentration of 601.9 mg/m³ and a combined flow rate of 1,940,876.9 m³/hr from 600 boilers, the annual PM emissions were 4056.365 tons. However, by 2023-24, the average PM concentration decreased to 451.425 mg/m³. Despite the same flow rate, this reduction in PM concentration resulted in lower annual emissions of 3042.273756 tons in 2023-24. This represents a 25% reduction in PM emissions from the 600 boilers over this period.

Table 3-2: Calculation of emissions from boilers in Lahore during 2020-21 and 2023-24 based on 09 hours a days and 350 days a year

		mg/m3	flow rate from all kind 600 Boilers m3/hr	Discharge mg/hr	Ton per hours	Ton per Day	Tons per Year	Reduction %
PM	2020-21	601.9	1940876.9	1168.21	1.28	11.58	4056.36	
PM	2023-24	451.4	1940876.9	876.16	0.96	8.69	3042.27	25%

Table 3-3 demonstrates a significant reduction in particulate matter (PM) emissions from 600 boilers located in the District of Lahore between 2020-21 and 2023-24. This reduction is attributed to the continuous efforts of the Environmental Protection Agency (EPA) in promoting and enforcing the installation of Emission Control Systems (ECS), specifically Wet Scrubbers, on these boilers.

The data reveals a steady decline in annual PM emissions. In 2020-21, the total annual PM emissions from these boilers were 4056.39 tons. Through consistent interventions by the EPA, this figure decreased to 3934.69 tons in 2021-22, further reduced to 3752.86 tons in 2022-23, and ultimately reached 3042.29 tons in 2023-24. This represents a substantial 25% reduction in PM emissions over the four-year period.

This trend suggests that the EPA's initiatives to encourage and enforce the installation of Wet Scrubbers on boilers have been effective in mitigating PM emissions and improving air quality

in the District of Lahore. These efforts are crucial for safeguarding public health and environmental sustainability in the region.

Table 3-3: Comparison of PM emissions from boilers in Lahore from 2020-21 to 2023-24

Sr. No	Category of Industry		2020-21	2021-22	2022-23	2023-24	Reduction%
1	**Boilers** Total: 600 Boilers with ECS: 540	PM (Tons per Year)	4056.39	3934.69	3752.86	**3042.29**	25%

The data demonstrates a significant reduction in PM emissions from steel induction furnaces in the region between 2021 and 2024. This decline can be primarily attributed to the successful implementation of Emission Control Systems (ECS) in a large number of units.

In 2021, a substantial portion of PM emissions originated from units operating without any ECS. However, by 2024, a significant number of units (from 2 to 70) had installed ECS, leading to a dramatic decrease in emissions from these sources. This highlights the effectiveness of the policy interventions aimed at promoting and enforcing the installation of pollution control equipment.

Similarly, there was a significant reduction in Particulate Matter (PM) emissions from 600 boilers in the District of Lahore between 2020-21 and 2023-24. This positive trend can be attributed to the proactive efforts of the Environmental Protection Agency (EPA) in promoting and enforcing the installation of Emission Control Systems (ECS), specifically Wet Scrubbers, on these boilers. The observed 25% decrease in PM emissions over the four-year period highlights the effectiveness of these interventions in mitigating air pollution and improving air quality in the region.

This success underscores the importance of continued and sustained efforts by the EPA in monitoring, regulating, and enforcing environmental regulations within the industrial sector. By promoting cleaner technologies and incentivizing the adoption of pollution control measures, the EPA can play a crucial role in safeguarding public health and environmental sustainability in Lahore and beyond.

8. Air Quality Monitoring Network

The Environmental Protection Agency (EPA) Punjab plays a vital role in monitoring and managing air quality across the province, with a particular focus on Lahore, given its severe air pollution challenges. To achieve this, the EPA has established an air quality monitoring network.

In 2024, the air quality monitoring network in Punjab, Pakistan, experienced significant expansion and enhancement. While the Punjab Environment Protection Agency (EPA) initially

operated three Air Quality Monitoring Stations (AQMS) in Lahore (two fixed and one mobile), an additional 13 AQMS were added during 2024 (eight fixed and five mobile), bringing the total to 15 stations within Lahore.

The Environment Protection Agency (EPA) Punjab, Pakistan, plays a crucial role in monitoring and managing the air quality across the province. At present, the EPA Punjab operates a network of 16 Air Quality Monitoring Stations (AQMS) within Lahore alone, forming a core part of its broader surveillance efforts. These stations are strategically located to gather real-time data on various ambient air pollutants, including particulate matter (PM2.5, PM10), carbon monoxide (CO), sulfur dioxide (SO2), nitrogen oxides (NOx), and ozone (O3). The data collected from this network is instrumental in assessing the Air Quality Index (AQI), identifying pollution hotspots, and informing policy decisions aimed at mitigating air pollution. Beyond Lahore, EPA Punjab is aiming to maintain additional AQMS in other major cities and industrial zones across the province, contributing to a more comprehensive understanding of regional air quality trends. This extensive monitoring infrastructure allows the EPA to track seasonal variations, identify major sources of pollution (such as industrial emissions, vehicular exhaust, and transboundary smog), and evaluate the effectiveness of implemented environmental regulations and initiatives, such as the "Clean Punjab" program or actions against industrial violators. The continuous collection of this data is vital for public health advisories, environmental impact assessments, and guiding efforts towards achieving cleaner and healthier air for all citizens of Punjab.

Beyond Lahore, the Punjab government initiated a broader installation program for future, planning to deploy 30 advanced air quality monitors across various cities. As part of this expansion, Lahore's monitoring capacity was specifically increased to eight units, with new fixed monitors strategically placed at key locations including THQ Kahna, Jiya Bhagga Police Station, Shahdara Teaching Hospital, Punjab University, and Wildlife Park, Raiwind. The five new mobile AQMS in Lahore were strategically positioned in highly polluted areas such as Defense Housing Authority, Model Town, Gulberg, Bhatta Chowk, and near Shimla Pahari, allowing for flexible monitoring of hot spots. The location of mobile AQMS could be changed as per requirement.

The network's reach is planned to be extended to other major cities across Punjab, including Rawalpindi (three monitors), Faisalabad, Sheikhupura, and Sialkot (one each), and Multan, Gujranwala, and Bahawalpur (two each). Additionally, Sargodha (two monitors) and Dera Ghazi Khan (one monitor) were expected to have their systems activated in near future. All these monitoring devices are linked to the EPA's central control room for real-time data collection. Daily air quality data from these stations is made available in the SMOG War Room (EPA Control Room) and on the EPA website for public access.

a. Air Quality Monitoring Network in Lahore:
- The EPA currently operates 15 Air Quality Monitoring Stations (AQMS) within Lahore, with 06 mobile and 09 fixed AQMS. These stations are strategically located to provide a representative picture of air quality across the city, capturing variations in pollution levels due to different sources and urban characteristics.
- These stations continuously measure key air pollutants, including PM2.5, PM10, nitrogen oxides (NOx), sulfur dioxide (SO2), ozone (O3), and carbon monoxide (CO).
- The real-time data collected from these stations is crucial for assessing air quality, identifying pollution hotspots, and informing policy decisions.

- Recognizing the growing air pollution concerns in other major cities of Punjab, the EPA is now expanding its air quality monitoring network to include Multan and Faisalabad.
- This expansion is crucial for:
- Assessing the extent of air pollution in these cities.
- Identifying the specific sources of pollution.
- Developing targeted mitigation strategies.
- Protecting the health of the residents.
- Multan and Faisalabad are experiencing rapid urbanization and industrial growth, leading to increased vehicular traffic, industrial emissions, and other pollution sources.
- Expanding the monitoring network will provide valuable data to understand the air quality situation in these cities and implement effective control measures.
- This expansion will allow for the EPA to have a broader understanding of the air quality across the province.

Figure 3-03: Mobile Ambient air Quality Monitoring Station

b. **Role of the Network:**

- **Data Collection and Analysis:** The AQMS network provides continuous data on air pollutant concentrations, which is analyzed to assess air quality trends and identify pollution sources.
- **Public Information:** The EPA disseminates air quality data to the public through websites, mobile apps, and other channels, raising awareness about air pollution and its health impacts.
- **Policy Formulation:** The data collected from the network informs the development of air quality management policies and regulations.
- **Enforcement:** The monitoring data is used to enforce environmental regulations and take action against polluters.
- **Research:** The network provides valuable data for research on air pollution and its health effects
- **Air Quality Monitoring network across the Lahore**

EPA Punjab has been monitoring air quality with 16 AQMSs across the Lahore. Four AQMSs have been deputed temporarily near the SCT to monitor its efficiency. Figure 3-4 shows air quality data of 14 AQMS across the Lahore on December 25, 2024. EPA Punjab's air quality monitoring network across Lahore recorded elevated AQI levels at all 14 monitoring sites, indicating widespread air pollution.

Note: Parameter used to Calculate AQI = *Particulate Matter (PM2.5)*-PEQs value of PM2.5= **35 μg/m³**
All hourly values of AQI in Lahore are monitored by EPA Punjab- Air Quality Monitoring Stations
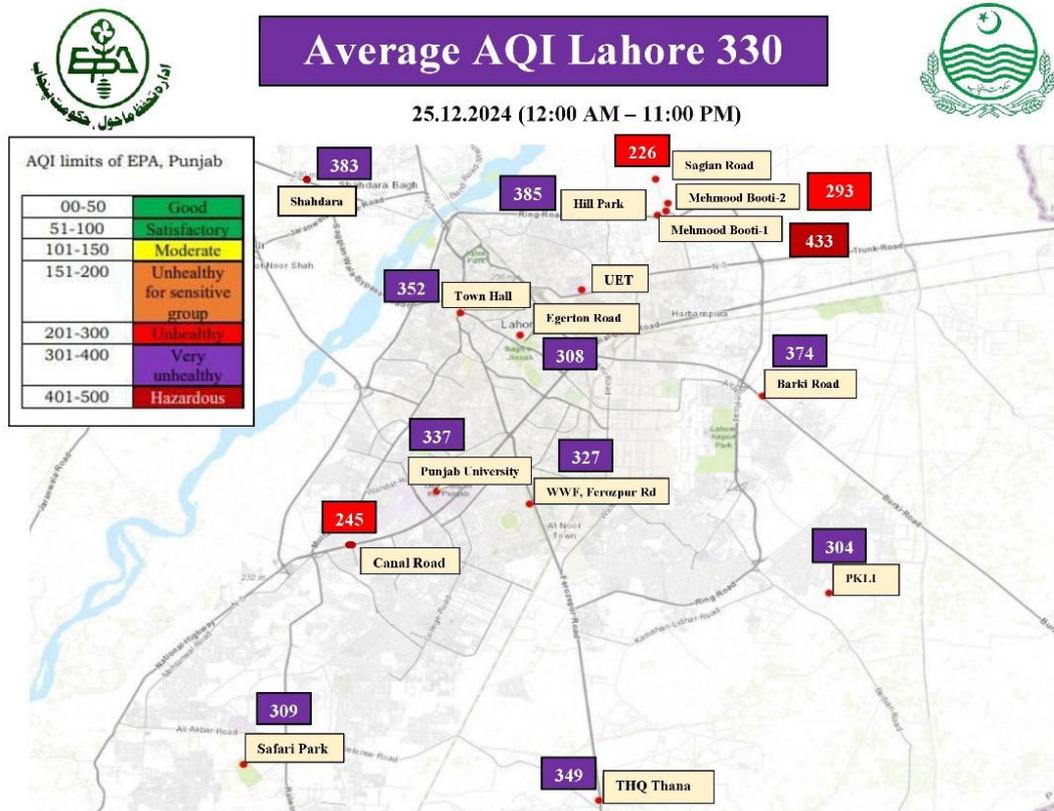
Figure 3-4: Ambient Air Quality Monitoring by EPA Punjab at 14 points across the Lahore

Monthly Trend of Air Quality

Figure 3-5 illustrates a potential relationship between temperature and PM 2.5 levels. The bars represent monthly average PM 2.5 concentrations, exhibiting a clear seasonal trend with peak levels during the colder months (October to February) and lower levels during the warmer months (April to September). The solid line depicts the average monthly temperature, which generally follows a similar seasonal pattern. A polynomial curve fitted to the PM 2.5 data (dotted line) suggests a correlation between temperature and PM 2.5 levels, with an R-squared value of 0.5927. This indicates that approximately 59% of the variation in PM 2.5 levels can be explained by temperature variations. But other factors not accounted for in the model (such

as wind speed, humidity, and human activities) play a significant role in determining the remaining 41% of the variation.

Higher PM 2.5 levels during winter months could be partially attributed to lower temperatures, which can facilitate temperature inversions and increase the use of residential heating systems. Conversely, higher temperatures in summer may lead to increased atmospheric mixing and dispersion of pollutants, contributing to lower PM2.5 levels. However, it is crucial to remember that this correlation does not necessarily imply causation. Other factors, such as wind speed, humidity, and human activities, significantly influence PM2.5 levels. Therefore, while temperature plays a role, it is not the sole determinant of PM2.5 concentrations. AQMS were not installed in other districts of Punjab. However, based on meteorological conditions and ambient air quality data from other resources (Private ambient air data reporting websites and satellite), the similar air quality pattern prevails in most areas of Punjab.

The chart shows the equation $y = 5.2735x^2 - 62.041x + 213.32$ with $R^2 = 0.5927$.
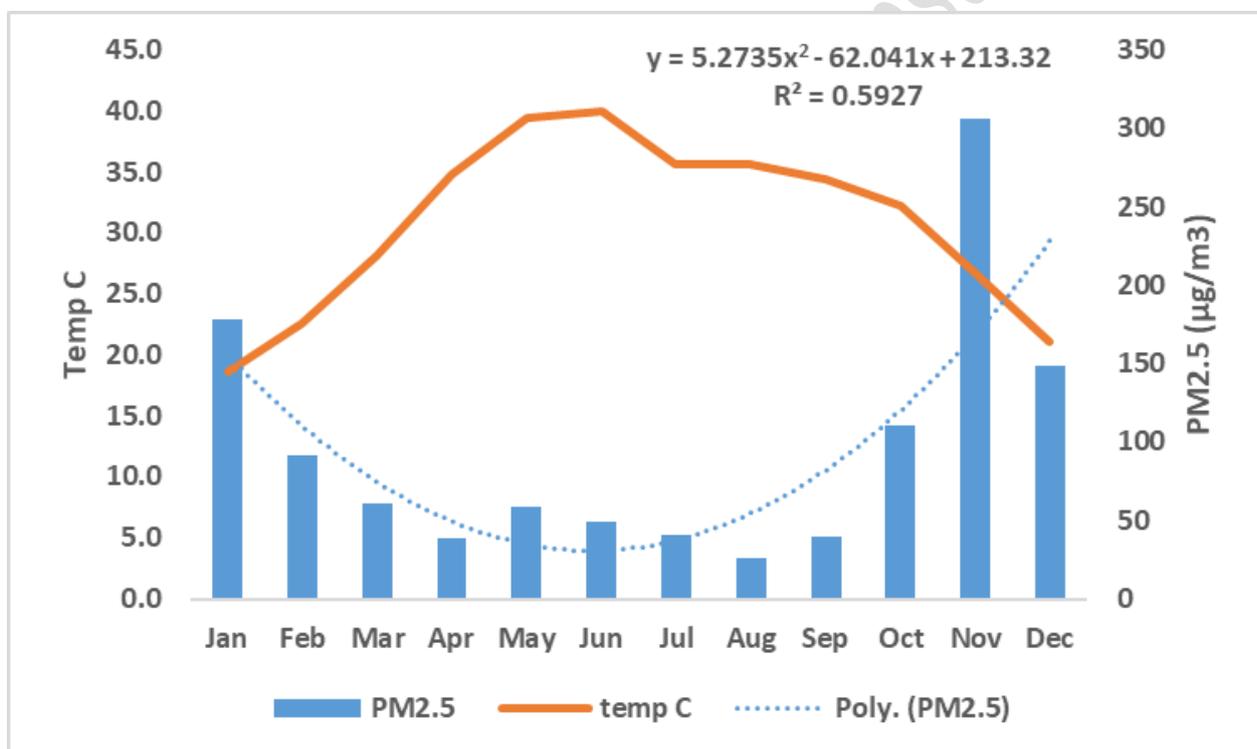
Figure 3-05: Monthly trend of PM$_{2.5}$: analysis of meteorological factors and anthropogenic factors

Diurnal Trend:
Figure 3-6 clearly shows a distinct diurnal trend in PM2.5 concentration, characterized by a peak in the morning hours and a gradual decline throughout the day. This pattern suggests that PM2.5 levels are significantly influenced by human activities and meteorological conditions that exhibit diurnal variations.

The peak in PM 2.5 concentration during the morning hours likely coincides with the morning rush hour. Increased vehicular traffic during this period leads to a significant increase in emissions of pollutants, including particulate matter.

During the night, with reduced wind speeds and atmospheric mixing, pollutants emitted during the day can accumulate near the ground. This accumulation can lead to higher PM2.5 concentrations in the early morning hours before atmospheric mixing starts to disperse the pollutants. If a temperature inversion occurs during the night, it can trap pollutants near the ground, further contributing to the high PM 2.5 levels in the morning.

For a given day in the given graph, the R-squared value of 0.4236 indicates that approximately 42.36% of the variation in PM 2.5 concentration can be explained by the variation in temperature. This implies that temperature is a contributing factor to the observed changes in PM 2.5 levels, but other factors not accounted for in the model (such as wind speed, humidity, and human activities) play a significant role in determining the remaining 57.64% of the variation.
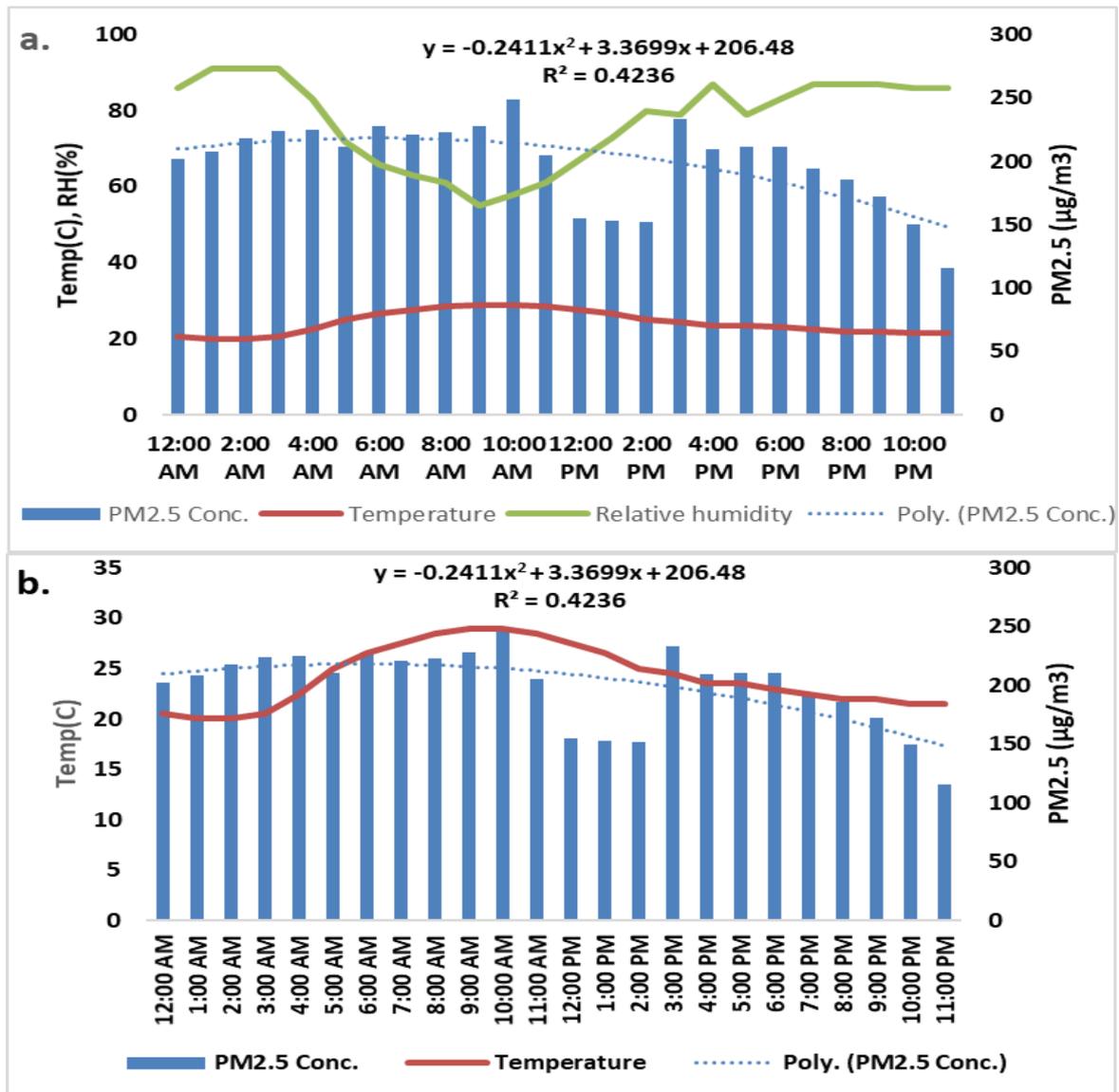
Figure 3-06:: Diurnal trend of PM$_{2.5}$: analysis of meteorological and anthropogenic factors

Statistical analysis of PM 2.5 concentrations in relation to meteorological parameters reveals significant correlations that help explain the seasonal and daily variations in air quality. Temperature, wind speed, relative humidity, and precipitation are critical meteorological factors influencing PM 2.5 levels. For instance, studies show that temperature inversions during winter trap pollutants close to the surface, leading to a substantial increase in PM2.5 concentrations[11]. During these periods, lower temperatures slow down atmospheric dispersion, and pollutants accumulate near the ground, causing smog and visibility reduction.

Wind speed and direction play a crucial role in the dispersion and transport of PM2.5. Low wind speeds are associated with higher PM2.5 concentrations due to limited pollutant dispersal,

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[11] Murhekar, M. V., Bhatnagar, T., Thangaraj, J. W. V., Saravanakumar, V., Kumar, M. S., Selvaraju, S., ... & Vinod, A. (2021). SARS-CoV-2 seroprevalence among the general population and healthcare workers in India, December 2020–January 2021. *International Journal of Infectious Diseases*, *108*, 145-155.

whereas moderate wind speeds help dilute and carry pollutants away from urban centers[12]. In contrast, higher wind speeds can lead to long-range transport of pollutants across regions, aggravating air quality in downwind areas such as Lahore. Additionally, relative humidity has a dual effect—higher humidity levels can facilitate the growth of secondary aerosols and increase the size of particulate matter, while rainfall is known to wash out $PM_{2.5}$ from the atmosphere, temporarily improving air quality [13].

A statistical analysis of PM 2.5 and meteorological variables from various cities in the region indicates that PM 2.5 levels show an inverse correlation with temperature (-0.6 to -0.8 in many studies) and wind speed but a positive correlation with relative humidity (+0.5 to +0.7) during winter months (Singh et al., 2021). Precipitation events, even short ones, can reduce PM 2.5 levels by up to 40%, emphasizing the role of rainfall in mitigating air pollution.

In Lahore, for instance, daily $PM_{2.5}$ data show higher values (150-200 μg/m³) under stagnant weather conditions with low wind speeds (<2 m/s) and temperatures below 15°C during peak winter months. These patterns highlight the need for integrating meteorological forecasting with air quality management strategies to predict and mitigate $PM_{2.5}$ pollution more effectively [14].

Findings

The analysis of monthly PM2.5 data revealed a distinct seasonal trend, with significantly higher concentrations observed during the winter months (October-February) compared to the summer months. This seasonal variation aligns with the typical meteorological conditions in Lahore, characterized by lower temperatures, reduced wind speeds, and increased occurrences of temperature inversions during winter. These factors contribute to the trapping of pollutants near the surface, leading to elevated PM2.5 levels.

Furthermore, the analysis demonstrated a moderate correlation between temperature and PM2.5 levels, with an R-squared value of 0.5927. This indicates that temperature variations explain a portion of the observed changes in PM2.5 concentrations. However, other factors, including wind speed, humidity, and human activities such as vehicular emissions, industrial activities, and crop burning, significantly influence PM2.5 levels and cannot be fully accounted for by temperature alone,

9. Steps taken by EPA Punjab for Mitigation:

- **Enforcement of Emission Standards:**
    - The EPA enforces Pakistan Environmental Quality Standards (PEQS) for industrial emissions.
    - This involves setting limits on the number of pollutants that industries can release.
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[12] Gupta, A., Gonzalez-Rojas, Y., Juarez, E., Casal, M. C., Moya, J., Falci, D. R., ... & COMET-ICE Investigators. (2022). Effect of sotrovimab on hospitalization or death among high-risk patients with mild to moderate COVID-19: a randomized clinical trial. *Jama*, *327*(13), 1236-1246.

[13] Sharma, Manu, et al. "Developing a framework for enhancing survivability of sustainable supply chains during and post-COVID-19 pandemic." *International Journal of Logistics Research and Applications* 25.4-5 (2022): 433-453.

[14] Ahmad, A., Saraswat, D., & El Gamal, A. (2023). A survey on using deep learning techniques for plant disease diagnosis and recommendations for development of appropriate tools. *Smart Agricultural Technology*, *3*, 100083.

- **Mandating Emission Control Technologies:**
  - The EPA requires industries, particularly steel mills and those using boilers, to install and maintain emission control technologies.
  - These technologies can include:
    - **Baghouse filters:** To remove particulate matter from exhaust gases.
    - **Scrubbers:** To remove sulfur oxides and other gaseous pollutants.
    - **Electrostatic precipitators:** To remove particulate matter.
    - **Catalytic converters:** To reduce NOx emissions.
- **Regular Inspections and Monitoring:**
  - The EPA conducts regular inspections of industrial facilities to ensure compliance with emission standards.
  - It also monitors air quality near industrial areas to assess the effectiveness of control measures.
- **Legal Action and Penalties:**
  - The EPA takes legal action against industries that violate emission standards, including imposing fines and shutting down non-compliant facilities.
- **Promoting Cleaner Technologies:**
  - The EPA encourages industries to adopt cleaner technologies and processes to reduce emissions.
  - This can involve providing technical assistance and incentives for the adoption of best practices

10. EPA enforcement activities: Brick Kilns Sector

Table 3-4 provides a snapshot of the brick kiln industry in Punjab, likely as of the end of 2024. Description is provided on the basis of Urban unit Survey data.

- **Total Brick Kilns:** The total number of brick kilns in Punjab is estimated to be 10,000.
- **Kiln Types:**
  - **Functional non-zigzag:** 2028 kilns are currently operating using traditional, non-Zigzag methods.
  - **Abandoned/Dis-functional:** 3899 kilns are no longer in operation.
  - **Functional Zigzag:** 4073 kilns have been converted to the more environmentally friendly Zigzag technology.
- **Coal Consumption:** The total coal consumption across all functional brick kilns in 2024 is estimated to be 3,429,000.68 tons.
- **Coal Consumption per Kiln:** On average, each functional brick kiln consumes approximately 312.62 tons of coal annually.

Sr. No	Total Brick Kiln In Punjab	Functional non-zigzag	Abandoned / Dis-Functional	Functional Zigzag	Total Coal Consumption Year 2024 (Tons)	Coal Consumption per Functional Brick Kiln (Tons)
%age	-	20.275%	38.993%	40.73%		
Brick Kiln in Punjab	10,000*	2028	3899	4073	3,429,000.68	312.62

Source: *Urban Unit, 2024*

According to EPA previous study, coal consumption per functional brick kiln is used to calculate annual brick production per functional brick kiln and it is estimated as 1.70319 million bricks for Zigzag & 1.46322 million bricks for BTK (Sheikh I.H. et al., 2024). The previous articles also report about emission factors of Particulate Matter (PM) and GHG gases against per million brick production. These emission factors have been applied to estimate PM & GHG reduction in the brick sector of Punjab since 2019 to end of December 2024.

Results of the current study are shown in Table 3 -5. In this present study, it has been assumed that in the year 2019, most of the brick kilns were operating on BTK and hence emissions have been assessed for this year accordingly. From 2019 to June 2024, both types of Zigzag and non-Zigzag brick kilns practically exist. After reporting to the Urban Unit, EPA expedited its stringent enforcement activities for the conversion of BTK to Zigzag technology. According to the initial survey 85-90% of the total brick kilns have been converted to Zigzag technology for which the emission reduction has been calculated.

This conversion of zigzag brick kiln showed 16.08% in reduction of Green House gases and 29.32 % reduction in PM from 2019 to December 2024. The substantial emission reduction was achieved by EPA enforcement activities as indicated in Table 3-5.

Table 3-5: Reduction of CO2 and PM emissions from Brick Kilns during 2024

Parameter Description	Kiln Type	Emission Factors	Emissions from Brick kiln in year 2019 (KTons)	Emissions from functional Brick kiln till June 2024 (KTons)	Emissions for functional brick kiln after June 2024 (KTons)	**Total Reduction**
CO2/GHG Per Million Brick Baking (Tons)	BTK	374.43	462.447243 (all BTK)	153.7195556	-	-

CO2/GHG Per Million Brick Baking (Tons)	ZigZag	445.039	-	259.7455683	330.7149 to 350.1687	-
Total			**462.447243**	**413.4651239**	330.7149 to 350.1687	-
Reduction percentage			**-10.59%**		**-5.33 to -5.64%**	**-15.92 to -16.23**
PM emission per Million Baking of Bricks (Tons)	ZigZag	0.81557	-	5657.685	7616.2735	
PM emission per Million Baking of Bricks (Tons)	BTK	1.46322	10571.22	3513.923	-	
Total			10571.22	9171.607	7616.2735	
Reduction percentage			**-13.24%**		**-15.92 to -16.23% =Ave. 16.08%**	**Ave. -29.32**

Key Findings:

- The conversion of BTKs to Zigzag technology has indicated substantial emission reduction.
- The vigilant enforcement activities by the EPA Punjab have played a crucial role in the adoption of Zigzag technology.
- During 2019, almost all brick kilns were operating on conventional BTK technology. By gradual EPA interventions 85-90% of conventional BTK have been converted to Zigzag technology by the end of 2024 leading to 29.32% reduction of PM and 16.08% reduction of CO_2.

11. Green Lockdown:

The EPA Punjab executed several measures during the "Green Lockdown" in November 2024 to mitigate the severe smog situation. These steps included:

- **Restricted Shop Timings:** Shops were mandated to operate within specific timings, likely with early closing hours, from November 15th to December 6th, 2024. This aimed to reduce vehicular traffic and associated emissions during peak hours.
- **School Closures:** Educational institutions remained closed from November 12th to 18th, 2024, to minimize the exposure of children to polluted air.
- **Reduced Office Hours:** A 50% workforce reduction was implemented in offices from November 12th, 2024, further reducing vehicular traffic and emissions.
- **Restrictions on Commercial Markets:** Commercial markets faced restrictions, likely to include adjusted operating hours or closures, from November 10th, 2024, to minimize vehicular traffic and associated emissions.
- **Ban on Construction Activities:** Construction activities were halted to reduce dust emissions and particulate matter in the air.

Despite the "green lockdown" implemented around the US Consulate in Lahore from November 9th to 16th, the Air Quality Index (AQI) remained consistently high during this period. This suggests that the lockdown measures, while intended to improve air quality, were not sufficient to significantly reduce pollution levels.

The subsequent decrease in AQI following the lockdown period likely indicates the influence of meteorological factors. Changes in wind patterns, increased wind speeds, or rainfall can effectively disperse pollutants and improve air quality.

The "green lockdown" may have had a limited impact on overall air pollution levels in Lahore. The area affected by the lockdown was likely relatively small compared to the city's overall size and the sources of pollution.

Other significant sources of air pollution, such as vehicular emissions, industrial emissions, and residential burning, continued to operate during the lockdown period, contributing to the high AQI.

Prior to the atmospheric disturbance, Lahore experienced stagnant air conditions with low wind speeds, trapping pollutants and leading to a buildup of air pollution. The subsequent change in weather patterns, such as increased wind speeds, helped to disperse these pollutants and improve air quality.

12. Emissions from Vehicles

Figure 3-07: Testing of car emissions at Toyota Garden Motors Lahore

12.1 Emissions from Two Wheelers

Figure 3-8 reveals a clear trend: older motorcycles (Pre-Euro) generally exhibit higher emission levels of HC+NO and CO compared to newer ones (Euro II and Euro IV). This is expected as emission standards have evolved over time, with newer standards (like Euro II and Euro IV) being more stringent and requiring vehicles to meet lower emission limits.

12.2 1Specific Observations:

- **Euro IV:** The Euro IV Honda ATK 151 with EGR demonstrates the lowest emissions across both HC+NO and CO, aligning with the stricter Euro IV standards.
- **Euro II:** The Euro II Honda 125CC with EGR also shows relatively low emissions, although slightly higher than the Euro IV model.
- **Pre-Euro:** The Pre-Euro motorcycles exhibit the highest emission levels, with some models exceeding the PEQS (Punjab Environmental Quality Standards) for CO. This highlights the significant pollution contribution from older, less regulated vehicles.

12.3 Factors Influencing Emissions

Several factors contribute to these emission differences:

- **Engine Technology:** Newer engines often incorporate technologies like electronic fuel injection, exhaust gas recirculation (EGR), and catalytic converters, which help reduce emissions.
- **Maintenance:** Poorly maintained vehicles, regardless of their age, can emit higher levels of pollutants.
- **Fuel Quality:** The quality of fuel used can also influence emissions.

12.4 Implications

The data underscores the importance of phasing out older, more polluting vehicles and promoting the use of newer, cleaner models. Implementing stricter emission standards and enforcing regular vehicle inspections can also help reduce air pollution from motorcycles in Lahore.
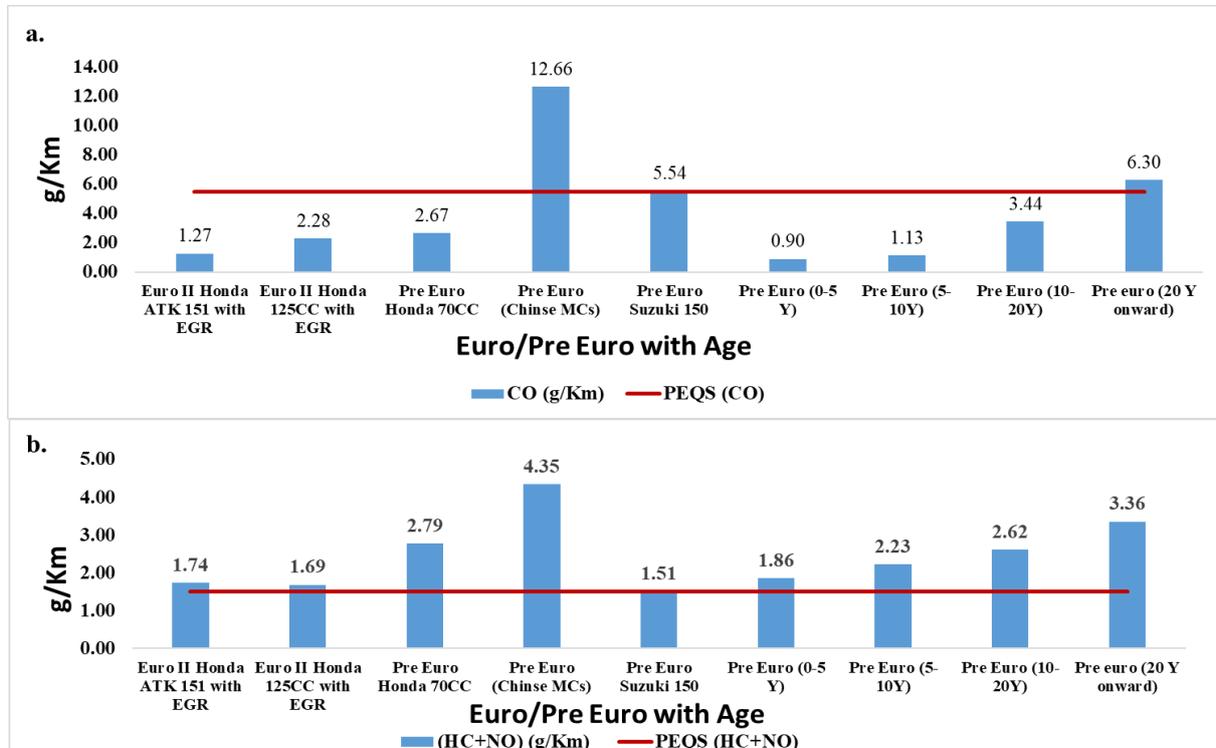
Figure 3-8: Comparison of Motorcycle emissions (a) CO emissions, (b) HC+NO emissions from Euro II and Pre Euro Motorcycles based on vehicle age

12.5 Emissions from 4 wheelers

Figure 3-9 presents car emissions in Lahore, categorized by emission standard (Euro IV, Euro II, and Pre-Euro) and further subdivided by age within the Pre-Euro category (presumably representing years since manufacture). Let's analyze the trends:

12.6 General Trend

The most striking observation is the clear correlation between vehicle age and emissions. As cars get older (moving down the table from Euro IV to older Pre-Euro categories), both HC+NO (Hydrocarbons + Nitrogen Oxides) and CO (Carbon Monoxide) emissions increase significantly. This is a common trend globally, as older vehicles typically lack the advanced emission control technologies found in newer models.

12.7 Specific Observations:

- **Euro IV:** Car's meeting Euro IV standards exhibit the lowest emissions, with HC+NO at 0.025 g/km and CO at 0.260 g/km. This demonstrates the effectiveness of stricter emission standards in reducing pollution.

- **Euro II:** Euro II cars show a moderate increase in emissions compared to Euro IV, with HC+NO at 0.142 g/km and CO at 0.519 g/km. While higher than Euro IV, these levels are still considerably lower than the Pre-Euro categories.
- **Pre-Euro:** This category shows a dramatic increase in emissions with age.
- The "Pre-Euro (0)" category (presumably the newest of the Pre-Euro cars) has emissions significantly higher than Euro II.
- As we move to "Pre-Euro (5)," "Pre-Euro (10)," and "Pre-Euro (20)," the emissions escalate rapidly. The "Pre-Euro (20)" category shows extremely high levels of both HC+NO (0.852 g/km) and CO (33.058 g/km), far exceeding the PEQS (Punjab Environmental Quality Standards) for CO (2.2 g/km).

12.8   Comparison with PEQS:

The PEQS provides a benchmark for acceptable emission levels. While Euro IV and Euro II cars comfortably meet these standards, the older Pre-Euro vehicles, especially those in the older age categories, significantly exceed the PEQS for CO. This highlights a critical issue: older vehicles are a major source of air pollution in Lahore.

12.9   Implications for Lahore's Air Quality:

The data strongly suggests that phasing out older, highly polluting vehicles is crucial for improving air quality in Lahore. Implementing stricter vehicle emission standards, promoting newer and cleaner vehicles, and enforcing regular vehicle inspections are essential measures. Additionally, programs that incentivize the scraping of older vehicles could be beneficial.

12.10   Possible Contributing Factors:

Besides age and emission standards, other factors can influence vehicle emissions:

- **Vehicle Maintenance:** Poorly maintained vehicles, regardless of age, will emit more pollutants.
- **Fuel Quality:** Lower quality fuels can lead to increased emissions.
- **Driving Conditions:** Stop-and-go traffic, common in urban areas like Lahore, can increase emissions.

The data clearly indicates that older cars are a significant contributor to air pollution in Lahore. Implementing policies to promote cleaner vehicles and remove older, highly polluting ones is essential for improving air quality and public health.
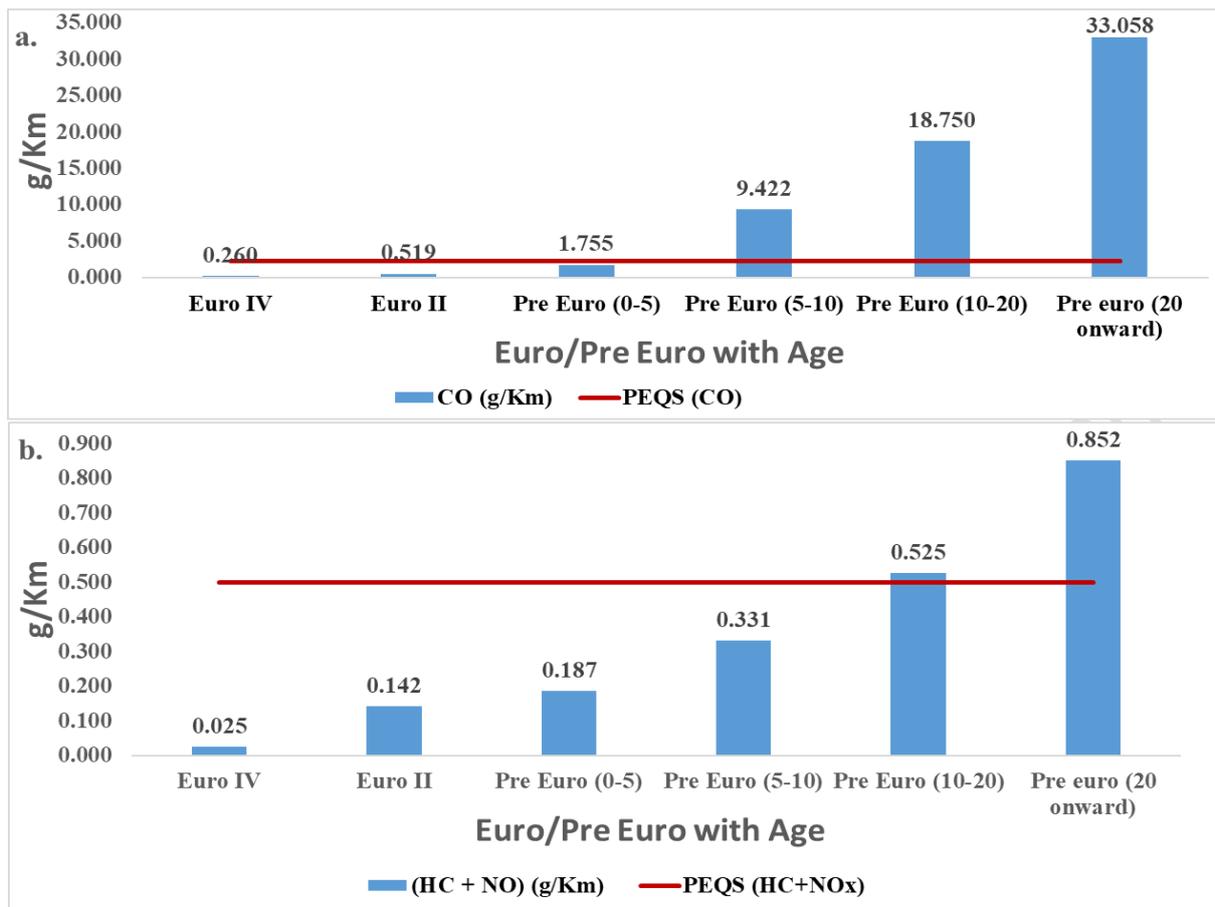
Figure 3-9: Comparison of car exhaust emissions (a) CO emissions, (b) (HC+NO) emissions from Euro IV, Euro II and Pre Euro vehicles

12.11 General Trends:

- **Age Matters:** For both cars and motorcycles, vehicle age is a strong predictor of emissions. Older vehicles, particularly those predating stricter emission standards (Pre-Euro), consistently exhibit significantly higher levels of CO, NO, and HC compared to newer models.
- **Emission Standards are Effective:** The data clearly demonstrates the positive impact of stricter emission standards like Euro II and Euro IV. Vehicles meeting these standards show substantially lower emissions compared to older, less regulated vehicles.

Specific to Cars:

- **Significant Improvement with Euro IV:** Car's meeting Euro IV standards shows the lowest emissions, highlighting the effectiveness of these stricter regulations.
- **Older Cars Exceed Standards:** Pre-Euro cars, especially those in the older age categories (10+ years), significantly exceed the PEQS for CO, indicating a major source of pollution.

Specific to Motorcycles:

- **Similar Trend with Age:** Motorcycles follow a similar trend, with older models and those not meeting Euro II standards exhibiting higher emissions.
- **Need for Further Regulation:** While Euro II motorcycles show some improvement, there might be a need for even stricter standards and better enforcement to further reduce emissions from this vehicle category.

