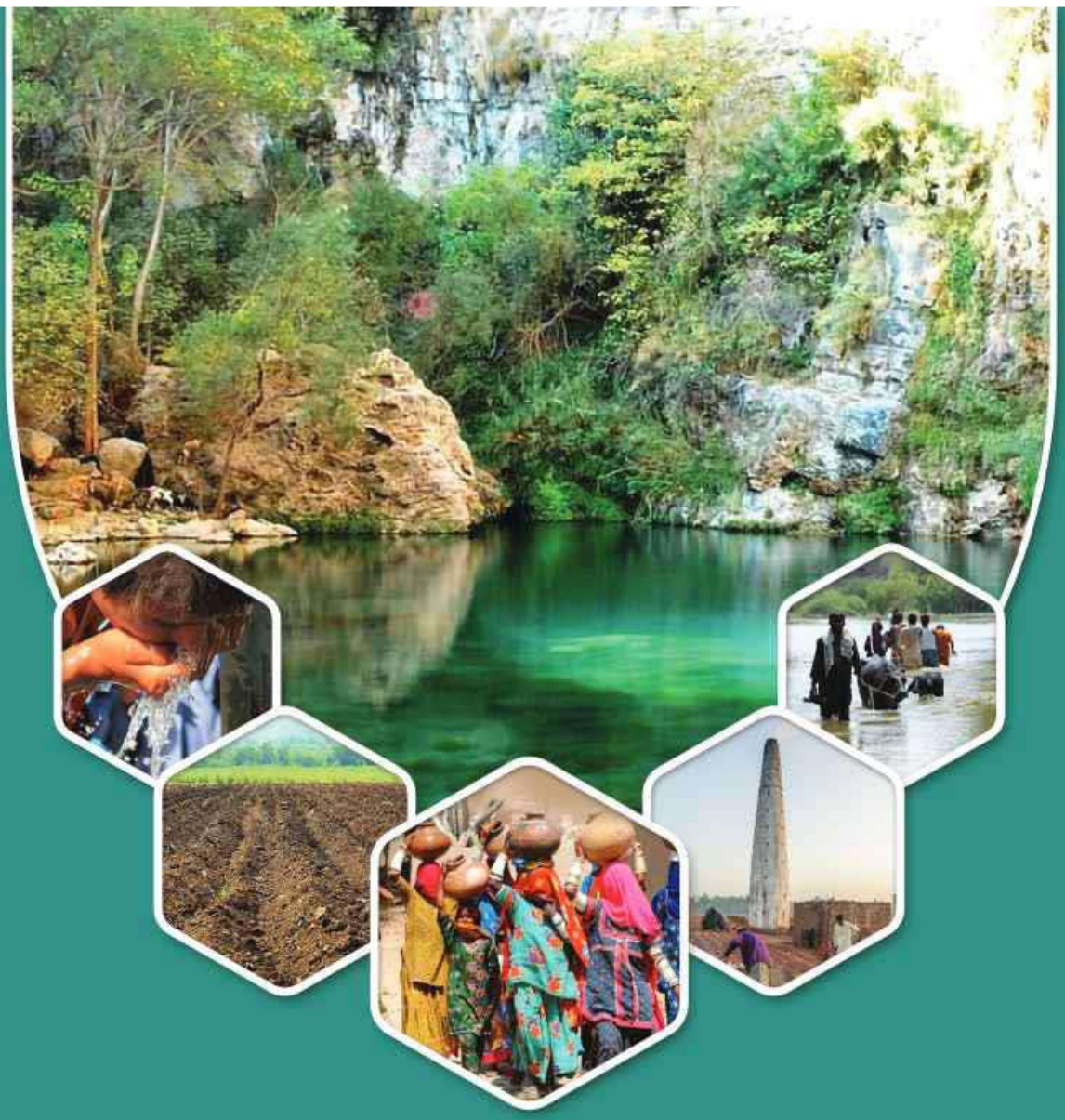

PUNJAB STATE OF THE ENVIRONMENT REPORT 2023

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DISCLAIMER

This “Punjab State of Environment Report, 2023” is based on limited primary data. A significant portion of the information is based on secondary sources. While every effort has been made to ensure accuracy, errors, and omissions are expected.

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LIST OF ABBREVIATIONS AND ACRONYMS

Abbreviation	Complete Name
AARI	Ayub Agriculture Research Institute
ADP	Annual Development Program
AEZ	Agro Ecological Zones
Ag	Silver
APHA	American Public Health Association
AQI	Air Quality Index
AQMS	Air Quality Monitoring Station
As	Arsenic
Ba	Barium
BDL	Below Detection Limit
BOD	Biological Oxygen Demand
BRB	Bambawali-Ravi-Bedian
C&W	Communication and Works Department
Ca	Calcium
CARP	Climate Adaptation and Resilience Plan
CARSC	Climate Adaptation and Resilience Support Centre
CBT	Climate Budget Tagging
CCRC	Climate Change Research Centre
Cd	Cadmium
CDG	City District Government
CERAD	Centre for Energy Research and Development
CETP	Combined Effluent Treatment Plant
CFLs	Compact fluorescent lamps
CGIAR	Consultative Group on International Agricultural Research
CH_4	Methane
Cl^-	Chloride
CN^-	Cyanide
CO	Carbon monoxide
COD	Chemical Oxygen Demand
CR	Critically Endangered
Cr	Chromium
CSOs	Civil Society Organizations
Cu	Copper
CY	Calendar Year
DECs	Divisional Environmental complexes
DGHS	Directorate General of Health Services
DHIS	District Health Information System
DLI	Disbursement Linked Indicator
DLR	Disbursement Linked Results
DPSIR	Drivers, Pressures, State, Impacts and Response
DRFS	Disaster Risk Financing Strategy
DSP	Deputy Superintendent of Police
E. coli	*Escherichia coli*
EAP	Employee Assistance Program
EC	Electrical Conductivity
ECA	Education Credential Assessment
EIA	Environmental Impact Assessment
EMC	Environmental Monitoring Centre

EN	Endangered
EPA	Environmental Protection Agency
EPCCD	Environment Protection and Climate Change Department
EPD	Environment Protection Department
EQS	Environmental Quality Standards
ESIA	Environmental and Social Impact Assessment
ESSA	Environment and Social Systems Assessment
ETC	Environmental Technology Centre
F^-	Fluoride
F. *coliform*	Faecal coliform
FAO	The Food and Agriculture Organization
FBR	Federal Board of Revenue
FCC	Forman Christian College (A Chartered University)
Fe	Iron
FPAP	Family Planning Association of Pakistan
FY	Financial Year
GCF	Green Climate Fund
GDP	Gross Domestic Product
GEF	Global Environment Facility
GHG	Green House Gases
GIS	Geographic Information System
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GoP	Government of Pakistan
GoPb	Government of the Punjab
GRM	Grievance Redressal Mechanism
HAS4CAPE	Health Advisory System for Critical Air Pollution Events
HCl	Hydrochloric Acid
Hg	Mercury
HSE	Health and Safety Executive
HUD & PHE	Housing Urban Development and Public Health Engineering Department
IBIS	Indus Basin Irrigation System
IDAP	Infrastructure Development Authority of the Punjab
IEE	Initial Environmental Examination
ILES	International Labor & Environmental Standards
IRSA	Indus River System Authority
IS	Indian Standard
IWMI	International Water Management Institute
IWRA	International Water Resources Association
KPI	Key Performance Indicator
LEED	Leadership in Energy and Environmental Design
LFP	Labor Force Participation
LG	Local Government
LG&CD	Local Government and Community Development
MAF	Million Acre Feet
MBAs	Methylene Blue-active Substance
Mg	Magnesium
mg/L	Milligrams per litre
MICS	Multiple *Indicator Cluster Survey*
Mn	Manganese
MOCC	Ministry of Climate Change and Environmental Coordination
mS/cm	Milli-Siemens per centimetre
MSW	Municipal Solid Waste
N_2O	Nitrous oxide