Overall Implications:

- **Targeting Older Vehicles:** Phasing out older, highly polluting vehicles (both cars and motorcycles) should be a priority for improving air quality. Scrappage schemes or incentives for upgrading to newer, cleaner vehicles could be effective strategies.
- **Enforcement of Standards:** Strict enforcement of existing emission standards and regular vehicle inspections are crucial to ensure compliance and identify high-emitting vehicles.
- **Promoting Cleaner Technologies:** Encouraging the adoption of cleaner vehicle technologies, such as hybrid or electric vehicles, can further reduce emissions in the long term.
- **Public Awareness:** Raising public awareness about the impact of vehicle emissions on air quality and promoting eco-friendly transportation choices can also contribute to reducing pollution.

In conclusion, the data underscores the need for a multi-pronged approach to address vehicular emissions, including stricter standards, enforcement, and promoting cleaner technologies, with a particular focus on targeting older, more polluting vehicles.

12.12 EPA Punjab Green Sticker Scheme

The EPA Punjab's Green Sticker Scheme is a commendable initiative aimed at tackling vehicular emissions, a significant contributor to air pollution, especially during smog season. Here's a breakdown and extension of the scheme:

Core Components:

1. **Enlisting Private Dealership Workshops:** The scheme leverages the existing network of authorized dealerships for major car brands (Honda, Toyota, Suzuki, Changan, KIA, Hyundai, Haval, etc.). This is a smart move for several reasons:
   - **Accessibility:** Dealerships are widely distributed, making it easier for vehicle owners to get their vehicles tested.
   - **Trust:** Vehicle owners generally trust authorized dealerships, increasing the likelihood of participation.
   - **Capacity:** Dealership workshops already have some of the necessary equipment and trained personnel.
2. **Vehicular Emission Testing:** The enlisted workshops will conduct standardized emission tests. This likely involves checking levels of pollutants like carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NOx), and particulate matter (PM). The exact testing procedure and standards will be defined by the EPA.
3. **Green Stickers for Compliant Vehicles:** Vehicles that pass the emission test will be issued a green sticker. This sticker serves as a visible marker of compliance and can be

a useful tool for enforcement. It's also a form of positive reinforcement, encouraging vehicle owners to maintain their vehicles properly.

4. **Green Zones During Smog Season:** This is a crucial part of the scheme. During periods of high smog, likely in the autumn and winter months, the EPA will designate certain areas as "green zones." Vehicles entering these zones may be required to display a valid green sticker. This can restrict the movement of highly polluting vehicles in the most affected areas.

Potential Extensions and Improvements:

- **Phased Implementation:** The scheme could be rolled out in phases, starting with major cities and then expanding to other areas. This allows the EPA to manage the process effectively and refine the scheme based on initial experiences.
- **Public Awareness Campaign:** A strong public awareness campaign is being conducted to ensure the success of the scheme. People need to understand the importance of vehicle emission testing and the benefits of compliance. The campaign is using various media channels to reach a wide audience.
- **Mobile Testing Units:** EPA has considered deploying mobile emission testing units/booths with the help of EPA certified Private Labs to reach all areas of the city and conduct random checks on vehicles.
- **Focus on Older Vehicles:** Older vehicles are often more polluting. The scheme could include specific measures to encourage the maintenance or replacement of older vehicles.
- **Long-Term Sustainability:** The scheme is designed to be sustainable in the long term, with clear funding mechanisms and continuous improvement based on data and feedback

Stack Emissions Monitoring

Punjab, Pakistan's most populous and agriculturally significant province, faces a growing challenge from industrial pollution. Driven by rapid industrialization and economic development, the province has witnessed a surge in manufacturing facilities across various sectors. While this growth has contributed to economic prosperity, it has also led to a significant increase in the release of pollutants into the air and water, posing serious risks to public health and the environment.

Industrial activities, ranging from textile production and tanneries to chemical manufacturing and steel mills, generate a wide array of pollutants. These include particulate matter (PM2.5 and PM10), sulfur oxides (SOx), nitrogen oxides (NOx), carbon monoxide (CO), volatile organic compounds (VOCs), and heavy metals. These pollutants are often released through industrial stacks, wastewater discharge, and improper waste disposal, contaminating the air, water, and soil.

The consequences of industrial pollution in Punjab are far-reaching. Air pollution contributes to respiratory illnesses, cardiovascular problems, and other health complications, particularly in urban centers where industrial activity is concentrated. Water pollution degrades water quality, impacting aquatic life and threatening access to clean drinking water for communities. Soil contamination can affect agricultural productivity and introduce harmful substances into the food chain.

Recognizing the severity of the issue, the Environmental Protection Agency (EPA) Punjab is actively working to monitor and control industrial emissions. During 2024 alone, the EPA Punjab monitored 257 industrial stacks, revealing a concerning trend: of those monitored, only 69 were found to be compliant with environmental standards, while a substantial 188 were deemed unfit. This highlights the urgent need for stricter enforcement and proactive measures to curb industrial pollution.

In response to these findings, the EPA Punjab has taken steps to compel industries to install and utilize effective emission control systems. This proactive approach aims to reduce the release of harmful pollutants at the source and bring industrial operations in line with environmental regulations. While progress has been made, continuous monitoring, stringent enforcement, and collaborative efforts between the government, industries, and communities are crucial to mitigate the detrimental effects of industrial pollution and ensure a healthier environment for the people of Punjab.

Monitoring through drones and patrolling force

That's a significant advancement in environmental monitoring by EPA Punjab! Using a patrolling force and drones equipped with cameras to monitor stack emissions offers several key advantages:

Benefits of this Approach:

- **Increased Coverage:** Drones can access areas that are difficult or dangerous for human inspectors to reach, such as rooftops, remote industrial sites, or areas with restricted access. This dramatically expands the EPA's monitoring coverage.
- **Deterrent Effect:** The knowledge that drones and patrolling forces are actively monitoring emissions acts as a powerful deterrent for industries that might otherwise be tempted to violate environmental regulations.
- **Evidence Collection:** Video and photographic evidence captured by drones and patrolling teams can be crucial in legal proceedings against polluting industries. This strengthens the EPA's enforcement capabilities.
- **Cost-Effectiveness (Potentially):** While there are upfront costs associated with drones and training personnel, in the long run, this approach can be more cost-effective than relying solely on traditional ground-based inspections, especially for covering large or remote areas.

How it Works:

1. **Patrolling Force:** EPA's ground teams patrol industrial areas, likely focusing on known polluters or areas with high industrial concentration.
2. **Drone Deployment:** Drones are launched to inspect industrial stacks, especially in areas difficult to access by ground teams.
3. **Camera Systems:** Both patrolling teams and drones are equipped with cameras to capture visual evidence of stack emissions. This can include still photos and videos.
4. **Data Transmission:** Data collected by drones and ground teams is transmitted to a central monitoring station for analysis.
5. **Violation Identification:** EPA personnel analyze the data to identify violations of environmental regulations.

6. **Enforcement Action:** Based on the evidence collected, the EPA takes appropriate enforcement action, which can include warnings, fines, or legal action.

13. Control of Fugitive Dust

The Environmental Protection Agency (EPA) Punjab has implemented a directive mandating the covering of trolleys transporting clay, sand, and construction materials across the province, with a particular focus on Lahore, to mitigate the substantial contribution of fugitive dust to air pollution. This measure is especially critical in Lahore, where approximately 450 trolleys traverse the city daily, carrying such materials. The EPA's assessment indicates that by enforcing the covering of these trolleys, a significant reduction of approximately 90% in dust emissions can be achieved. This initiative directly addresses a major source of particulate matter, which is a key component of the alarming PM2.5 levels recorded in Lahore, as evidenced by the provided data. By controlling this fugitive dust, the EPA aims to substantially improve air quality and protect public health, demonstrating a proactive approach to managing construction-related pollution.

Installation of Smog Cleaning Tower in Lahore

The installation of a smog tower (or air purification tower) in Mehmood Booti, Lahore, is indeed a noteworthy effort to combat air pollution, and it's positive that the EPA Punjab is supportive of such initiatives. Here's a breakdown of the situation and the EPA's likely role:

Smog Tower in Mehmood Booti, Lahore:

- **Purpose:**
    - Smog towers are designed to filter pollutants, particularly particulate matter (PM2.5 and PM10), from the surrounding air.
    - They aim to create localized zones of cleaner air, especially in heavily polluted areas.
- **Location:**
    - Mehmood Booti is likely chosen due to its high pollution levels, potentially stemming from industrial activity, traffic congestion, or other local sources.
- **Technology:**
    - These towers typically use a combination of filters and fans to draw in polluted air, remove pollutants, and release cleaner air.

EPA Punjab's Role:

- **Promotion of Innovative Solutions:**
    - The EPA Punjab is likely promoting such efforts as part of a broader strategy to explore and implement innovative air pollution control measures.
    - This demonstrates a willingness to consider diverse solutions beyond traditional regulatory approaches.
- **Performance Assessment:**
    - It is crucial that the EPA Punjab assesses the performance of the smog tower to determine its effectiveness.
    - This assessment would likely involve:
        - Monitoring air quality before and after the tower's installation.
        - Measuring the tower's efficiency in removing pollutants.

- Evaluating the tower's operational costs and maintenance requirements.
- **Potential Benefits of Assessment:**
  - Informing future decisions about the feasibility and scalability of smog tower technology.
  - Providing data to optimize the tower's operation.
  - Ensuring that public resources are used effectively.
- **Integration with Broader Strategy:**
  - It is very important to note that smog towers are not a replacement for source control of air pollution. Smog towers should be seen as one tool in a larger more comprehensive plan.
  - The EPA Punjab likely views smog towers as a complementary measure to its regulatory and enforcement efforts.

Key Considerations:

- **Scale of Impact:**
  - The effectiveness of smog towers in significantly reducing city-wide pollution is a subject of debate.
  - Their impact is likely to be localized, creating cleaner air zones in their immediate vicinity.
- **Energy Consumption:**
  - Smog towers require energy to operate, which can contribute to indirect emissions if the energy source is not clean.
- **Cost-Effectiveness:**
  - The cost-effectiveness of smog towers compared to other pollution control measures needs to be carefully evaluated

14. DPSIR Report on Air Pollution in Punjab, Pakistan

14.1 Driving Forces

Air pollution in Punjab, Pakistan, is driven by several socio-economic and environmental factors. The primary driving forces include:

- **Rapid Urbanization:** The expansion of cities like Lahore, Faisalabad, and Multan has led to increased vehicular traffic, construction activities, and industrial growth.
- **Population Growth:** Punjab is the most populous province of Pakistan, leading to higher energy demands and increased pollution from domestic heating and cooking.
- **Economic Development:** Industrialization, particularly in sectors like textile, steel, brick kilns, and agriculture, contributes to emissions of pollutants.
- **Agricultural Practices:** Burning of crop residues, particularly rice stubble, is a significant seasonal contributor to air pollution.
- **Energy Production:** Reliance on fossil fuels for electricity generation and industrial processes further adds to air pollution.

14.2 Pressures

The above driving forces lead to various pressures on air quality, including:

- **Vehicular Emissions:** High traffic density and use of outdated vehicles lead to increased PM2.5, NOx, CO, and SO2 emissions.
- **Industrial Emissions:** Factories, brick kilns, and power plants release particulate matter, sulfur dioxide, nitrogen oxides, and volatile organic compounds (VOCs).
- **Agricultural Burning:** Open burning of crop residues contributes significantly to PM2.5 levels during harvesting seasons.
- **Construction Activities:** Dust and particulates from construction sites add to the air pollution burden.
- **Domestic Emissions:** Burning of biomass and solid fuels for cooking and heating contributes to indoor and outdoor air pollution.

14.3 State

The current state of air quality in Punjab is alarming, particularly in urban areas such as Lahore, Faisalabad, and Multan.

- PM2.5 levels often exceed national and international air quality guidelines, particularly during winter months.
- Data from air pollution indicates severe pollution episodes occurring consistently from 2019 to 2023 in major cities.
- Poor air quality is particularly evident during the post-monsoon and winter seasons, often exacerbated by temperature inversions and stagnant atmospheric conditions.

14.4 Impacts

The impacts of poor air quality in Punjab include:

- **Public Health Risks:** Increased incidence of respiratory diseases, cardiovascular problems, and premature deaths.
- **Economic Losses:** Reduced labor productivity, increased healthcare costs, and loss of agricultural yield.
- **Environmental Damage:** Damage to crops, ecosystems, and overall reduction in biodiversity.
- **Reduced Quality of Life:** Visibility reduction, unpleasant odors, and reduced outdoor activity.

14.5 Responses

The Government of Punjab and other stakeholders have initiated various measures to combat air pollution, including:

- **Regulatory Actions:** Implementation of the Punjab Clean Air Action Plan and Punjab Environmental Quality Standards (PEQS).
- **Technological Improvements:** Adoption of cleaner technologies in industries and brick kilns, including zigzag technology for brick kilns.
- **Vehicular Emission Controls:** Encouraging electric vehicles, phasing out older vehicles, and improving public transportation systems.
- **Awareness Campaigns:** Promoting public awareness about air pollution and its impact.

- **Monitoring & Research:** Improved air quality monitoring systems and collaboration with other organizations for data sharing.
- **Policy Enforcement:** Strengthening environmental regulations and encouraging compliance through incentives and penalties.

14.6 Recommendations

- Enhance air quality monitoring coverage to include rural areas and smaller cities.
- Strengthening enforcement of environmental regulations and promoting cleaner technologies in all sectors.
- Increase public awareness and involvement in pollution reduction efforts.
- Promote sustainable agricultural practices to reduce crop burning.
- Collaborate with international agencies for technical and financial support in implementing clean air initiatives

The Punjab Environmental Protection Agency (EPA) has taken several measures to control vehicular pollution in Lahore and other cities of Punjab, Pakistan. These measures aim to reduce emissions from vehicles and improve air quality. Here's a summary of some key actions:

15. Vehicle Inspection and Certification System (VICS):

- The EPA has implemented a Vehicle Inspection and Certification System to ensure that vehicles meet emission standards.
- This involves regular inspections of vehicles to check their emissions and roadworthiness.
- Vehicles that fail the inspection are required to undergo repairs or adjustments to meet the standards.

15.1. Enforcement of Emission Standards:

- The EPA enforces emission standards for new and used vehicles.
- The standards are under revision to control air pollution from vehicles.
- This includes setting limits on the number of pollutants that vehicles can emit.
- The EPA conducts roadside checks to ensure that vehicles comply with these standards.

15.2. Promotion of Cleaner Fuels:

- The EPA is promoting the use of cleaner fuels, such as compressed Euro V gasoline and liquefied petroleum gas (LPG), which produce fewer emissions.
- The EPA has also encouraged the use of higher-quality fuels that meet international emission standards.

15.3. Control of Smoke-Emitting Vehicles:

- The EPA takes action against smoke-emitting vehicles, which are a major source of particulate matter pollution.
- This includes imposing fines and impounding vehicles that emit excessive smoke.

16. Awareness Campaigns:

- The EPA conducts public awareness campaigns to educate the public about the harmful effects of vehicular pollution and encourage them to adopt more sustainable transportation practices.
- These campaigns often involve the use of media, workshops, and seminars.

17. Promotion of Electric Vehicles (EVs):

- The Punjab EPA is working to promote the use of electric vehicles to reduce reliance on fossil fuels.
- Incentives and infrastructure development for EVs are being considered.

18. Traffic Management:

- While not directly an EPA function, the EPA collaborates with traffic authorities to improve traffic flow and reduce congestion, which can contribute to lower emissions.

19. Challenges:

- Enforcement of regulations can be challenging due to the large number of vehicles and limited resources.
- The availability and affordability of cleaner fuels and technologies can be a barrier to their widespread adoption.
- Public awareness and behavior change are essential for long-term success.

The Punjab EPA is continuously working to improve air quality and address the challenges of vehicular pollution

20. Way Forward

The environmental landscape of Punjab, particularly as exemplified by the data from Lahore, indicates a pressing need for robust and sustained air pollution control measures. The EPA Punjab's air quality monitoring network, while expanding, provides critical data that underscores the severity of PM2.5 pollution, especially during the winter months when temperature inversions exacerbate the problem. The high levels recorded in Lahore and other industrial cities like Multan, Faisalabad and Gujranwala point to significant contributions from industrial emissions, necessitating stricter enforcement of emission control technologies in sectors like steel and industrial boilers. Furthermore, the issue of fugitive dust, arising from construction activities and general urban development, requires more comprehensive management strategies to reduce particulate matter in the air. While initiatives like fog cannons represent innovative attempts to mitigate pollution, their efficacy and cost-effectiveness need rigorous assessment alongside broader, more systemic solutions. The EPA's efforts to control vehicular pollution through inspection systems and the promotion of cleaner fuels, alongside its regulatory oversight of brick kilns and other industrial sources, are vital. Furthermore, the EPA's support for innovative solutions like smog towers, while promising, must be accompanied by rigorous performance assessments and integrated into a comprehensive air quality management strategy. However, the sheer scale of the pollution problem necessitates a multi-faceted approach that integrates stringent enforcement, technological innovation, and public awareness campaigns to achieve meaningful and lasting improvements in Punjab's air quality.

CHAPTER 4   Water Quality at Punjab

1. Introduction

Punjab, a fertile and populous province of Pakistan, is defined by its extensive agricultural landscape, a network of rivers originating from the Himalayas (primarily the Indus River system including the Sutlej, Beas, Ravi, and Chenab), and an intricate system of canals that have historically supported its agrarian economy. Drinking water sources vary across the region, with a significant reliance on groundwater, supplemented by surface water drawn from rivers and canals, and minimal contribution from distant snow glaciers. The province supports a large and growing population, coupled with a substantial industrial sector concentrated in urban centers like Lahore, Faisalabad, and Gujranwala, and a predominantly agrarian economy characterized by intensive farming practices.

The diverse zones of Punjab exhibit varying water quality. Industrial and urban areas often experience significant water pollution due to the discharge of untreated or partially treated industrial effluents and domestic wastewater into rivers and canals. This contamination introduces a range of pollutants, including heavy metals, toxic chemicals, and organic matter, leading to a decline in water quality and altered water flow regimes. Consequently, certain zones, particularly those downstream of major industrial clusters and densely populated cities, are identified as most polluted.

The impact of these pollutants extends to soil fertility and agricultural productivity. Contaminated irrigation water can lead to the accumulation of toxic substances in the soil, affecting its fertility and potentially leading to crop toxicity. This can result in reduced agricultural yields and pose risks to human health through the consumption of contaminated food. Furthermore, the presence of pollutants in drinking water and the environment has significant health implications for the population, contributing to waterborne diseases, chronic illnesses, and other adverse health outcomes. The interconnectedness of water sources, industrial and urban discharge, agricultural practices, and human health underscores the urgent need for effective water quality management and pollution control measures across Punjab.

Water quality in Punjab, Pakistan, faces significant challenges due to a combination of factors stemming from rapid urbanization, industrial growth, and agricultural practices. Untreated industrial effluents and domestic sewage are frequently discharged into rivers and canals, contaminating surface water sources with heavy metals, chemicals, and pathogens. Agricultural runoff, laden with fertilizers and pesticides, further enhance the problem, leading to increased levels of nitrates and other harmful substances in both surface and groundwater. Over-extraction of groundwater has also contributed to the intrusion of saline water in some areas, making it unsuitable for consumption. The lack of adequate wastewater treatment facilities and insufficient enforcement of environmental regulations compound these issues, resulting in widespread contamination of drinking water sources. Consequently, waterborne diseases are prevalent, posing a serious threat to public health, especially among vulnerable populations. The need for improved water management practices, stricter environmental regulations, and investment in water treatment infrastructure is critical to ensure access to safe and clean water for the residents of Punjab.

2. Surface Water Resources

Punjab, Pakistan, is endowed with a network of surface water resources primarily fed by the Indus River and its tributaries. The five major rivers, namely the Jhelum, Chenab, Ravi, Beas, and Sutlej, contribute significantly to the region's water availability, forming an intricate irrigation system that supports its agrarian economy. These rivers, originating from the Himalayan glaciers, carry substantial volumes of water, which are diverted through a complex network of canals and barrages for irrigation, industrial, and domestic use. Additionally, numerous smaller streams, seasonal tributaries, and natural depressions also contribute to the surface water resources, though to a lesser extent. The availability and quality of these surface water resources are crucial for the sustenance of Punjab's population and its agricultural productivity, making their effective management and conservation paramount.
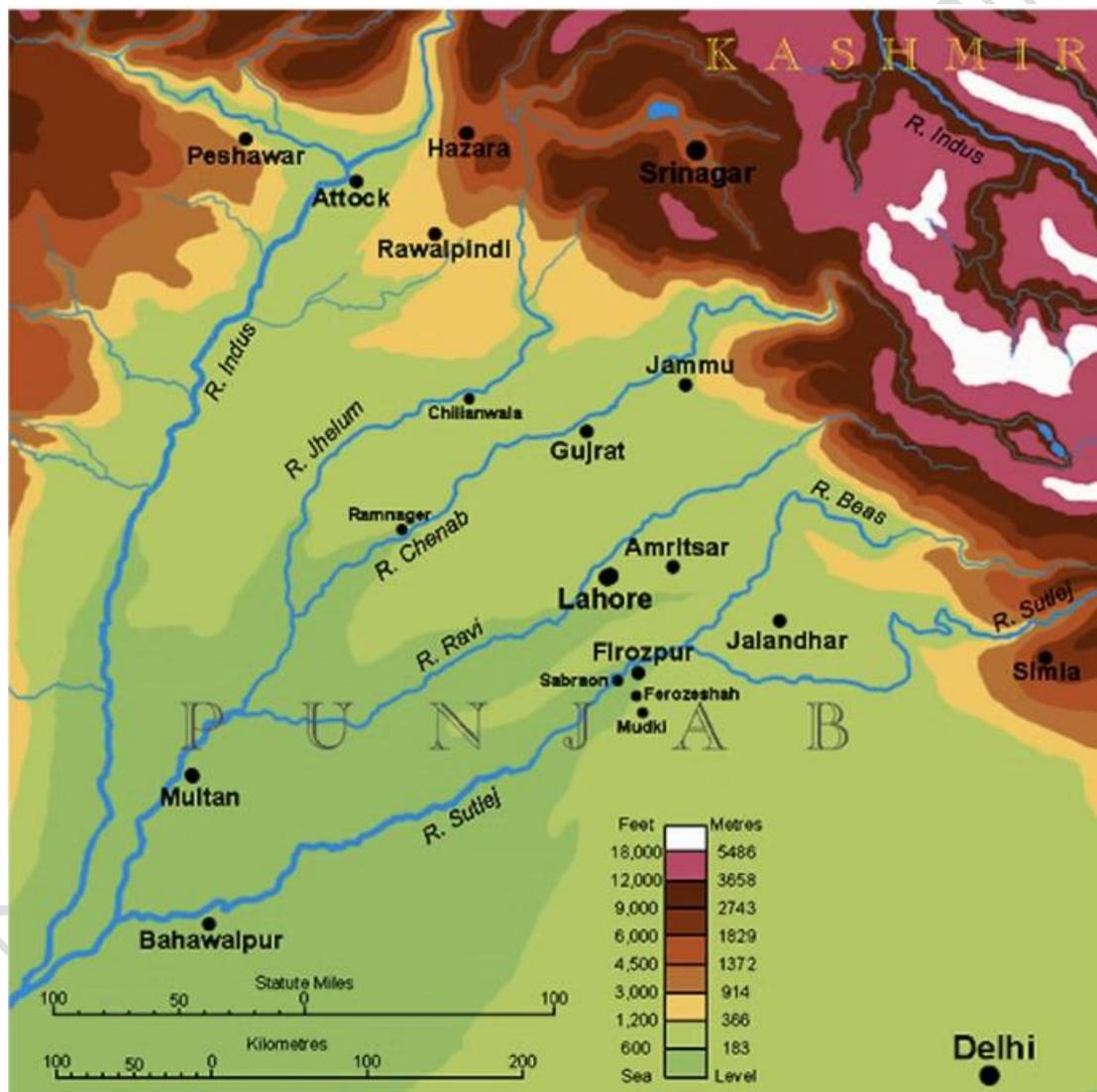
Figure 4-1: Rivers of Punjab (Source: https://www.my-lekh.com/post/rivers-of-punjab)

3. Canals

The canal system in Punjab, Pakistan, a cornerstone of the region's agriculture, forms an intricate network fed by the Indus River and its tributaries, including the Jhelum, Chenab, Ravi, Beas, and Sutlej. This vast system, essential for irrigating the fertile plains of Punjab, includes

numerous barrages and distributaries, allowing for the regulated diversion of water to support a wide range of crops. Historically developed and expanded, particularly during the British colonial era, the canal network has significantly shaped the landscape and economy of Punjab. While it remains crucial for agricultural productivity, the system faces challenges related to water management, maintenance, environmental concerns like waterlogging and salinity, and the constraints of the Indus Waters Treaty. Given Lahore's central location within Punjab, this canal network is vital for its surrounding agricultural lands and indirectly influences the city's resources.

4. Surface Water Quality

Surface water quality in Punjab, Pakistan, is a pressing environmental concern, largely compromised by a confluence of anthropogenic activities. The region's rivers and canals, vital for irrigation and domestic use, suffer from significant contamination. Industrial effluents, often discharged untreated, introduce heavy metals and toxic chemicals into these water bodies. Similarly, untreated municipal sewage contributes to high levels of pathogens and organic pollutants. Agricultural runoff, laden with fertilizers and pesticides, further degrades water quality, leading to eutrophication and the presence of harmful chemical residues. Consequently, the surface waters of Punjab exhibit elevated levels of pollutants, posing serious risks to public health and aquatic ecosystems. This contamination not only threatens the availability of clean drinking water but also impacts agricultural productivity and biodiversity. The urgent need for stricter enforcement of environmental regulations, improved wastewater treatment facilities, and sustainable agricultural practices is paramount to safeguard the surface water resources of Punjab.

5. Rivers

Punjab, the "Land of Five Rivers," owes its very existence and fertility to its intricate network of rivers, primarily tributaries of the mighty Indus. These rivers, the Jhelum, Chenab, Ravi, Beas, and Sutlej, originate from the Himalayan glaciers, carving their way through the landscape and providing life-sustaining water for agriculture, industry, and domestic use. The Jhelum, the westernmost of the five, flows from Indian-administered Kashmir into Pakistan, contributing significantly to the region's irrigation system. The Chenab, the largest of the five, also originates in the Himalayas and joins the Jhelum further downstream. The Ravi, flowing from the Indian state of Himachal Pradesh, plays a crucial role in irrigating the central Punjab region, including the area surrounding Lahore. The Beas and Sutlej, the easternmost rivers, also originate in India and converge before joining the Chenab. These rivers, along with their extensive canal systems, have historically shaped Punjab's agricultural landscape, turning it into a fertile breadbasket. However, these rivers also face challenges, including reduced flows due to upstream diversions and climate change, as well as pollution from industrial and agricultural runoff, impacting water quality and availability. Their effective management and conservation are vital for the sustainability of Punjab's economy and environment.

6. Canals

The canal system in Punjab, Pakistan, is a vital lifeline, particularly crucial in the context of Lahore, the provincial capital. This vast and intricate network, fed by the five rivers of the

region—the Jhelum, Chenab, Ravi, Beas, and Sutlej—forms one of the largest contiguous irrigation systems in the world. Its primary purpose is to distribute water for agricultural purposes, turning the fertile plains of Punjab into a highly productive breadbasket.

Originating from barrages strategically placed on these rivers, the canal system branches out into a complex web of main canals, branch canals, distributaries, and minors, reaching far and wide across the province.

Historically, the development of this canal system has played a pivotal role in shaping Punjab's landscape and economy, with significant expansion occurring during the British colonial era. In the area surrounding Lahore, the canal network is especially critical for irrigating the agricultural lands that provide sustenance to the city's large population. The efficient management of this system is essential for maintaining agricultural productivity, ensuring food security, and supporting the livelihoods of millions of people in Punjab.

However, the canal system also faces challenges, including waterlogging, salinity, and the need for continuous maintenance. The Indus Waters Treaty also significantly influences water allocation within the system. Moreover, climate change and increasing water demand are putting additional pressure on this vital resource. Given Lahore's central role in Punjab, the health and efficiency of the canal system are intrinsically linked to the city's well-being and the region's overall development

7. Drains

In Punjab, Pakistan, including the densely populated area around Lahore, the drainage system plays a crucial, though often overlooked, role in managing water resources and preventing environmental degradation. The network of drains is designed to carry away excess water, including rainwater, agricultural runoff, and industrial and domestic wastewater, preventing flooding and waterlogging. However, the functionality and maintenance of these drains are often compromised by a variety of factors. Many drains are poorly maintained, becoming clogged with solid waste, vegetation, and sediment, which impedes water flow and increases the risk of flooding during heavy rainfall. Furthermore, a significant portion of industrial and domestic wastewater is discharged directly into these drains, often without proper treatment, leading to severe pollution of downstream water bodies. This contamination poses serious threats to public health and aquatic ecosystems. In the agricultural areas surrounding Lahore, drainage systems are vital for preventing waterlogging and salinity, which can severely impact crop yields. However, inefficient drainage practices and the use of polluted drainage water for irrigation can exacerbate soil degradation and introduce harmful pollutants into the food chain. Therefore, improving the management of drainage systems in Punjab, through regular maintenance, effective waste management, and the implementation of wastewater treatment facilities, is essential for ensuring environmental sustainability and protecting the health of the region's population

8. Ground Water

Groundwater resources in Punjab, Pakistan, are under significant strain due to over-extraction and contamination, posing a critical challenge for the region, including Lahore. Punjab's reliance on groundwater for agriculture, domestic use, and industry has led to a rapid decline in water tables. Studies indicate that in many areas, the groundwater table is falling by as much

as 1-2 meters annually. According to reports, over 90% of Punjab's drinking water comes from groundwater sources, highlighting the vulnerability of the population to contamination. Aquifer depletion is exacerbated by the intensive use of tube wells, particularly in the agricultural sector, where inefficient irrigation practices contribute to excessive water consumption. Furthermore, the quality of groundwater is compromised by the leaching of agricultural chemicals, industrial effluents, and untreated sewage. High levels of arsenic, fluoride, and nitrates have been detected in various areas, exceeding permissible limits set by the World Health Organization. For instance, reports indicate that arsenic contamination affects millions in the southern districts of Punjab. In Lahore, rapid urbanization and industrial growth have further intensified pressure on groundwater resources, leading to localized depletion and contamination. The Punjab government has initiated some measures to regulate groundwater extraction and improve water quality, but more stringent policies and effective implementation are needed to ensure the sustainable management of this vital resource.

9. Ground water quality for drinking purposes

The groundwater quality in Punjab, Pakistan, particularly concerning contaminants like fluoride and arsenic, presents a mixed and often concerning picture. Studies and reports indicate that several districts across Punjab face elevated levels of these geogenic contaminants, posing significant health risks to the population relying on groundwater for drinking and irrigation.

9.1 Fluoride:

Elevated fluoride concentrations in groundwater are a documented issue in certain parts of Punjab. While fluoride at optimal levels is beneficial for dental health, prolonged ingestion of water with high fluoride content (above the WHO guideline value of 1.5 mg/L) can lead to dental fluorosis, characterized by teeth discoloration and pitting, and in severe cases, to skeletal fluorosis, a debilitating bone disease. The distribution of high fluoride zones is not uniform across the province, with some areas showing significantly higher prevalence than others. Factors such as the geological composition of the aquifers and the residence time of water underground contribute to the dissolution of fluoride-bearing minerals.

9.2 Arsenic:

Arsenic contamination of groundwater is another serious public health concern in Punjab, mirroring the situation in other parts of the Indus River basin. Chronic exposure to arsenic through drinking water (above the WHO guideline value of 10 µg/L) is linked to various health problems, including skin lesions, cardiovascular diseases, neurological disorders, diabetes, and an increased risk of several types of cancer. Studies have identified specific areas in Punjab, particularly in the southern and eastern parts of the province, where arsenic levels in groundwater exceed permissible limits. The source of arsenic is primarily geogenic, originating from arsenic-bearing minerals in the alluvial aquifers. The mobilization of arsenic into groundwater is influenced by hydrogeochemical conditions, including pH, redox potential, and the presence of organic matter.

9.3 Other Contaminants: Besides fluoride and arsenic, groundwater in Punjab can also be affected by other contaminants, including:

- **Salinity:** Particularly in arid and semi-arid regions, high levels of dissolved salts can make groundwater unsuitable for drinking and irrigation.

- **Nitrates:** Primarily from agricultural runoff (fertilizers) and sewage contamination, elevated nitrate levels in drinking water can pose health risks, especially to infants.
- **Heavy Metals:** Industrial discharge, although more impacting surface water, can also seep into groundwater, introducing heavy metals like lead, chromium, and cadmium.
- **Microbiological Contamination:** Inadequate sanitation and leakage from sewage systems can lead to the contamination of groundwater with bacteria and other pathogens, causing waterborne diseases.

9.4 Monitoring and Mitigation: The Punjab EPA and other relevant organizations are involved in monitoring groundwater quality. Efforts to mitigate the problem include identifying affected areas, raising public awareness about the risks, and exploring solutions such as alternative water sources, treatment technologies (like arsenic and fluoride removal filters), and rainwater harvesting. However, the scale of the contamination and the reliance on groundwater pose significant challenges for ensuring safe drinking water access for the entire population of Punjab. Continuous monitoring, research, and the implementation of sustainable water management practices are crucial to addressing these groundwater quality issues effectively

10. Ground water quality for agricultural purposes

The groundwater quality in Punjab, Pakistan, is a complex issue with varying levels of contamination by different pollutants across the province. Given Lahore's location and the broader environmental context of Punjab, it's crucial to understand the spectrum of these contaminants and their implications.

10.2   Arsenic Contamination: As highlighted earlier, arsenic is a significant concern in Punjab's groundwater, particularly in the southern and eastern regions. This geogenic contaminant leaches from arsenic-bearing minerals in the alluvial aquifers. The hydrogeochemical conditions, including pH, redox potential, and organic matter content, influence its mobilization into the water. Prolonged exposure, common through drinking water, is linked to severe health issues like skin lesions, cardiovascular diseases, various cancers, and neurological problems. The extent of arsenic contamination varies geographically, with some districts showing alarmingly high percentages of wells exceeding the WHO guideline of 10 µg/L.

10.3   Fluoride Levels: Elevated fluoride concentrations are prevalent in certain belts of Punjab, often associated with specific geological formations. While optimal fluoride levels are beneficial for dental health, exceeding the permissible limit (1.5 mg/L by WHO) can lead to fluorosis. Dental fluorosis, characterized by enamel defects, is common, and in areas with very high concentrations, skeletal fluorosis, a debilitating bone disease, can occur. The distribution of high fluoride zones is not uniform, necessitating localized assessments.

10.4   Salinity: In the more arid and semi-arid parts of Punjab, particularly towards the southwest, groundwater salinity is a growing problem. This is due to natural dissolution of salts from the soil and underlying geological formations, coupled with unsustainable irrigation practices that can lead to salt accumulation in the root zone and leaching into groundwater. High salinity renders water unsuitable for both drinking and agriculture, impacting livelihoods and water availability.

10.5   Nitrate Pollution: Agricultural activities play a significant role in nitrate contamination of groundwater. The excessive use of nitrogenous fertilizers can lead to leaching of nitrates into

aquifers, especially in areas with permeable soils and shallow water tables. High nitrate levels in drinking water pose a risk to infants, causing "blue baby syndrome" (methemoglobinemia), and have been linked to other health issues in adults. Urban areas also contribute through sewage leakage.

10.6   Heavy Metal Contamination: Industrial discharge, both historical and ongoing, introduces various heavy metals into the environment, which can eventually contaminate groundwater. While surface water bodies often bear the brunt, seepage and improper disposal practices can lead to the presence of heavy metals like lead, chromium, cadmium, and mercury in aquifers. These metals are toxic even at low concentrations and can accumulate in the body, causing neurological damage, kidney problems, and other chronic diseases. Industrial areas in and around Lahore and other major cities are potential hotspots for this type of contamination.

10.7   Microbiological Contamination: The contamination of groundwater with bacteria, viruses, and protozoa from sewage leakage, inadequate sanitation, and improper disposal of human and animal waste is a widespread concern, particularly in densely populated and poorly sewered areas, both urban and rural. This leads to waterborne diseases like typhoid, cholera, hepatitis, and diarrheal illnesses, posing a significant public health burden.

10.8   Pesticide and Herbicide Residues: As an agricultural hub, Punjab's groundwater is also susceptible to contamination from the leaching of pesticides and herbicides used in farming. The persistence and mobility of these chemicals vary, but their presence in drinking water sources can have long-term health implications, including potential carcinogenic and endocrine-disruption effects.

10.9   Emerging Contaminants: Increasingly, attention is being drawn to emerging contaminants like pharmaceuticals, personal care products, and microplastics in water sources globally, and Punjab may not be immune. While research in this area is still evolving in the specific context of Punjab's groundwater, these contaminants pose potential risks to human and environmental health even at trace levels.

11. Industrial Pollution Load

A significant discrepancy exists between the number of wastewater samples deemed fit versus unfit from industrial outlets across Punjab. Out of a total of 1280 samples collected, a mere 252 met the established quality standards, representing a concerningly low percentage. Conversely, a substantial 1028 samples were classified as unfit, indicating widespread contamination and non-compliance with environmental regulations. This stark disparity highlights a critical issue of industrial pollution in the region, posing potential risks to public health and the environment. The overwhelming majority of samples failing to meet the required standards suggests a systemic problem requiring urgent attention and stricter enforcement of wastewater treatment protocols within Punjab's industrial sector.

12. Industrial Wastewater in Lahore

12.1 Analysis of Results:

- **Significant Improvement Post-Treatment:** In most cases, there is a clear reduction in BOD5, COD, TSS, and TDS after treatment. This demonstrates that the treatment processes are generally effective in removing pollutants.

- **Variable Treatment Effectiveness:** The degree of improvement varies across industries. Some industries, like the Sugar Mill and Tobacco, show dramatic reductions in pollutants, while others, like Textile and Food, still have relatively high levels after treatment.
- **Sulfide Reduction:** The presence of Sulfide is an issue that is shown to be addressed by the treatment, with many of the after-treatment results being 0.
- **TDS Reduction:** TDS reduction is also shown to be effective, but many of the industries still have very high TDS levels after treatment.
- **pH Levels:** The pH levels are generally within an acceptable range both before and after treatment.
- **Rice Mill Data:** The Rice Mill data is incomplete, with only "B" values provided. This makes it impossible to assess the effectiveness of its treatment process.
- **High Initial Pollution:** Several industries, particularly Food, Paint, and Paper & Board, exhibit very high levels of pollution before treatment, indicating a need for more stringent pollution control measures at the source.

Table 4-1: ***State of effluent wastewater from different industries before and after treatment in Lahore***

SR. NO.	TYPE OF INDUSTRY	pH		BOD$_5$		COD		SULFIDE		SULFATE		CHLORIDE		TSS		TDS	
		B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A
1	Textile	8	7	335	63	652	148	0	0	394	239	729	329	376	67	3558	1852
2	Food	7	7	967	56	1796	131	1	0	311	162	316	225	4575	48	2181	1331
3	Sugar Mill	8	7	392	12	712	36	4	0	248	112	190	85	230	60	2140	640
4	Rice Mill	8	-	339	-	693	-	0	-	731	-	1390	-	350	-	7135	-
5	Paint	7	7	2201	66	4642	168	0	0	362	193	316	207	1899	85	3256	1577
6	Cement	7	7	151	45	329	97	3	0	125	85	90	52	202	62	883	623
7	Pharmaceutical	7	7	251	69	558	159	0	0	202	129	338	182	142	55	1699	983
8	Beverages	8	7	297	32	688	71	1	0	302	196	623	218	193	58	4676	1604
9	Paper and Board	7	7	1059	312	2253	715	16	3	465	230	420	227	680	157	3613	1733
10	Tobacco	8	7	196	12	413	64	1	0	78	48	55	25	235	20	550	270

Source: EPA Punjab Lahore Laboratory

Faisalabad and rest of the Punjab

12.2 Key Parameters:

- **pH:** Measures acidity or alkalinity. PEQs range is 7-9.
- **BOD (Biochemical Oxygen Demand):** Measures organic pollution. PEQ value is 80 mg/l.
- **COD (Chemical Oxygen Demand):** Measures total organic matter. PEQ value is 150 mg/l.
- **Sulfide:** Toxic compound. PEQ value is 1.0 mg/l.
- **Sulfate:** High concentrations can cause problems. PEQ value is 600 mg/l.
- **Chloride:** High levels affect salinity. PEQ value is 1000 mg/l.
- **TSS (Total Suspended Solids):** Measures suspended solids. PEQ value is 200 mg/l.
- **TDS (Total Dissolved Solids):** Measures dissolved substances. PEQ value is 3500 mg/l.

12.3 Analysis of Results:

- **pH:**
  - Several industries, particularly Textile Dyeing and Sugar Mills, have pH levels exceeding the PEQs before treatment.
  - After treatment, pH levels generally fall within the acceptable range.
- **BOD:**
  - BOD data is not available (N/A) in this report.
- **COD:**
  - All industries show a reduction in COD after treatment.
  - However, several industries, especially Sugar Mills and Food Industries, still have COD levels significantly exceeding the PEQs even after treatment.
- **Sulfide:**
  - Sulfide levels are generally reduced after treatment.
  - Most industries exceed the PEQs for sulfide before treatment.
- **Sulfate:**
  - Sulfate levels are reduced after treatment.
  - Many industries exceed the PEQs for sulfate before treatment.
- **Chloride:**
  - Chloride levels are generally reduced after treatment.
  - Many industries exceed the PEQs for chloride before treatment.
- **TSS:**
  - TSS levels are significantly reduced after treatment.
  - All of the Textile based industries greatly exceed the PEQs before treatment.
- **TDS:**
  - TDS levels are reduced after treatment.
  - All of the industry samples greatly exceed the PEQs before treatment, and all of the industry samples except for the sugar mills, greatly exceed the PEQs after treatment.
- **Textile Industry:**
  - Textile industries show significant improvements in all parameters after treatment, but still have issues with TDS and in some cases, sulfate, and chloride.
- **Sugar Mills and Food Industries:**

- These industries exhibit very high COD and TDS levels, even after treatment, indicating substantial organic and dissolved solids pollution.
- **Chemical Industry:**
  - The Chemical industry shows good improvement in all measured parameters.

12.4 Implications for Faisalabad:

- Industrial wastewater in Faisalabad poses a serious environmental challenge.
- Treatment processes are generally effective in reducing pollution loads, but further optimization is needed.
- COD and TDS levels are a major concern, particularly in Sugar Mills and Food Industries.
- Stricter enforcement of PEQs and investment in advanced treatment technologies are crucial.
- The TDS levels across the board are a large concern for ground water contamination.
- The lack of BOD data is a problem for proper analysis of the wastewater.

Table 4-2: State of effluent wastewater from different industries before and after treatment in Faisalabad

Type of Industry	pH		BOD (mg/l)		COD (mg/l)		Sulfide (mg/l)		Sulfate (mg/l)		Chloride (mg/l)		TSS (mg/l)		TDS (mg/l)	
	B*	A*	B*	A*	B*	A*	B*	A*	B*	A*	B*	A*	B*	A*	B*	A*
Textile Processing	7.46	7.2	N/A	N/A	616	208	13.2	10.8	1006	834	2180	1163	1725	124	5710	3859
Textile Processing	8.20	7.63	N/A	N/A	640	140	5.6	0.8	1316	510	1843	984	809	147	6099	3053
Textile Dyeing	10.59	7.75	N/A	N/A	724	392	6.0	2.0	1078	593	2620	1168	545	382	3908	2789
Textile Dyeing	9.15	8.31	N/A	N/A	324	136	3.6	2.0	760	691	1179	1135	596	250	3790	3363
Sugar Mills	10.33	7.42	N/A	N/A	3600	3400	1.8	1.2	309	310	341	383	292	166	2800	2750
Food Industry	3.43	7.58	N/A	N/A	2528	128	0.4	0.4	993	463	814	329	552	93	3642	3190
Food Industry	7.62	7.66	N/A	N/A	2200	440	4.4	1.2	248	246	2209	1159	217	63	4848	3376
Chemical Industry	7.44	7.36	N/A	N/A	568	104	8.4	1.6	1934	840	1674	855	1547	877	6952	3297
PEQs Values	7-9		80		150		1.0		600		1000		200		3500	

(Source: EPA Punjab Faisalabad Laboratory)

13. Role of EPA to control wastewater pollution from Industry

The Environmental Protection Agency (EPA) +Punjab plays a vital role in managing and controlling wastewater pollution across the province, with a particular focus on urban centers like Lahore. Below is an overview of their key responsibilities and actions:

13.1   Key Roles and Responsibilities:

- **Enforcement of Environmental Laws and Regulations:**
    o   The EPA is responsible for enforcing the Punjab Environmental Protection Act and other relevant environmental laws and regulations related to wastewater discharge.
    o   This includes setting and enforcing standards for wastewater discharge from industries, municipalities, and other sources.
- **Setting and Enforcing Punjab Environmental Quality Standards (PEQS):**
    o   The EPA sets and enforces the NEQS for wastewater, which specify the maximum permissible levels of pollutants in discharged wastewater.
    o   These standards cover various parameters, including biological oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), and heavy metals.
- **Environmental Impact Assessments (EIAs):**
    o   The EPA requires industries and other development projects to conduct EIAs to assess the potential environmental impacts of their wastewater discharge.
    o   This helps ensure that new projects are designed and operated in a way that minimizes wastewater pollution.
- **Issuance of Environmental Approvals (EAs):**
    o   The EPA issues EAs to industries and other entities that meet the required environmental standards for wastewater discharge.
    o   These approvals specify the conditions under which wastewater can be discharged.
- **Monitoring and Inspection:**
    o   The EPA conducts regular inspections of industrial facilities, sewage treatment plants, and other wastewater discharge points to ensure compliance with environmental regulations.
    o   They also monitor the quality of water bodies to assess the impact of wastewater pollution.
- **Enforcement Actions:**
    o   The EPA takes enforcement actions against violators of environmental regulations, including issuing fines, imposing penalties, and even closing down polluting facilities.
- **Promotion of Wastewater Treatment and Reuse:**
    o   The EPA promotes the adoption of effective wastewater treatment technologies and encourages the reuse of treated wastewater for irrigation, industrial purposes, and other beneficial uses.
- **Public Awareness and Education:**
    o   The EPA conducts public awareness campaigns to educate the public about the importance of responsible wastewater management and the environmental consequences of untreated discharge.
- **Collaboration and Coordination:**

- o The EPA collaborates with other government agencies, industries, and civil society organizations to address wastewater pollution issues.
- o They work closely with the water and sanitation agencies in the urban areas.

13.2 Context of Lahore and major cities:

Given Lahore's dense population and industrial activity, the EPA's role in controlling wastewater pollution is particularly critical. The city faces significant challenges in managing its wastewater, and the EPA's efforts are essential to protect the Ravi River and other water resources from contamination.

14. DSPIR Framework

To understand the complexities of industrial wastewater in Punjab, Pakistan, particularly in locations like Lahore and Faisalabad, the DPSIR (Drivers, Pressures, State, Impacts, Responses) framework is highly useful. Let's elaborate on each component:

14.1 Drivers:

- **Rapid Industrialization:** Punjab's economic growth is fueled by industries like textiles, food processing, sugar mills, chemicals, and pharmaceuticals. This expansion leads to increased wastewater generation.
- **Urbanization:** Growing urban centers concentrate industrial activity and increase the demand for water, leading to higher volumes of wastewater discharge.
- **Population Growth:** A rising population increases the overall demand for industrial products, further driving industrial expansion and wastewater production.
- **Lack of Enforcement:** Weak enforcement of environmental regulations and inadequate monitoring create a permissive environment for industries to discharge untreated or partially treated wastewater.
- **Economic Pressures:** Industries, especially small and medium-sized enterprises (SMEs), may prioritize cost-cutting over environmental compliance.

14.2 Pressures:

- **Increased Wastewater Discharge:** Industries release large volumes of wastewater containing various pollutants.
- **Pollutant Load:** Wastewater contains high levels of BOD, COD, TSS, TDS, heavy metals, chemicals, and pathogens.
- **Untreated or Partially Treated Discharge:** Many industries lack adequate wastewater treatment facilities or operate them inefficiently.
- **Direct Discharge into Water Bodies:** Wastewater is often discharged directly into rivers, canals, and drains, contaminating surface water resources.
- **Groundwater Contamination:** Leaching of pollutants from industrial sites and improper disposal practices contaminate groundwater.

14.3 State:

- **Degraded Surface Water Quality:** Rivers and canals exhibit high levels of pollutants, making them unsuitable for drinking, irrigation, and aquatic life.

- **Contaminated Groundwater:** Groundwater sources are contaminated with heavy metals, nitrates, and other pollutants, posing risks to human health.
- **Reduced Aquatic Biodiversity:** Pollution leads to the decline of fish populations and other aquatic organisms.
- **Soil Degradation:** Irrigation with contaminated water leads to soil salinization and reduced fertility.
- **Public Health Risks:** Waterborne diseases and other health problems are prevalent due to contaminated water.

14.4 Impacts:

- **Human Health:** Contaminated water causes waterborne diseases, respiratory problems, and other health issues.
- **Environmental Degradation:** Loss of aquatic biodiversity, soil degradation, and ecosystem disruption.
- **Economic Losses:** Reduced agricultural productivity, increased healthcare costs, and decreased tourism.
- **Social Impacts:** Water scarcity, social unrest, and displacement of communities.
- **Loss of Ecosystem Services:** Reduced capacity of ecosystems to provide clean water, regulate climate, and support biodiversity.

14.5 Responses:

- **Regulatory Measures:** Strengthening environmental regulations, enforcing effluent discharge standards, and implementing pollution control policies.
- **Infrastructure Development:** Investing in wastewater treatment plants, sewage systems, and industrial effluent treatment facilities.
- **Technological Solutions:** Promoting the adoption of cleaner production technologies and advanced wastewater treatment methods.
- **Monitoring and Enforcement:** Enhancing monitoring of industrial discharges and enforcing penalties for non-compliance.
- **Public Awareness and Education:** Raising awareness about the impacts of industrial pollution and promoting responsible water use.
- **Community Participation:** Engaging communities in water resource management and pollution control.
- **Incentive Programs:** Providing incentives for industries to adopt sustainable practices and invest in pollution control.
- **Research and Development:** Supporting research on innovative wastewater treatment technologies and pollution prevention strategies.

CHAPTER 5   **Soil Quality**

1. Overview

Punjab's soil composition and quality exhibit significant variation due to factors such as topography, climate, and geological formations. The dominant soil type, alluvial soil, results from sediment deposits carried by rivers, particularly the Indus River. Some regions feature clayey soil, known for its high-water retention capacity. While clay-rich soils are inherently fertile, efficient drainage is crucial to prevent waterlogging. In contrast, sandy soil, prevalent in South Punjab, offers excellent drainage but requires frequent irrigation due to limited water retention. Additionally, soil salinity and alkalinity pose fertility challenges in various parts of the province.

To address these issues, effective soil management strategies are necessary. The distribution of soil types varies across Punjab's districts, influencing agricultural practices and crop selection. Farmers and experts regularly conduct soil tests to analyze soil properties, aiding in informed decision-making regarding crop cultivation and management techniques.

KEY FINDINGS

Soil Salinity

Soils in most districts (except Faisalabad) show a more alkaline trend, with pH often exceeding 8.0 in urban and industrial zones.

Faisalabad's industrial soils show localized acidification with the lowest pH (~6.5).

Electrical Conductivity (EC) is highest in wastewater-irrigated soils, particularly in Sahiwal (~3.6 dS/cm).

Soil Fertility

Phosphorus remains deficient in industrial soils, especially in Attock and Hafizabad.

Wastewater-irrigated soils have the highest phosphorus concentrations, notably in Faisalabad and Sargodha.

Potassium is elevated in urban and industrial soils of Sahiwal, and in agricultural soils of Sargodha and Attock.

Heavy Metals

Zinc levels have risen significantly across most land uses, with Faisalabad reaching critically high values.

Iron concentrations have increased sharply, particularly in Faisalabad, Okara, Sahiwal, and Sargodha.

Manganese is generally adequate to high, especially in industrial and effluent-irrigated soils of Faisalabad and Hafizabad.

Adopting soil health management systems, diverse crop rotations, and no-till/strip-till cropping systems are recommended for improving soil quality.

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2. Environment

2.1 Soil Quality

Eight key parameters were analyzed based on secondary data sources, including pH, Electrical Conductivity (EC), and concentrations of heavy metals (Copper, Manganese) along with essential nutrients such as Zinc, Iron, Potassium, and Phosphorus. The results were compared with international soil quality standards for heavy metals. For soil salinity Water and Power Development Authority, Pakistan classification[1] was used and for fertility assessment standards referred in International Center for Agricultural Research in the Dry Areas were used[2].

Table 5-1:. Critical limit of different soil parameters[1,2]

Parameter	Critical Limit		
pH	Normal		Sodic
	<8.4		>8.4
EC (ds/cm)	Normal		Saline
	<4		>4
Copper (mg/kg)	Low	Moderate	Adequate
	<0.20	0.20-0.50	>0.50
Manganese (mg/kg)	Low	Moderate	Adequate
	<1.0	1.0-2.0	>2.0
Zinc(mg/kg)	Low	Moderate	Adequate
	<0.5	0.5-1.0	>20
Iron (mg/kg)	Low	Moderate	Adequate
	<4.5	4.5	>4.5
Potassium (mg/kg)	Low	Moderate	Adequate
	<100	100-150	>150
Phosphorous (mg/kg)	Low	Moderate	Adequate
	<8	8-15	>15

2.2 Soil Salinity

The pH level of all soil types across different districts was <8.5 indicating that soil were normal (Table 1). However, compared to the earlier reported pH range of 6.7 to 8.0 in Punjab, the current data shows a generally more alkaline trend across Sahiwal, Sargodha, Hafizabad, and Attock, with urban and industrial soils often exceeding pH 8.0. Wastewater-irrigated soils show varied pH levels—lower in Sargodha and Sahiwal (~7.2–7.5), and higher in Attock and Hafizabad. Faisalabad stands out with the lowest pH values, especially in industrial areas (~6.5), indicating localized soil acidification. Overall, this suggests greater regional variation and stronger alkalinity in most districts than previously observed (Figure 5-1a). These findings align with a 2025 study, which reported an average soil pH ranging from neutral to moderately alkaline (7.1–8.8) across diverse cropping systems in Punjab, highlighting both the rise in alkalinity and pockets of acidification under industrial and wastewater influence[3]

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1   Water and Power Development Authority (1981).

2   Ryan,J., George Estefan and Abdul Rashid. 2001. Soil and Plant Analysis Laboratory Manual. Second Edition. Jointly published by the International Center for Agricultural Research in the Dry Areas (ICARDA) and the National Agricultural Research Center (NARC). Available from ICARDA, Aleppo, Syria. x +172 pp.

3   Aziz, I., Qayyum, A., et al. (2025*). Long-term impact of different prevalent cropping systems on soil physico-chemical characteristics under subtropical climate conditions of Punjab, Pakistan. Scientific Reports, 15:3874.*

The current EC analysis shows Sahiwal's wastewater-irrigated lands having the highest EC (~3.6 dS/cm) among all samples—consistent with the earlier observation about Sahiwal's effluent-irrigated soils (Figure 5-1b). Overall, EC level of all soil types across the districts was below 4 ds/cm indicating non-saline soil type (Table 1).
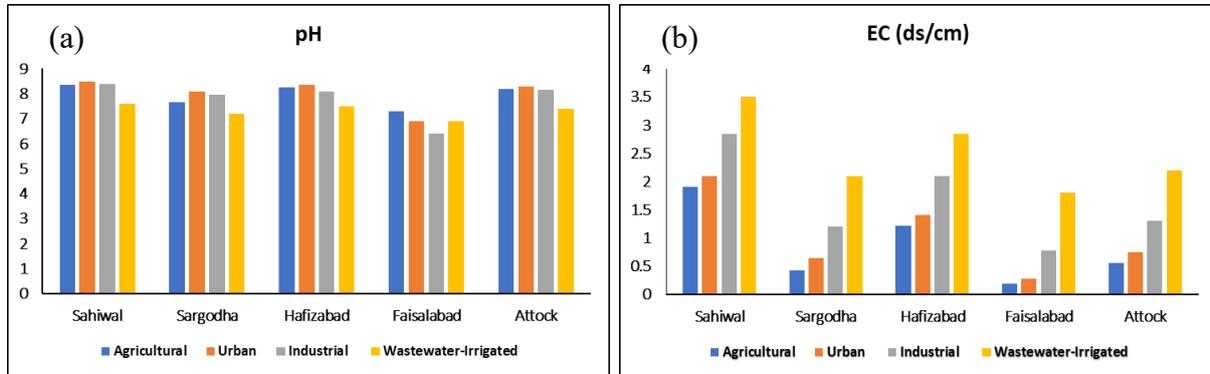
Figure 0-1: pH (a) and EC (b) in four soil types of selected districts in Punjab (Source: Published data) [4-8]

2.3 Soil Fertility

The current data aligns with previous findings, reaffirming that industrial soil remains low in available phosphorus, notably in Attock and Hafizabad, as was earlier observed in Rawalpindi, Bahawalpur, and Gujranwala. Urban and agricultural soils continue to exhibit marginal phosphorus levels, consistent with trends reported in Sahiwal and Multan. In contrast, wastewater-irrigated soils show consistently elevated phosphorus concentrations across all districts, particularly in Faisalabad and Sargodha, supporting earlier observations of nutrient enrichment in effluent-irrigated lands (Figure 5-2a). These findings are corroborated by a recent study[9], which reported that available phosphorus in treated wastewater-irrigated soils ranged from 15.2 to 160 mg/kg, significantly higher than in control soils, confirming long-term nutrient accumulation in such environments.

The recent data in Figure 5-2b confirms elevated potassium levels in urban and industrial soils of Sahiwal, aligning with earlier findings. The updated figure also highlights high potassium in agricultural soils of Sargodha and Attock and wastewater-irrigated soils of Hafizabad and Faisalabad, offering a broader view of regional variability.

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4   Rebi, A., Wang, G., Flynn, T., Hussain, A., Ejaz, I., Afzal, A., Nadeem, M., Ilyas, M. Z., Alharbi, S. A., Almansour, M. I., Zhou, J., and Li, G. (2025). Harvesting Nature's Treasure: Examining Soil Properties and Nutrient Bounty in the Crop Fields of Hafizabad, Punjab, Pakistan using Geostatistical Kriging. Polish Journal of Environmental Studies.

5   Rebi, A., Wang, G., Hussain, A., Flynn, T., Ullah, H., Chenghao, Z., Jamil, M., Afzal, A., Ahmed, M.I. and Zhou, J., 2023. Spatial distribution and quantification of plant-available nutrients and soil properties in Punjab, Pakistan

6   Bibi, D., Gutiérrez Pérez, D.I., Tóthmérész, B. and Simon, E., 2025. Pollution Assessment Using Soil and Plant Leaves in Faisalabad, Pakistan. Atmosphere, *16*(5), p.580.

7   Sarwar, M.A., Qazi, M.A., Iqbal, H.I., Alvi, S., Khan, S.U., Raza, R.A., Ali, S. and Rashid, M., 2025. Macro and Micro Nutrient Profiling in Tehsil Hazro Soils: Insights into Spatial Variability. Pak-Euro Journal of Medical and Life Sciences, *8*(1), pp.13-22.

8   *Rubab, S., Khan, M. U., Mehboob, M., & Malik, R. N. (2025).* Spatial insights into microplastics and heavy metals levels, and risks in wastewater irrigated surface soils of Okara, Pakistan: Microplastics sizes impacts on heavy metals distribution using structure equation model. Environmental Pollution, 368, 125786

9   Najafpour, H., Javid, A., Fathi, N., & Farid, M. (2025). Effects of long-term wastewater irrigation on microplastics pollution in agricultural soil. Environmental Science and Pollution Research.

(a)   (b)
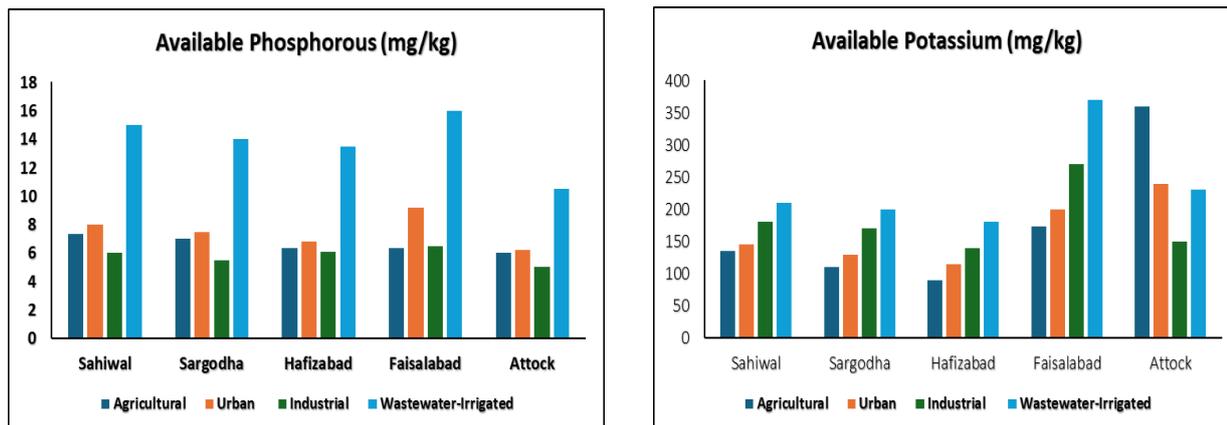
Figure 5-2:   Phosphorus (a) and Potassium (b) in four soil types of selected districts in Punjab (Source: Published data)[4-8]

2.4 Heavy Metals

The concentration of heavy metals (mg/kg) across all soil types in Punjab remained within the permissible limits established by international standards. While SOE 2023 reports several instances of marginal and even deficient zinc levels—especially in urban soils and irrigated lands of divisions like Faisalabad, Rawalpindi, and Sargodha—the 2025 data points to a significant rise in concentrations, particularly in Faisalabad, where all land use types now exceed adequate levels, with some reaching critically high values. The only notable exception is Attock, where agricultural soils remain in the low category and urban soils fall within the marginal range. Sargodha shows a positive shift, with elevated zinc levels in industrial and effluent-irrigated soils, and a significant recovery in urban zones that were previously categorized as deficient. Sahiwal, which displayed stable conditions in 2024, continues to reflect adequate levels across all zones. Overall, the comparison indicates a widespread rise in zinc content, transforming many previously marginal or deficient areas into adequately enriched zones. However, in some zones, the buildup has become so pronounced that it now raises environmental concern due to its excessive accumulation (Figure 5-3a). Excessive zinc in soil is known to pose human health risks. A comprehensive 2025 review emphasizes that high zinc exposure can lead to gastrointestinal distress etc.[10]

As reported in SOE 2023, iron levels across most zones were within a moderate, sufficient range, with the highest concentrations noted in wastewater-irrigated soils of Faisalabad. In contrast, the 2024 data reveal a significant spike in iron levels, especially in Faisalabad's urban and agricultural soils as well as in Okara's wastewater irrigated soils. Even Sahiwal and Sargodha, which were previously stable, now exhibit high iron concentrations (>4.5 mg/kg) across all land use types. (Figure 5-3b). Prolonged irrigation with sewage effluents leads to excessive accumulation of iron in soils, which can result in leaching into groundwater and uptake by food crops—potentially causing long-term human exposure through the food chain[11].

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10   Fatima, G., Raza, A. M., & Dhole, P. (2025). *Heavy Metal Exposure and its Health Implications: A Comprehensive Review*. *Indian Journal of Clinical Biochemistry*.

11   Ahmad, N., Shahid, M., Ali, T., & Hassan, M. (2025). *Long-term impact of sewage irrigation on iron*
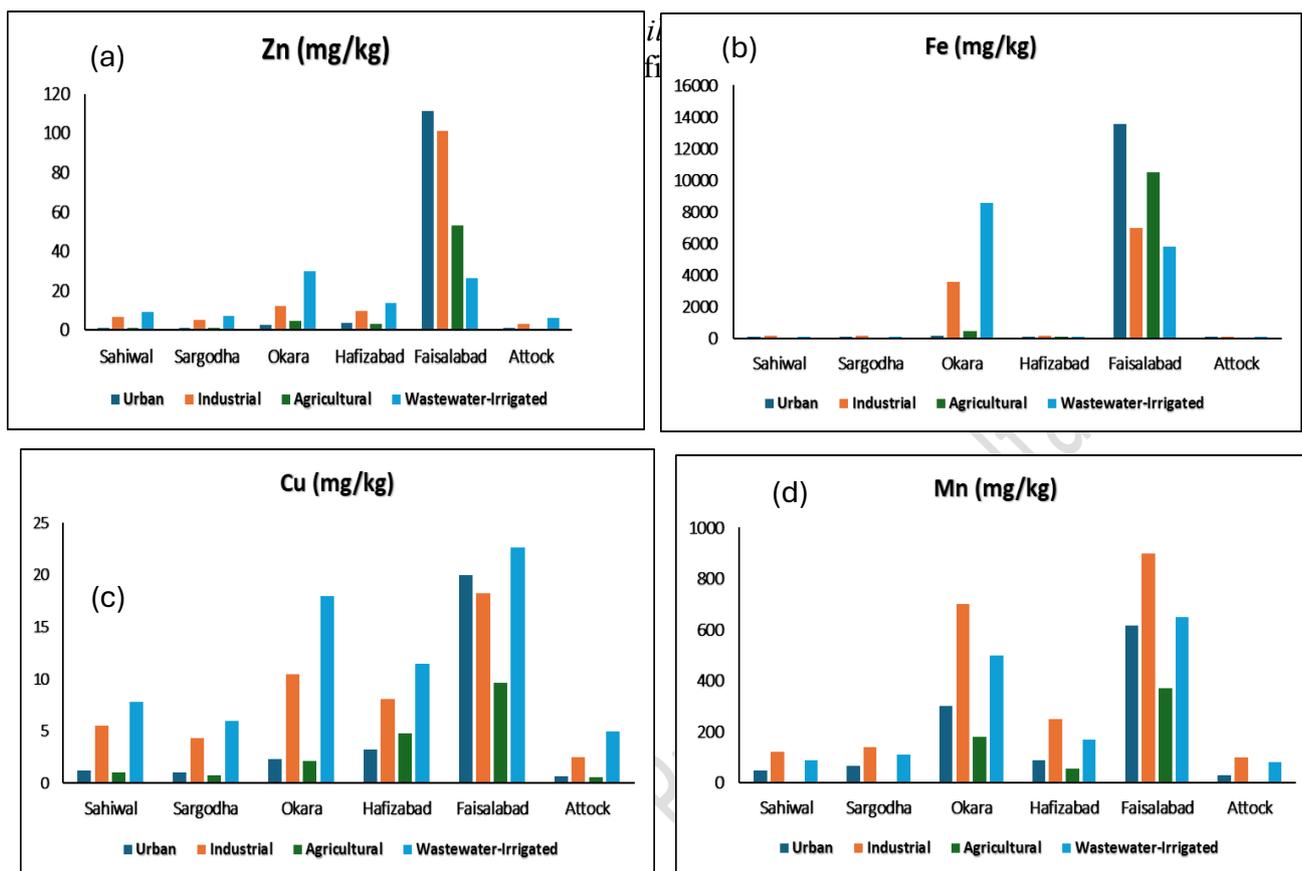
Figure 0-3: *Heavy Metals in four soil types of selected districts in Punjab*

(Source: Published data)[15]

The analysis of copper (Cu) concentrations across different districts and land-use types reveals significant spatial variation, with wastewater-irrigated soils consistently showing the highest levels. Faisalabad emerges as the most contaminated zone. Manganese (Mn) concentrations across all districts and land use types generally indicate adequate to high levels, with notable enrichment in industrial and wastewater-irrigated soils, particularly in Faisalabad, Okara, and Hafizabad. These elevated values suggest ongoing input from anthropogenic sources such as effluent discharge and industrial activity. Urban and agricultural zones in Sahiwal and Sargodha also show moderate Mn levels, while Attock remains comparatively lower but within a sufficient range.

3. Management

Soil plays a crucial role in maintaining ecosystem health, which is vital for the survival of living organisms. As the backbone of the country's agricultural economy, preserving soil quality in Punjab requires collective efforts from both public and private sectors. Collaboration

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Water and Power Development Authority (1981).

1   Ryan,J., George Estefan and Abdul Rashid. 2001. Soil and Plant Analysis Laboratory Manual. Second Edition. Jointly published by the International Center for Agricultural Research in the Dry Areas (ICARDA) and the National Agricultural Research Center (NARC). Available from ICARDA, Aleppo, Syria. x +172 pp.

among farmers, government bodies, and agricultural experts is essential to ensure the success of soil quality management initiatives.

3.1 Soil Salinity and Waterlogging

Soil salinity refers to the concentration of various salts in the soil, primarily potassium nitrate, magnesium sulfate, sodium chloride, and sodium bicarbonate. Among these, sodium chloride is the dominant contributor to salinity. This issue arises from multiple sources, including human activities such as land development and agricultural practices. Industrial and agricultural effluents often contain high salt concentrations, while excessive irrigation raises the groundwater table, exacerbating salinity.

Waterlogging occurs when the soil becomes saturated with water, restricting air circulation and harming plant growth. This condition is closely linked to salinity, particularly in agricultural soils, where excess moisture and salt accumulation reduce crop productivity. Addressing these challenges requires effective groundwater management, improved drainage systems, sustainable irrigation practices, and the cultivation of salt-tolerant crops.

It is estimated that approximately 7,044,000 acres of agricultural land in Punjab have become unproductive due to waterlogging and salinity, posing a severe threat to sustainable agriculture. With over 50% of extracted groundwater being saline, irrigated soils are increasingly at risk. Tackling these issues demands coordinated efforts from the government, the agricultural sector, and local farmers.

3.2 Soil Fertility and Use of Agrochemicals

Soil fertility is largely dependent on organic matter, which consists of decomposed plant and animal material. Organic matter enhances nutrient availability, improves water retention, supports soil porosity, and fosters microbial activity. Fertile soils result in higher crop yields and sustainable agricultural production.

Although cultivated land in Punjab has remained relatively stable over the past four decades, the intensive use of fertilizers and pesticides has increased due to limited available farmland. This trend has significant implications for soil quality, necessitating careful management of agrochemical use to maintain long-term soil health.

3.3 Physical Properties of Soil

Soil texture and hydraulic properties significantly influence soil fertility and quality. Studies indicate that loam, silt loam, and sandy loam are the predominant soil textures in the Potohar region, where sandy content decreases with depth due to erosion and rainfall. Similar soil textures are found in the Doab region, although variations occur with depth due to surface erosion. Compared to the Doab region, Potohar exhibits greater soil diversity, highlighting the need for region-specific soil conservation strategies.

3.4 DPSIR Framework

The DPSIR (Drivers, Pressures, State, Impact, Response) framework provides a structured approach to understanding soil quality dynamics in Punjab:

- **Drivers**: Factors influencing soil quality include urbanization, industrialization, intensive agriculture, deforestation, and extreme weather events.
- **Pressures**: Land-use changes, overgrazing, soil contamination, and erosion exacerbate soil degradation.
- **State**: High pollution load index, elevated sodium adsorption ratio (SAR), and excessive sodium levels indicate declining soil health.
- **Impact**: Poor soil quality leads to soil erosion, reduced crop yields, impaired water quality, and adverse effects on human health due to nutrient deficiencies in food crops.
- **Response**: Sustainable soil management practices improved agricultural policies, afforestation initiatives, and enhanced research and monitoring efforts are necessary to counteract soil degradation.
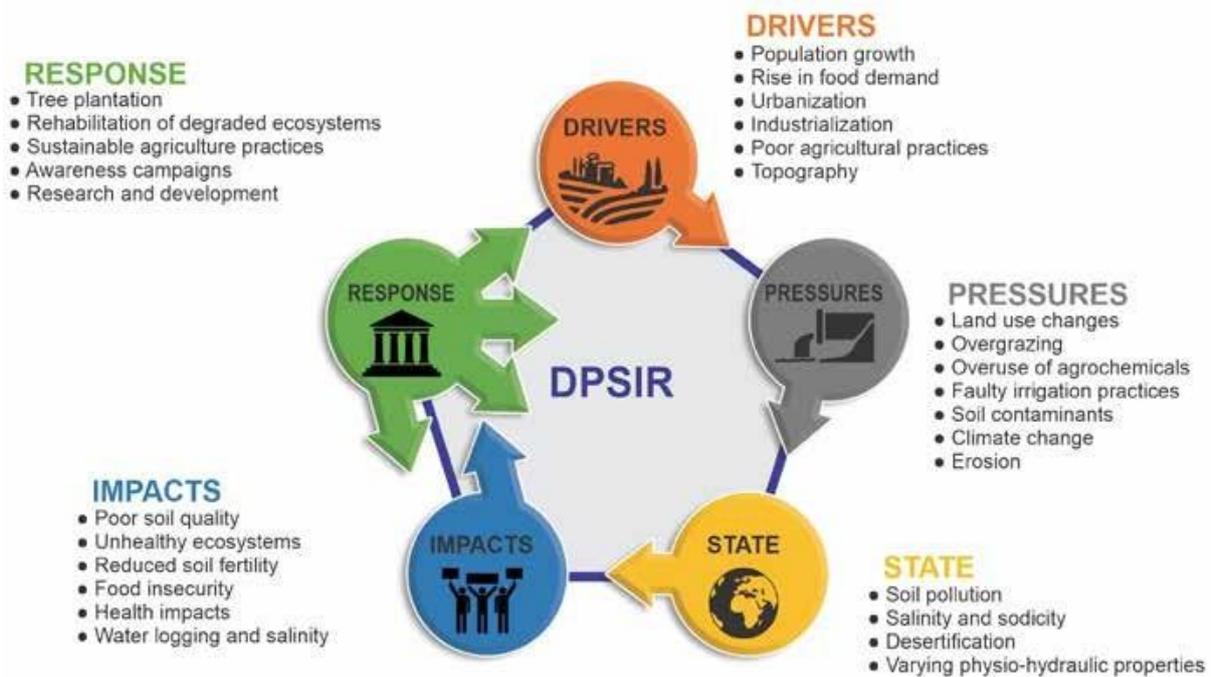
Figure 0-4:   DPSIR framework of soil quality in Punjab

4. Way Forward

Enhancing soil quality requires a multi-pronged approach, integrating modern techniques with traditional knowledge. Key strategies include:

- **Adopting soil health management systems**: Practices such as crop rotation, cover cropping, and organic farming improve soil fertility and reduce reliance on chemical inputs.
- **Promoting conservation tillage**: No-till and strip-till systems help preserve soil structure, prevent erosion, and maintain moisture retention.
- **Improving nutrient and grazing management**: Incorporating compost, biochar, and manure enhances soil microbial activity and nutrient availability.

- **Government intervention and policy planning**: Authorities should implement sustainable land management practices, incentivize conservation techniques, and promote soil research.
- **Investing in farmer education and awareness**: Training programs on sustainable soil management practices ensure long-term agricultural productivity.
- **Collaborative research efforts**: Partnerships with research institutions, NGOs, and agricultural organizations can drive innovation and effective soil conservation strategies.
- **Establishing nationwide soil monitoring systems**: Regular assessments of soil health will facilitate targeted interventions to maintain soil quality.
- **Encouraging agroforestry**: Integrating trees and shrubs into agricultural landscapes improves soil stability and fertility.
- **Regulating agrochemical use**: Policies to control excessive fertilizer and pesticide application will prevent long-term soil degradation.
- **Enhancing drainage systems**: Proper drainage infrastructure is crucial for mitigating waterlogging and salinity in vulnerable regions.

By implementing these strategies, Punjab can ensure sustainable soil management, safeguard agricultural productivity, and promote environmental resilience.

CHAPTER 6 CLIMATE CHANGE

1. Overview

Islamic Republic of Pakistan, and the rest of the world, has experienced the aspects of urbanization, economic development, rapid population growth and what comes along with all that like the huge demand on natural resources. With the changes in modern life, there has been increasing pressure on fragile ecosystems, increasing waste production and accelerating pollution of resources. With the global weight of climate change, the situation has been an alarming threat to human welfare.

South Asia faces severe challenges due to climate change, with projections indicating severe impacts by 2100. Projections suggest that, even with global emission reductions, South Asia could warm by an additional 3°C to 4°C by 2100. This temperature increase is expected to exacerbate the frequency and severity of extreme weather events, further threatening the region's development. Over the past 24 years, a number of climate-driven extreme events have affected more than half of this region. According to projections, South Asian states are expected to suffer economic losses from climate change that are roughly 7% greater than the world average, with Pakistan potentially suffering a 10% loss 2100[1].

2. Environment

2.1 Punjab's Climate Change Outlook

Asia was responsible for 51.3% of global CO_2 emissions[2]. Only 0.9% of the world's greenhouse gas emissions and 0.5% of its CO_2 emissions come from Pakistan[3,4]. As the fifth most climate-vulnerable nation, Pakistan faces significant risks from sudden climate change events. Agriculture accounts for 45.6% of Pakistan's GHG emissions, Energy came in second at 44.7%. Trash and industrial activities account for 4.43% and 5.3% of the sectoral distribution of greenhouse gas emissions, respectively[5].

The nation's most populous province, Punjab, is particularly susceptible to the consequences of climate change. Heat waves and a rise in riverine, flash, and urban flooding frequency and severity are some of the province's climate change manifestations.

On the sectors that are most at risk, such as water resources, agriculture, health, and ecosystems, these occurrences have a variety of downstream repercussions. Even though the province's

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[1] Climate Change Action Plan 2021-2025 South Asia Roadmap (2021). The World Bank Group

[2] BPStatistical Review of World Energy, 71st edition, 2022.

[3] Inamullah, M., Rehman, A., 2022. The impact of financial sector development on environmental degradation (carbon dioxide emission) in Pakistan. J. Econ. Impact 4 (3), 244–251. https://doi.org/10.52223/jei4032211.

[4] Ali, S. R., &Mujahid, N. (2024).Sectoral carbon dioxide emissions and environmental sustainability in Pakistan. Environmental and Sustainability Indicators, 23, 100448.

[5] MinistryofClimateChange,GovernmentofPakistan.Pakistan'sSecondNationalCommunicationonClimate Change-toUnitedNations Framework Convention on Climate Change (UNFCCC); Ministry of Climate Change: Islamabad, Pakistan, 2018.

"emissions" from climate change are increasing quickly, the top priorities for climate action continue to be vulnerability, adaptation, institutional capacity, and resilience.

2.2 Weather Patterns and Normals

A thorough assessment of Punjab's environmental status is provided by the "Punjab State of Environment Report, 2024" (SOE), which looks at important topics such waste management efficacy, climate change, and the quality of the air, water, and soil. According to SOE-2024 Punjab has a diverse climate, with semi-arid to desert temperatures in the south and chilly, humid weather in the Salt Range's north.[5]

According to climate norms documented between 1991 and 2020, Punjab experienced mean annual precipitation of 49.8 mm[6,7](Figure 6-1) and mean annual minimum and maximum temperatures of 17.1°C and 30.1°C (Figure 6-2), respectively. There is significant temperature variability throughout the province, as evidenced by temperature extremes recorded from the 1880s to 2020, which show a minimum temperature of -12°C in Northern Punjab and a maximum temperature of 50.8°C in Southern Punjab[8].

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[6]Pakistan Meteorological Department CDPC(https://cdpc.pmd.gov.pk/Pakistan_Monthly_Climate_Summary_Jun_2024.pdf)

[7]Pakistan Monthly Climate Summary 2024-PMD

[8]Climate Resilient Punjab Vision & Action Plan 2024

[9]Climate Data Processing Centre PMD

[10]https://climate.copernicus.eu/global-climate-highlights-2024

[11]World Meteorological Organisation

[12]https://www.nasa.gov/centers-and-facilities/goddard/nasa-finds-summer-2024-hottest-to-date/

[13]Ibid

[14]NOAA (2020) (https://www.climate.gov/news-features/climate-qa/does-global-warming-mean-it%E2%80%99s-warming-everywhere)
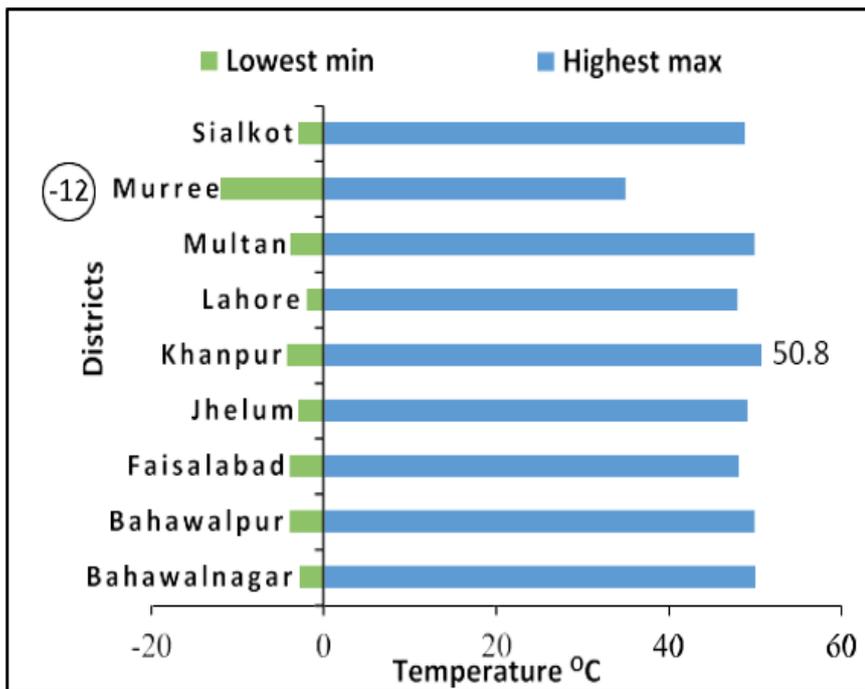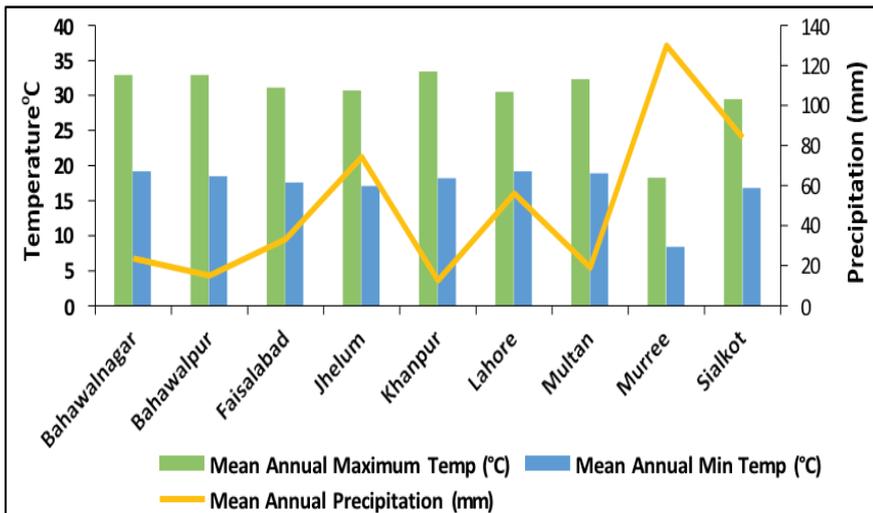
Figure 6-1 Climate Normals in Punjab (1991-2020)   *Figure 6-02 Extreme Punjab (1880s to 2020)*

2.3 Weather Anomalies-2024

    i.   Temperature

Global average temperatures in the summer of 2024 broke previous records, with the maximum recorded temperature for June–August being 0.69°C higher than the average for 1991–2020. This was higher than the June-August 2023 record[9]. The WMO confirmed 2024 as the hottest year recorded with temperatures rising by almost 1.55°C over pre-industrial levels[10]. Over 52% of land areas were more than 1°C warmer than usual. Sea surface temperature anomalies were mostly mirrored by surface air temperature anomalies over the ocean as shown in Figure 2-3(a

& b). NASA reported a 1.28°C rise above the 20th-century baseline, marking 2024 as the warmest year since records began in 1880[11]. Climate change is driven by factors like air pressure, wind patterns, cloud cover, solar radiation, and regional geography[12,13].

Figure 6-03 (a)Surface Air Temperature Anomaly 2024   *b) Anomalies and extremes in surface air temperature in 2024*
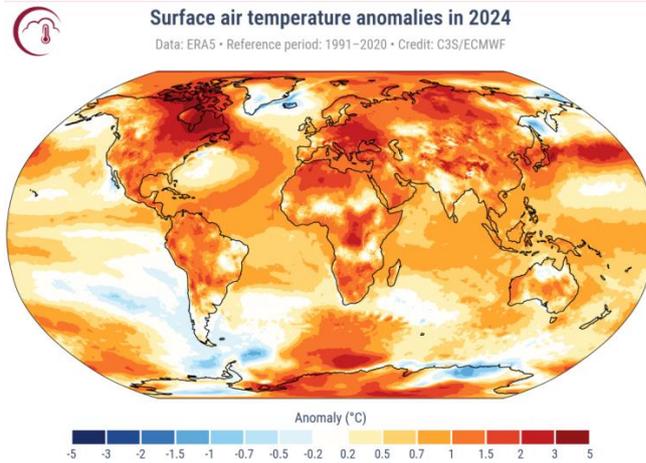
a   b
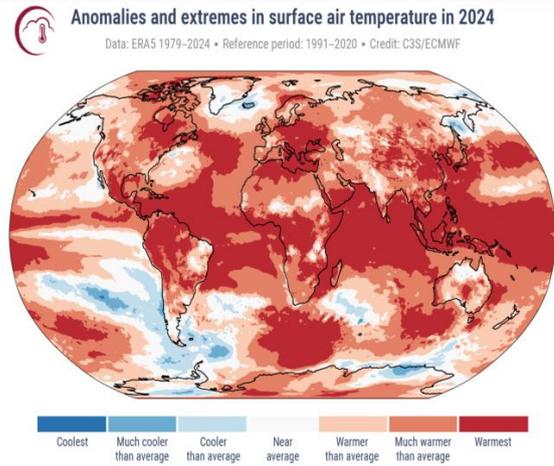
The study over the period 1961-2024 shown in Figure 6-4 indicates a combination tendency of positive and negative anomalies during 1961-97, with three consecutive positive anomalous years in the early 1970s, to illustrate the evolution of Pakistan's annual average temperature over an extended time frame (64 years). However, it became noticeable after 1998, with a notable exception of a few particular years like 2005, 2021, and 2022. Out of these, 2002 stood out as having a positive anomaly of more than 1 °C, while 2016 was close to +1 °C. According to the slope equation, the average yearly temperature rise is 0.0082 °C[14]. As per Pakistan's mean monthly temperatures in 2024, showing in Figure 2-5, highest temperature was recorded in June (32.62°C), with a peak summer period from May to August and a decline towards winter.

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[15]Pakistan Meterological Department

[16]*The* black solid line indicates 7-year moving average with average positioned over middle year of each 7-year block. The black dotted line shows the trend over the period.

[17] ibid

Pakistan's Area Average Mean Temperature (°) 1961-2024

$y = 0.0082x - 0.122$
$R^2 = 0.1005$

Pakistan's Mean Monthly temperatures (°C) in 2024
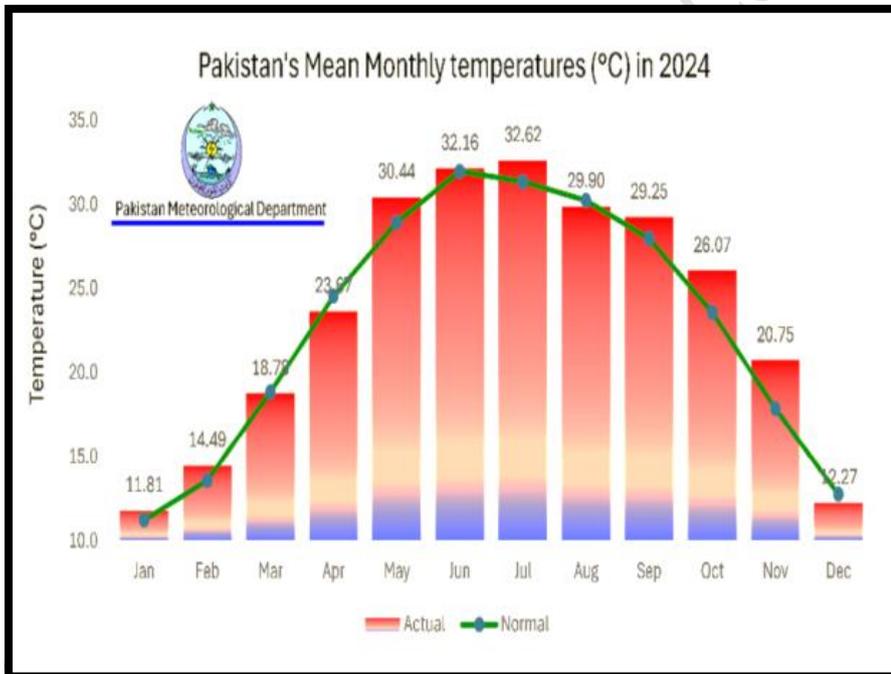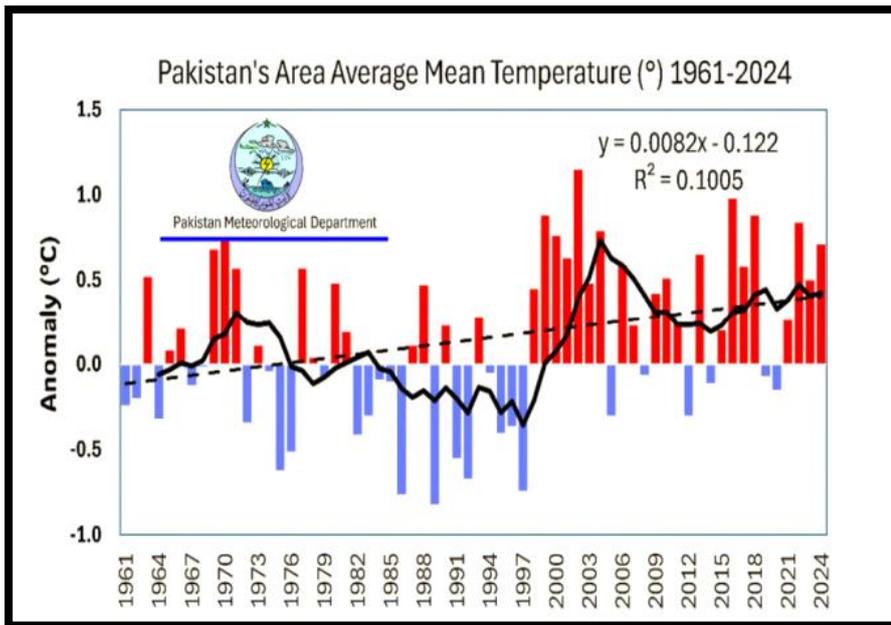
Figure 6-04 Pakistan annual mean temperature anomalies (with 1961-1990 base period) over 1961-2024. [15]	*Figure 6-5 Monthly mean Temperature 2024 versus corresponding averages*[16]

The maps (Figure 6-6) of Punjab province indicate a slight increase in maximum temperatures from 2001-2010 to 2011-2020. While southern Punjab consistently shows the highest temperatures, the later decade 2013-2023, appears to have a wider area of high temperatures.

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[18] State of Pakistan's Climate – 2023, Pakistan Meteorological Department

Northern regions remain relatively cooler in both periods but may also show a small temperature increase in the 2001-202. Punjab saw a range of temperature anomalies in 2024. With an anomaly of -0.13°C, the annual mean maximum temperature was somewhat below normal. With an anomaly of +1.70°C, the annual mean minimum temperature was noticeably higher and ranked third highest on record as shown in Figure 6-7 (a). Conditions in January 2024 were in contrast, with Punjab recording the lowest monthly mean temperature in 64 years (a -2.75°C anomaly), mostly as a result of prolonged fog.
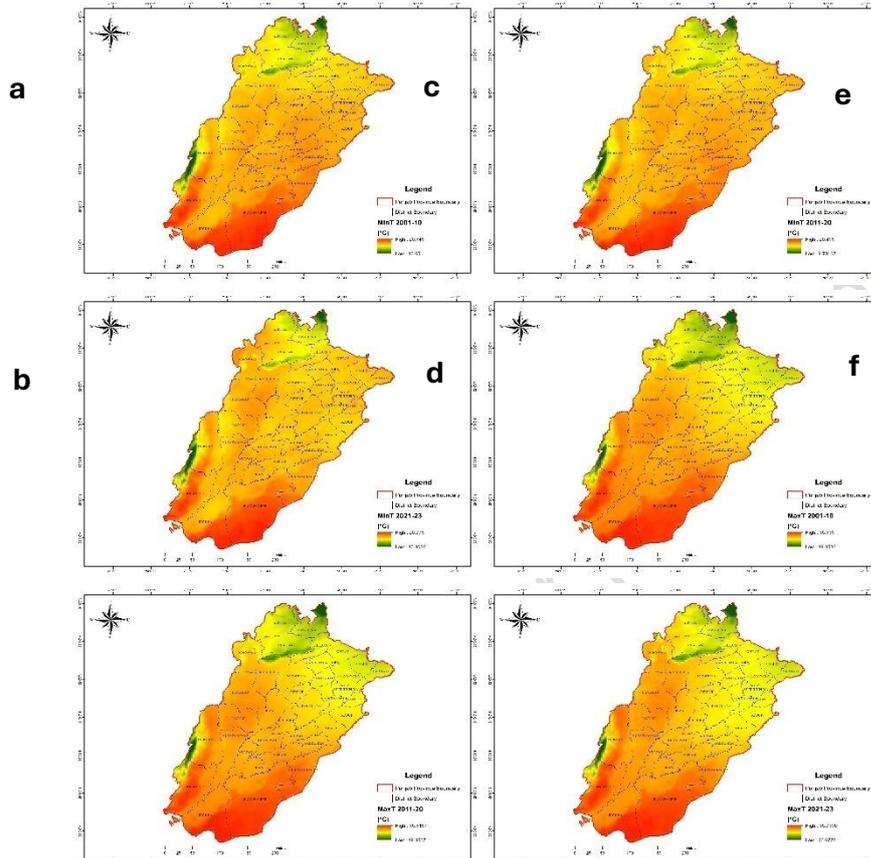
Figure 60-6 Study Map of Punjab showing Maximum and Minimum Temperature from (a, b)2001 to 2010 (c, d) 2011–2020 (d, f) 2021-2023

Temperatures were above average (Figure 6-7(b)) in the remaining months, nevertheless. In July, Punjab had one of the highest 10 mean temperatures of the year and established a new record for the greatest lowest (nighttime) temperature. Temperatures in September were similarly above normal, ranking third for mean temperature (+1.47 °C) and tenth for mean maximum temperature (+0.77 °C). It was also the second highest in terms of mean low temperature (+2.73 °C). With the highest average temperature and the highest average low temperature ever measured for the month, October also offered unprecedented temperatures. In a similar vein, November had above-normal temperatures, with the second-highest mean temperature (+1.96 °C)[17].

Punjab Monthly Temperature 2024

Legend: ■ Maximum Temperature Actual ■ Minimum Temperature Actual ■ Mean Temperature Actual

a

Punjab Monthly Temperature Anomaly 2024

Legend: ■ Maximum Temperature Anomaly ■ Minimum Temperature Anomaly ■ Mean Temperature Anomaly

b
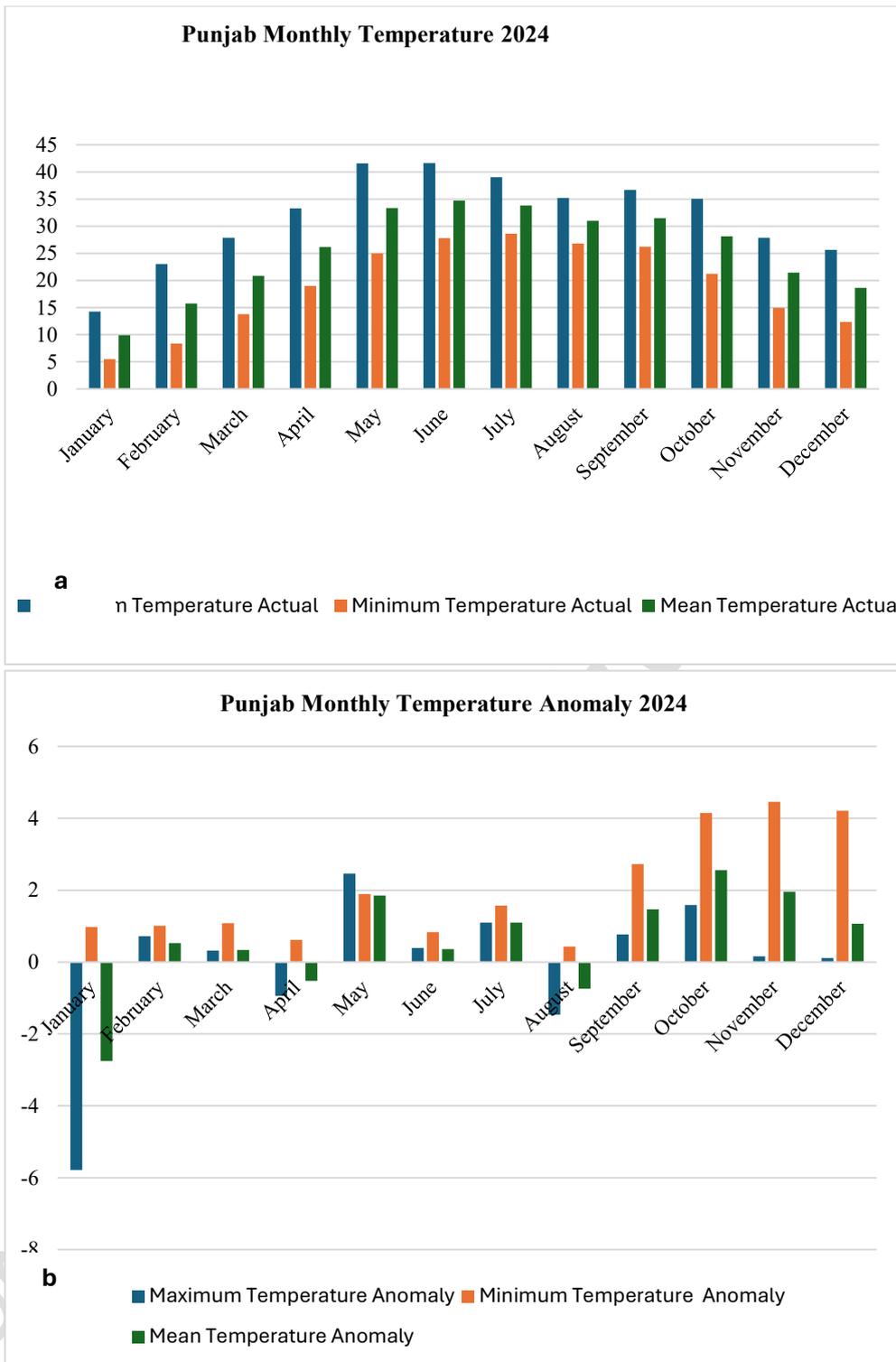
Figure 6-7(a) Punjab Monthly Temperature for 2024   *(b)Punjab Monthly Temperature Anomaly 2024*

ii. **Precipitation**

Pakistan's time series plot of the 64-year annual rainfall trend is also displayed in Figure 6-8, which shows three periods of surplus, wetter-than-average (1975–1983, 1988–1989) and deficiency, drier-than-average (1961–1972, 1984–1987, 1998–2002, and 2017–2018, with

some mixed patterns within). Rainfall in 1997, 2003, and 2005, with insufficient rainfall in 2009, 2014, and 2021. Throughout the examined time, there is some discernible inter annual rainfall variability in addition to these clear patterns. Particularly after 2003, the dotted black line exhibits a growing tendency (about 1.4 mm/year but with a lower R2 value).[18]
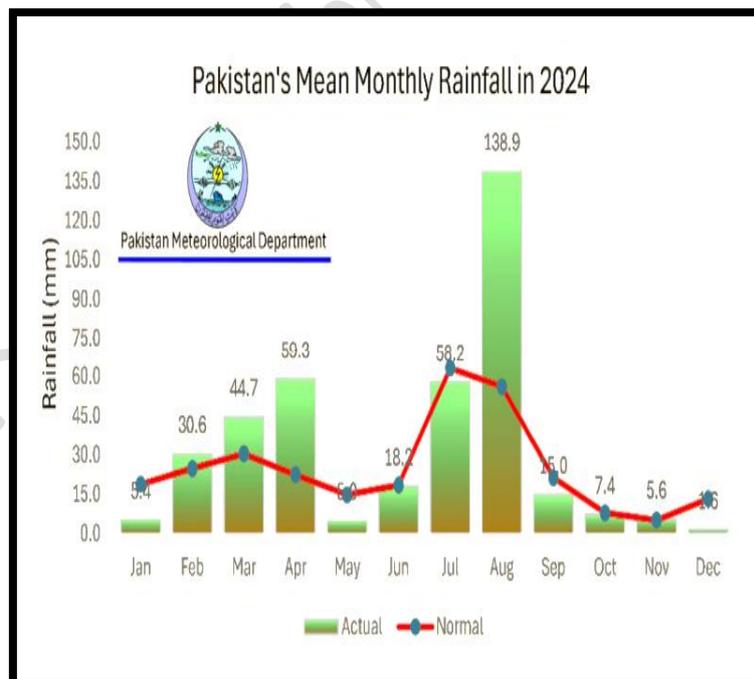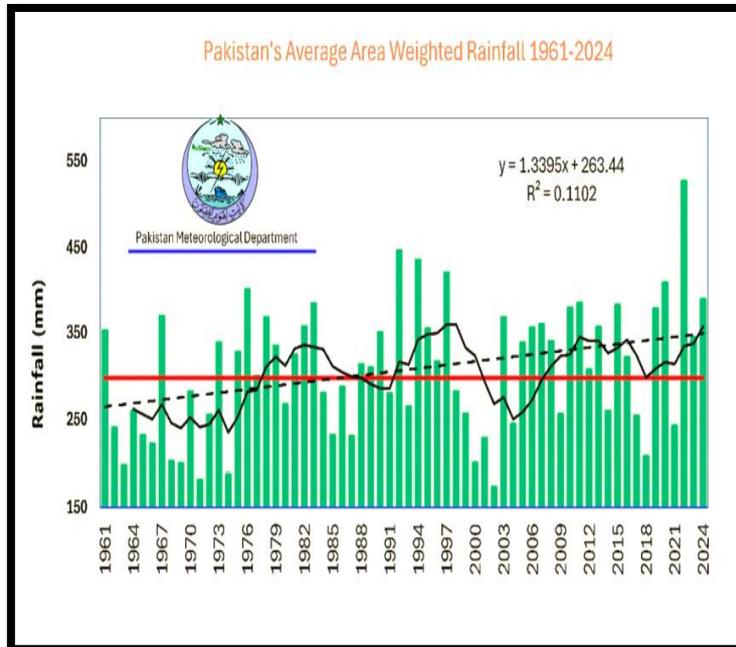
Figure 6-8 Pakistan annual rainfall time-series over 64-years (1961-2024).[19]	*Figure 6-9 Monthly mean rainfall in 2024 versus corresponding averages.*

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[19] NDMA
[20] PMD

Rainfall in Punjab was above average in 2024, totaling 454.8 mm, 18% more than the typical amount of 387.0 mm. In the last 63 years, this is the 22nd-highest rainfall that Punjab has seen. Throughout the year, there were variations in the rainfall's temporal distribution. Although Punjab still saw inadequate rainfall in February, conditions improved in February and March after January's precipitation was much below normal (Figure 6-9). Rainfall in April was much above average, and May was the seventh driest month in Punjab's history. Rainfall was below normal in June. Punjab saw above-average rainfall during the monsoon season (July–September), with 344.0 mm, or 48% more than usual.

In particular, August was Punjab's fourth wettest August ever. Rainfall in September, however, was significantly less than usual. October through December, the post-monsoon season, was much below normal. Punjab saw an anomaly of -0.13°C in the annual mean maximum temperature, which was somewhat below normal as represented by Figure 6-9. With an anomaly of +1.70°C, the annual mean minimum temperature was noticeably higher and ranked third highest on record. The mean temperature in January 2024 was the lowest in 64 years, while temperatures in the months that followed were above average. July was notable because it set a record for the greatest low temperature and had one of the top 10 mean temperatures. Temperatures in September and October were considerably above average, breaking a number of mean and minimum temperature records. Overall, the distribution of precipitation is similar in both years, with the south/southwest receiving the least amount and the northeast receiving the most. The precipitation ranges in 2024 appear to be less drastic. The lowest precipitation is somewhat higher (148.194 mm vs. 113.289 mm) and the maximum precipitation is slightly lower than in 2023 (1810.14 mm vs. 1974.76 mm). In comparison to 2023, this may indicate a somewhat more uniform rainfall distribution throughout the province in 2024 (Shown in Figure 6-10 & 11). With greater rates in the center regions and lower rates in other regions, the evapotranspiration pattern remains mostly constant throughout the two years. Nonetheless, evapotranspiration is significantly less in 2024. The 2024 maximum evapotranspiration is 1470 mm, while the 2023 maximum was 1827 mm.[20]

Figure 6-0-10 Precipitation Map for Punjab (2023& 2024)
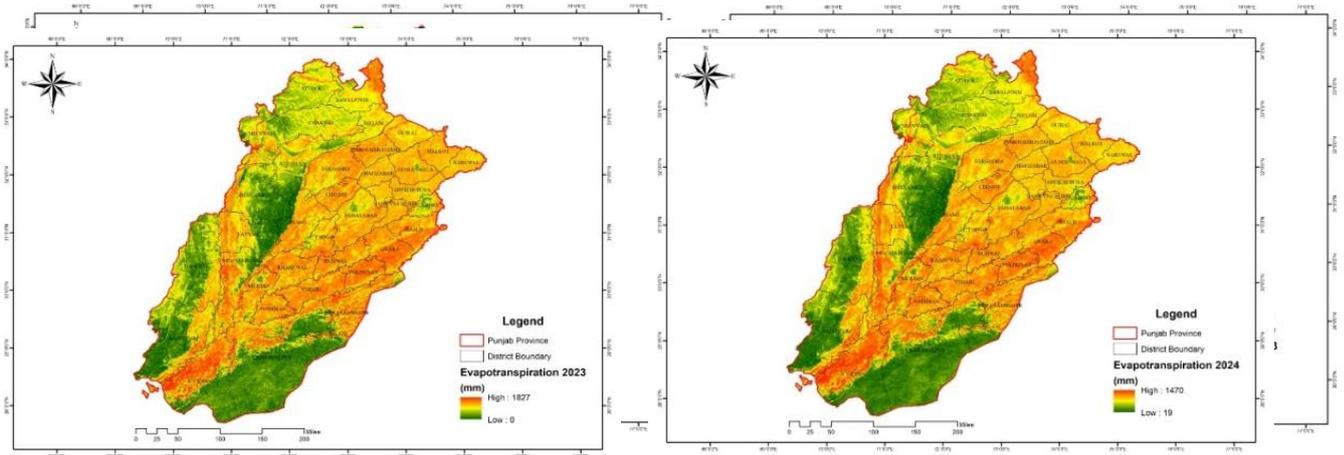
Figure 6-11 Evapotranspiration Map for Punjab (2023 & 2024)

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[21] Temperature and Precipitation Outlook across Pakistan and its Implications in Early 2024 (PMD Technical Report)

2.4 Extreme Events

The highest temperature during 2024 was 52.5°C recorded in Mohenjo-Daro, Sindh on May 26, whereas in August 2024 was the second wettest August in the previous 64 years, with 138.9 mm of national area-weighted rainfall, which was significantly above normal (+147%) (record is 193.2 mm in 2022). On August 1, the Lahore Airport in Punjab saw the most one-day rainfall, totaling 337.0 mm. With a total of 603.0 mm each month, it has been the wettest location.
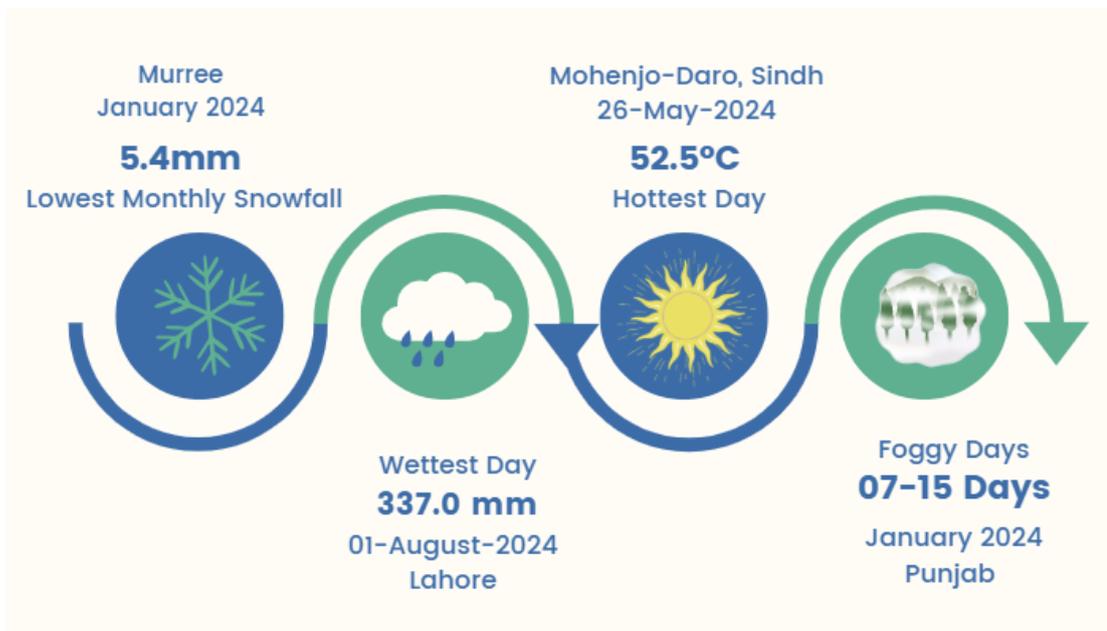
Figure 6-012 Extreme weather records in Punjab –2024

2.5 Sectoral Impacts of Climate Change in Punjab

The economy of Punjab is greatly impacted by climate change, with complex intra- and inter-sectoral effects.[21] It is still difficult to get comprehensive data that measures these effects and the risks that follow in different economic sectors. The province is experiencing more frequent and severe riverine, flash, and urban floods, as well as heatwaves, as a result of climate change.[22] There are several downstream implications of these extreme climatic events on susceptible industries, including ecosystems, agriculture, water supplies, and health.

2.6 Water Sector

Over 95% of Pakistan's freshwater resources are used for agriculture, which is the province's primary industry. Punjab accounts for 74.1% of Pakistan's total irrigated land and provides more than 50% of the country's overall agricultural output[23]. According to the Climate Change Commission, Punjab's water table is steadily dropping, and the province's water use especially for agriculture, will be significantly impacted by these degrading water supplies. Punjab uses its water resources for agriculture, industry, electricity generation, and homes. Lakes, rivers,

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[22] National Disaster Risk Management Fund (https://ndrmf.pk/wp-content/uploads/2024/08/Punjab_Climate_Change_Policy_Action_Plan__1723738609_compressed.pdf)
[23] Punjab Green Development Program

streams, springs, and precipitation are examples of surface water. On the other hand, aquifers and alluvial deposits contain groundwater[24].

Although Punjab is regarded as Pakistan's breadbasket, climate change may reduce agricultural productivity and worsen the province's water scarcity. Floods, a rise in the frequency and intensity of extreme weather events, and a decline in water quality are all threats to water resources. Lack of coordination, a shortage of technical experts, a lack of water storage reservoirs, and a lack of historical data are some of the obstacles Punjab faces when putting plans into practice[25]. The water industry is extremely susceptible to the effects of climate change. Along the Indus tributaries, Punjab is facing a water-stress scenario. The massive irrigation apparatus of the Indus Basin was choked by water logging and salinity[26] due to an inadequate drainage system.

Furthermore, due to inadequate irrigation methods, a huge amount of groundwater is extracted to augment surface water sources, increasing the salinity of the groundwater. The Punjab Irrigation Department says that between 1976 and 2020[27], the average annual availability of all the rivers that make up the flows of the Indus River System for canal withdrawals declined from 145.20 to 124.90 MAF. According to a NASA study conducted between 2003 and 2013, the Indus Basin aquifer was the second most overstressed of 37 major aquifers and was draining at an alarming rate. As a result, the province's groundwater supplies are under extreme stress. A recent assessment by the Punjab Irrigation Department[28] found that excessive abstraction has increased groundwater levels in seven regions of Punjab.

In 2010, 2014, and 2020, the percentage of land with subpar groundwater quality rose by 35%, 38%, and 49%, respectively. Prior floods in 2010 (River Indus), 2014 (River Chenab), 2022 (Hill torrents in DG Khan & Rajanpur), and 2023 (Eastern rivers) seriously damaged irrigation and drainage systems[27]

2.7 Agriculture and livestock Sector

A significant amount of greenhouse gases (GHG) is released into the atmosphere by the agriculture industry. Deforestation decreases the soil's capacity to store carbon by making land available for agriculture. Last but not least, the fast urbanization process also renders fertile ground unusable for farming. Two thirds of Pakistan's total milk output come from livestock in Punjab. 75% of the province's rural population depends on this industry for their livelihoods[27].Major crops produced more than expected and showed growth of 11.03% in FY24, contributing to Pakistan's agriculture sector's robust 6.25% growth. Punjab makes up around 57% of Pakistan's total cultivated land and 69% of its total cropped area. 80% of the nation's wheat, 83% of its cotton, 97% of its rice, 51% of its maize, and 63% of its sugar cane come from Punjab. Conversely, the province contributes more than 95% of citrus fruits, 34% of dates, 82% of guavas, and 66% of mangoes to the nation's fruit industry[28]. The province's

[24] Punjab Development Statistics, 2014, retrieved from: http://bos.gop.pk/system/files/Dev-2014.pdf
[25] Asian Water Development Outlook (2017). Country Paper Pakistan
[26] PUNJAB PROVINCIAL CLIMATE CHANGE ACTION PLAN (EPD)
[27] Qureshi, A. S., McCornick, P. G., Qadir, M., & Aslam, Z. (2008). Managing salinity and waterlogging in the Indus Basin of Pakistan. Agricultural Water Management, 95(1), 1-10.

agricultural contribution has decreased from 31% to 20% as a result of climate change's effects, which include crop failure, water shortages, environmental and soil degradation, inefficient use of agricultural inputs, and decreased crop yield[29]. Punjab uses river basins, canal farming, and, in certain places, hill torrents for agricultural purposes. These methods can all be significantly impacted by the effects of climate change. However, the lack of affordable input materials and growing energy prices provide difficulties for farmers, raising questions about their capacity to buy the agricultural inputs they will need for the upcoming planting seasons[30]. The government's 2% growth objective for the upcoming year has sparked worries that farmers would not be able to pay necessary inputs like pesticides and urea, which might lead to poor production. Financial institutions disbursed Rs1.64 trillion between July and March, reaching 72.7% of the annual target, while agricultural credit climbed by 33.8% in FY24[31]. According to the Economic Survey Report 2023-24, the agricultural growth rate has drastically decreased to 1.4% in 2023–24 from 4.7% in 2022–23, mostly as a result of a decline in food grain output brought on by El Nino-induced delayed and subpar monsoons.[32]
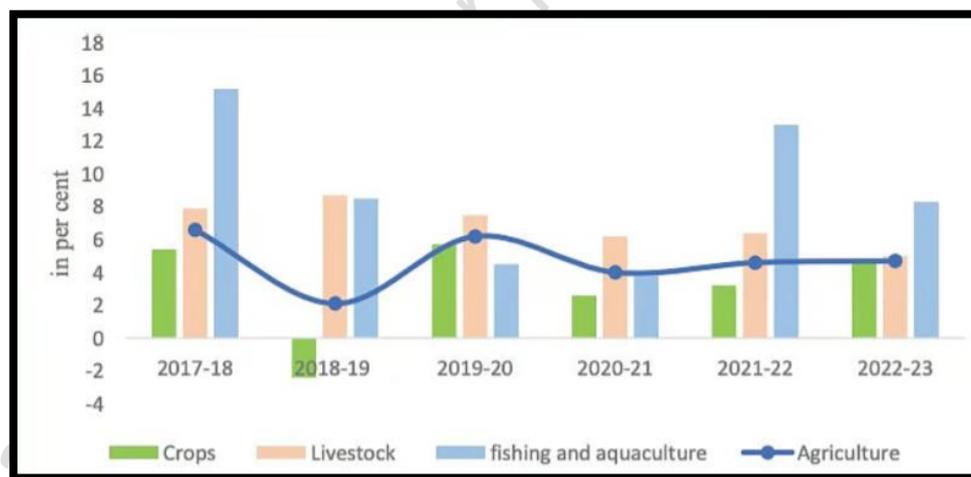
Figure 6-013 AgricultureSectorGrowthRates2017-2023

[28] Technical Paper 8 water and Irrigation (https://pbit.punjab.gov.pk/system/files/8.%20Water.pdf)

[29] ibid

[30] Waqas MM, Shah SHH, Awan UK, Waseem M, Ahmad I, Fahad M, Niaz Y, Ali S. Evaluating the Impact of Climate Change on Water Productivity of Maize in the Semi-Arid Environment of Punjab, Pakistan. Sustainability. 2020; 12(9):3905. https://doi.org/10.3390/su12093905

[31] Planning and Development Department. (2015). Punjab Growth Strategy 2018. Lahore: Government of Punjab.

[32] (www.agripunjab.gov.pk).

[33] Punjab Growth Strategy 2018 (PGS), (2015) retrieved from: http://www.theigc.org/wpcontent/uploads/2015/04/Punjab-Growth-Strategy-2018-Full-report.pdf

[34] https://finance.gov.pk/survey/chapter_24/2_agriculture.pdf

[35] Imtiaz, A., Zakir, F., & Fatima, N. (2024). Revolutionizing Food Security, Industrial Growth, and Agricultural Sustainability through Technological Advancements: A Comprehensive Research Analysis. *Annals of Human and Social Sciences*, 5(2), 205-211.

[36] PakistanEconomicSurvey2022-23(Agriculture)

Given that 75% of Punjab's population works in the livestock industry, there is room for growth. Compared to agriculture and industries, it is growing at a rate that is 4% faster. Compared to agriculture's 22% GDP contribution, it accounts for 55%. Animal byproducts, including milk, tannery, meat, gelatin, and others, are essential to 85% of livestock production and 64 large-scale businesses. Maintaining food security requires animals and making sure they are safe and healthy may save medical expenses by 71%[33]. Livestock is employed for transportation, farm labor, and the production of meat, dairy products, and manure in Punjab. Sheep, goats, camels, poultry, horses, donkeys, mules, buffalo, and cattle are among the animals that are commonly seen in Punjab. The 2022 floods killed an estimated 1,164,270 livestock heads, with 205,106 (17.6%) of the deaths occurring in Punjab, according to NDMA reports on 18-11-2022. [34]

2.8 Health Sector

There are direct and indirect health risks associated with climate change. The direct effects of climate change and its expressions include diseases, injuries, and fatalities brought on by heat waves, storms, forest fires, droughts, floods, landslides, and other occurrences. In 2024, heatwaves have affected almost 700,000 people in Central and Eastern Punjab.[35] The floods in 2024 were more severe and frequent, particularly in Central regions. For the 2024 monsoon season, which runs from June to August, the Pakistan Meteorological Department (PMD) predicted above-average rainfall.[36] The season's first two months saw 60% more rainfall than usual.[37] Between April 20 and 24, 2024, flood waters impacted about 9,000 km² of land, and an estimated 1.5 million people in Pakistan may have been exposed to or lived in flooded areas. From early July to September 2024 the flood results in 117 mortalities and 139 injuries, with wide damage reported including 464 schools, over 5,800 houses and more than 700 livestock countrywide.[38] Northern and eastern Punjab experienced 377 forest fire occurrences in 2024 and 199 in 2023, an 89% increase from the previous year.[39]

However, the primary causes of climate change's indirect health effects in Pakistan include the environment (air and water quality), food production, and the spread of infectious and chronic diseases. Hunger, poverty, food insecurity, and poor health can result from these impacts.[40] Between January and November, 2,179 dengue cases with one fatality and more over 17,000

37 Punjab Growth Strategy 2018 (PGS), (2015) retrieved from: http://www.theigc.org/wpcontent/uploads/2015/04/Punjab-Growth-Strategy-2018-Full-report.pdf

38 Pakistan Economic Survey 2022-2023

39 Climate Change Policy and Action Plan, EPCCD, GoP-2024

40 https://www.unocha.org/publications/report/pakistan/pakistan-inter-agency-monsoon-contingency-plan-2024

41 https://www.acaps.org/fileadmin/Data_Product/Main_media/20241009_ACAPS_Pakistan_-_2024_Monsoon_floods.pdf

42 https://reliefweb.int/disaster/fl-2024-000020-pak

43 Climate Reslient Punjab Vision and Action Plan, EPD-2024

44 Iqbal, M.P., 2020., Effect of Climate Change on Health in Pakistan, Pakistan Academy of Sciences (PAS) (https://www.paspk.org/wp-content/ uploads/2021/02/LS-624.pdf)

45 Vector-borne diseases rise in Sindh amid lack of fumigation

46 https://earth.org/elections-2024-pakistans-next-government-faces-pressing-environmental-issues/

47 Global Climate Change Impact Study Centre(https://gcisc.org.pk/health/)

48 https://www.ipcinfo.org/ipc-country-analysis/details-map/en/c/1157024/

49 https://www.pakistantoday.com.pk/2024/12/05/climate-change-and-food-security/

malaria cases were reported in Sindh in just two weeks.[41] Asthma, bronchitis, and cardiovascular disorders have all been made worse by the increased air pollution brought on by global warming, particularly in large cities like Lahore, Islamabad, and Peshawar.[42] In Pakistan, it is estimated that outdoor air pollution kills about 22,000 people annually.[43] According to the Global Hunger Index 2023, Pakistan has a severe level of hunger, ranking 102nd out of 125 countries. 8.4 million individuals experienced severe food insecurity between March and June of 2024.[44] Between July and November 2024, there will likely be a modest improvement in the situation, but 7.9 million people will still be severely food insecure. By 2050, climate change is expected to cut wheat yields by 19%, and Kharif maize yields would be impacted as well.[45]

2.9 Urban Sector

Punjab's urban sector continues to face significant climate change vulnerabilities in 2024, hindering adaptation to extreme weather events and increasing exposure, especially for vulnerable populations.

a. Population Growth and Urbanization:

- Punjab's population reached 127.6 million in the 2023 census, with an annual growth rate of 2.53%.[46] Rapid urbanization continues to lead to land-use changes, encroachment, environmental issues, and strained services[47].
- Housing shortages persist, with Lahore reporting 3.4 persons per room. The backlog of approximately 400,000 housing units, coupled with an annual demand of 78,000 houses, exacerbates the problem.
- Tracking spatial emergence of climate vulnerabilities and utilizing urban planning tools are increasingly important to address climate vulnerabilities and risks. Integrating social vulnerabilities, such as poverty, inequality, and demographics, with physical vulnerabilities like infrastructure and environmental risks is crucial for comprehensive risk assessment.

b. Air Pollution:

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[50] Punjab State of Enviironment Report 2023
[51] Vulnerability to Climate Change and Socio-Economic Factors: A Comparison of Selected Districts of Punjab (https://www.researchgate.net/publication/351054364_Vulnerability_to_Climate_Change_and_Socio-Economic_Factors_A_Comparison_of_Selected_Districts_of_Punjab).
[52] https://www.aljazeera.com/gallery/2024/11/4/record-high-air-pollution-shuts-schools-in-pakistans-lahore
[53] https://www.bbc.com/news/articles/cm20k76d5xno
[54] https://phys.org/news/2024-11-air-pollution-lahore-limit.html
[55] https://www.paradigmshift.com.pk/smog-in-lahore/
[56] https://www.iqair.com/pakistan/punjab/lahore
[57] Ibid (https://www.bbc.com/news/articles/cm20k76d5xno)
[58] Ibid (vulnerability to Climate Change and Socio economic factor a comparison of selected Districts of Punjab)
[59] Academic Inputs from urban Flooding: Analytical Perspective 2024 (https://www.ndma.gov.pk/storage/publications/December2024/OJVEu8JCwHDSN32K3Han.pdf)
[60] TECHNICAL PAPER 10 ENVIRONMENT PROTECTION AND CONSERVATION(https://urbanunit.gov.pk/Download/publications/Files/12/2021/10%20Environment%20.pdf)

In 2024, Lahore's air pollution soared to hazardous levels, frequently topping global pollution charts[48,49]. The Air Quality Index (AQI) often exceeded 300, even reaching 1,900 in some areas, far beyond WHO's recommended PM2.5 limit[50]. This crisis stems from vehicle and industrial emissions, brick kilns, crops and waste burning, and construction dust[51,52]. The toxic air has led to a surge in respiratory issues. Measures like market closures and traffic restrictions were mandated[53]. Experts call for sustainable solutions, including improved public transport and addressing pollution sources beyond Lahore.

c. Urban Flooding:

Urban flooding due to heavy rainfall remains a serious concern in Punjab cities[54]. Poor planning, inadequate drainage, and infrastructure continue to cause streets and low-lying areas to submerge, affecting mobility and creating issues for residents[55,56]. he monsoon season witnessed intense rainfalls, with Lahore recording nearly 360 mm and up to 180mm in Faisalabad. Mitigation and adaptation strategies are priority areas, including climate change action in urban development. This involves developing future climate change scenarios with mapping of risk to urban service delivery sectors, and identifying adaptation strategies that could enhance the resilience of climate-sensitive development projects' components at design and construction phases. Cities need to prioritize climate-resilient urban planning and enforce building codes that prevent construction in high-risk flood zones[57]. The NDMA has taken steps toward improving flood preparedness, including the establishment of early warning systems and community-based disaster risk reduction programs.[58]

2.10   Loss and Damages

Significant losses and damages were caused by climate change-related extreme events in Punjab Province in 2024. Already known for its high temperatures, Multan faced extreme heatwaves that put millions at risk, and a severe drought in 2023 further reduced crop yields and water availability, putting additional pressure on public spending.[59] Punjab agriculture, which employs roughly half of Pakistan's workforce and contributes nearly a quarter of its GDP, is particularly vulnerable to extreme heat and water scarcity; disturbed weather patterns are shifting farming calendars, and higher rates of water evaporation are stressing limited water supplies; Punjab also saw an unprecedented spike in forest fires, affecting both northern and eastern regions[60]and these climate-induced events, such as floods and droughts, have caused

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[61] National Disaster Management Authority.
[62] PUNJAB CLIMATE CHANGE POLICY(draft 1.12)
[58]**Punjab's climate change policy ready for cabinet approval**
[64] Environmental Protection Department (https://epd.punjab.gov.pk/system/files/Climate%20Change%20Book%20(3)_compressed.pdf)
[65] Digital ecosystems and migration responses to climate extremes: case study from Rahim Yar Khan District, Punjab in Pakistan (December 2024) (www.Reliefweb.com)

migration, affecting vulnerable communities, particularly women[61]. The Punjab province's heatwave vulnerability map shows a distinct geographic pattern of risk, with districts divided into three groups: Category A (highest vulnerability), which is mainly found in the southern regions and includes districts like Rahim Yar Khan and Bahawalpur; Category B (moderate vulnerability), which affects central districts like Faisalabad and Sahiwal; and Category C (lowest vulnerability), which is found in the northern regions and includes Attock and Rawalpindi. This geographical distribution emphasizes the necessity of focused heatwave adaptation and mitigation plans, directing resources toward the southern districts that are most at risk while preserving readiness and oversight throughout the whole area.

Figure 6-14 Punjab Heat Wave Vulnerability Map

The Punjab Climate Change Policy & Action Plan 2024 seeks to address these issues, with an emphasis on elimination of smog and reducing the harmful effects of climate change. The province emits roughly 95,000 kilotons of greenhouse gases and 7,000 kilotons of health-injurious gases, and major cities continue to experience high-temperature hotspots.[62]

2.11 Floods

The majority of Punjab experience scorching summer temperatures and chilly, foggy winters, particularly in the plains. The temperature fluctuates from -1°C to 42°C throughout time. On occasion, though, it can drop as low as -05°C in the winter and climb as high as 48°C in the summer. Although there have been anomalies in weather patterns and rainfall distribution since the early 1970s, the majority of the rainfall received during the monsoon season is expected to reach Punjab by the end of June and continue into the first half of September. The average annual rainfall ranges between 120mm in Bahawalpur division to 1778.2mm in Rawalpindi

and in 1004mm in Sialkot district. The North Western parts of the province lie on the foothills of the Himalayan range and hence experience higher rainfall, especially in the monsoon season. Murree, which lies in the Rawalpindi division, experiences 1778mm of rainfall on average annually. The rest of the province is mostly semi-arid and plain, which receives considerably less rainfall throughout the year. The southern parts of the province are predominantly dry arid land, with deserts in the extreme south bordering India and Sindh Province. Figure 2-10 elaborating Temperature and precipitation Patterns. [63]
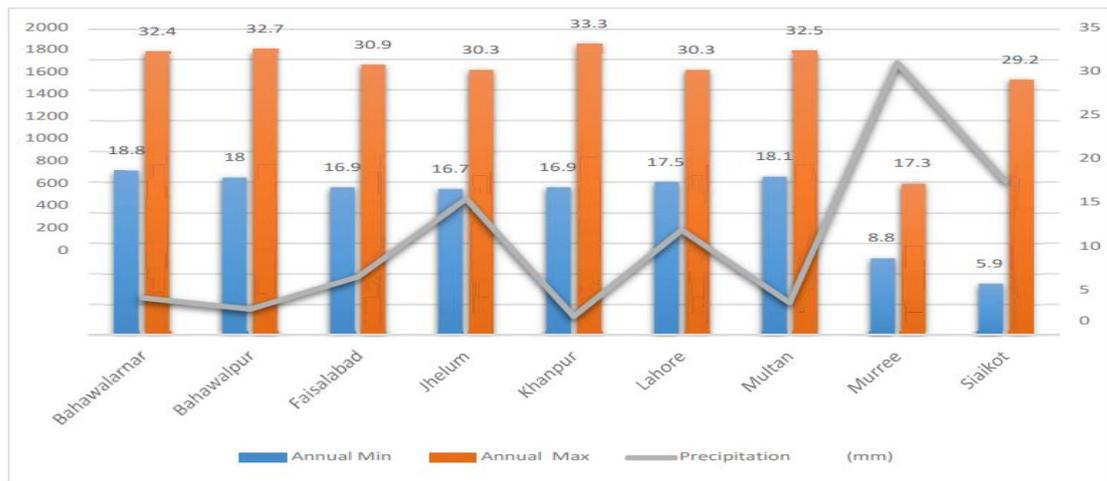
Figure 6-15 Climatograph of Punjab Province Showing Average Annual Temperature and Precipitation

During the monsoon season, Punjab faces flooding primarily as a result of hill torrents and heavy rains. Every year in mid-June, a monsoon system that is caused by a low depression begins in the Bay of Bengal, which is located in the northeastern part of the Indian Ocean. From India, the system enters in the Punjab from west or north-west before heading north. Because of the continuous, intense rainfall in the northern mountain ranges, Punjab's rivers receive significant inflows. These significant inflows, along with the substantial glacier melt throughout the summer, result in the main causes of flooding in Punjab during the monsoon season, hill torrents and intense rains. In the northeastern region of the Bay of Bengal, a monsoon system that is brought on by a low depression starts every year in mid-June.

Floods have seriously destroyed infrastructure and taken lives from the 1970s. The Punjab Provincial Disaster Management Authority (PDMA) reports that over 863 million people were stuck by the historical floods that arose between 1973 and 2022. The map highlights flood vulnerability across Punjab, categorizing districts as High, Medium, or Low Risk. Western districts along the Indus River face the highest risk, while a central band shows medium vulnerability, and northern/southern areas have varying, generally lower risk. (Figure 6-16). These floods have claimed the lives of almost 3000 persons (Figure 6-17).

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[66] https://www.dawn.com/news/1851460/punjabs-climate-change-policy-ready-for-cabinet-approval
[67] PDMA Monsoon Contigency Plan 2024.pdf
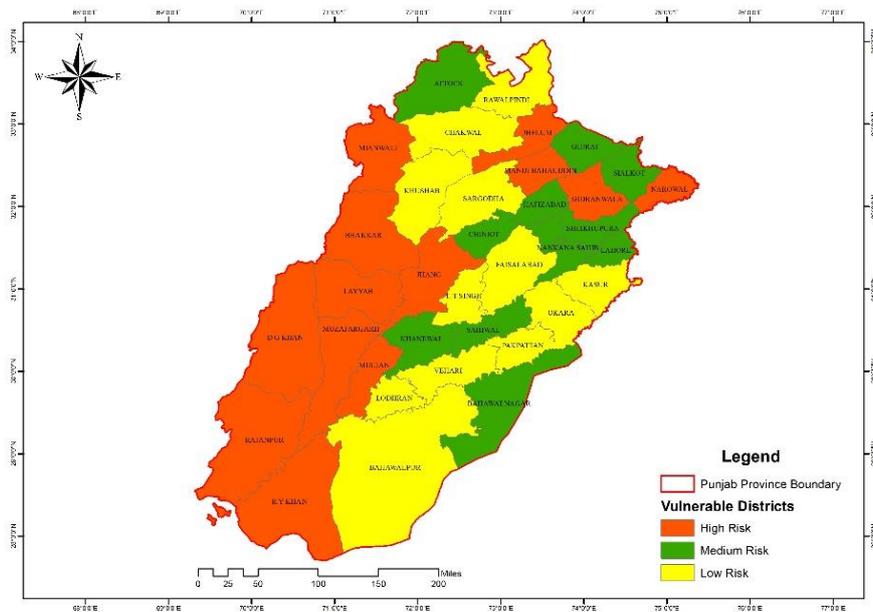
Figure 6-16 Punjab Flood Vulnerable Districts
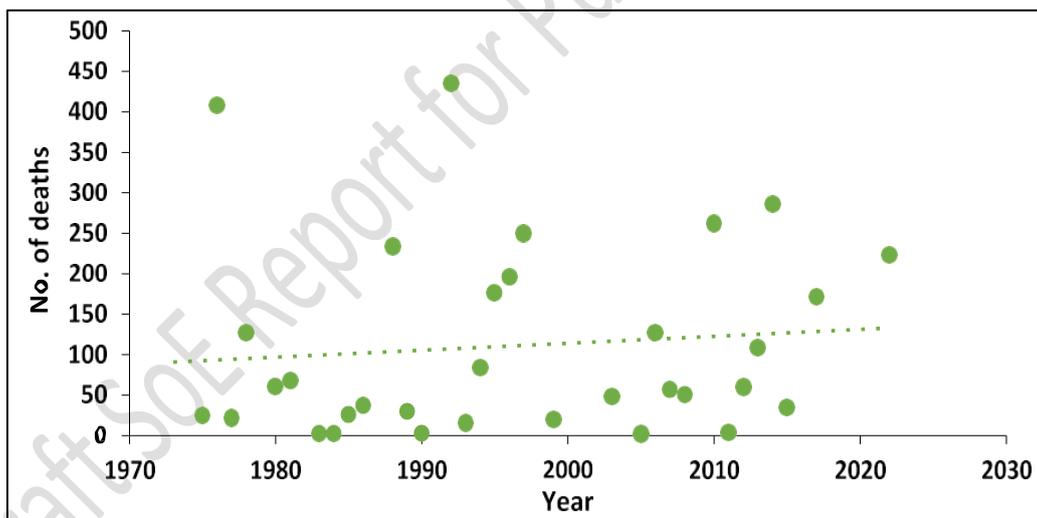
Figure 60-17 No. of deaths reported during historical floods in Punjab (1973-2022)

Most recently, Extreme weather occurrences continue to pose serious problems for Punjab in 2024–2025, especially flooding along the Sutlej River[64]. The region is still susceptible to such events in the wake of the severe floods that struck in August 2023, which devastated many regions and caused significant damage[65]. To lessen potential effects, the Provincial Disaster

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[68] Pakistan Meteorological Department Flood Situation Report (17th Aug 2023 To 30th Sep 2023), PDMA, Punjab

69 Punjab Youth Summit on Climate Change (https://lcwu.edu.pk/news-aug2020/4075-punjab-youth-summit-on-climate-change.html)

70 https://lums.edu.pk/news/breathe-pakistan-pakistans-climate-future-starts-now
[71] https://reliefweb.int/report/pakistan/monsoon-rainfall-pakistan-situation-report-july-24-2024

[72]Punjab Green Development Program.(https://www.pgdp.pk/?utm_source=chatgpt.com)

Management Authority (PDMA) has been keeping a close eye on water levels and putting emergency response plans into action.

The Sutlej River's water levels are still a worry in 2024, with possible floods during the monsoon season predicted. Over 24,000 homes and 545,270 acres of agriculture land were damaged in the previous year, and the hit districts—Bahawalnagar, Bahawalpur, and Multan— are still getting over the setback. Concerns over food have also been highlighted by the loss of cattle during these incidents. [66]

2.12   Torrential Rains and Thunderstorms

In Extreme weather occurrences, especially heavy rains and thunderstorms, presented major issues for Punjab in 2024 and posed a considerable risk to infrastructure and the lives of people and animals. Above-normal rainfall during the monsoon season caused infrastructure damage and urban floods in several areas. Heavy rains caused widespread disruption and at least 39 fatalities and 113 injuries in Punjab alone, according to reports. Lahore recorded historic rainfall levels of 337 mm. Over 61 homes were reported damaged, and there were major transportation-related effects, such as road closures and submerged regions (PDMA).

Structural collapses were also caused by the persistent thunderstorm threats, and emergency services responded to multiple lightning strike and heatstroke situations. The combined effects of these extreme weather events caused significant damage to houses and vital infrastructure by September 2024, highlighting the urgent need for better disaster preparedness and response systems. Residents in flood-prone areas were advised by the National Disaster Management Authority (NDMA) to take preventative measures, such as protecting their properties and avoiding flooding. Better infrastructure development and urban planning are being used to increase resilience while the region continues to struggle with the effects of climate change.[67]

3.   Managerial Activities

3.1 Government Initiatives

In 2024, the Government of Punjab intensified its efforts to combat climate change through the **Punjab Climate Change Policy & Action Plan 2024**, which was finalized and submitted for cabinet approval. This landmark policy focuses on mitigation, adaptation, resilience, and climate finance, addressing critical issues such as smog, water conservation, and sustainable development. Some vital actions taken by Government of the Punjab relating to climate action are as:

3.2 Energy, Transport and Industry Sector

i.   **Solarization Projects:** Public institutions achieved energy savings of 55 GWh through solarization under the Punjab Green Development Program (PGDP).
ii.   **Electric Buses**: A pilot project for 27 electric buses was launched to reduce emissions and promote low-carbon transport.
iii.   **Cleaner Production Technologies**: Financial support was provided to 500 micro-enterprises in sectors like stone crushing and steel furnaces to adopt Resource Efficient and Cleaner Production (RECP) technologies.[68]
iv.   **Free Solar Panel Distribution:** The Punjab government allocated Rs. 4 billion for the distribution of free solar panels to households consuming up to 200 units of electricity per

month. For those consuming between 200 and 500 units, the government covers 90% of the cost, making renewable energy more accessible to low- and middle-income families.[69]

v. **Waste-to-Energy Projects:** The government is developing multiple waste-to-energy projects, including a 50 MW facility in Lahore and four additional 120 MW projects across urban areas. These initiatives aim to convert municipal waste into energy, addressing both waste management and energy generation.[70]

vi. **Hydropower Development**: Plans are underway for the completion of several hydropower projects, including a 250 MW Wind Hydropower Project in Rojhan and multiple mini hydropower projects across Punjab's canals. These projects aim to harness local water resources for sustainable energy production.

vii. **Rooftop Solar Initiatives:** The Punjab Energy Department is promoting rooftop solar installations for households and businesses as part of its strategy to increase renewable energy capacity in the province.

viii. **Energy Efficiency Programs:** The establishment of an energy efficiency and conservation agency aims to promote the best practices in energy use across various sectors, including standardization and labeling of electrical appliances.

3.3 Agriculture

Some initiatives have been taken by the Punjab Government for climate change mitigation/adaptation in the agriculture sector: The Punjab Government has implemented several initiatives to mitigate and adapt to climate change within the agriculture sector:

i. **Agriculture Climate Water Portal (ACWA): A** collaborative initiative between FAO-UN and Punjab, the ACWA Portal provides timely and reliable information to government agencies, empowering decision-makers to formulate strategies for sustainable agriculture and water management. This initiative aims to mitigate climate change impacts on agriculture, food security, and rural livelihoods[71].

ii. **Transforming Punjab Agriculture**: Together with cutting-edge, contemporary irrigation systems that prioritize water efficiency, the "Transforming Punjab Agriculture" campaign advocates climate-smart farming methods that emphasize crop variety, resilient cultivars, and improved soil health[72]

iii. **Promotion of Gram Cultivation:** A project in the Thal areas of Punjab promotes gram cultivation through climate-smart technologies to enhance farmers' resilience to climate change. This includes the implementation of sprinkler irrigation systems, solar power, and capacity-building activities.[72]

iv. **FACE Partnership:** FACE (Food Security and Agriculture Centre of Excellence) has partnered with the Punjab government to modernize agriculture, boost productivity, and empower farmers with climate-smart solutions. This includes technological support, access to international expertise, and assistance in infrastructure development. In 2024, FACE

[73] https://punjab.gov.pk/cm-punjab-free-solar-panel-scheme

[74] https://www.finance.gov.pk/survey/chapter_24/14_energy.pdf

[75] https://www.fao.org/pakistan/news/detail-events/en/c/1697294/

[76] https://ndrmf.pk/wp-content/uploads/2024/08/Punjab_Climate_Change_Policy_Action_Plan__1723738609_compressed.pdf

[77] https://ofwm.agripunjab.gov.pk/node/389

[78] https://www.dawn.com/news/1880133

distributed subsidized certified wheat seeds, covering 15,000 acres, and introduced precision agriculture techniques, including agricultural drones, across 25,000 acres[73].

v. **Enhancing Fertilizer Use Efficiency**: To increase fertilizer use efficiency and lower losses and greenhouse gas emissions, field experiments are being carried out.

vi. **Soil Health Improvement**: Research on the application of green manures and farmyard manures is underway to boost yields, enhance soil health, and increase carbon sequestration.

vii. **Farmer Advisory Services**: Soil and water samples are analyzed, and advisory services are provided to farmers to optimize input use under changing climate conditions.

viii. **Dissemination of Climate-Smart Technologies**: The farming community is informed about developed technologies through a variety of media outlets, farmer days, and production plans.

ix. **High-Efficiency Irrigation Systems**: Installation of high-efficiency irrigation systems has been completed on 3,200 acres of land, with solar-powered systems implemented on 2,000 acres.

x. vi. **Water Conservation Structures**: Construction of 55 farm ponds and 55 dug wells in rain-fed areas has been undertaken to enhance water storage and availability.

xi. **Watercourse Improvement**: Lining improvements have been made to 732 watercourses to reduce water losses.

xii. **Irrigation Scheme Rehabilitation**: A total of 445 irrigation schemes outside canal commands have been rehabilitated to improve water management.

xiii. **Laser Land Leveling**: Provision of 300 laser land leveling units to service providers and farmers has been facilitated to promote efficient use.

xiv. **Heatwave Adaptation Guidance**: In order to minimize heat stress on crops, the Agriculture Extension Wing is offering farmers advice on how to deal with heatwave conditions. This advice includes choosing the right crops, irrigation methods, and planting and harvesting dates.

xv. **Climate Change Awareness Activities**: Awareness workshops are held to educate farmers about conservation tillage practices, managing manure, improving water consumption efficiency, and alternative methods such as direct planting for rice crops.

xvi. **Tree Planting Initiatives**: Every year, agriculture offices and farmer fields participate in aggressive tree planting campaigns aimed at lowering air pollution. 67,480 seedlings were planted in farmer fields and offices in 2023.

xvii. **Development of Drought-Resistant Crop Varieties**: For important crops like wheat, rice, maize, cotton, sugarcane, legumes, and oilseeds, research institutes under the Ayub Agricultural Research Institute (AARI), Faisalabad, are working to create and introduce drought-resistant crop varieties.

xviii. **Climate Change Research Center (CCRC)**: The CCRC was established at AARI in 2015 and focuses on climate-smart agriculture technologies and activities, such as climate-smart breeding assessments, drip irrigation, planting cotton on raised beds or ridges, regulated deficit irrigation, redefining and updating agro-ecological zones, crop residue and farm waste management, developing a climate-smart agriculture plan, and climate-smart management for rice production[74].

3.4 Irrigation Sector

Through a number of initiatives started by the irrigation department, the Punjabi government is working to increase climate adaptation and resilience in the following areas: Through a number of initiatives, the Punjabi government is improving climate adaptation and resilience in the irrigation industry:

i. **Demand Management Measures**: Initiatives to increase water use efficiency and productivity are being implemented.

ii. **Water Storage and Management**: To increase inter-seasonal water supply, projects for groundwater recharge, rainwater harvesting and storage systems, big and small reservoir construction, and groundwater management are now under progress.

iii. **Disaster Resilience Strengthening**: Efforts are being made to strengthen resilience and adaptive capacity to climate-related disasters.[74]

3.5 Forestry Sector

The Government of Punjab has launched several impactful forestry projects to combat climate change, improve air quality, and enhance biodiversity. Below is a detailed overview of these initiatives, including the Miyawaki forest approach:

i. **Mass Tree Plantation Drive (2024-2025):** Aimed at planting **634,000 trees** in Lahore alone to combat smog and improve air quality[75]. A green belt is being developed on **978 acres** along the banks of the River Ravi in Lahore. **105,000 trees** have already been planted on **144 acres** near the River Ravi as part of this effort.

ii. **Urban Forestry Projects:** Urban tree plantations were carried out in 2023, with **328,428 trees** planted across Punjab to meet environmental approval requirements. Expansion of urban forests in cities like Lahore to reduce urban heat islands and improve air quality.

iii. **Miyawaki Forests[76]:**The Miyawaki method has been adopted for creating dense urban forests in limited spaces. These forests use native species and high-density planting techniques to grow forests 10 times faster than traditional methods. Examples include:

- The establishment of Miyawaki forests in Lahore under the "Clean Green Pakistan" initiative.
- Several Miyawaki sites were created in urban areas to mitigate smog and provide a cooling effect.

iv. **Nestlé's Urban Forest Initiative:** Nestlé Pakistan planted **25,000 trees** at Allama Iqbal International Airport under its "Nestlé Cares" program. Additional plantations are planned at Canal-Jalo Park Junction, Sheikhupura, and Kabirwala, with another **25,000 trees**.[77]

v. **Tree Plantation in Cholistan:** A groundbreaking project was launched to plant trees in the Cholistan desert to combat desertification and promote wildlife conservation[78].

[79] https://www.mocc.gov.pk/NewsDetail/MGYzZjU2ZmQtM2U5Zi00NzZjLWIyNTctZjA2NGQ1NTRhYTg1

[80] https://www.brecorder.com/news/40316903

[81] https://www.arabnews.pk/node/2590400/pakistan

[82] https://epd.punjab.gov.pk/tree_plant_2024

83https://www.nestle.pk/media/pressreleases/allpressreleases/nestle-pakistan-kicks-off-urban-forests-tree-plantation

[84] https://www.radio.gov.pk/22-12-2024/punjab-govt-launches-first-tree-plantation-project-in-cholistan

[85] https://www.reuters.com/world/asia-pacific/pakistans-punjab-sets-up-smog-war-room-combat-hazardous-air-2024-11-06/

[86] https://finance.punjab.gov.pk/system/files/StrategyReport.pdf

[87] https://ndrmf.pk/wp-content/uploads/2024/08/Punjab_Climate_Change_Policy_Action_Plan__1723738609_compressed.pdf

88https://epd.punjab.gov.pk/system/files/Climate%20Resilient%20Punjab%20Vision%20%26%20Action%20Plan%202024.pdf

[89] https://inff.org/assets/resource/Punjab-integrated-financing-strategy-FINAL.pdf

3.6 Climate Finance

The Government of Punjab has undertaken several initiatives to secure and manage climate finance:

i. **Allocation for Environmental and Climate Sector Reforms**: Under the PGDP, a budget of US$273 million has been set aside for green development and reforms in the environmental and climatic sectors through May 2025.[79][80]

ii. **Green Financing Strategy**: A thorough plan has been created to handle climatic vulnerabilities, environmental issues, and international agreement commitments.

iii. **Green Climate Fund Project**: Enhancing climate resilience among vulnerable farmers in the Indus basin is the goal of an ongoing initiative called "Transforming Indus Basin with Climate Resilient Agriculture and Water Management."[81]

iv. **Climate Budget Tagging (CBT)**: The Planning and Development (P&D) Board has prioritized the use of CBT to enhance decision-making in the provincial climate change framework.[82]

v. **Environment and Climate Change Cell**: This cell, which operates under the P&D Board, promotes Green Climate Fund (GCF) accreditation and helps with climate-related initiatives and funding.

vi. **Budget Strategy Commitment**: The Punjab Budget Strategy Paper (2022–2025) pledges to provide funding for adaptation and mitigation of climate events in addition[83]

vii. **Climate Resilient Infrastructure Challenge Fund:** Launched in January 2025, this fund supports projects that strengthen adaptive capacity in vulnerable areas of Punjab by prioritizing sustainable infrastructure development aligned with the National Adaptation Plan (NAP). It focuses on high-impact, gender-responsive projects that enhance local resilience.[84]

viii. **Sustainable Development Goals (SDGs) Integration:** The government is aligning its climate finance strategies with the Sustainable Development Goals (SDGs), particularly those related to clean water, sustainable cities, responsible consumption, and climate action. Efforts include promoting renewable energy, enhancing urban green spaces, and implementing waste management solutions.[85]

ix. **Breathe Pakistan Initiative:** Punjab has joined the breathe Pakistan climate initiative as a strategic partner, focusing on advancing climate advocacy, ecological preservation, and meaningful policy reform. This partnership aims to implement actionable strategies to reduce carbon emissions and promote sustainable practices.[86]

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[84] https://finance.punjab.gov.pk/system/files/StrategyReport.pdf
[85]https://mocc.gov.pk/SiteImage/Misc/files/NCFS.pdf
[86]https://www.unicef.org/pakistan/press-releases/over-11-million-children-under-5-peril-they-breathe-toxic-air-punjab-pakistan-unicef

CHAPTER 7 INDUSTRIAL WASTEWATER TREATMENT, SOLID WASTE MANAGEMENT AND INCINERATION FACILITIES

1. Overview

This chapter provides an overview of wastewater treatment plants (WWTPs) operating within various industries across Punjab. It also provides details about solid waste management facilities, including municipal and hospital waste disposal systems.

Industrial wastewater treatment and solid waste management are cornerstones of environmental sustainability, public health, and economic resilience in Punjab. Rapid industrialization and urbanization over the past two decades have amplified waste generation, placing immense pressure on Punjab's ecosystems and infrastructure. This chapter offers an overview of Punjab's industrial wastewater treatment plants (WWTPs), municipal solid waste management (MSWM) systems, and incineration facilities[1]. By identifying current practices, systemic challenges, and proposing actionable solutions, this chapter aims to chart a path toward sustainable waste management aligned with global environmental standards.

Punjab, as Pakistan's most populous and industrialized province, contributes over 60% of the country's GDP. However, unchecked industrial growth has led to severe environmental degradation. Rivers like Ravi and Sutlej are heavily contaminated with untreated effluents, while air quality in cities such as Lahore and Faisalabad deteriorate due to open waste burning. The absence of comprehensive waste management frameworks aggravates risks to human health, including waterborne diseases, respiratory illnesses, and soil contamination. This chapter underscores the urgency of adopting integrated, technology-driven solutions to mitigate these challenges.

2. Industrial Wastewater Treatment

Industrial wastewater, characterized by its toxic chemical composition and high pollutant load, poses significant threats to aquatic ecosystems and groundwater reserves mostly dispose of in the water bodies and river without proper treatment.

2.1 Major Contributing Industrial Sectors

Punjab's industrial landscape is dominated by sectors with high water consumption and effluent discharge:

1.1.1 Textile Industry

Punjab's textile sector, contributing 68% of Pakistan's total exports[2], is the largest wastewater generator. Processes such as dyeing, bleaching, and finishing consume vast quantities of water and release effluents laden with synthetic dyes, sulfates, and heavy metals

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[1] Naveed, M., M. F. Maqsood and A. R. J. J. o. E. i. S. S. Cheema (2024). "Modeling the contribution of district-level cotton production to aggregate cotton production in Punjab (Pakistan): an empirical evidence using correlated component regression approach." 3(3): 147-16

[2] Hussain, M. A., A. K. Jadoon, G. Nabi and S. Ahmed "Destination And Direction of Pakistan's Textile Exports: An Application of Hidden Markov Chain Approach

(e.g., lead, cadmium). The Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) levels in textile wastewater often exceed the permissible limits.

1.1.2 Sugar Mills

Operating seasonally, sugar mills generate wastewater rich in organic matter from cane washing and juice extraction. High BOD levels deplete oxygen in water bodies, causing fish kills and algal blooms.

1.1.3 Leather Processing

Tanneries in Kasur and Sialkot discharge chromium-laden wastewater, a byproduct of tanning processes. Chromium (VI), a carcinogen, infiltrates groundwater, rendering it unsafe for consumption.

1.1.4 Pharmaceuticals and Chemical Industries

These sectors produce complex effluents containing antibiotics, solvents, and endocrine disruptors, which resist conventional treatment methods and pose long-term ecological risks.

1.1.5 Thermal Power Plants

Coal-fired plants discharge cooling water contaminated with heavy metals (arsenic, mercury) and thermal pollution, disrupting aquatic ecosystems.

2.2 Wastewater Treatment Plants (WWTPs)

Industrial wastewater management is a critical environmental challenge, particularly in regions with a high concentration of industries. This dataset provides an overview of wastewater-generating industries across all districts, highlighting the status of wastewater treatment plant (WWTP) installations.

A survey was carried out through field offices of Environmental Protection Agency (EPA) to collect updated data about wastewater generating industries and WWTPs installed. The data depicts that there are 467 WWTPs installed and operating in different industrial units over the Punjab. In 2023, total 434 WWTPs were identified in Punjab.

2.3 Types of Treatment

- **Primary Treatment**: Involves screening, sedimentation, and oil-grease removal. Common in small-scale industries but ineffective against dissolved pollutants.

- **Secondary Treatment**: Utilizes aerobic/anaerobic biological processes (e.g., activated sludge, trickling filters) to degrade organic matter.

- **Tertiary Treatment**: Employs advanced methods like reverse osmosis, ozonation, and ion exchange to remove heavy metals and pathogens. Only 2% of Punjab's WWTPs employ tertiary treatment due to high costs.

2.4 Challenges

- **Financial Constraints**: SMEs often lack capital for WWTP installation.

- **Energy Costs**: Secondary and tertiary treatments are energy intensive.

- **Area Constraints**: Small and medium units also have capacity and area limitations to install and operate the WWTP.

- **Miscellaneous**: Some industrial units operate in rented buildings, operations based on work order and operations linked with seasons also poses limitations in terms of regulatory requirements and compliance.
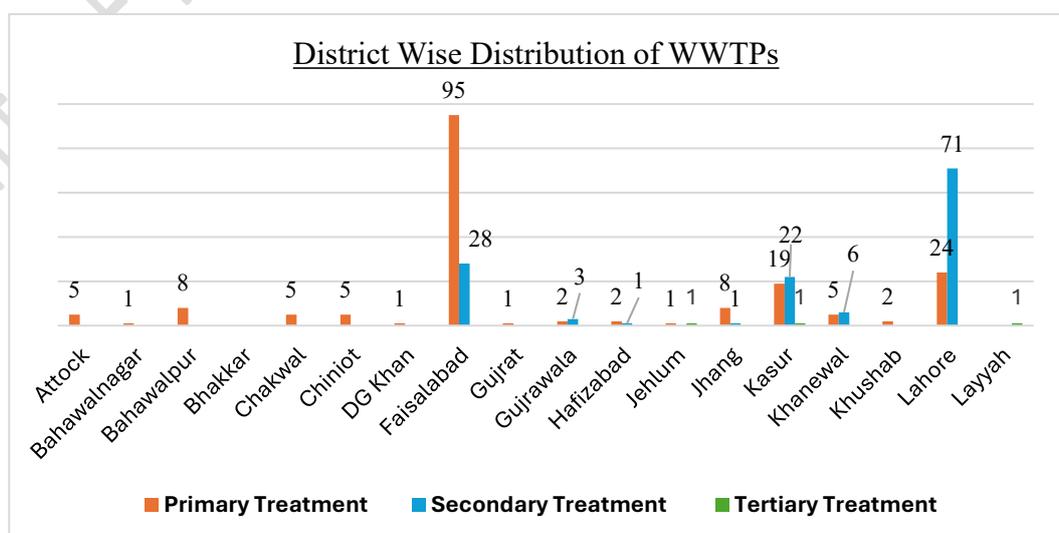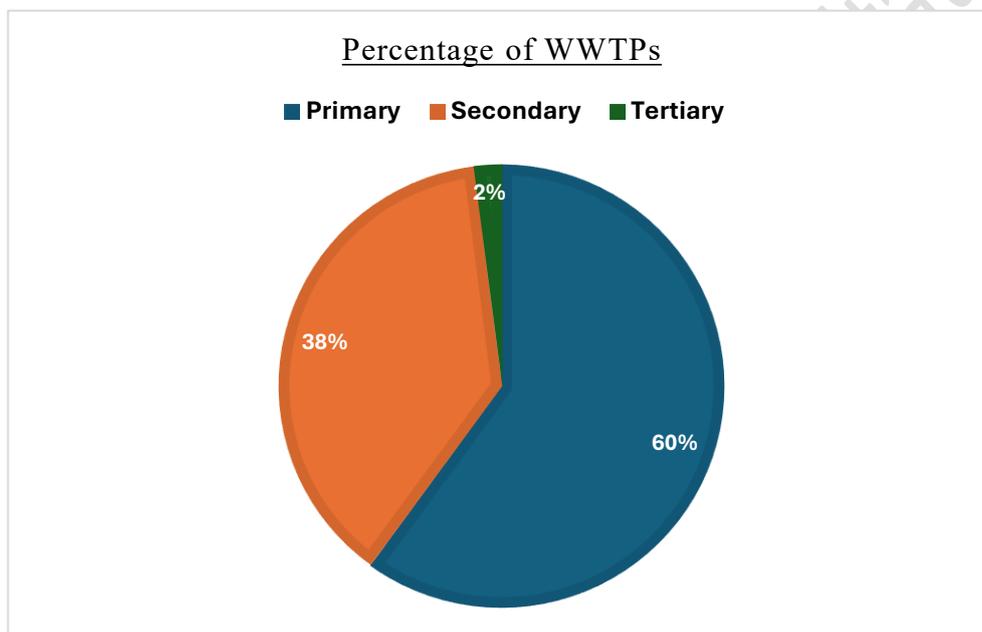
Figure 7-1: Percentage of Treatment Plants
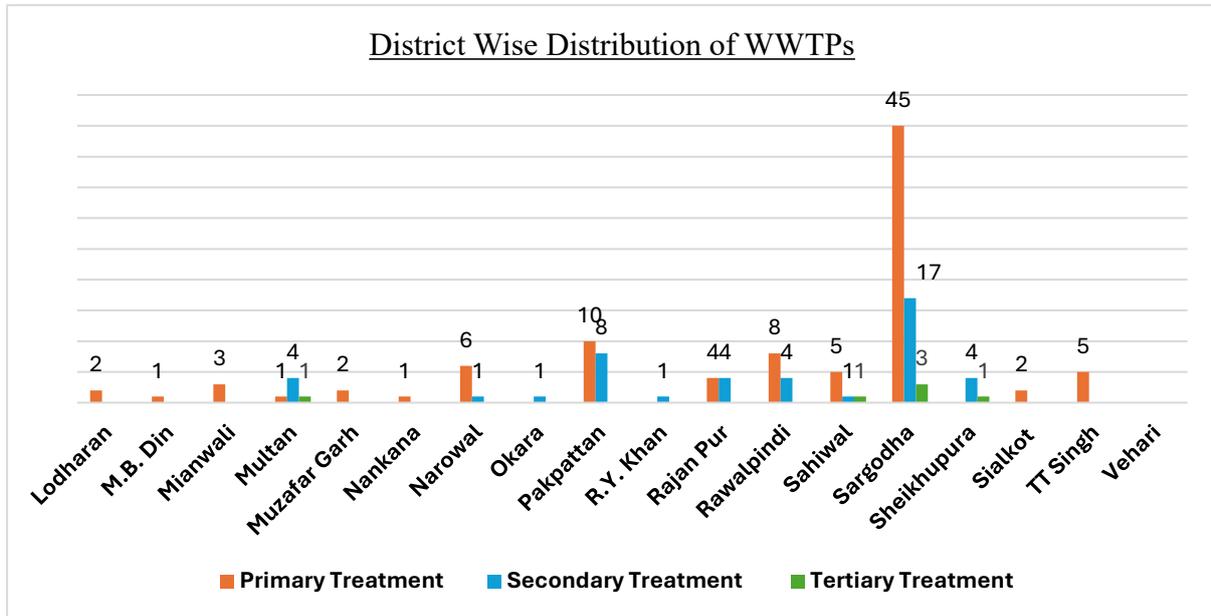
Figure 7-2: District Wise Distribution of WWTPs

2.5 Geographical Distribution

The geographical distribution of WWTPs is as follows:

- Faisalabad (26%)
- Lahore (20%)
- Sheikhupura (14%)
- Kasur (9%)
- Rahim Yar Khan (4%)
- Sahiwal (3%)
- Khanewal (2%)
- Gujranwala (1%)
- Bahawalpur (1%)
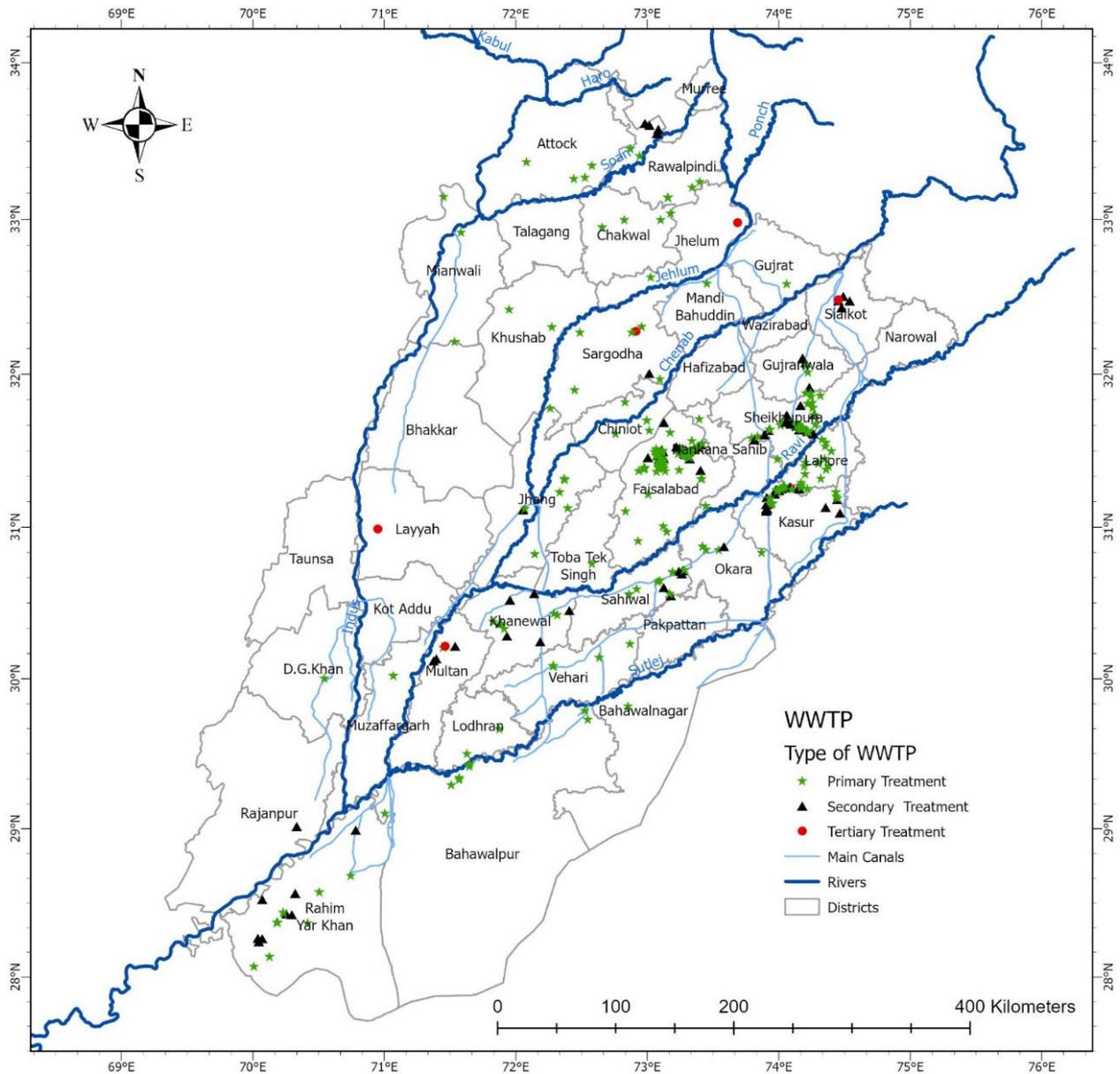
Figure 0-3: **Graphical representation: Map of WWTPs across Punjab**

3. Municipal Solid Waste Management

Punjab generates approximately 50,000 tons of municipal solid waste (MSW) daily, with collection rates hovering around 60–70% in urban areas and <30% in rural zones[3]

3.1 Generation

Municipal solid waste (MSW) in Punjab includes plastics, rubber, textile waste, paper, food, glass, leaves & grass, animal waste, demolition waste, and residues. Waste generation rates depend on population, consumption levels, and lifestyles. The quantities of these components vary in the waste depending upon the source. Waste generation rates depend on

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[3] Ayub, F., S. L. H. Naqvi, S. H. Z. Naqvi, A. Yasar, R. Akram and J. J. E. P. R. Niamat (2024). "Assessment of Municipal Solid Waste Management Practices in Urban Centers of Pakistan: A Comprehensive Review." 87-103.

the population, consumption level and lifestyles. The data of waste production in Divisional HQs of the Punjab has been collected which ranges from 182 tons/day (Sahiwal) to 5,500 tons/day (Lahore), reflecting that the waste generation rates are higher in large and urbanized metropolises.

3.2 Collection

There are two types of waste collection services: primary collection and secondary collection. According to the size of the city and the local waste management system, primary collection refers to the process of gathering, lifting, and removing municipal solid waste from its point of generation, which may include homes, businesses, offices, markets, hotels, institutions, and other residential or non-residential premises. The waste is then transported to a storage depot, transfer station, or directly to the disposal site.

Picking up waste from community bins, waste storage facilities, or transfer stations and moving it to final disposal facilities or waste processing facilities is known as secondary collection. MCs must ensure that waste in secondary storage locations/sites is handled daily or before the container fills to capacity.

- **Primary Collection**: Door-to-door collection in cities like Lahore and Rawalpindi uses bins and handcarts. Informal waste pickers play a critical role but lack legal recognition.

- **Secondary Collection**: Waste is transported via compactor trucks to transfer stations, though rural areas rely on open tractor trolleys, causing spillage.

3.3 Transportation

The waste is collected from specific secondary storage sites/locations in some areas of the municipality through tractor trolley or dumper trucks and direct disposal to main dumping sites. For this purpose, a front loader tractor is used to fill trolleys. Collection of waste through waste containers placed at specific locations in each major area of the municipality. These waste containers are removed, and the waste is transported to main dumping sites. Mainly the following vehicles and equipment are used for waste collection and transportation in municipalities:

- Loader Rickshaw
- Mini Dumper
- Hand Carts
- Dumper Trucks
- Tractor Trolley
- Front Loader Tractor
- Arm Roll Truck
- Compactor Trucks

3.4 Disposal

The waste collected by the workforce is dumped at designated dump sites in each district. However, these dumpsites are not scientifically designed landfills. Each district usually has

only one designated dump site. The concerned Waste Management Company or Local Government was contacted to get data related waste generation and disposal. The state of municipal solid waste management in the province is summarized in Table:

Table 7-1: Municipal Solid Waste Generation and Collection in Divisional HQs of Punjab

Solid Waste Generation (Tons/day)	Solid Waste Collection Rate (Tons/day)	Quantity of Waste Dumped (Tons)		
		Daily	Monthly	Annually
Lahore				
5000-6000	5000-5500	5,000	150,000	1,800,000
Rawalpindi				
1900	1670	1670	50,100	601,200
Faisalabad				
3720	3348	3348	100,440	1,205,280
Gujranwala				
1500	1300	1300	33,000	500,000
Sargodha				
400	350	350	10,500	126,000
Multan				
2350	1400	1400	42,000	504,000
Bahawalpur				
367	290	290	8,700	104,400
DG khan				
274	258	250	7740	92,880
Sahiwal				
182	174	174	5,220	62,640
Gujrat				
450	450	450	13,500	162,000

3.5 Environmental Issues

Open dumping along roadsides, drains, canal banks and low lying area is a common practice in the province, the burning of waste leads to air pollution and disease spread. Primary issues include inadequate waste collection and improper waste disposal. The release of pollutants and leachate from the dump sites to the environment makes these sites a significant health and

environmental risk. The problem is exacerbated by inadequate transportation and collection systems.

4. Incineration Facilities

The incinerators have been installed in the public as well as private sector for incineration of hazardous waste.

4.1 Public Sector

In the public sector, a total of 46 incinerators have been installed in different public hospitals for incineration of infectious hospital waste that is being generated from these hospitals.

4.2 Private Sector

Presently, 29 incineration facilities are installed in the private sector. These incinerators provide services for incineration of infectious hospital waste as well as industrial waste.

All the incinerators, public and private, are equipped with emission control systems for treatment/control of emissions that are generated during operations. The district wise distribution of public and private incineration facilities is as shown in figures below:
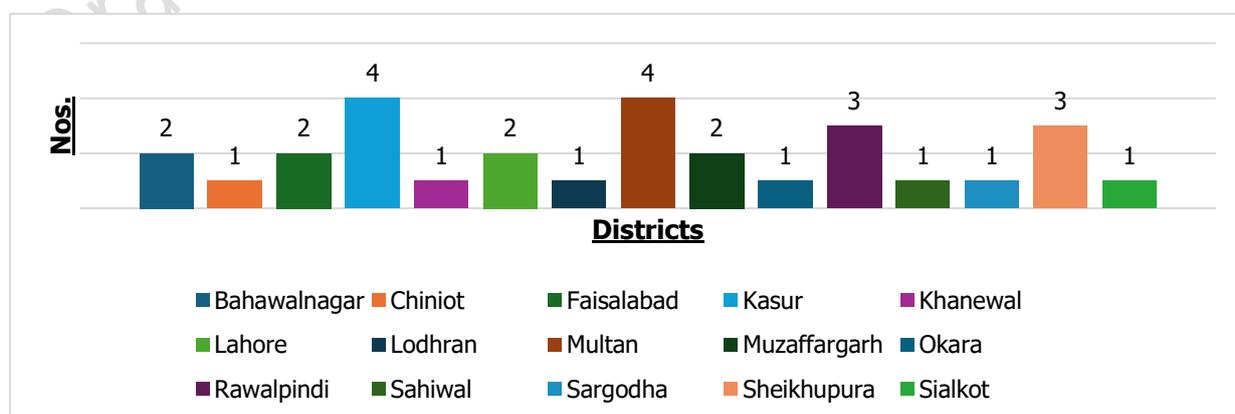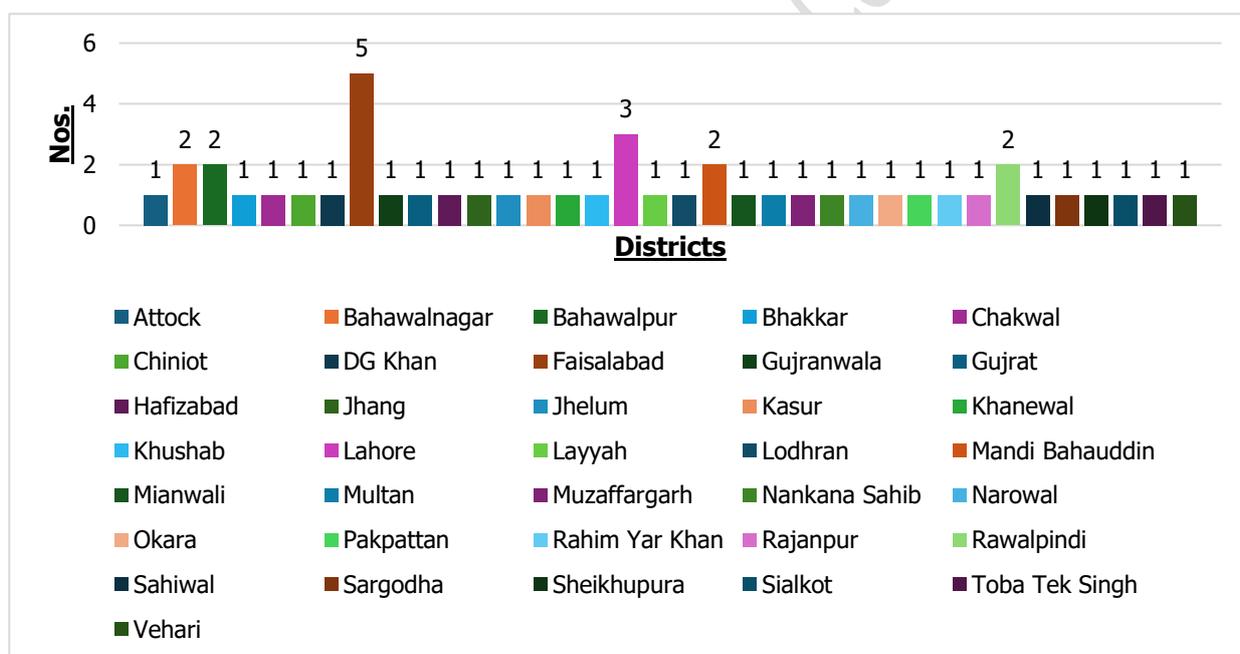
Figure 7-4: District-Wise Distribution Of Public Incinerators

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5. Key Findings

5.1. Industrial Wastewater Treatment Plants Comparison

- A total of 467 wastewater treatment plants (WWTPs) were identified in Punjab, with Faisalabad (26%), Lahore (20%), and Sheikhupura (14%) having the highest concentration.
- The textile industry has the highest number of WWTPs, followed by sugar mills, leather processing, and apparel manufacturing.
- WWTPs are categorized into primary (physical), secondary (biological/chemical), and tertiary (advanced) treatment systems.
- A significant disparity in WWTP availability exists across different industrial sectors, impacting treatment efficiency and environmental compliance.

5.2 Municipal Solid Waste Management

- Waste generation varies across Punjab's divisional headquarters, with Lahore generating the highest (5,500 tons/day) and Sahiwal the lowest (182 tons/day).
- Collection rates vary, with major cities like Lahore and Faisalabad achieving over 80% collection efficiency, while smaller cities struggle with inadequate collection and disposal.
- Improper waste disposal and open burning contribute to air pollution and environmental hazards.
- Most dump sites lack proper landfill design, increasing the risk of leachate contamination and public health concerns.
- A lack of efficient waste transfer stations leads to direct dumping in open sites or unregulated areas.

5.3 Incineration Facilities

As per survey and information collected through field offices of EPA, 75 incineration facilities exit in the province.

- A total of **46 incinerators** have been installed in public hospitals for infectious hospital waste management and disposal through incineration.
- **29 private incinerators** handle both hospital and industrial waste.

- The incinerators, public and private, are equipped with emission control systems for treatment/control of emissions that are generated during operations. The district wise distribution of public and private incineration facilities is as shown in figures below:
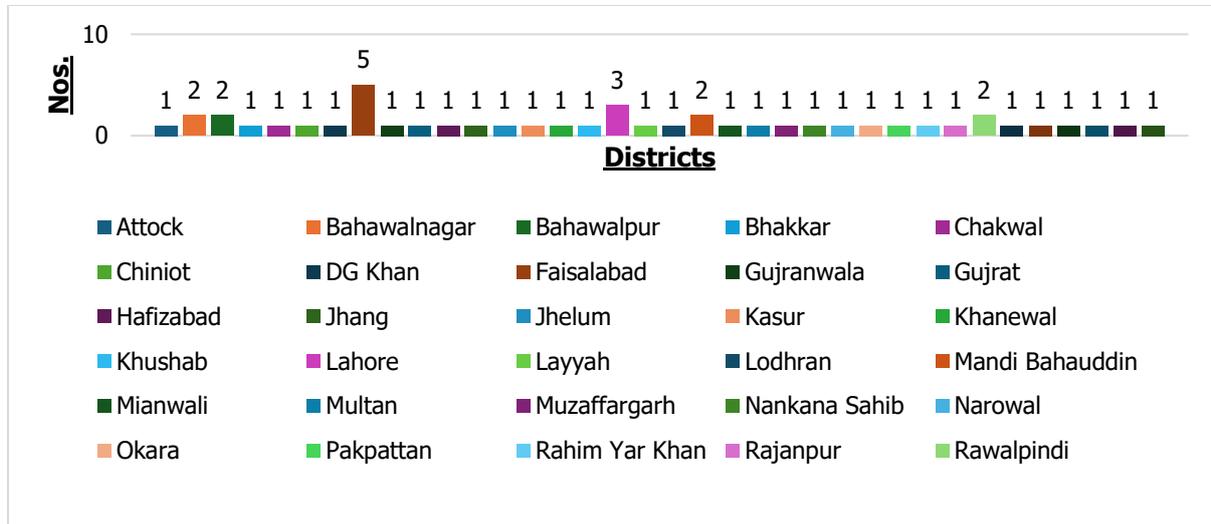
Figure 7-5: District-Wise Distribution Of Public Incinerators
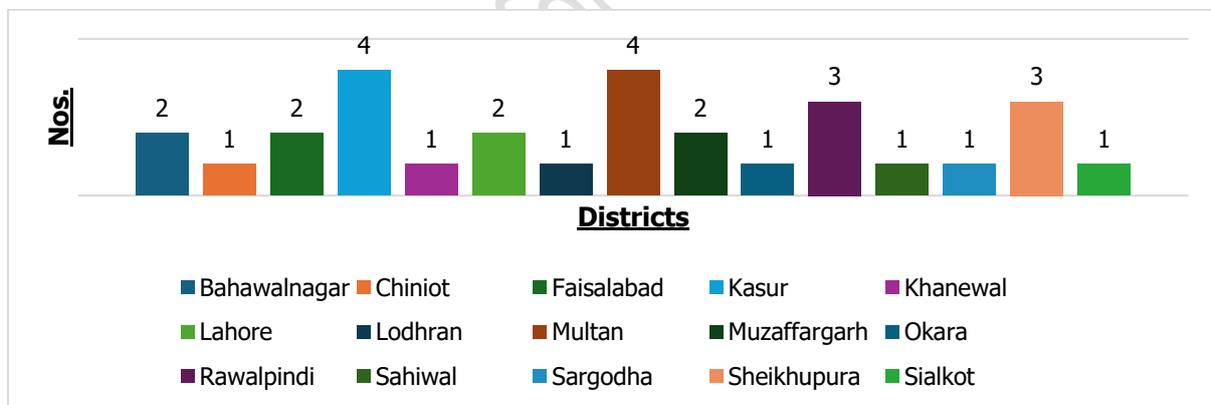
Figure 7-6: District-Wise Distribution Of Private Incinerators

6. Way Forward

6.1. Industrial Wastewater Treatment Improvements

- Financial assistance for industries to establish or upgrade WWTPs.
- Establishment of Combined Effluent Treatment Plants (CETPs) in major industrial hubs and industrial estates for wastewater treatment and compliance.
- Localized technology solutions to make treatment plants cost-effective and sustainable.

6.2 Enhancing Municipal Solid Waste Management

- Integrated Solid Waste Management. Development of scientifically designed landfills with leachate management and waste segregation.
- Implementation of waste-to-energy projects to utilize non-recyclable waste for energy generation.
- Strengthening waste collection and transportation systems with smart tracking and route optimization.

6.3 Policy and Regulatory Strengthening

- Formulation of strict compliance policies for waste management and disposal.
- Encouraging public-private partnerships (PPP) for sustainable waste management solutions.
- Incentivizing recycling and composting initiatives to reduce waste volume.

6.4 Incineration and Hazardous Waste Management

- Expansion of incineration facilities based on catchment area analysis to ensure efficient hazardous waste disposal.
- Development of best practices for hazardous waste management to prevent environmental contamination.
- Strengthening monitoring and regulatory frameworks to ensure emission control and compliance in existing incinerators.

CHAPTER 8: MEASURES TAKEN TO CONTROL POLLUTION & IMPROVE AIR QUALITY

1. Overview

EP & CCD Punjab has made significant progress in the protection, conservation, and rehabilitation of the environment through prevention and control of pollution, and promotion of sustainable development in the province under the provisions of Punjab Environmental Protection Act, 1997 and rules and regulations made thereunder. The department has initiated a multisectoral approach to cater for the pollution in the province. The EPA Punjab has advanced its approach through institutional, regulatory and policy reforms, capacity building initiatives, research and development, environmental and social safeguards and awareness activities in addition to its regular operations.

2. Policy Reforms

2.1 Punjab Clean Air Policy-2023

In April 2023, the Government of Punjab approved and notified the Punjab Clean Air Policy, accompanied by a phased Action Plan. This initiative aligns with the fundamental rights mentioned in the Constitution of Pakistan (1973), the United Nations Sustainable Development Goals, the Clean and Green Pakistan Movement, and the Nationally Determined Contributions (NDCs) of 2021. The primary objective of the policy is to ensure clean air in the province by reducing emissions and promoting sustainable development, ultimately fostering a healthier and more liveable environment. The policy includes a phased action plan that clearly defines the roles and responsibilities of all relevant sectors. Furthermore, the policy strengthens and enhances the existing regulatory and inspection mechanisms for air pollution control in the province. Relevant departments have already begun implementing the policy and action plan within their respective jurisdictions.

2.2 Smog Prevention and Control Rules-2023

On June 7, 2023, the Government of Punjab notified the Punjab Environmental Protection (Prevention and Control of Smog) Rules, which establish standard operating procedures for brick kilns, industrial units, resource recovery units, and pyrolysis plants to mitigate their contribution to air pollution. The rules also impose further restrictions on stubble burning and open waste burning in the province.

2.3 Plastic Management Strategy

In 2023, the Punjab Environmental Protection Council, constituted under the Punjab Environmental Protection Act (PEPA), approved the Plastic Management Strategy,

developed under DLI-4 of the Punjab Green Development Program (PGDP). The strategy is based on five pillars and 22 targets, with a proposed three-phase Action Plan for implementation through 2030. The strategy's pillars include: (i) the induction of a plastics regulatory regime, (ii) technological innovation and recycling infrastructure, (iii) economic incentives and levies, (iv) institutional capacity building, and (v) citizen engagement and awareness. The strategy also proposes the establishment of a Provincial Steering Committee, chaired by the Chief Secretary, the creation of a plastic management cell, mandatory registration, the setting up of a plastic management information system, mandatory Extended Producer Responsibility (EPR), and public awareness initiatives.

2.4 Punjab Environmental Protection (Production and Consumption of Single Use Plastic Product) Regulations, 2023

In addition to the Plastic Management Strategy, the Government of Punjab has regulated the production and consumption of single-use plastics by notifying relevant regulations in June 2023. These regulations apply to producers, consumers, collectors, and recyclers of single-use plastics. They prohibit the production and consumption of certain single-use plastic products, including plastic cotton bud sticks, plastic balloon sticks, plastic flag sticks, disposable plastic cutlery, and others.

2.5 Revision of Existing Punjab Environmental Quality Standards (PEQS) and Development of Industry-Specific Environmental Quality Standards (EQS)

The Environment Protection & Climate Change (EP & CCD) and Disaster Management Department is implementing an ADP scheme titled 'Development of Missing Environmental Quality Standards (EQSs) & Revision of Existing Environmental Quality Standards for Punjab.' The project is divided into two components: Component-A focuses on the development of missing Environmental Quality Standards and the revision of existing standards for Punjab, while Component-B is dedicated to the development of industry-specific Environmental Quality Standards for sixteen industrial sectors.

A panel of experts, including specialists from relevant departments and organizations such as academia, PCSIR, and PCRWR, was designated to review the draft Punjab Environmental Quality Standards (PEQS) and provide recommendations. In addition to a series of meetings with the panel of experts, eight consultative sessions were held with stakeholders from relevant industries, chambers of commerce, government departments, NGOs, and academia to gather their opinions and feedback on the draft PEQS. Based on the

feedback received during these stakeholder consultative sessions and the recommendations from the panel of experts, the final draft reports have been updated accordingly.

2.6 Climate Resilient Punjab Vision and Action Plan 2024.

The draft Punjab Climate Change Policy has progressed to the stage where it has been endorsed by a panel of experts, including members from United Nations entities, GIZ Pakistan, and senior academics. The policy was developed through comprehensive consultations and contributions from relevant stakeholders in the government sector. Four working groups, comprising 25 government departments, were established to finalize the policy document.

In the last quarter of CY 2023, a consultative session was organized to finalize the draft policy, incorporating a gender perspective. As a result of this session, the policy draft was revised to ensure it is both gender-inclusive and gender-responsive. These struggles lead to the approval and notification of Climate Resilient Punjab Vision and Action Plan, 2024.

3. Environmental Monitoring

The department is currently expanding and strengthening one of its most critical areas of jurisdiction: environmental monitoring. DLI-2 of the PGDP specifically focuses on enhancing the environmental monitoring regime of EP & CCD Punjab. The updated progress on key initiatives related to environmental monitoring is as follows:

3.1 Air and Water Quality Monitoring Stations

In Punjab, a total of 30 Air Quality Monitoring Stations (AQMS) have been installed across ten districts, including eight in Lahore Under DLI-2 in the year 2024. Of these, twenty-five will be fixed stations, while five will be mobile AQMS, which can be relocated across the province as needed. In October 2023, SP&IU and Norico International (Pakistan Branch) signed an agreement for the procurement of AQMS. Additionally, contracts have been awarded to international consulting firms for the installation of 15 Water Quality Monitoring Stations at major water bodies in Punjab. Priority has been given to surface waters, including rivers, canals, drains, and lakes, for the installation of stations that will collect real-time data on water quality.

These interventions, while primarily targeting conventional pollutants such as Nitrogen Oxides (NO_x) and Sulfur Oxides (SO_x), contribute indirectly to the broader climate agenda by mitigating pollutants that serve as precursors to GHGs or exacerbate atmospheric warming.

This proactive approach reflects a transitional strategy toward integrated air quality and climate management in the province.

EPA Punjab's Laboratory has documented substantial reductions in **Particulate Matter (PM2.5)** emissions from **<u>targeted industrial sectors</u>** as a result of pollution abatement initiatives of the department:

- **Brick Kilns:** 48% reduction
- **Steel Re-Rolling Mills:** 23% reduction
- **Steel Induction Furnaces:** 49% reduction
- **Boilers:** 45% reduction
- **Overall average reduction in PM2.5 emissions:** 41.25%

These interventions contribute indirectly to climate change mitigation by reducing the atmospheric load of harmful pollutants and fostering cleaner industrial practices.

3.2 Industrial Inspections

Under the PGDP (DLI 1), EPA has actively conducted more than 2,000 inspections for industrial effluents and 250 inspections for stack emissions. Throughout 2023, the EPA, has successfully completed half of these inspections, comprising 1000 checks for industrial effluents and 125 assessments for stack emissions. These milestones have been meticulously recorded, emphasizing the commitment and thoroughness demonstrated during these inspections.

4. Restructuring and capacity building

Environment Protection Department, Punjab has improved its sectoral regime in the previous year, by incorporating climate change into its business regulations. The issue of Climate Change is going to be addressed by an independent center named Environment Policy Centre (EPC). The center is in line with the official Business of the Department. These efforts lead to change in the name of department as the Environment Protection and Climate Change Department (EP & CCD).

Currently, EPA labs and field offices are located on the campuses of other government agencies or in leased facilities. The EP & CCD plans to consolidate the offices of the Deputy Director (Field) and Deputy Director (Labs) into a single location within the newly constructed Divisional Environmental Complexes. This restructuring of the field operations at the district and divisional levels will enhance the EPA's field response capabilities.

Currently, the Secretariat and its attached departments at the provincial level are housed in rented buildings owned by the Sports Board Punjab. The EP & CCD plans to consolidate the Secretariat and the headquarters of all its attached offices into the newly constructed Green Building. This multi-story office building is designed with infrastructure aimed at minimizing environmental impact during both construction and operations. A groundbreaking initiative in Punjab, the EP & CCD Green Building will be the first of its kind in the public sector. Its development focuses on sustainable site development, water conservation, energy efficiency, the use of eco-friendly materials, and improved indoor environmental quality. The project was approved by the Provincial Development Working Party, and the Infrastructure Development Authority of Punjab has been commissioned to design and construct the building. It is expected to be completed and handed over to EP & CCD by the end of March 2026.

The implementation of the 'Automation Regime of EPCCD Punjab' project is progressing rapidly. The PITB has been mobilized for the development of six key components: E-Environmental Approvals, E-Enforcement, E-Laboratories, E-Industrial Mapping, E-Monitoring System, and E-Information Sharing. Procurement of hardware has also been initiated.

5. Measures taken to control pollution & improve Air Quality.

5.1 Media campaigns and social awareness.

A comprehensive Public Communication Campaign was carried out to highlight the issue of environmental degradation due to anthropogenic activities across the province of Punjab. The primary goal of the campaign was the awareness of the people to reduce pollution load and take measures at individual level to mitigate the negative environmental and health impacts of single-use plastics, wastewater, smoke and other environmental befouling.

The campaign was carried out by a well-organized media cell at EPA Headquarters. The officers remain engaged throughout the year 2024 in a wide campaign to aware the people of the province and tried to communicate the message to the public at large. Media cell was made equipped with state-of-the-art media tools. The EPA has exceeded its limits by exploring every possible media platform, including print, mainstream, social media, messaging apps, advertisements, and more, to effectively reach the public. In this regard, awareness sessions, seminars at schools, and outdoor activities have also been conducted. Moreover, environmental consultancies played a crucial role through active engagement with

chambers of commerce, large retailers, civil society organizations, primary and secondary schools, and the media.

5.2 Delegation of powers to Field formation.

The Director General EPA has delegated his powers to the officers of different cadres under section 5(5) of Punjab Environmental Protection Act 1999 (amended 2012) to perform their Job Descriptions effectively. The Director General EPA Punjab has delegated the powers under section 16 of PEPA 1997 for issuance of Hearing Notices and Environmental Protection Order (EPO) for violation of section 11 and 12 of the Act ibid, and violation of Punjab Hospital Waste Management Rules, 2014 at district and provincial tiers. The Director General EPA authorized the district in-Charge and officers in-charge of special Anti-Smog Squads under Punjab Environmental Protection (Smog Prevention and Control) Rules, 2023. The in-charge officers of anti-smog squads of major districts were authorized to exercise the powers conferred under the said rules for their effective implementation and enforcement in Punjab. The Director General EPA Punjab also authorized the field formation under Punjab Environmental Protection (production and consumption of single use plastic products) regulations, 2023 to reduce the pollution load due to plastic bags in the province. The delegation of powers by the Directorate General of EPA to field formation at district and provincial tiers has equipped the field formation legally. These legal efforts from the Directorate General have uplifted the morals of field formation and prestige of EPA officers in the province.

5.3 Special Anti-smog squads

Special anti-smog squads were constituted during smog episode in the province. These squads were in addition to regular field activities. These special squads operated in major districts of Punjab, including Lahore, Gujranwala, Faisalabad, Multan, Rawalpindi, Sheikhupura and Sialkot. The squads stayed active 24/7 with three shifts. These squads performed operations 24/7 and actively responded towards the polluting sources and heard the grievances of the people. The squads were assigned with the duty of enforcement activities i.e., inspections, inquiries, investigations and personal hearings under Punjab Environmental Protection, Smog (prevention & control) Rules, 2023. In the provisions of the rules ibid smog squads were enabled to immediate stoppage of the pollution source. Hence, a significant improvement in the Air Quality of sensitive areas were observed. Smoke emitting violators that contribute in smog formation and subsequent adverse environmental effects were dealt with Iron hands under the provisions of rules ibid. The EPA Headquarters equipped these special

squads with adequate strength in terms of manpower and technology. The financial and moral assistance from the Punjab Government has brought new vehicles for these squads. Special drones equipped with webcams with the consent of Home Department were used to find the smoke emitting stacks. EPA take pride in stating that he centralized the activities of these squads in the Smog War Room established at EPA Headquarters. The authorized persons of these squads were facilitated by the online dashboard and android app namely 'EcoWatch' developed in assistance with PITB, where they could upload the geo-tagged monitoring data of industrial units inspected, while the control room monitored and tracked the movement of squads.

5.4 Tree Plantation campaign

In order to enhance the Green Cover and aesthetics of Environment EPA Punjab has significantly contributed to afforestation by integrating tree plantation requirements into Environmental Approvals (EAs) under Section 12 of the Punjab Environmental Protection Act 1997 (Amended 2012). This initiative has mandated industrial project proponents to plant trees within project areas or provide plants to respective PHAs/Forest Departments under EPA Punjab's supervision.

Furthermore, the Directorate General of EPA Punjab has nominated all District In-Charges, as representatives in the District Afforestation Committees (DACs). The Directorate of Environment Dengue and Hazardous substances (EDH) has devised a structured Monthly Reporting Mechanism to monitor progress. EPA has also ensured the accountability in tree plantation campaign at District and Provincial tier.

Moreover, as part of Spring Tree Plantation Drives, EPA Punjab spearheaded targeted initiatives, leading to Thematic Tree Plantation at Brick Kilns: Over 300,000 trees were planted to mitigate carbon emissions, aligning with the theme "Joining Carbon Hotspots with Carbon Sinks." For the first time, all planted trees were geotagged on the Plant for Pakistan App to ensure real-time monitoring and sustainability and Eco-Restoration at Hiran Minar: A dedicated Miyawaki Forest was developed at this historic site, significantly enhancing biodiversity and environmental resilience.

5.5 Single use Plastic Waste Management

EPA Punjab has Strengthened his campaign against polluters of Plastic Waste. In this regard the District In-Charge are authorized in line with the Punjab Environmental Protection (Production and Consumption of Single-Use Plastic Product) Regulations 2023.

Furthermore, the District Plastic Management Committees are notified to take punitive actions against the violators. The authorized officers at District and Provincial level are authorized to enter, inspect any premises and take samples or carryout out test of single-use plastic product in accordance with the Environmental Samples Rules, 2001 at the spot through a calibrated gauge. In order to establish accountability a reporting mechanism has been developed to report the confiscated amount to EPA Headquarters. Innovative recycling initiative repurposed confiscated plastic waste into 300 school chairs, 10 hospital benches, and a children's play area in a model bazaar, setting a benchmark for sustainable waste management. The current efforts against the violators have been acknowledged by the provincial government. This is why the provincial government has amended the plastic regulations and completely banned the Single-Use Plastic products of thickness less than 75 microns. The administrative actions against plastic products include inspections, sampling, issuance of notices, confiscation, reporting, imposition of fines and lodging FIRs against the violators. EPA has also established a registration mechanism "Punjab Management Licensing Information System" for the banned single-use plastic. The registered person may produce, consume, distribute, store and recycle the single-use plastic product under a license issued by the Agency. This provision is for the existing producer, consumer, collector and recycler of single-use plastic product, shall get themselves registered with the Agency within a period of twelve months from the commencement of the regulations ibid. The said mechanism of registration is improving regulation and monitoring of the plastic production in the province.

5.6 Establishment of Android Application and Complaint Line

The EPA Punjab has propounded his vision "Stay Informed, Stay Protected" by launching "Green Punjab" android app with the assistance of PITB. This app has been launched to resolve smog-related concerns from citizens. Citizens can now file complaints against individuals who burn hospital waste and garbage, operate smoke-emitting kilns and vehicles, and factories that run without smoke control devices. Complaints submitted through the app will be swiftly reported to the appropriate authorities, and urgent action will be taken to resolve them. Complainants will also be kept up to date on the status of their complaints. Among the institutions linked to the app are PDMA, metropolitan corporation, traffic police, Parks and Horticulture Authority, and departments of agriculture, transportation. EPA has also established help line 1373 for any complaint regarding smog. In nutshell, use the Green Punjab app for air quality tracking, traffic alerts, route planning, and submitting public complaints- all in one place. In addition to android application and helpline the WhatsApp complaint number

and dashboard launched for receiving complaints on the pollution sources from all over the province remained active throughout the year and received complaints from different districts.

5.7 Fugitive Dust Control Measures

Fugitive dust is finely divided solids that may become airborne from their original state without any chemical or physical change other than fracture.[4]
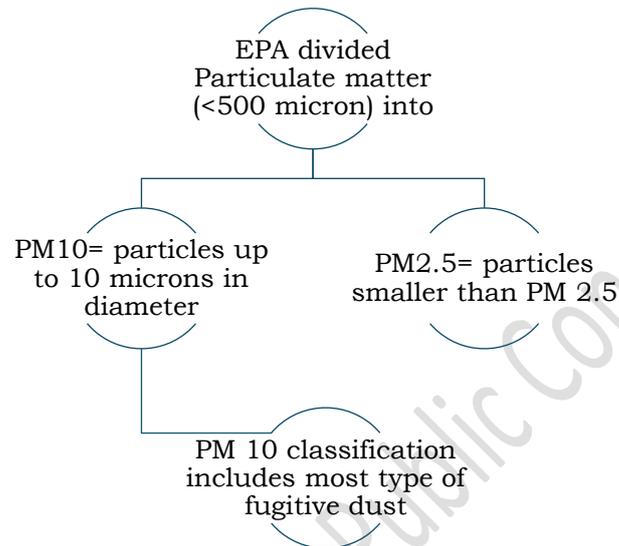
Figure 08-1: Classification of Fugitive Dust

Fugitive dust is primarily generated when solid materials are broken down through impact, crushing, abrasion, grinding, or through the transportation of construction materials to under-construction sites. It can also be recirculated by wind, workers, and machinery. In Lahore, inadequate dust suppression practices have become a significant contributor to air pollution.

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[4] https://www.epa.gov/system/files/documents/2022-02/fugitive-dust-control-best-practices.pdf

To address this issue, the Punjab Environmental Protection Agency (EPA) has launched a series of regulatory and enforcement actions aimed at reducing dust emissions, improving air quality, and protecting public health. According to the EPA, the main sources of fugitive dust include the transportation of construction materials in uncovered, overloaded trolleys and airborne particles from construction sites. These dust emissions contribute to respiratory illnesses, reduced visibility, and overall environmental degradation. In response, the EPA Punjab is actively working to regulate vehicles transporting sand and clay by enforcing the mandatory covering of materials using tarpaulins or similar wet covers to prevent dust dispersion. Another key initiative includes the installation of mist-sprinkling systems at construction sites to lower dust levels. Additionally, the washing of vehicle tires before exiting construction areas has been made mandatory. These measures are being implemented in accordance with Section 6(1)(t) of the Punjab Environmental Protection Act, 1997, with non-compliance punishable under Section 188 of the Pakistan Penal Code (PPC). Other stakeholders, including personnel from the Lahore Development Authority, Health Department, and Police Department, are also contributing to this vital cause.

Figure 8-2: Measures Taken to Control Fugitive Dust

The EPA Punjab conducted research in this regard to scientifically establish the validity of the actions taken against violators. The following table establishes this fact that up to 90% dust reduction can be achieved by covering and wetting materials.

Table 8-1: % Fugitive Emission Reduction By Sand And Clay Dropping During Transportation

	Total No. of vehicles transporting sand and clay in Lahore/day	Ave. Travelling Distance. (Km)	Fugitive emission/ Vehicle/ Km	amount of sand/ clay dropped during travelling (Kg) by all vehicle/ day	amount of sand dropped during travelling (Ton)/ day	amount of sand dropped during travelling/ vehicle/ day	%Reduction
Uncovered material	450	20	0.5	4500	4.5	10	
only by wetting the material	450	20	0.15	1350	1.35	3	70%
Only by covering the material	450	20	0.25	2250	2.25	5	50%
Both by wetting and covering the material	450	20	0.05	450	0.45	1	90%

6. Actions Against violating industrial units & Non-Zigzag Brick Kilns

While exercising the powers vested under Section 16 of the PEPA, and Smog (prevention & control) Rules, 2023 EPA carried out enforcement activities throughout Punjab and initiated legal actions against air polluting industries, including the steel re-rolling mills, stone crushers and BTK brick kilns. The following table enlist the actions taken against the violating Brick kilns.

Table 8-2: Summary Of the Actions Taken Against Non-Zigzag Brick Kilns from May 2024 to December 2024

Brick Kilns						
Sr.	District Name	Visited	Sealed	Demolished	FIRs Lodged	Fine Imposed
1	Attock	1798	1	26	1	3900000
2	Bahawalnagar	1372	32	27	121	10010000
3	Bahawalpur	2891	10	44	121	620000
4	Bhakkar	1935	8	36	88	2600000
5	Chakwal	1956	34	9	7	2600000
6	Chiniot	841	1	11	10	3400000
7	DG Khan	1981	7	44	29	0
8	Faisalabad	1267	86	25	85	7400000

9	Gujranwala	913	5	6	10	1600000
10	Gujrat	1195	0	3	0	1550000
11	Hafizabad	1496	45	5	3	3300000
12	Jhang	4825	160	52	103	16900000
13	Jhelum	1567	3	20	0	1100000
14	Kasur	2748	109	59	31	11855000
15	Khanewal	2404	36	21	41	3400000
16	Khushab	1265	5	20	26	200000
17	Kot Addu	260	0	0	0	0
18	Lahore	663	22	26	8	600000
19	Layyah	1750	17	108	45	400000
20	Lodhran	3803	30	46	89	2900000
21	MB Din	1208	8	12	5	300000
22	Mianwali	1201	32	73	93	0
23	Multan	3942	136	132	337	10000000
24	Muzaffargarh	2550	31	20	91	500000
25	Nankana Sahib	1304	33	9	19	2200000
26	Narowal	990	40	4	52	3100000
27	Okara	1503	2	65	15	500000
28	Pakpattan	2125	7	27	21	3000000
29	RY Khan	1797	32	43	121	1800001
30	Rajanpur	1607	13	19	38	250000
31	Rawalpindi	1243	46	18	5	8450000
32	Sahiwal	3108	36	24	28	11100001
33	Sargodha	1663	44	61	20	300000
34	Sheikhupura	2213	92	63	97	5725000
35	Sialkot	936	86	11	51	4700000
36	TT Singh	1336	46	23	40	3450000
37	Vehari	2913	80	27	116	2300000
	Total	**68569**	**1375**	**1219**	**1967**	**132010002**

Table 8-3: Summary Of The Actions Against Violating Industrial Units

Industrial Units						
Sr.	District Name	Visited	Sealed	Demolished	FIRs Lodged	EPO Issued	Fine Imposed
1	Attock	662	4	0	0	0	1400000
2	Bahawalnagar	1289	12	0	68	2	4800000
3	Bahawalpur	184	0	0	27	0	500000
4	Bhakkar	59	12	0	0	0	800000
5	Chakwal	460	2	6	0	0	200000
6	Chiniot	303	5	0	3	0	2100000
7	DG Khan	514	8	0	15	0	400000
8	Faisalabad	1782	256	7	105	0	53900000
9	Gujranwala	1420	222	41	72	0	15235000

10	Gujrat	789	6	0	10	0	100009
11	Hafizabad	1103	5	0	0	0	3400000
12	Jhang	996	30	0	62	0	5200000
13	Jhelum	632	21	0	1	0	2200000
14	Kasur	1800	105	23	28	1	5460000
15	Khanewal	487	1	0	0	0	300000
16	Khushab	130	4	1	0	2	400000
17	Kot Addu	41	0	0	0	0	0
18	Lahore	5334	539	63	193	1	37670000
19	Layyah	140	8	0	0	0	0
20	Lodhran	585	1	0	0	0	100000
21	MB Din	170	4	0	0	0	200000
22	Mianwali	221	6	0	0	0	0
23	Multan	1305	78	5	32	0	13800000
24	Muzaffargarh	410	2	1	1	0	100000
25	Nankana Sahib	979	60	3	3	0	3500000
26	Narowal	245	7	0	0	0	500000
27	Okara	534	4	0	3	0	1110000
28	Pakpattan	354	0	0	2	0	100000
29	RY Khan	398	11	22	13	0	200000
30	Rajanpur	107	1	0	9	0	100000
31	Rawalpindi	980	7	4	0	0	900000
32	Sahiwal	598	13	0	9	0	1400000
33	Sargodha	384	58	4	8	1	7360000
34	Sheikhupura	1212	95	43	8	0	5700000
35	Sialkot	308	12	0	0	0	100000
36	TT Singh	270	16	0	2	0	1000000
37	Vehari	207	5	2	3	0	600000
	Total	**27392**	**1620**	**225**	**677**	**7**	**170835009**

7. Measures to reduce pollutant load from Stubble Burning

Stubble burning significantly contributes to smog formation, particularly in agricultural regions during the post-harvest season. When farmers burn leftover crop residues, such as paddy straw, it releases large amounts of air pollutants including particulate matter (PM2.5 and PM10)—tiny particles that can penetrate deep into the lungs and reduce visibility—carbon monoxide (CO), a toxic gas, volatile organic compounds (VOCs), and nitrogen oxides (NOx). These pollutants contribute to the formation of ground-level ozone. Additionally, carbon dioxide (CO_2) is released, which exacerbates climate change.

When these pollutants interact with moisture and sunlight, they lead to the formation of smog. Photochemical smog develops when NOx and VOCs react under sunlight, producing ground-level ozone and other irritants. Meanwhile, particulate-laden smog forms when particulate matter combines with water vapor, creating a dense, hazy layer. The problem intensifies during the winter months, especially from October to December, when cooler temperatures and low wind speeds trap pollutants near the ground—a phenomenon known as temperature inversion. This results in persistent smog, particularly in urban areas, where it combines with emissions from vehicles and industrial sources.

EPA Punjab coordinating with Agriculture Department and Rescue1122 to identify, extinguish fire from the stubble burning. EPA Punjab also educating the local farmers to shift from their traditional approach. Government of Punjab also advancing the technique with the provisions of happy speeders.

8. Measures to reduce pollution load from Single-use Plastic Products

The Director General of the Environmental Protection Agency (EPA) Punjab authorized field formations to implement the Punjab Environmental Protection (Production and Consumption of Single-Use Plastic Products) Regulations, 2023, aimed at reducing plastic bag pollution across the province. EPA Punjab has intensified its efforts to combat plastic pollution by enforcing stringent regulations and adopting innovative waste management strategies to ensure long-term environmental sustainability. As a result of these efforts, the Lahore Waste Management Company reported a 60% reduction in plastic load. EPA teams conducted inspections to ensure compliance, issued notices to violators, confiscated illegal plastic bags, and imposed administrative penalties totaling PKR 5.33 million. These measures helped mitigate environmental hazards and deter further violations. First Information Reports (FIRs) were registered against repeat offenders, non-compliant premises were sealed, and legal actions were pursued through complaints filed before the Environmental Magistrate to ensure accountability. A province-wide enforcement campaign was conducted under the 2023 regulations. Additionally, amendments spearheaded by the Executive Director (Headquarters) enhanced enforcement mechanisms and legal coverage. An innovative recycling initiative repurposed confiscated plastic waste into 300 school chairs, 10 hospital benches, and a children's play area in a model bazaar—setting a benchmark for sustainable waste reuse. To strengthen localized plastic waste management, District Plastic Management Committees were established throughout Punjab. Furthermore, the Punjab Management Licensing Information

System was launched under the supervision of the DG EPA, streamlining the regulation and monitoring of plastic-related stakeholders.

9. Conclusion

EPA Punjab is striving hard to curb the pollution in the province. The concerted efforts to reduce pollution load across Punjab reflect a proactive and multi-dimensional approach to environmental protection. Through the implementation of robust regulations, strict enforcement mechanisms, and innovative waste management practices, significant progress has been made—most notably the substantial reduction in plastic pollution. The collaboration between regulatory authorities, local committees, and the public has been instrumental in driving compliance and fostering a culture of environmental responsibility. Moving forward, sustaining and scaling these measures will be crucial to ensuring long-term ecological balance and public health across the province.

CHAPTER 9   ENVIRONMENTAL COMPLAINTS

1. Overview

PEPA has a distinctive set of institutional arrangements through a formalized established Grievance Redressal mechanism (GRM) for proactively resolving environmental complaints across Punjab. Pertaining to Section 6 sub- section 2 (a) of the PEPA, the Agency may undertake inquiries or carry investigation into environmental issues, either at its own accord or upon complaint from any person or organization. GRM is an effective avenue for expressing concerns for community and bringing positive social change by adopting remedial measures. It is a means of fulfilling an individual's right to effective remedy and providing a direct, accessible way for individuals and communities to complain directly to the department or by using other channels (by email, web or mail) linked with compliant redressal.

GRM operates through an efficient, responsive, and accessible complaint handling system as described below Figure 9-1.

Easily accessible
Maintaining easily accessible complaint handling channels (email, web, or postal mail)

Time-bound and efficient
Providing time-bound and efficient preliminary analysis of all incoming complaints, with a public registry and notice of all eligible complaints to department.

Transparent
Operating under a set of protocols defining the procedures for complaints resolution

Highly Responsive
Facilitating resolution of complaints through a variety of means.

Figure 4-1: Grievance Redressal Mechanism of EPCCD

2. Grievance Redressal Mechanism

A number of channels are available to any aggrieved persons to access EPA through different media and institutional arrangements:

●   To the Office of the Chief Minister, Chief Secretary, Secretary Environment, Director General EPA, Commissioner, Deputy Commissioner and Environment officer of the relevant districts in person.

●   Electronically through Prime Minister Delivery Unit, CRM Portal, Chief Secretary complaint cell or by sending an email to the quarters concerned

●   By mail/post, through posting a hard copy of the complaint to the concerned office

3. Grievance Redressal in 2024

Contrary to the year 2023 where 908 complaints were received by the EPCCD, 1906 complaints were received in 2024. Lahore district received the highest number of complaints (483), followed by Faisalabad (218), Gujranwala (126) and Multan (94) (Figure 9-2). Majority of the complaints lodged in Lahore, Faisalabad, Gujranwala and districts were against the foundries, brick kilns, pyrolysis plants, rice sheller, woolen looms, steel mills, welding plants, melting furnaces, dying units, generators, power looms, metal works, ceramics and textile industries.
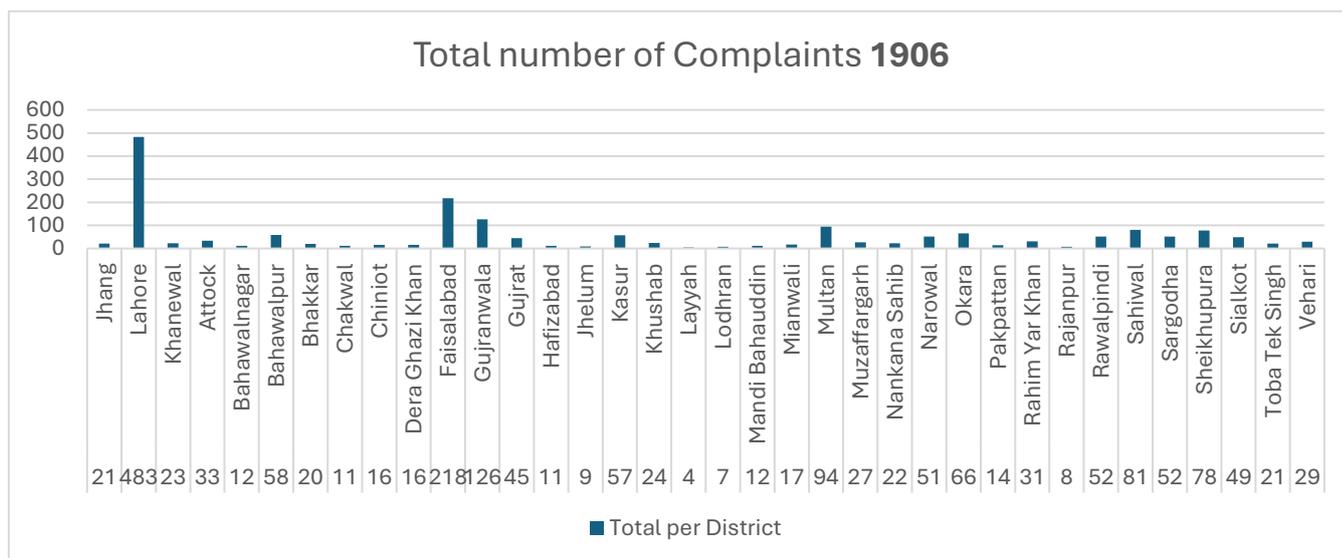
Figure 9-2: Total number of complaints received in each district of Punjab in 2024

The registered complaints were related to a wide variety of environmental issue as air pollution, noise pollution, hazardous/hospitals/municipal solid waste, sub-standard fuel used for combustion, cancellation of environmental approval/operation without environmental approval, soil pollution/land degradation and others (poly-ethylene bags, dust, spray polish, crop residue burning, odor and traffic management etc.).

The registered complaints were related to a wide variety of environmental issue as air pollution, noise pollution, hazardous/hospitals/municipal solid waste, sub-standard fuel used for combustion, cancellation of environmental approval/operation without environmental approval, soil pollution/land degradation and others (poly-ethylene bags, dust, spray polish, crop residue burning, odor and traffic management etc.).

4. EPA Helpline for Environmental Complaints (2024)

In 2024, EPA Punjab operationalized a dedicated complaint helpline, enabling citizens to lodge complaints via phone. A total of 1,649 complaints were received through this platform. Each call was answered, necessary field investigations were conducted, and all complaints were resolved through appropriate regulatory actions. This initiative not only simplified access to EPA services but also significantly enhanced public trust in environmental enforcement mechanisms.

5. Green Punjab Mobile Application

Launched to promote digital citizen engagement, the Green Punjab app allows users to file complaints directly through mobile phones. The system includes geotagging, photo upload, and real-time status tracking. In 2024, 24,491 complaints were registered via the app, all of which were successfully addressed. This initiative showcases EPA Punjab's commitment to leveraging technology-driven solutions for improved environmental compliance.

6. Environmental Complaints Filed Before the Tribunal

In addition to field-level actions, the EPA also pursued legal action through the Punjab Environmental Tribunal (PET). In 2024:

- 585 new complaints were instituted by EPA.

- 632 complaints were disposed of.

- Rs. 23.73 million fines were imposed on non-compliant units.

- 49 complaints remained pending by year-end.

These complaints mostly related to violations of Section 11 (emission/discharge without control), Section 12 (lack of environmental approvals), and Section 16 (non-compliance with EPOs) under PEPA, 1997.

7. Way Forward

- Promoting awareness and enhancing capacity building among field staff and stakeholders regarding complaint handling procedures will further strengthen accountability and foster a culture for continuous learning across the system.

- With the successful launch of the EPA Helpline and the Green Punjab mobile application, the shift toward a digitally integrated grievance redressal system has already begun. These platforms have eliminated the need for physical visits, thereby improving public access, reducing response time, and promoting e-governance.

- To build on this momentum, there is a need to integrate a real-time complaint tracking system within these platforms, enabling complainants to monitor the status of their complaints at each stage until resolution.

- District-wise generation of GRM reports, summarizing total complaints received, actions taken, and resolution status, should be institutionalized. These reports will not only highlight public concerns but also serve as an important indicator for environmental governance and conflict resolution at the local level.

- A structured mechanism for citizen feedback on complaint resolution should also be introduced through both digital platforms (app and helpline follow-up) and field surveys. This will help evaluate public satisfaction, identify service gaps, and guide future improvements in the grievance management system.

Key Findings

EPCCD has established an easily accessible, efficient, transparent and responsive Grievance Redressal Mechanism for addressing environmental complaints, which is working proactively across Punjab.

Environmental issues can be reported to the EPCCD through various channels and media including in-person at the concerned offices and via email.

Total 1906 complaints were registered during 2024 related to various environmental issues, with the majority pertaining to air pollution (50%).

The Lahore district received the highest number of complaints (483) and remained at the top among all 36 districts.

1874 registered complaints were successfully resolved, while 32 complaints are currently being processed in the Environmental Tribunal.

83 units were sealed, and 42 FIRs were filed in 2023 due to non-compliance with the Punjab Environment Protection Act, 1997, read with PEQS.

Most of the complaints (57%) were lodged through CRM and (53%) were lodged through PMDU portals.

Under PGDP, a formal Grievance Redressal Mechanism has been established since August 2023 to address the grievances pertaining to the program.

CHAPTER 10   **ENVIRONMENTAL ACTION PLAN**

1. Introduction

The Environmental Action Plan is a strategic document detailing specific objectives, actions, and initiatives aimed at tackling environmental challenges and promoting sustainable development. Its goal is to alleviate the adverse environmental effects of conserve natural resources and promote sustainable development. The aim of this action plan is to mitigate the negative environmental impacts arising from anthropogenic activities, conserving natural resources and fostering environmentally sustainable practices. It is a commitment amongst the stakeholders for taking corrective actions within stipulated timeline. The State of Environment Report (2022) introduced an Environmental Action Plan with 11 interventions and 71 sub-interventions, fixing responsibilities and timelines among provincial government departments [1]. It identified short-term (CY-23), medium-term (CY- 24), and long-term (CY-25) measures required to be taken by government departments. In CY-23, significant achievements were made in the legislative, citizen engagement, industry regulation, vehicular emissions control, monitoring enhancements, sustainable green financing, fugitive dust mitigation, and remodeling environmental governance interventions [2]. Environmental Action Plan 2023 is also a three years' plan startinfg from CY-24 and ending at CY-26. Whereas Environmental Action Plan 2024 is also pertaining Short Term (within 1-2years), Medium Term (3-5years) and Long Term (5-10years) as mentioned in Punjab Climate Action Plan 2024. Two additional interventions (Air and Climate Change) had been added along with some new sub-interventions in the Environmental Action Plan 2023. Whereas a dashboard will be set-up for monitoring of Environmental Action Plan by EPCCD Environmental Action Plan 2024 [3].

Action plans contain a set of interventions, sub-interventions, responsibilities with specific timelines. The details are as follows:

- Interventions: Interventions are the broader areas where actions are to be taken.

- Sub-Interventions: Sub-interventions are the details and explicit actions to be taken under respective interventions.

- Responsibilities: Responsibilities are the duties entrusted to the Government organizations in the action plan for carrying out the interventions and sub-interventions.

- Timelines: Timelines mean the time duration envisaged for carrying out sub-interventions.

SOE Report, 2022 contains the Environmental Action Plan based on *Short Term* for Calendar year, 2023(CY-23), *Medium Term* for Calendar year 2024 (CY-24) and *Long Term* for Calendar year, 2025(CY-25) measures. The progress on actions initiated / completed during CY-23 (short term) is described in first part of the chapter. In the second part, the Environmental Action Plan for SOE Report, 2024 (starting from CY-25) is given. Hence, all

the sub-Interventions pertaining to Medium Term CY-24 (in SOE, 2023) are now Short-Term CY-25 (in SOE, 2024), Medium Term (3-5years) and Long-Term (5-10years) in SOE, 2024.

1.3 Status of Implementation of Environmental Action Plan-SOE (2022) [1]

The SOE Report, 2022 included a thorough Environmental Action Plan that outlined a set of interventions and sub-interventions to be taken by certain departments for improvement and betterment of the environment. Responsibilities for execution of these interventions with timelines ranging from CY-23 to CY-25 we real so mentioned. The status of this Environmental action plan is as follows:

- Interventions & sub-interventions: There were 11 interventions in this Environmental action plan (Table10-1)

Table 5-1: Interventions in Environmental Action Plan, 2022

Sr. No	Intervention	Sr. No	Intervention
1	Legislative	7	Solid/Hospital/Industrial waste
2	Citizen Engagement	8	Punjab Sustainable Development Fund
3	Industries	9	Fugitive Dust Control
4	Vehicular	10	Remodeling Environmental Governance
5	Monitoring	11	Others
6	Water and wastewater		

- Responsibilities: The implementation of these interventions and sub-interventions were distributed among the respective agencies from where focal persons are nominated for the successful implementation of the environmental action plan. These focal persons are working as pioneers in their respective departments for betterment of the environment (Table10-2).

Table 10-2: Agencies and Focal Persons for Implementation of Environmental Action Plan

No	Agencies	No	Agencies
I	Federal Board of Revenue Department	Vii	Traffic Police Department
Ii	Transport Department	Viii	Industry Department
Iii	LG&CD	Xi	WASA (Lahore, Faisalabad, Multan, Gujranwala, Rawalpindi)
Iv	C&W Department	X	HUD&PHE Department
V	Irrigation Department	Xi	EPCCD

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[1] Punjab State of The Environment Report 2022 (http://epd.punjab.gov.pk/system/files/Report%202022-hi-res%20%284%29.pdf)

2   Punjab State of The Environment Report 2023
(https://epd.punjab.gov.pk/system/files/SOE%20Report%2020-June%20low%20res.pdf)

3

- Timelines: Total 71 sub-interventions under the given 11 interventions were outlined on a specific time scale i.e., 21 Short Term (1-2years), 33 Medium Term (3-5years) and 17 Long Term (5-10years). These interventions were either initiated or to be completed during the stipulated timeframe.

Actions initiated / completed: progress on the interventions / sub-interventions for the actions were taken during CY-23.

Table 10-3 : Actions initiated / completed were taken during CY-23.

1-Legislative interventions		
No	**Sub-interventions**	**Status (Initiated/Completed)**
1-1	Punjab Clean Air Policy	Was notified vide Gazette No. 72 of 2023 dated 19.04.2023
1-2	Smog Prevention and Control Rules	Were notified vide Gazette No. 96 of 2023 dated 17.06.2023
1-3	Plastic Management Strategy	Was notified vide Gazette No.71 of 2023 dated 19.04.2023
1-4	Production and consumption of single-use plastic regulations 2023	Were notified vide Gazette No 95 of 2023 dated 07.06.2023
1-5	Revision of Environmental Quality Standards	Draft is ready for proceeding for approval of the authority.
1-6	Hazardous Substance / Waste Management Policy and Rules	Draft was completed and is under scrutiny at various levels for approval.
1-7	Green Financing Strategy	Draft was completed and is under scrutiny at various level for approval.
1-8	Pollution Inventory in Punjab	New scheme draft concept paper is ready after consultationsforincorporationintheADP2024-25
2- Citizen Engagement and Industries		
2-1	Establishment of hotline	PITB is added in revised PC-I. Work is going to be allotted.
2-2	Establishment of Interactive Data Portal	For getting public input on environmental management. Beta version has been designed & deployed at https://idm.pgdp.pk/ippi.
2-3	Disclosure of environmental information through Electronic means	PC-I revised with provision of consultancy services for development of formats and protocols for disclosure of environmental information. Recruitment of project staff is under process.
2-4	Geo Tagging of Industries	Module has been developed and will be deployed for the Data input i.e., https://idm.pgdp.pk/admin/pim/industrydetail/
2-5	Financial Assistance to Green Micro-Enterprises	For "Punjab Economic Stimulus Program (support to Micro Enterprises)" was merged into "Punjab Rozgar Scheme" to achieve the target of DLR 7-3 of PGDP. Under this scheme, the Bank of Punjab has disbursed 582 green loans amounting Rs. 776 Million (approx.) to ME/Microenterprises.
3- Vehicular and Monitoring		
3-1	Retiring excessively old vehicles and installation of catalytic converters/diesel particulate filter	Devising mechanism in the vehicles.

3-2	Establishment of a GIS Cell in EPCCD	After consultations a new scheme is going to be introduced titled as "Establishment of a Climate Adaptation and Resilience Support Center (CARSC)" which will contain the component of GIS Cell. Draft concept paper is ready for incorporation in the ADP 2024-25.
4- Sustainable Green Financing, Fugitive Dust Control and Remodeling Environmental Governance		
4-1	Operationalization of Environment Endowment Fund Management Unit	A Section 42 company named "Punjab Environment & Climate Change Endowment Funds" was going to be incorporated in SECP. Transport Department
4-2	Devising Operational Guidelines for the Disbursement of the Fund	PC-I is under the process of revision for hiring a consultancy firm for the said task. Excise Department
4-3	Devising standards for controlling fugitive/ construction dust from road shoulders and construction sites	Draft in preparation and it would be shared soon with the relevant stakeholders. Transport Department
4-4	Automation Regime to Expedite the Public Service Delivery in EPCCD	Development of six modules i.e., E-Industrial Mapping, E-Environmental Approvals, E-Monitoring System, E-Enforcement Sharing and E-Laboratories. Procurement of IT equipment was initiated.
4-5	Establishment of Environmental Policy Center	For hiring human resource, draft service rules were sent to Authority for approval. For hiring of office building, procurement of machinery and equipment and for allied expenditures, draft concept paper is ready for incorporation in the ADP 2024-25.

The progress on the interventions / sub-interventions for the actions required to be initiated / completed during CY-24, as stipulated in SOE report 2023, is given in table 10-4.

Table 10-4: Key Achievements For Legislative Interventions In 2024.

1-Legislative			
No	Sub-interventions	Status (Initiated/Completed)	Responsibility
1-1	Notification of rules & regulations under the Punjab Environmental Protection Act, 1997 (like Hazardous Substance Rules and implementation of MEAs given in the Schedule (e.g., Green House Gases/ UNFCCC, Biodiversity etc.)	Hazardous waste Rules 2020 were drafted and made available as EPCCD website for public comments. Others are in progress.	EPCCD
1-2	Certification and labeling system for green, energy-saving products	In progress	Energy Department

1-3	Energy conservation standards for newly built urban buildings and industrial establishments	In progress	Energy Department
1-4	Energy saving renovations/ retrofitting in existing buildings and improved energy efficiency guidelines/ regulations/rules	In progress	Energy Department
1-5	E-Waste Management Rules	In progress	EPCCD
2-Citizen Engagement			
2-1	Establishment of air and water web-based data portal. Further, engage public, private and civil sectors in the development to form joint policy frame work to address environmental challenges like air, water quality	Installation of 30 AQMS, others in progress	EPCCD
2-2	Public communication campaigns on negative environmental and health impacts of single use plastic	Completed	EPCCD
3-Industries			
3-1	Implementation of resource efficiency and cleaner production technologies	In progress	Industry Department
3-2	Evaluation of impacts of pollution sources on the soil quality.	Not available	EPCCD
4-Monitoring			
4-1	Installation of at least 30 ambient air quality monitoring stations	Completed	EPCCD
4-2	Installation of at least 15 water quality monitoring stations	Not completed	EPCCD
4-3	Establishment of a reference laboratory	Completed	EPCCD
4-4	Establishment of noise and vibration monitoring networks	Not completed	EPCCD
4-5	Environmental monitoring of industrial effluents deteriorating the quality of river Ravi in Sheikhupura and Faisalabad	Completed	EPCCD
5-Vehicular			
5-1	Enhancing the area of jurisdiction of vehicles inspection and certification regime to the private vehicles	In progress	Transport Department

5-2	Mandatory vehicle inspection certificate prior to sale and purchase of any vehicle regarding emission compliance	In progress	Excise Department
5-3	Promote mass transport facilities in the major urban centers of the province	Completed	Transport Department
5-4	Piloting of electric buses in Lahore, Punjab	Completed	Transport Department
5-5	Devising mechanism to increase road denials of excessively old/ pollution causing vehicles	In progress	Transport Department/ EPCCD
5-6	Road Engineering for removing traffic congestions in the major roads of the urban centers	Completed	Traffic Police/ Development Authorities/MC
6-Air			
6-1	Enactment of "The Punjab Clean Air Act"	Completed 2023	EPCCD
6-2	Area pollution and dust control/ urban dust management	Not available	EPCCD/ Housing Authorities/ C&W
6-3	Implementation of zero sand spillage regime regarding sand moving trolleys	Not available	Mines & Minerals/ District Govt./ Traffic Police
6-4	Investigation of sources of particulate matter for informed decision making	Not completed	EPCCD
6-5	Implementation of health advisory in the wake of critical air pollution events	Completed	EPCCD
7-Water & Waste Water			
7-1	Water metering for every connection of domestic and industrial establishments along with provision of clean surface water	Completed	WASAs and municipal authorities
8- Solid Waste & Hospital/Industrial waste			
8-1	Waste minimization at source (reduce, recycle, and reuse)	Completed	LG&CD
8-2	Improve waste collection efficiency	Completed	LG&CD
8-3	Provision of hospital waste management facilities by large private hospitals (having more than 30 beds)	Completed	Private/Health Department
9-Climate Change			
9-1	Establishment of a Climate Adaptation	Not made yet	EPCCD

	and Resilience Support Center (CARSC)		
10 – Remodeling Environmental Governance			
10-1	Establishment of Environmental Technology Transfer Center	Completed	EPCCD
10-2	Incentivization of the environmentally compliant industries	In progress	EPCCD/ MOCC/FBR
10-3	Establishment of Environmental Policy Center	Completed	EPCCD
10-4	Implementation of Plastic Management Strategy	Completed	EPCCD
11-Others			
11-1	Construction of Green Buildings in Lahore	In progress	EPCCD
11-2	Establishment of noise-free zones in Punjab	In progress	EPCCD/ Development Authorities

2. Environmental Action Plan for SOE, 2024 [3]

Environmental Action Plan, 2024 is also containing three plans starting from Short Term (1-2yers), Medium Term (3-5years) and Long Term (5-10years)[2]. All the interventions and sub-interventions of previous environmental action plan are adjusted accordingly. In addition to these, some new interventions / sub-interventions are added. Two new interventions namely "Air" and "Climate Change" have been added. Description of Short Term, Medium Term and Long Term interventions is given at Table10-5.

Table 10-5: Timeline to complete / initiate sub-interventions of Environmental Action Plan.

Short Term (1-2years)	The targets under Short-Term category include immediate interventions. These sub- interventions had been completed / initiated within 1-2years.
Medium Term (3-5years)	The targets under Medium-Term category require implementation of modern strategies and policy support. These sub-interventions are to be completed / initiated with 3-5years.
Long Term (5-10yrs)	Long Term category targets are to be completed / initiated till 5-10years. These sub- interventions require sustained policy measures.

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[2]CLIMATE RESILIENT PUNJAB VISION ACTION PLAN 2024
(https://epd.punjab.gov.pk/system/files/Climate%20Change%20Book%20%283%29_compressed.pdf)
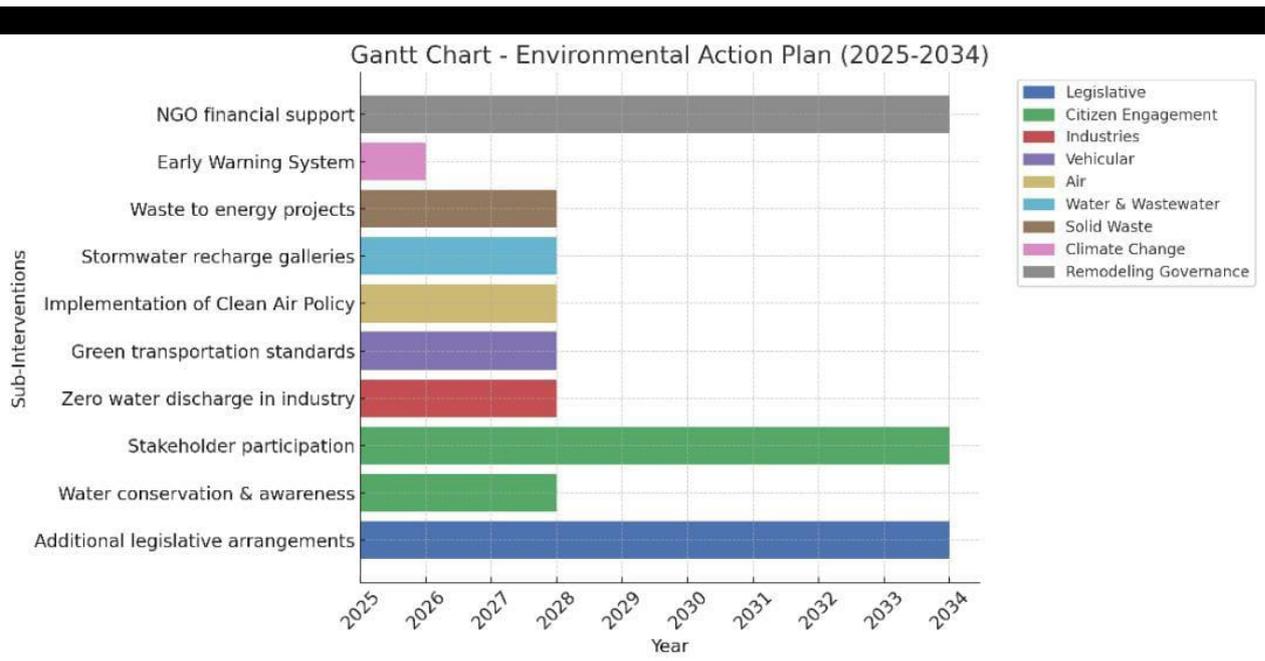
Figure 10-01: Environmental action plan (2025-2034)

Sub-interventions and respective responsibilities on the time scales were redefined as given in Table 10-6.

Table 10-6: Environmental Action Plan

1-Legislative		
Term	**Sub-interventions**	**Responsibility**
Long Term (5-10yrs)	1-1 Additional legislative arrangements other than the Environment Act	EPCCD

2-Citizen Engagement		
Medium Term (3-5years)	2-1 Public communication campaigns on water conservation, rain water harvesting, and environment conservation etc.	EPCCD
Long Term (5-10yrs)	2-2 Effective participation of stake holders and public-private sector cooperation in decisions making-processes	EPCCD
Long Term (5-10yrs)	2-3 Enhancement of environmental health awareness and environmental concerns	EPCCD

3-Industries		
Medium Term (3-5years)	3-1 Implementation of zero water discharge/water conservations schemes in the water intensive industries like textiles, sugar etc.	Industry Department / EPCCD

Medium Term (3-5years)	3-2	Introduction of carbon neutrality regime	EPCCD
Medium Term (3-5years)	3-3	Installation of continuous emission monitoring systems	Industry
Long Term (5-10yrs)	3-4	Designing, Development and implementation of technologies for prevention of pollution at source	EPCCD
Long Term (5-10yrs)	3-5	Introduction of measures for the prevention of the production of hazardous wastes at the source	Industry / EPCCD
Long Term (5-10yrs)	3-6	Increasing collaboration with the academia for research and development for sustainable development	EPCCD/ Universities

4-Vehicular

Term	**Sub-interventions**		**Responsibility**
Medium Term (3-5years)	4-1	Green transportation, standards, action plans & solutions	Transport Department
Medium Term (3-5years)	4-2	Increase the counters for issuance/ renewal of fitness certificates/ route permits	Transport Department
Medium Term (3-5years)	4-3	Deploy the teams to check vehicles playing on road without fitness certificates & route permits	Transport Department/ Traffic Police

5-Air

Medium Term (3-5years)	5-1	Implementation of Punjab Clean Air Policy (with phased Action Plan)	EPCCD
Medium Term (3-5years)	5-2	Establishment of pollution inventory and pollution release and transfer register	EPCCD

6-Water & Waste Water

Medium Term (3-5years)	6-1	Construction of storm/rain water underground water recharge galleries in establishments (including public as well as private)	LG&CD/C&W Department

Medium Term (CY-25)	6-3	Rehabilitation of dams, rivers, drains, and canals. Also ensure the implementation of watershed management practices and increase in water storage capacity of the province[5]	Irrigation Department
	6-4	Conservation of natural habitats especially the Ramsar sites	EPCCD
	6-5	Installation of municipal waste water treatment plants against each existing disposal station	LG&CD/ Housing Authorities/ WASA's
	6-6	Construction of industrial waste water treatment plants	Private/EPCCD
	6-7	Mandatory provision of construction of municipal waste water treatment plants in new establishment of disposal stations	LG&CD

7- Solid Waste & Hospital/Industrial waste

Medium Term (3-5years)	7-1	Establishment of Integrated solid waste management facilities in each urban as well as rural are as	LG&CD
Medium Term (3-5years)	7-2	Installation of waste to energy projects	LG&CD/Energy Department
Medium Term (3-5years)	7-3	Provision of industrial waste management facilities in industrial or cluster levels	Industry Department
Long Term (5-10yrs)	7-4	Piloting and handing over of a catalytic hydro de-chlorination unit for treatment of PCBs and similar hazardous chemicals	EPCCD&LG&CD

8-Climate Change

Medium Term (CY-25)	8-1	Establishment of Early Warning System for extreme weather events in Southern Punjab	EPCCD
Medium Term (3-5years)	8-2	Mapping the climate change vulnerability to develop a Climate Adaptation and Resilience Plan (CARP)for South Punjab	EPCCD
Medium Term (3-5years)	8-3	Piloting of a community conserved area in South Punjab for protection of desert ecosystems	EPCCD

9– Remodeling Environmental Governance

| Medium Term (3-5years) | 9-1 | Collaboration/regional dialogues on transboundary water and air pollution | EPCCD/MOCC |

Long Term (5-10yrs)	9-2	Provision of financial resources to NGOs and collaboration with them for sustainable development	EPCCD

10-Others			
Medium Term (3-5years)	10-1	Research and development for developing / adoption of indigenous technologies for pollution abatement preferably through industry academia licenses	EPCCD
	10-2	Establishment of woodlands especially in urban centers of indigenous and environment-friendly species	Forest Department
Medium Term (3-5years)	10-3	Preparation of local environment action plans at the district levels with special reference to environmental protection and pollution prevention	LG&CD/ EPCCD
Medium Term (3-5years)	10-4	Land-use classification of each district to gauge the urban sprawl, development pattern etc.	LG&CD/ Development Authorities
Medium Term (3-5years)	10-5	Development of policy instruments to deal with the problem of noise pollution	EPCCD
Long Term (5-10yrs)	10-6	Intensification of R & D activities for abatement of air and water pollution	EPCCD
Long Term (5-10yrs)	10-7	Establishment of a Noise prevention cell under EPA Punjab	EPCCD
Long Term (5-10yrs)	10-8	Tapping of domestic and external sources of finance to investments for environmental protection and climate change	EPCCD

Table 10-7: Climate Change Adaptation and Resilience (Adaptive Measure) [3]

No.	Actions	Responsible Entity	Short Term (1-2yrs)	Medium Term (3-5yrs)	Long Term (5-10 yrs)
1. Water Resources: Enhance water security by conserving and protecting water resources. Improve integrated water resource management and ensure water quality via regulatory and technical measures. Promote water storage and distribution infrastructure such as recharging wells, rainwater harvesting, and community ponds.					
1.1	Install water quality monitoring stations at major surface water bodies	EPCCD/EPA, Irrigation	→		
1.2	Deploy floating trash barriers to prevent waste and plastics from accumulating in water bodies	WASAs, Irrigation, EPCCD/EPA	→		
1.3	Effective and immediate implementation of the Punjab Water Act 2019 for sustainable groundwater governance.	Irrigation, HUD&PHED, EPCCD/EPA	→		
1.4	Enforce water re-use and recycling in water-dependent industries, artificial wetlands, agriculture, and groundwater recharge through regulatory instruments	EPCCD/EPA, ICI&SDD, WASAs, Agriculture	→———→		
1.5	Implement the water accounting system at the canal command scale	Irrigation, EPCCD/EPA	→———→		
1.6	Introduce a water quality ranking system for natural water bodies and barrage-barrage channel reach for cleansing of contaminants	Irrigation, EPCCD/EPA	→———→		
1.7	Establish aquifer storage and recovery technology in canal command and rain-fed areas	Irrigation, WASAs, Agriculture, EPCCD/EPA, C&W	→————————————→		
1.8	Introduce a water rights trading system to optimize water allocation	Irrigation Department, EPCCD/EPA		→————→	
1.9	Allocate water budget for conservation and rehabilitation of threatened wetlands	Irrigation, FW&FD, EPCCD/EPA		→————→	
2. Biodiversity & Vulnerable Ecosystems: Formulate and implement integrated biodiversity conservation programs to conserve and protect high conservation value areas. Rehabilitate degraded habitats through ecosystem-based adaptation, and establish new protected areas to ensure the survival of threatened ecosystems. Improve the health of					

wetlands (i.e. RAMSAR sites) that act as floodgates, rangelands, pastures, and deserts (arid and hyper-arid areas) and conserve aquatic diversity and habitat conditions.					
2.1	Conduct a baseline survey and demark protected areas, and vulnerable & degraded habitats, and develop a dashboard	FW&FD, EPCCD/EPA	→		
2.2	Establish a legal framework at the provincial level to implement the international conventions and commitments for biodiversity	FW&FD, EPCCD/EPA	→		
2.3	Identify and notify new protected areas across the province and prepare their ecosystem management plans. Ensure women's participation in the management of protected areas	FW&FD, EPCCD/EPA	→		
2.4	Initiate community-led ecosystem rehabilitation programs	FW&FD, EPCCD/EPA	→		
2.5	Create new biodiversity reserves along the Indus Basin while also revitalizing and supporting existing national parks and protected areas to boost biodiversity	FW&FD, EPCCD/EPA	→		
2.6	Organize training and manage resources to empower communities to actively participate in biodiversity monitoring, habitat restoration, and sustainable resource management	FW&FD, EPCCD/EPA, Emergency Services Department	→		
2.7	Develop a comprehensive master plan for the restoration and rehabilitation of all (old and new) protected areas, incorporating community-driven management plans tailored to each area's unique ecological and biodiversity needs, and implement Punjab Protected Areas Act 2020	FW&FD, EPCCD/EPA		→	
2.8	Prepare City Biodiversity Index and Action Plans, with a focus on migratory species	FW&FD, EPCCD/EPA		→	
2.9	Develop Wetlands and RAMSAR site conservation and management plan to improve the health of wetlands by conserving aquatic diversity and protecting habitat conditions, and promoting	FW&FD, EPCCD/EPA		→	

	cooperation & research for the protection of Ramsar Sites				
2.10	Establish a Center of Excellence on forestry & biodiversity for international-level research and basic-advance level training focusing on climate change	FW&FD, EPCCD/EPA	→→→		
2.11	Coordinate with the federal government and the international community to get assistance for developing biodiversity projects	FW&FD, EPCCD/EPA	→→→		

3. Climate-Induced Disasters: Strengthen climate-induced disaster management capacity by prioritizing disaster-resilient infrastructure, effective forecasting, early warning systems and services, zoning, and investing in cost-effective nature-based solutions. Conduct scientific studies and assessments for climate-induced disasters and prepare action plans.

3.1	Develop district-wise hazard maps highlighting areas prone to floods, droughts, heatwaves, and other hazards	PDMA, EPCCD/ EPA, DAs, LG&CDD, HUD&PHED	→		
3.2	Adopt a proactive approach toward disaster risk management	PDMA, EPCCD/EPA, DAs, LG&CDD, HUD&PHED	→		
3.3	Provide shady/shelter places on heatwave hotspots	LGCDD, PDMA, EPCCD/EPA, DAs,	→		
3.4	Launch drought management programs for Southern Punjab	CDA, PDMA, EPCCD/EPA, LG&CDD	→		
3.5	Retrofit public buildings and infrastructure to withstand climate-induced disasters	PDMA, EPCCD/ EPA, DAs, LG&CDD, HUD&PHED, C&W, Energy	→→		
3.6	Develop an institutional setup and regulatory framework for the management of climate-induced migrations	PDMA, EPCCD/EPA, DAs, LG&CDD, IOM	→→		
3.7	Establish a mechanism to assess transboundary climate risks that can be linked with early warning system	Met department, EPCCD	→→		

4. Climate Justice: Integrate gender-responsive adaptation in sectoral development/investment plans and uplift the climate-hit population groups through poverty alleviation initiatives by offering social and financial protection schemes.

| 4.1 | Engage non-governmental organizations and civil society organizations to initiate schemes to support climate-hit populations at the district level, particularly in south Punjab | PDMA, EPCCD/EPA | → | | |
| 4.2 | Develop district-level emergency relief action plans and funds with a gender lens to ensure that women and vulnerable groups receive timely and adequate support during climate-induced disasters. | PDMA, EPCCD/EPA, WDD, Emergency Services Department | → | | |

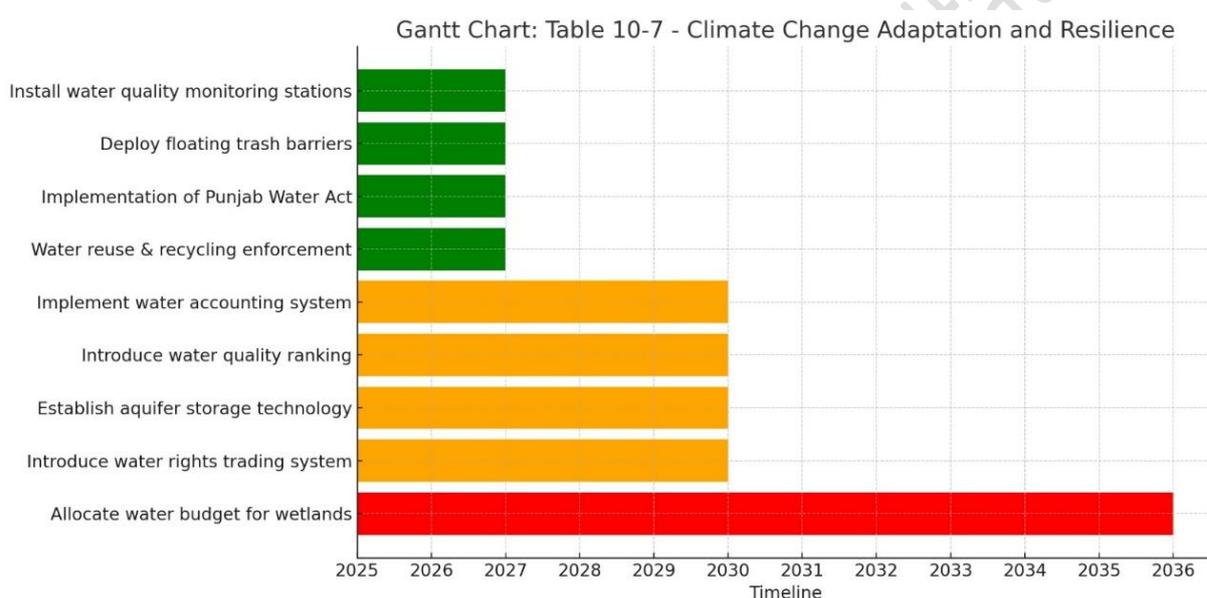Gantt Chart: Table 10-7 - Climate Change Adaptation and Resilience

Figure 0-2: Climate change adaptation and resilience as details given in table 10-7.

Figure 10-3: Climate change adaptation and resilience (with terms) as details given in table 10-7.

Table 10-8: Mitigation and Low Carbon Development (Mitigative Measure) [3]

No.	Actions	Responsible Entity	Short Term (1-2yrs)	Medium Term (3-5yrs)	Long Term (5-10 yrs)
1. Energy Generation: Introduce cleaner power generation technologies using alternative fuels and energy resources. Promote off-grid renewable energy in rural and remote areas, expand smart grids, and prioritize the transition of public sector buildings to renewables. Focus on energy security, energy transition, domestic market creation, and global commitments to ensure low-emission development.					
1.1	Support major industrial units for phasing out coal and inefficient boilers. 1.3 Energy	EPCCD/EPA, Irrigation	→		

	Dept, EP&CCD/EPA, ICI&SDD				
1.2	Deploy floating trash barriers to prevent waste and plastics from accumulating in water bodies	WASAs, Irrigation, EPCCD/EPA	→		
1.3	Effective and immediate implementation of the Punjab Water Act 2019 for sustainable groundwater governance.	Irrigation, HUD&PHED, EPCCD/EPA	→		
1.4	Enforce water re-use and recycling in water-dependent industries, artificial wetlands, agriculture, and groundwater recharge through regulatory instruments	EPCCD/EPA, ICI&SDD, WASAs, Agriculture	→		
1.5	Implement the water accounting system at the canal command scale	Irrigation, EPCCD/EPA	→		
1.6	Introduce a water quality ranking system for natural water bodies and barrage-barrage channel reach for cleansing of contaminants	Irrigation, EPCCD/EPA	→		
1.7	Eliminate inefficient boilers from all industries through legislative support; and expand the use of biofuels/biomass in the industrial and power generation sector. 1.14 Energy Dept, EP&CCD/EPA, ICI&SDD	Irrigation, WASAs, Agriculture, EPCCD/EPA, C&W			→
1.8	Introduce a water rights trading system to optimize water allocation	Irrigation Department, EPCCD/EPA			→
1.9	Allocate water budget for conservation and rehabilitation of threatened wetlands	Irrigation, FW&FD, EPCCD/EPA			→

2. Energy Efficiency: Enforce energy efficiency audits, standards, and labeling to enhance energy performance and reduce reliance on fossil fuel consumption.

2.1	Map out the energy-intensive industries and update the database periodically 2.1 Energy Dept, EP&CCD/EPA, ICI&SDD	FW&FD, EPCCD/EPA	→		
2.2	Advocate for deploying energyefficient appliances across households, governmental, and private sectors, as well as irrigation, agricultural zones, and	FW&FD, EPCCD/EPA	→		

	industries. 2.3 Energy Dept, PEECA, EP&CCD/EPA				
2.3	Conduct energy audits for energy-intensive industries and commercial buildings and introduce measures to promote sustainable energy consumption and production 2.5 Energy Dept, EP&CCD/EPA, ICI&SDD	FW&FD, EPCCD/EPA	→		
2.4	Initiate community-led ecosystem rehabilitation programs	FW&FD, EPCCD/EPA	→		
2.5	Create new biodiversity reserves along the Indus Basin while also revitalizing and supporting existing national parks and protected areas to boost biodiversity	FW&FD, EPCCD/EPA	→		
2.6	Organize training and manage resources to empower communities to actively participate in biodiversity monitoring, habitat restoration, and sustainable resource management	FW&FD, EPCCD/EPA, Emergency Services Department	→		
2.7	Develop a comprehensive master plan for the restoration and rehabilitation of all (old and new) protected areas, incorporating community-driven management plans tailored to each area's unique ecological and biodiversity needs, and implement Punjab Protected Areas Act 2020	FW&FD, EPCCD/EPA		→	
2.8	Prepare City Biodiversity Index and Action Plans, with a focus on migratory species	FW&FD, EPCCD/EPA		→	
2.9	Develop Wetlands and RAMSAR site conservation and management plan to improve the health of wetlands by conserving aquatic diversity and protecting habitat conditions, and promoting cooperation & research for the protection of Ramsar Sites	FW&FD, EPCCD/EPA		→	
2.10	Establish a Center of Excellence on forestry & biodiversity for international-level research and	FW&FD, EPCCD/EPA			→

#	Action	Responsible	Timeline
	basic-advance level training focusing on climate change		
2.11	Coordinate with the federal government and the international community to get assistance for developing biodiversity projects	FW&FD, EPCCD/EPA	——————————→

3. Industry: Establish and implement incentive-based systems to reduce GHGs & air pollutants. Implement Resource Efficiency and Cleaner Production technologies. Make planned investments in installing Combined Effluent Treatment Plants in key polluting industries in the shortest possible period of time. Ensure that the Emission Control System (ECS) covers the polluting industry through regulations and incentives.

#	Action	Responsible	Timeline
3.1	Develop matrices for assessing carbon footprint to develop the ranking system	EP&CCD/EPA	——→
3.2	Develop a result-based framework to support industries for RECP technology adoption	ICI&SDD, EP&CCD/EPA	——→
3.3	Establish a regulatory framework to implement the concept of a circular economy	EP&CCD/EPA, LGCD, WMCs	——→
3.4	Assess the feasibility of implementing an AI-based emission monitoring system	EP&CCD/EPA, ICI&SDD	——→
3.5	100% installation and operationalization of 30 Air Quality Monitoring Stations (AQMS) and monitoring dashboard and tools in Punjab	EP&CCD/EPA	——→
3.6	Set emission reduction targets and annual caps on emissions	EP&CCD/EPA, ICI&SDD	———→
3.7	Install continuous emissions monitoring systems in major manufacturing units	EP&CCD/EPA, ICI&SDD	———→
3.8	Prepare a negative list of carbonintensive industries	EP&CCD/EPA, ICI&SDD	———→
3.9	Phase-wise implementation to Install Emission Control Systems (ECS) starting from polluting industries through regulation and incentives.	EP&CCD/EPA, ICI&SDD	———→
3.10	100% conversion of conventional Brick Kilns to Zig-Zag or other suitable technology	EP&CCD/EPA, ICI&SDD	———→
3.11	Support industries to implement RECP technology adoption program	EP&CCD/EPA, ICI&SDD	——————————→

3.12	Develop linkages of the domestic ETS with international carbon markets/ETS	EP&CCD/EPA, ICI&SDD	——————————→		
3.13	Support industries to develop and implement carbon-neutral and net-zero programs	EP&CCD/EPA, ICI&SDD	——————————→		
3.14	Install combined effluent treatment plants before the disposal point of each industrial estate/cluster/park	ICI&SDD, C&W, WASAs, Irrigation, EPCCD/EPA	——————————→		

4. Transport: Ensure the provision of a fuel-efficient public transport system (addressing gender-specific travel needs) and encourage non-motorized modes of travel. Enforce vehicle emission standards, and certification, and promote electric vehicle adoption in the public and private sectors. Enhance the capacity and mandate of the Vehicle Inspection and Certification System (VICS) for private vehicles including two/three-wheelers and implement in close coordination with the federal government.

4.1	Append the issuance of fitness certificate with compliance of environmental quality standards for vehicular emissions 4.4 Transport, EP&CCD/EPA	PDMA, EPCCD/EPA	——→		
4.2	Develop dedicated lanes and pathways for bicycles and pedestrians and encourage non-motorized modes of travel	Transport, EP&CCCD/EPA, C&W	——→		
4.3	Demark vehicle-free zones (emission-free)	Transport, EP&CCD/EPA, C&W	——→		
4.4	Configure state-of-the-art vehicular emission testing setup in existing and prospective VICS Stations	Transport, EP&CCD/EPA	———————→		
4.5	Revise and make the environmental quality standards for vehicular emissions more stringent progressively	EP&CCD/EPA	———————→		
4.6	Support the private transport sector by providing incentives for reducing emissions and environmentally friendly transport services	Transport, EP&CCD/EPA, Private Sector	——————————→		

5. Waste & Wastewater: Promote an integrated waste management system that includes solid waste and wastewater treatment facilities, waste-to-energy projects, and methane-capturing systems at waste disposal sites. Implement plastic waste management regulations and strategies.

5.1	Develop a methane-specific time-bound strategy of Punjab based on Pakistan's Global Methane Emission Pledge	LGCDD, WMCs, MCs, EP&CCD/EPA	——→		

|					
	(reduce methane emissions by 30% by 2030)				
5.2	Establish scientific landfills in megacities	LGCDD, WMCs, MCs, EP&CCD/EPA	→		
5.3	Prepare a strategy for implementation of the 5Rs (Rethink, Refuse, Reduce, Reuse, Recycle) concept in all sectors, along with quantifiable targets and indicators	LGCDD, WMCs, MCs, EP&CCD/EPA	→		
5.4	Mainstream Sustainable Consumption and Production National Action Plan (SCPNAP) implementation at the provincial level for achieving sustainable city goals	LGCDD, WMCs, MCs, EP&CCD/EPA	→		
5.5	Implement Plastic Management Strategy and Regulations	EPCCD/EPA	→		
5.6	Launch "Zero Plastic Waste Cities" initiatives in major cities along the Indus Basin by partnering with the private sector and expanding successful existing programs	LGCDD, WMCs, MCs, EP&CCD/EPA	→		
5.7	Launch public awareness campaigns on waste and wastewater management, conservation practices, and the benefits of treating and reusing wastewater, with active involvement of women in dissemination efforts and also at the receiving end	LGCDD, WASAs, WMCs, MCs, EP&CCD/EPA	→		
5.8	Enforce the phase-wise installation of wastewater treatment plants in industries. (Industrial estates must specify areas for landfill sites, and solid waste management in accordance with provincial environmental policy)	ICI&SDD, EPCCD/EPA		→	
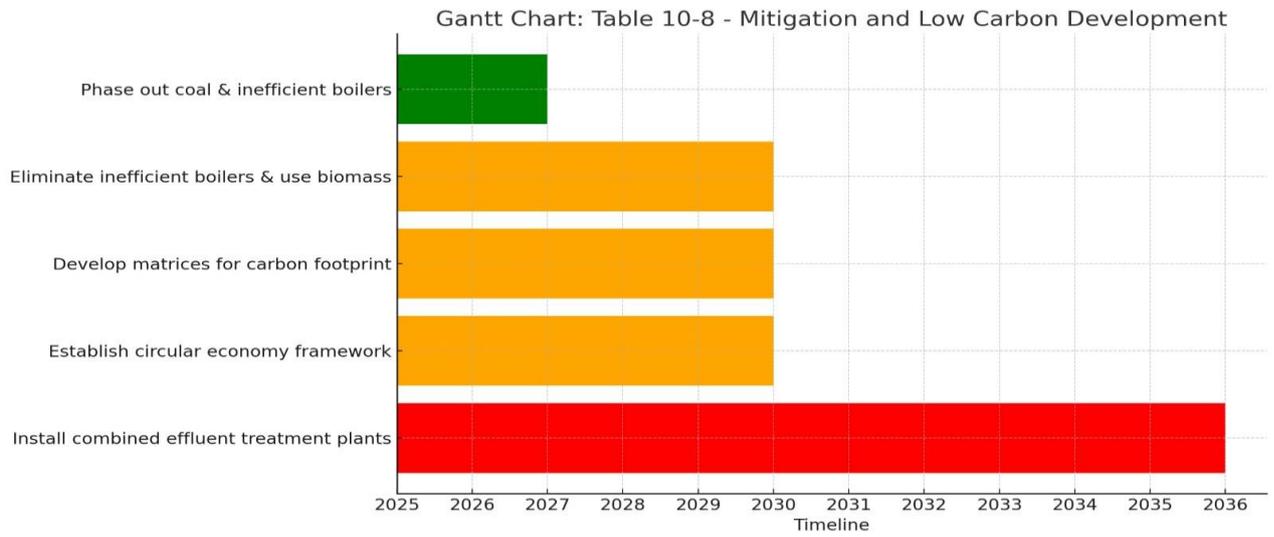
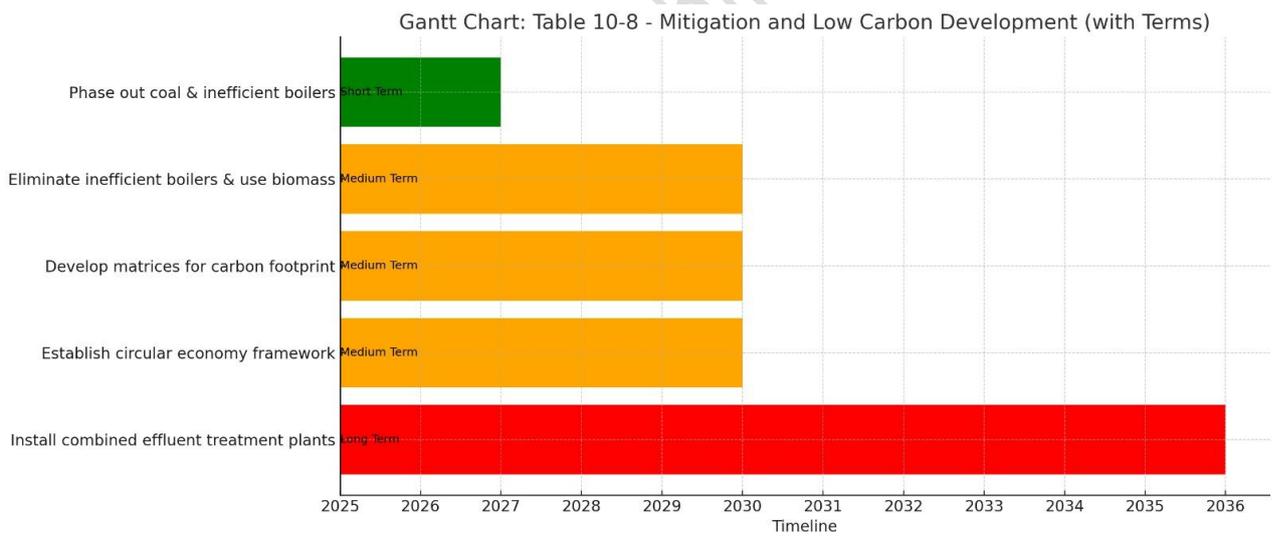*Figure 0-4 : Mitigation and low carbon development as details given in table 10-8.*

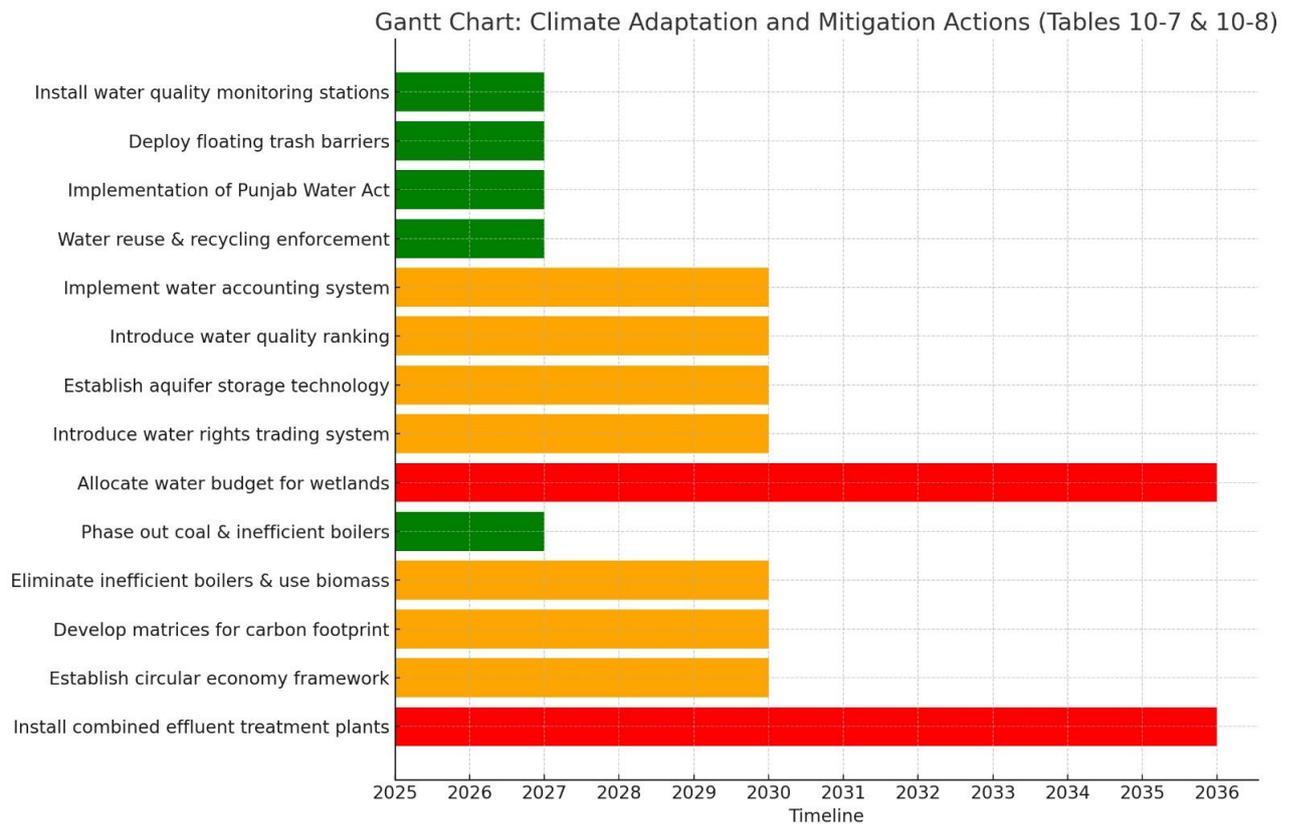*Figure 10-5: Mitigation and low carbon development (with terms) as details given in table 10-8.*

Gantt Chart: Climate Adaptation and Mitigation Actions (Tables 10-7 & 10-8)

Figure 10-6: Climate adaptation and mitigation actions detail is given in table 10-7 and 10-8.

3. Monitoring & Evaluation

A dashboard will be established for the current Environmental Action Plan by EP&CCD for continuous monitoring and updating of this action plan. Every sub-intervention will be systematically divided into small, measurable steps, with timelines, to better monitor the pace of the sub-interventions. The focal persons will play a pivotal role in the implementation of this plan at their respective organizations.

CHAPTER 11 ENVIRONMENTAL APPROVAL

1. Overview:

PEPA focuses on maintaining sustainable development in Punjab and hence gives extreme importance to utilization of the EIA/IEE processes for early consideration of environmental implications of projects for imparting mitigations.

In order to achieve, the EIA/IEE processes have been made legal binding for proponent to obtain mandatory Environmental Approval from the Director General before commencement and operation of project, under the Punjab Environment Protection Act (PEPA), 1997 (amended 2012), read with IEE/EIA Regulations 2022. Contrary to many developed and developing countries of the world, EPA, Punjab has made every best possible effort to make a system of review of the EIA/IEE reports, submitted by applicants, for proposed projects as well as for confirmation of compliance, through an efficient, responsive, and accessible review process.

2. Sources of Applications for Environmental clearance

Sources of Application for Environmental clearance (NOC) by EPA, Punjab include but not limited to followings:

- Cases referred through Business Facilitation Centers (BFCs) of Government of the Punjab

- National and International Financial Institutions

- Government Departments

- Mandatory requirement of Service Providers

3. Environmental Approvals

Review of the EIA/IEE reports submitted by applicants, for proposed projects as well as for confirmation of compliance, is carried out through an efficient, responsive, and accessible system as illustrated below in **Figures 11-1** and **Figure 11-2**.

In addition to perform the review of EIA/IEE application, EPA, Punjab, to facilitate the proponents of the projects of smaller nature and having minimal environmental impacts delegated powers to process IEEs of projects to EPA field offices through approval of committee(s) made under chairmanship of respective Commissioners and Deputy Commissioners vide notification No. SO(Tech)/EPD/1-26/2004 dated 15-06-2017 and vide notification No. SO(G)/EPD/5-86/2019 dated 28-01-2020 respectively. Conclusively, EPA, Punjab at its Head Quarter at Lahore reviews both IEEs and EIA reports submitted by proponents and District and Divisional Environmental Approval Committees are entrusted the task of evaluation of IEE reports in areas of their jurisdiction.

Key Findings

√ EPA, Punjab received 316 EIA reports. Out of these, 85 met the criteria for approval and were awarded with environmental approvals. Whereas 231 reports remained under process

√ Out of 1703 IEE reports, 922 reports were awarded environmental approvals. Whereas 781 IEE reports remained under process.

√ Incomplete information, non-issuance of land use clearance by concerned district government, permission from other controlling government departments and missing treatment proposals in IEE/EIA reports were main reasons behind under process cases etc.

√ A trend prevails establishment of small industrial enterprises and housing schemes in Districts Lahore, Sheikhupura, Faisalabad, Rawalpindi and Rahim Yar Khan.

√ District Lahore, Faisalabad, Rawalpindi, and Gujranwala have trend of establishment of large size industrial enterprises and housing schemes.

√ Districts Lahore, Sheikhupura, Faisalabad and Rawalpindi will probably experience more pollution and management issues due to addition of new enterprises.

√ Out of 386 IEEs submitted in EPA. Lahore, 61 (16%) projects were related to housing schemes. Whereas textile and food sectors submitted 47 (12%) and 40(10%) IEEs.

√ Out of 316 projects, energy sector, housing schemes, and Textile sector submitted 70 (22%), 25 (11%) and 28 (9%) respectively
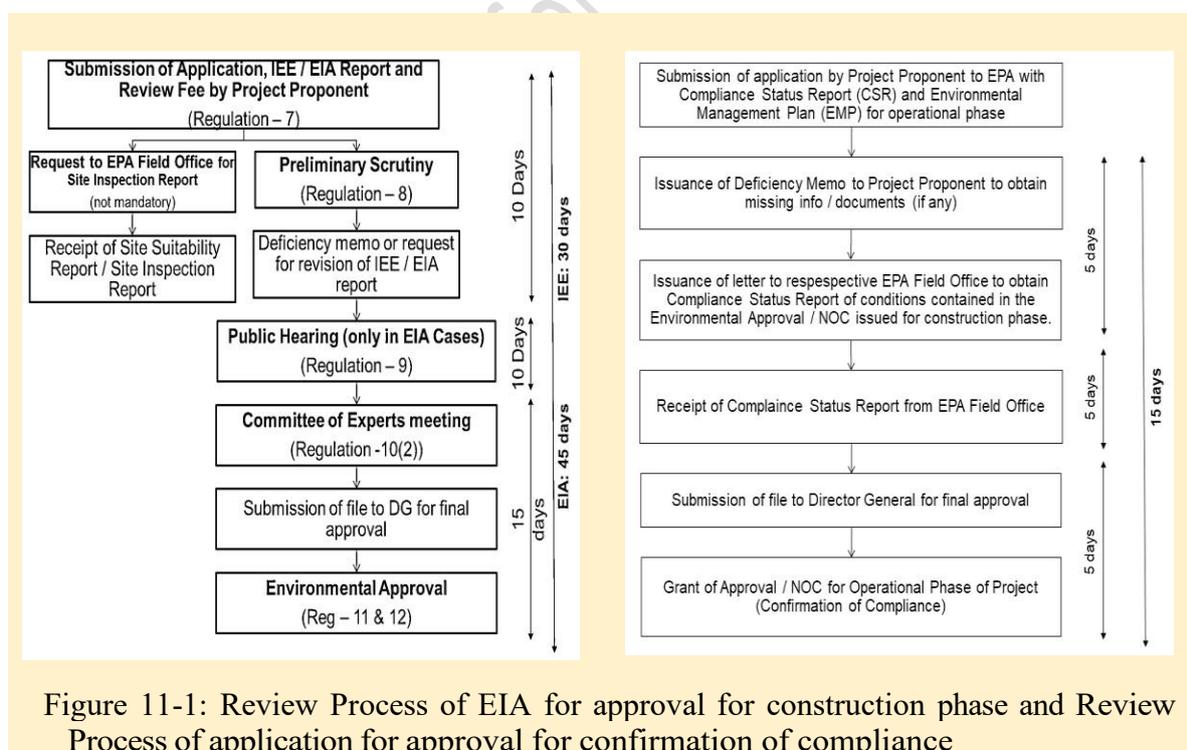
Figure 11-1: Review Process of EIA for approval for construction phase and Review Process of application for approval for confirmation of compliance

3.1 Review of Initial Environmental Examination (IEE) Reports at EPA Head Quarter

During the year 2024 Directorate of EIA, EPA, Punjab, Head Quarter received 385 Initial Environmental Examination Reports of different types of projects to be installed in different

districts of province, both for construction and confirmation of compliance, for evaluation to, for evaluation. Out of these 182 IEE reports were found meeting the criteria for issuance of approvals. Whereas, 176 applications remained under process to fulfill the criteria to accord approval under IEE/EIA Regulations, 2022. Review process these IEE reports identified several shortcomings including but not limited to incomplete information, non-issuance of land use clearance by concerned district government, permission from other controlling government departments and missing treatment proposals in IEE reports. Correspondence with the proponents of the project is in process and the process will be finalized as soon as complete information is received from proponents.

Site Inspection reports, conducted in response to IEE reports indicated violation of section 12 of PEPA committed by 28 projects. Since in the light of site inspection reports, the location of these projects was found suitable for establishment, hence cases had been forwarded to concerned sections in EPA to present before the Punjab Environment Protection Tribunal (PET) for prosecution under law

Table 6-1: District wise distribution of the IEE cases received in Directorate of EIA in year 2024

Sr. No	District	IEE, 2024			
		Received	Decided	Violation	Under Process
1	Lahore	111	39	20	52
2	Nankana sahib	5	2	0	3
3	Sheikhupura	37	25	0	12
4	Kasur	19	14	0	5
5	Lodhran	4	0	0	4
6	Vehari	4	4	0	0
7	Multan	29	18	2	9

Sr. No	District	IEE, 2024			
		Received	Decided	Violation	Under Process
8	Khanewal	6	4	0	2
9	Sargodha	6	3	0	3
10	Bhakkar	0	0	0	0
11	Khushab	1	1	0	0
12	Mianwali	1	0	0	1
13	Gujranwala	10	4	2	4
14	Gujrat	1	1	0	0
15	Hafiz abad	0	0	0	0
16	M.B.Din	3	1	0	2
17	Narowal	0	0	0	0
18	Sialkot	9	2	0	7
19	Rawalpindi	23	17	2	4
20	Attock	8	3	0	5
21	Chakwal	9	2	0	7
22	Jhelum	4	3	0	1

23	Chiniot	1	1	0	0
24	Jhang	2	0	0	2
25	T.T. Singh	8	3	0	5
26	Faisalabad	35	20	0	15
27	Bwp	8	0	0	8
28	Bwn	5	1	0	4
29	R.Y. Khan	13	4	0	9
30	D.G.Khan	4	3	0	1
31	Layyah	1	0	1	0
32	M. Garh	4	1	1	2
33	Rajanpur	2	0	0	2
34	Sahiwal	5	2	0	3
35	Pakpattan	0	0	0	0
36	Okara	7	4	0	3
	Total	**386**	**182**	**28**	**175**
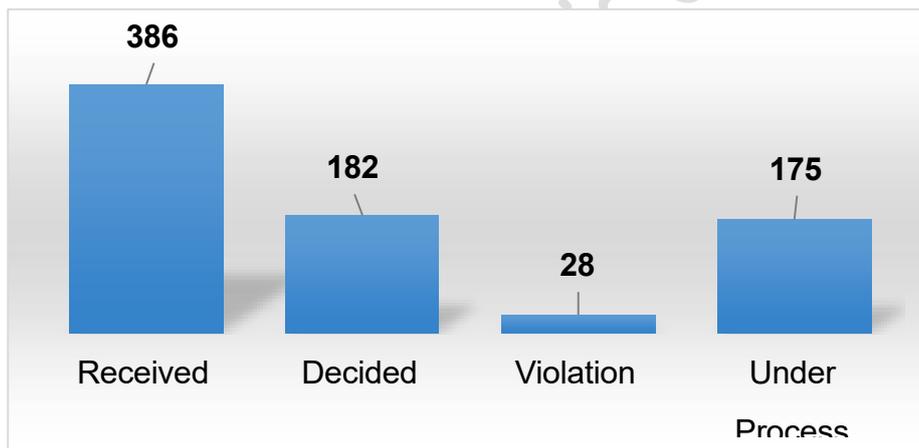
Figure 110-2: Status of IEE cases received in Directorate of EIA during, 2024.

Table 10-2 below indicates the various sectors which submitted IEE reports to EPA headquarters. Whereas, **Figure 10-4** indicates the different types of units which submitted IEE reports to seek environmental approvals after processing IEE reports under section (12) of PEPA, 1997 (amended 2012).

Table 11-2 Numbers of IEE Reports by different sectors

Sector Name	Number of IEEs
Housing Schemes/ Apartments	61
Commercial Buildings	25
Food & Agro-based Industry	40
Energy Sector	25

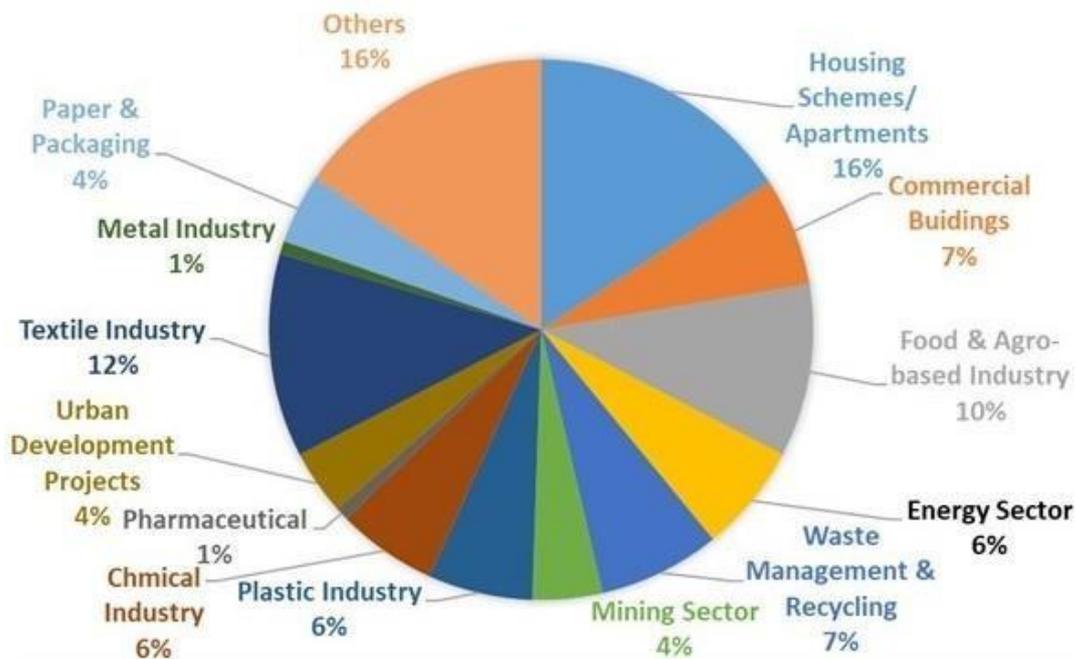| Waste Management & Recycling	28
Mining Sector	16
Plastic Industry	24
Chemical Industry	23
Pharmaceutical	3
Urban Development Projects	15
Textile Industry	47
Metal Industry	3
Paper & Packaging	16
Others	60
Total	386

Figure 0-3: Sector wise Cases of IEE

3.2 Review of Environmental Impact Assessment (EIA) Reports at EPA Head Quarter

During the year 2024 EPA, Punjab Received 316 Environmental Impact Assessment (EIA) Reports for construction phase and confirmation of compliance for evaluation. **Out of these 85 EIA reports were found meeting the criteria for issuance of approvals.** Whereas, 213 applications remained in process to meet several shortcomings including but not limited to incomplete information, non-issuance of land use clearance by concerned district government, permission from other controlling government departments and missing treatment proposals in IEE/EIA reports. Correspondence with the proponents of the project is in process and the process will be finalized as soon as complete information is received from proponents.

Site Inspection reports, conducted in response to EIA reports indicated violation of section 12 of PEPA committed by 18 projects. The site of these projects was found suitable for establishment; hence cases had been forwarded to concerned sections in EPA to present before

the Punjab Environment Protection Tribunal (PET) for prosecution under law

Table 11-3: District wise distribution of the EIA cases received in Directorate of EIA in year 2024

| Sr. No	District	EIA, 2024			
		Received	Decided	Violation	Under Process
1	Lahore	40	8	5	27
2	Nankana sahib	4	1	1	2
3	Sheikhupura	28	11	0	17
4	Kasur	13	4	0	9
5	Lodhran	0	0	0	0
6	Vehari	10	7	0	3
7	Multan	13	5	1	7
8	Khanewal	1	1	0	0
9	Sargodha	11	5	0	6
10	Bhakkar	2	0	0	2
11	Khushab	1	0	0	1
12	Mianwali	10	3	1	6
13	Gujranwala	17	4	0	13
14	Gujrat	4	1	0	3
15	Hafiz abad	2	0	0	2
16	M.B.Din	2	0	0	2
17	Narowal	2	0	0	2
18	Sialkot	17	2	0	15
19	Rawalpindi	30	2	4	24
20	Attock	11	3	1	7
21	Chakwal	12	2	2	8
22	Jhelum	5	1	0	4
23	Chiniot	2	0	0	2
24	Jhang	3	1	0	2
25	T.T. Singh	0	0	0	0
26	Faisalabad	38	10	2	26
27	Bahawalpur	3	2	0	1
28	Bahawalnagar	0	0	0	0
29	R.Y. Khan	7	3	1	3
30	D.G.Khan	1	0	0	1
31	Layyah	1	0	0	1
Sr. No	District	EIA, 2024			
		Received	Decided	Violation	Under Process
32	M. Garh	9	3	0	6
33	Rajanpur	2	1	0	1
34	Sahiwal	7	2	0	5
35	Pakpattan	3	1	0	2
36	Okara	5	2	0	3
	Total	**316**	**85**	**18**	**213**
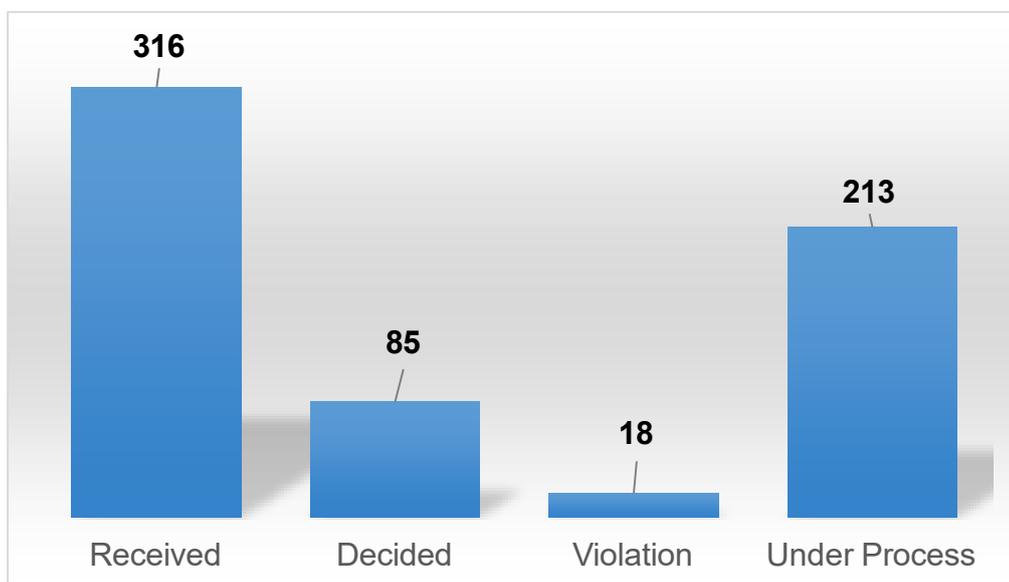
Figure 0-4:Status of EIA cases received in Directorate of EIA

Table 11-4: Number Of EIA Reports By Different Sectors

Sector Name	Number of EIAs
Food & Agro-based Industry	7
Urban Development	25
Energy Sector	70
Chemical & Manufacturing	14
Textile & Tanneries	28
Housing Schemes	34
Metal Industry	5
Plastic Products	2
Mining & Mineral Processing	22
Paper & Packaging	5
Engineering & Construction	10
Waste Management & Recycling	12
Others	82
TOTAL	316

Figure 11-6 indicates the different types of units applied for environmental approvals by submitting EIA reports under section (12) of PEPA, 1997 (amended 2012).
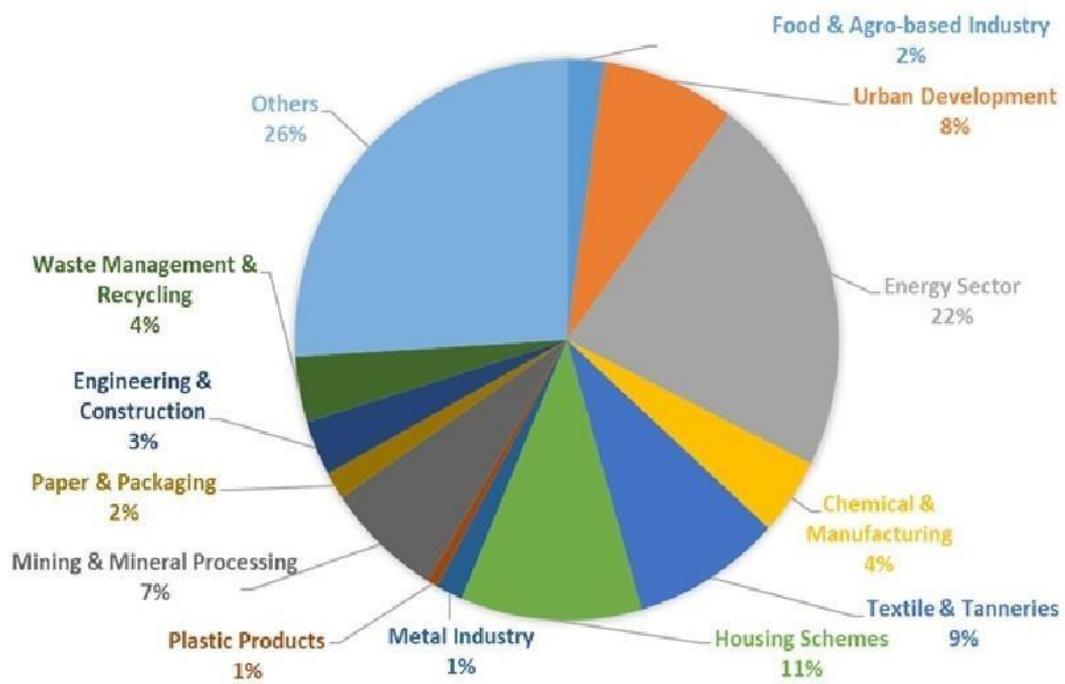
Figure 0-5: Sector wise Cases of EIA

3.3 Review of Initial Environmental Examination Reports by EPA Field Offices.

During the year 2024 field offices of EPA, Punjab received 375 Initial Environmental Examination (IEE) Reports relating to different types of projects. Out of these 214 IEE reports were found meeting the criteria for issuance of approvals. Whereas, 119 applications remained under process to meet the criteria for approval under IEE/EIA Regulations, 2022. On account of the unsuitable sites, non-provision of missing information and not meeting the legal requirement 42 cases of IEE in various district offices of EPA were rejected. **Table 10-5** below describes below the district wise distribution of the IEE cases received at EPA district offices for processing under section (12) of PEPA, 1997 (amended 2012).

Table 11-5: District wise status of IEE cases received at district offices of EPA

Sr. No.	District Name	Cases Received	Environmental Approvals Issued	Cases Rejected	Cases under Process
1	Attock	18	18	0	0
2	Bahawalnagar	25	20	4	1
3	Bahawalpur	8	4	0	4
4	Bhakkar	8	8	0	0
5	Chakwal	39	12	18	9
6	Chiniot	0	0	0	0
7	DG Khan	8	2	0	6
8	Faisalabad	7	5	1	1
9	Gujranwala	21	9	0	12
10	Gujrat	17	15	0	2
11	Hafizabad	10	1	1	8
12	Jhang	2	2	0	0
13	Jhelum	21	2	9	10

Sr. No.	District Name	Cases Received	Environmental Approvals Issued	Cases Rejected	Cases under Process
14	Kasur	7	1	0	6
15	Khanewal	1	0	0	1
16	Khushab	6	6	0	0
17	Lahore	11	6	2	3
18	Layyah	11	2	1	8
19	Lodhran	5	1	0	4
20	MB Din	8	5	0	3
21	Mianwali	20	18	0	2
22	Multan	9	9	0	0
23	Muzaffargarh	2	0	0	2
24	Nankana Sahib	17	12	5	0
25	Narowal	1	0	0	1
26	Okara	8	1	0	7
27	Pakpattan	0	0	0	0
28	Rajanpur	6	0	0	6
29	Rawalpindi	7	0	0	7
30	RY Khan	4	4	0	0

31	Sahiwal	10	10	0	0
32	Sargodha	20	16	0	4
33	Sheikhupura	8	3	0	5
34	Sialkot	13	9	1	3
35	TT Singh	7	3	0	4
36	Vehari	10	10	0	0
	TOTAL	**375**	**214**	**42**	**119**

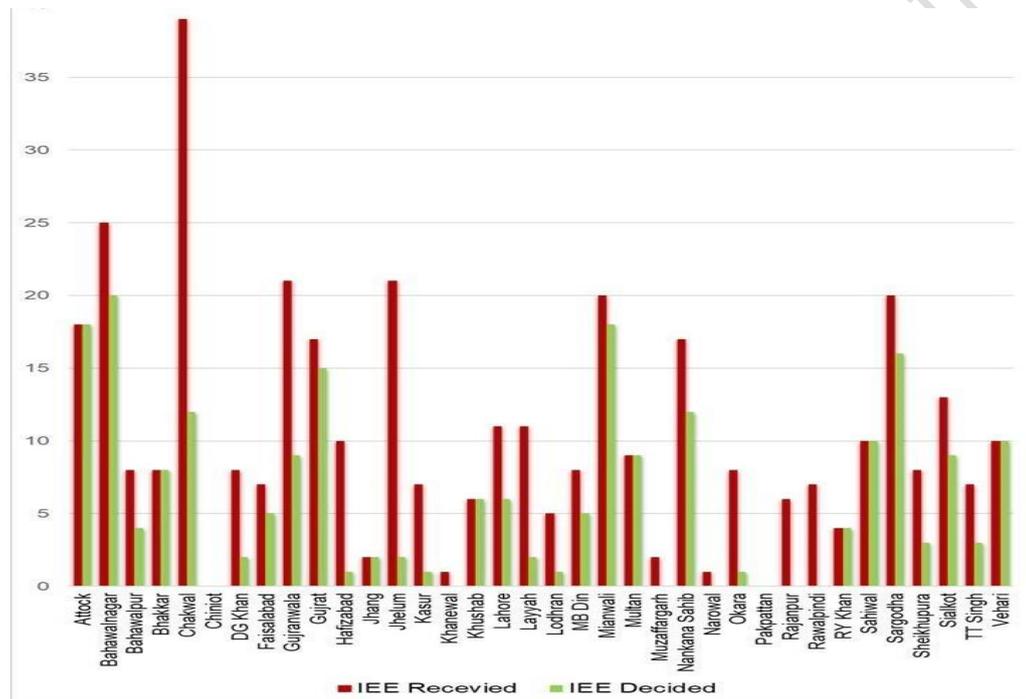**Figure 11-7** below indicates the number of IEE applications received in field offices of EPA during the year 2024.

Figure 11-6: Status of IEE applications received in field offices of EPA during the year 2024

EPA, Punjab in order to facilitate the proponents, delegated powers for awarding divisional level environmental approval under section 12 of PEPA, 1997 (amended 2012) after evaluation of IEE reports. During the year 2024, 945 Initial Environmental Examination (IEE) Reports relating to different types of projects were submitted by proponents at divisional level. Out of these 531 IEE reports were found meeting the criteria for issuance of approvals. Whereas, 271 applications remained under process to meet the criteria for approval under IEE/EIA Regulations, 2022. On account of the unsuitable sites, non-provision of missing information and not meeting the legal requirement 141 cases of IEE were rejected. **Table 11-6** below describes below the divisional wise distribution of the IEE cases received at divisional level for processing under section (12) of PEPA, 1997 (amended 2012).

Table 11-6: Division wise status of IEE cases received at district offices of EPA

Sr. No.	Division	Cases Received	Environmental Approvals Issued	Cases Rejected	Cases under Process
1	Bahawalpur	63	25	0	38
2	DG Khan	43	23	20	0
3	Faisalabad	114	67	39	8
4	Gujranwala	51	26	3	22
5	Gujrat	51	26	0	25
6	Lahore	166	122	26	18
7	Multan	176	93	0	83
8	Rawalpindi	115	52	26	37
9	Sahiwal	106	64	27	15
10	Sargodha	58	33	0	25
	Total	**943**	**531**	**141**	**271**

4. Processing of IEE/EIA cases referred through BFC of Government of the Punjab.

The Business Facilitation Centre (BFC) is a flagship initiative of the Government of the Punjab to help facilitate the business community and domestic & foreign investors by providing more than 100 services under one roof. These services include obtaining NOCs, licenses and permits etc. necessary for starting up and up scaling business. The initiative aims at reducing business barriers by connecting multiple Government Agencies through a software application. It is anticipated that the initiative would substantially contribute to creation of an enabling environment for businesses, thereby fostering enterprise creation and operations.

EPA, Punjab deputed a dedicated officer to hold office in in BFC to join the Government of the Punjab to achieve the aforementioned objectives. The officer is performing duties and dedicatedly following the IEE/EIA reports referred to EPA through BFC for ultimate decision and intimation to proponents. EPA Punjab received 952 applications through BFC during 2024. Out of these 547 (57%) applications have been completed and 405 (43%) applications remained in process. **Table 11-7** below indicates the status of IEE/EIA cases received in BFC established by Government of the Punjab.

It has been assessed that more than 70% of the under process applications is due to the fact that proponents did not response to the queries raised during the evaluation of IEE/EIA reports, did not advertise the notices of public hearing, and in few cases expert opinion of the committee could not be solicited due non availability of members of expert committee to complete EIA process to meet the legal requirement of IEE/EIA Regulations 2022. EPA, Punjab, always secured position in first 10 departments of the Government of the Punjab, in the ranking prepared by BFC.

Table 11-7:Status of IEE/EIA cases received in Business Facilitation Centre (BFC)

IEE/EDIA Cases Received	Cases Decided	Under Process cases
952	547	405

5. Revenue Generated

IEE/EIA Regulations, 2022, authorizes EPA, Punjab to receive Rupees 15000/- and Rs. 30,000/-, as processing and evaluation fee of IEE and EIA respectively. This fee is collected in form of cross cheques to be deposited in the Government exchequer. During the year 2024, Directorate of EPA, Punjab generated revenue of Rs.152,55000/- as processing fee of IEE/EIA reports. Whereas, field offices of EPA Punjab through district and divisional environmental approval committees, processed 375 cases and 943 cases respectively, and deposited Rs. 50,55,000/- and Rs 13,320,000/-in government exchequer. Conclusively EPA, Punjab generated a revenue of Rs.**33,63,0000** and deposited in government exchequer as processing fee of IEE/EIA applications under IEE/EIA Regulations made under section 12 of PEPA, 1997.

6. Way forward

- Collection of more precise digital data to observe district wise trend of industrialization to more relevant pollution control measures

- Capacity building of EIA Directorate with human resource for review of EIAs as the IEE/EIA Regulations, 2022,

- Closure of non-responsive EIA and IEE applications.

- Capacity enhancement at both levels of EIA Directorate, Lahore as well as EPA field offices to review EIAs and IEEs in accordance with provisions of IEE/EIA Regulations, 2022.

CHAPTER 12   INTERNATIONAL AND LOCAL COORDINATION IN EPA PUNJAB

1. Introduction

The Environmental Protection Agency (EPA) Punjab has evolved into a dynamic institution capable of navigating the complexities of both national and international environmental governance. Recognizing that local environmental challenges are increasingly influenced by global trends, EPA Punjab established a dedicated portfolio on International and Local Coordination in 2024. This strategic realignment reflects a broader understanding that achieving provincial environmental objectives necessitates integrated actions across borders, disciplines, and institutions. Through this portfolio, EPA Punjab has embraced a multi-scalar approach, leveraging global expertise while strengthening local capacities to achieve sustainable development goals (SDGs), climate resilience, and environmental protection.

2. International Collaborations

2.1 EPA Punjab's Participation at COP-29: Advancing Global Environmental Engagement

The formal participation of the Environmental Protection Agency (EPA) Punjab at the Twenty-Ninth Conference of the Parties (COP-29) to the United Nations Framework Convention on Climate Change (UNFCCC), held in Baku, Azerbaijan in November 2024, marked a historic milestone in the Agency's evolution. For the first time, a EPA represented itself at one of the world's foremost international climate negotiation platforms. This participation signified not only an expansion of EPA Punjab's international outreach but also its readiness to contribute meaningfully to global environmental discourse.

As part of the official proceedings within the Blue Zone, the core venue for official negotiations and high-level events, EPA Punjab hosted a dedicated session titled *"Transforming Air Quality in Punjab."* This session highlighted the province's progressive initiatives in addressing environmental challenges, with a particular focus on urban air pollution. Presentations elaborated on key strategic interventions, including the adoption of the CM Smog mitigation plan 2024 the operationalization of real-time **Air Quality Monitoring Stations (AQMS)** across key urban centers, and the implementation of regulatory frameworks such as the Smog Prevention and Control Rules 2023. Technological advancements, notably the transition of traditional brick kilns to environmentally friendly Zig-Zag technology, were also prominently featured. Through these interventions, EPA Punjab demonstrated a comprehensive multi-sectoral approach to air quality management, integrating enforcement measures, technological innovation, public awareness campaigns, and policy reform to build climate resilience and reduce pollutant emissions.

Figure 0-1: Punjab's Panel discussion at COP-29

Dr. Imran Hamid Sheikh, DG EPA highlighting EPA's interventions

Panel discussion at Pakistan Pavilion

Figure 0-2:. Representation of Punjab at COP-29

Further, in the Green Zone, which provided a space for civil society and sub-national actors, EPA Punjab collaborated with the Ravi Urban Development Authority (RUDA) to organize a session on *"Eco-Friendly Business in Punjab."* This platform underscored the province's ambition to position itself as an active member in sustainable industrialization and green economic development. Discussions centered around policy initiatives aimed at facilitating eco-friendly businesses, including regulatory streamlining, fiscal incentives such as tax rebates for sustainable enterprises, and the embedding of environmental compliance into broader industrial expansion strategies. The session attracted significant interest from international investors, development partners, and environmental think tanks, highlighting Punjab's potential for sustainable investment in South Asia.

Figure 12-3: Representation of EPA Punjab in Green Zone at COP-29

Ms. Romina Khurshid Alam
Coordinator to PM on Climate Change

Raja Jahangir Anwar
Secretary EP&CCD Punjab

Dr. Imran Hamid Sheikh
Director General, EPA Punjab

Figure 0-4: Representation of Govt. of Punjab in Green Zone at COP-29

Beyond the formal sessions, EPA Punjab leveraged its participation at COP-29 to engage in bilateral meetings with international stakeholders. High-level dialogues were conducted with representatives from the **US-EPA** and the **Bangladesh Environmental Protection Agency**, among others. These interactions focused on exploring technical cooperation opportunities in fields such as air quality monitoring, environmental technology transfer, and collaborative research initiatives. The willingness of international partners to engage with EPA Punjab reflected a growing recognition of the province's environmental leadership and its commitment to adopting global best practices for environmental management.

Through its dynamic and substantive presence at COP-29[1], EPA Punjab not only showcased its own transformative initiatives but also contributed to projecting Pakistan's sub-national environmental efforts onto the global stage. This milestone signals a new era of international engagement for EPA Punjab, laying the foundation for deeper global collaborations, enhanced technical capacity, and stronger contributions to national and global environmental goals.

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[1]COP29 Azerbaijan. (2024). Blue Zone – Official UN-managed negotiation space at COP29. https://cop29.az/en/blue-zone
COP29 Presidency. (2024). COP29 Green Zone: inclusive public space for non accredited participants at COP29. Retrieved from https://www.cop29greenzone.com/cop29-green-zone

2.2 Building Scientific Infrastructure for Climate and Air Quality Monitoring: Collaboration with CRAES

In 2024, the Environmental Protection Agency (EPA) Punjab initiated a significant technical collaboration with the **Chinese Research Academy of Environmental Sciences (CRAES)** to enhance scientific infrastructure for environmental monitoring. This partnership is aimed at addressing critical data gaps in climate variables, air pollution levels, and meteorological parameters, which have historically limited the province's capacity for evidence-based environmental management.

Punjab's persistent challenge of smog and deteriorating air quality has necessitated a strategic shift toward data-driven environmental governance. Environmental Protection Agency (EPA) Punjab has started collaboration with international experts. This partnership aims to enhance Punjab's scientific infrastructure to systematically monitor and manage atmospheric pollution and climate-related variables.

The collaboration encompasses a wide range of activities, including in-depth on-site assessments of Lahore and neighboring cities to diagnose pollution patterns and infrastructure needs. These assessments inform the design of a robust monitoring network and guide the selection of appropriate technologies and methodologies. Data analysis will leverage satellite-based observations, ground-level monitoring, and advanced modeling techniques to construct an integrated understanding of pollution dynamics across the province.

By investing in scientific infrastructure and technical expertise, EPA Punjab is positioning itself to lead a new era of evidence-based environmental governance. The Punjab Smog, Air Quality, and Climate Observatory Project is a significant advancement toward improving air quality, enhancing climate resilience, and safeguarding public health in the province. It marks a critical evolution in the province's environmental management strategy, ensuring that future interventions are grounded in comprehensive, high-quality data and international best practices.

2.3 Partnership with ICIMOD

The partnership between EPA Punjab and the International Centre for Integrated Mountain Development (ICIMOD) embodies a regional approach to addressing transboundary environmental challenges. Through collaborative research, EPA Punjab and ICIMOD are engaged in studying the dynamics of transboundary air pollution, and the socio-economic impacts of climate change on vulnerable communities. These engagements not only enhance Punjab's technical capacities but also promote regional solidarity in tackling shared environmental threats.

Figure 0-5:Collaborative workshop by EPA Punjab and ICIMOD for scaling up Brick Kilns to Zig-Zag in Sindh

2.4 Collaboration with International Universities for Research

Recognizing the critical role of research in informed decision-making, EPA Punjab has initiated collaborative partnerships with international renowned for environmental science and policy expertise. These collaborations aim to bridge the research-policy gap by fostering knowledge co-production, facilitating faculty and student exchanges, and promoting joint research projects on topics such as climate adaptation, biodiversity conservation, and pollution control.

Particular emphasis has been placed on developing Research-Policy Nexus models, ensuring that scientific findings are systematically translated into regulatory reforms, monitoring protocols, and environmental management strategies. Such collaborations underscore EPA Punjab's commitment to integrating global scientific advancements within local governance frameworks.

3. Local Collaborations

3.1 Academic and Research Linkages

Locally, EPA Punjab has prioritized the establishment of a robust Policy Academia Nexus. This initiative aims to cultivate symbiotic relationships with universities and research institutions to jointly address pressing environmental issues. Universities are now actively engaged in conducting applied research on air pollution dynamics, water resource management, and climate vulnerability assessments, feeding directly into provincial policy development.

A flagship achievement within this domain has been the collaboration with Government College University (GCU) Lahore, leading to the launch of Pakistan's first Diploma in Environmental Impact Assessment (EIA). This academic program provides technical certification in environmental compliance, creating a skilled workforce capable of conducting rigorous environmental assessments aligned with both national and international standards.

Figure 0-6: MoU signing between EPA Punjab and Government College University, Lahore

3.2 Strategic Collaboration for Climate Action

Beyond academia, EPA Punjab has engaged with premier policy think tanks including the Civil Society Coalition for Climate Change (CSCCC), the Global Climate Change Impact Studies Centre (GCISC), and the Sustainable Development Policy Institute (SDPI). Through these partnerships, EPA Punjab has strengthened its policy advocacy efforts, enhanced the visibility of subnational climate actions, and facilitated research dissemination through seminars, policy briefs, and collaborative studies.

These partnerships have been instrumental in promoting integrated approaches to climate resilience, encouraging the adoption of market-based mechanisms such as carbon trading, and fostering innovations in nature-based solutions for urban and rural sustainability.

3.3 Linkages with Professional Training Institutes

Professional development remains central to EPA Punjab's strategy for institutional strengthening. Collaborations with the Civil Services Academy (CSA) Lahore and the Management and Professional Development Department (MPDD) have enabled the integration of environmental governance, pollution control technologies, and climate negotiation skills into the training curricula for civil servants.

Figure 12-7:Briefing to the officers from CSA regarding EPA Punjab's progress

By institutionalizing environmental modules within standard training programs, EPA Punjab ensures that environmental stewardship becomes an intrinsic competency across multiple government departments.

3.4 Schools Council for Environmental Awareness

EPA Punjab has proactively expanded its engagement to the educational sector by establishing the Schools Council for Environmental Awareness. Through this initiative, hundreds of environmental clubs have been formed in schools across the province, involving students in activities such as plantation drives, waste management campaigns, and climate change awareness sessions.
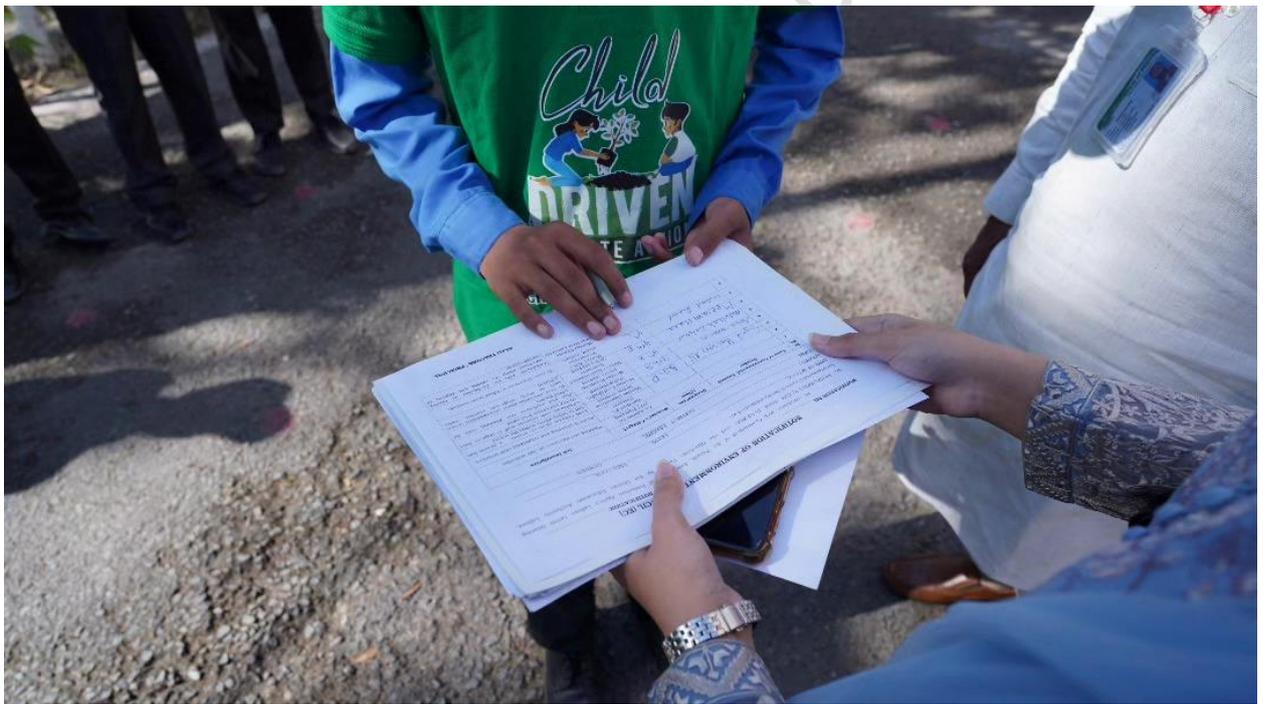
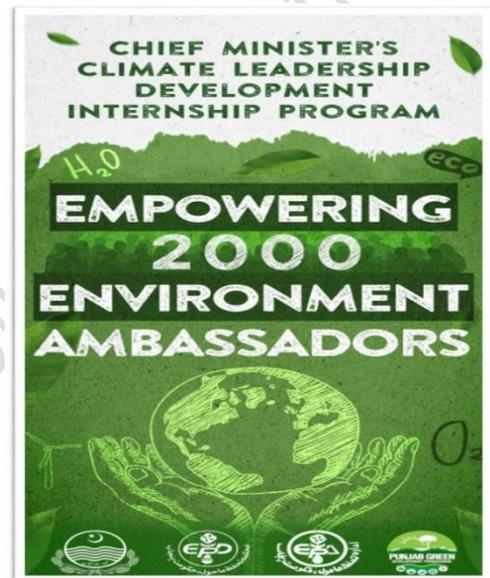*Figure 0-8: Launch of Environmental Coucils in Schools by EPA Punjab*

Figure 12-9: Launch of Environmental Councils, Eco-Intership Program and CM Punjab Climate Leadership Development Internship by EPA Punjab

Figure 0: Activities by Interns of CM Punjab Climate Leadership Development Internship

Notably, simulated events like "COP in My City" celebrated in collaboration with Government Collage University has provided students with practical exposure to international climate negotiation processes, fostering environmental leadership from a young age. These initiatives are critical in nurturing a future generation committed to sustainable development.

***Figure 12-11:. Collaborative "COP in MY City" event by EPA Punjab and Government
College University Lahore***

3.5 Stakeholder Involvement and Community Participation

A critical component of EPA Punjab's local coordination efforts has been the promotion of
multi-stakeholder engagement platforms. Events such as the International Conference on
Environment (ICE-2024), the Pedal 2024 cycling event, and the citizen engagement campaigns
through the Green Punjab App have significantly expanded public participation in
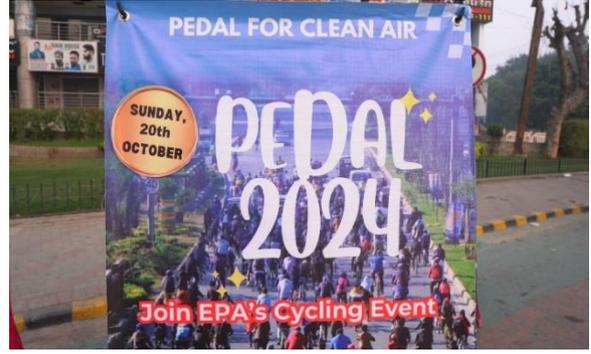environmental governance.

Figure12-12: Celebration of World Environmnet Day by EPA Punjab

Through these initiatives, EPA Punjab has mainstreamed environmental concerns into public discourse, mobilizing communities, industries, academia, and civil society organizations towards collective environmental action.

4. Key Findings

EPA Punjab's concerted efforts in international and local coordination have yielded significant operational, policy, and socio-environmental benefits. The agency has witnessed an enhancement in technical capacities; regulatory reforms aligned with the best international practices and improved public awareness. Research collaborations have led to more evidence-

based policymaking, while community engagement has fostered a culture of shared environmental responsibility[2].

Nonetheless, challenges persist. Ensuring sustained funding for international partnerships, overcoming bureaucratic inertia, and rapidly adapting global solutions to local contexts remain critical areas requiring ongoing attention.

5. Way Forward

Looking ahead, EPA Punjab must prioritize the institutionalization of its international engagements through the establishment of a dedicated International and Local Coordination Unit. This unit should oversee partnership management, capacity-building programs, and research dissemination.

Expanding international collaborations, particularly with multilateral funding agencies and global think tanks, will be essential to support large-scale environmental projects. Simultaneously, deepening local academic linkages and embedding environmental education at all levels of formal schooling will be crucial for long-term sustainability.

Finally, EPA Punjab must leverage its growing global presence to champion provincial interests in international climate negotiations, ensuring that subnational voices are effectively represented in shaping the global environmental agenda.

Through strategic coordination at both international and local levels, EPA Punjab is poised to play a transformative role in advancing sustainable development and climate resilience, not only within Pakistan but across the broader South Asian region.

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[2] COP29 Azerbaijan. (2024). COP29 – 29th United Nations Climate Change Conference. https://cop29.az/en/home