NASA	National Aeronautics and Space Administration
NDCs	Nationally Determined Contributions
NDMA	National Disaster Management Authority
NDVI	Normalized Difference Vegetation Index
NEAPSP	National Environmental Action Plan Support Program
NEQS	National Environmental Quality Standards
NGOs	Non-Government Organizations
NGVS	No Guideline Value Set
Ni	Nickel
NO_2	Nitrogen dioxide
NOx	Oxides of Nitrogen
NSL	Natural Surface Level
NT	Near Threatened
OOSC	Out of School Children
OPD	Outpatient (Outdoor) Department
P&D	Planning and Development Department
Pb	Lead
PCAN	Punjab Climate Action Network
PCRWR	Pakistan Council of Research in Water Resources
PCSIR	Pakistan Council of Scientific and Industrial Research
PDMA	Provincial Disaster Management Authority
PDWP	Provincial Development Working Party
PECCEF	Punjab Environmental and Climate Change Endowment Fund
PEPA	Pakistan Environmental Protection Act, 1997
PEQS	Punjab Environmental Quality Standards
PGDP	Punjab Green Development Program
pH	Potential of Hydrogen
PHWMR	Punjab Hospital Waste Management Rules
PIDE	Pakistan Institute of Development Economics
PITB	Punjab Information Technology Board
PLI	Pollution Load Index
PM_{10}	Particulate Matter ≤ 10µm
$PM_{2.5}$	Particulate Matter ≤ 2.5µm
PMD	Pakistan Meteorological Department
PMDU	Prime Minister Delivery Unit
PMU	Project Management Unit
PRIDE	Punjab Resource Improvement and Digital Effectiveness
PSDF	Punjab Skills Development Funds
PSIC	Punjab Small Industries Corporation
PSQCA	Pakistan Standards and Quality Control Authority
RDI	Regulated Deficit Irrigation
RECP	Resource Efficient and Cleaner Production
RSC	Residual Sodium Carbonate
S^{-2}	Sulphide
SAR	Sodium Adsorption Ratio
SDGs	Sustainable Development Goals
SDPI	Sustainable Development Policy Institute
Se	Selenium
SECP	Securities and Exchange Commission of Pakistan
SEMPs	Smart Environmental Management Practices
SMEs	Small and Midsize Enterprises
SNE	Statement of New Expenditure
SO_2	Sulphur dioxide

SO_4^-	Sulphate
SOE	Sate of the Environment
SP&IU	Strategic Planning & Implementation Unit
SPC	Smog Prevention and Control
SPM	Suspended Particulate Matter
SROs	Statutory Regulatory Orders
STAGL	The Sialkot Tannery Association (Guarantee) Limited
STZ	Sialkot Tannery Zone
SUPARCO	Space and Upper Atmosphere Research Commission
SWMFs	Solid Waste Management Facilities
T. *coliform*	Total *coliform*
TCU	True Colour Units
TDS	Total Dissolved Solids
TMA	Town Municipal Administration
TSS	Total Suspended Solids
UN	The United Nations
UNDP	United Nations Development Programme, UN
UNFCCC	United Nations Framework Convention on Climate Change
UNIDO	United Nations Industrial Development Organization
USAID	United States Agency for International Development
USEPA	United States Environmental Protection Agency
USGBC	U.S. Green Building Council
VU	Vulnerable
WASA	Water and Sanitation Agency
WASH	Water, Sanitation and Hygiene
WHO	World Health Organization
WQI	Water Quality Index
WQMS	Water Quality Monitoring Station
WRI	World Resources Institute
WTPs	Water Treatment Plants
WWF	World Wildlife Fund
WWTPs	Waste water treatment plants
Zn	Zinc

EXECUTIVE SUMMARY

The Punjab State of the Environment Report, 2023 is the second report in the series with the first being published reporting the state of the environment in the year 2022. on comprehensive assessment of the conditions of various aspects of the environment such as air, water, soil, climate change, wastewater and solid waste management in Punjab. This report provides an insight on the prevailing environmental conditions with updated sets of data and issues in the province, remedial measures taken by the EPCCD Punjab and other relevant departments, along with the way forward for environmental protection and conservation. SOE Report 2023 has been improved in light of comments and feedback from concerned stakeholders as well as the lessons learnt and gaps identified in the previous SOE Report. The sectors untouched or briefly discussed in SOE Report 2022 have also been incorporated and elaborated in the current report, which inter-alia include the energy, industry, mines and minerals, forest cover change, agriculture and livestock, Water, Sanitation & Hygiene (WASH) and social aspects. A new chapter on 'climate change' has been included in this report. In addition to providing a candid picture of state and trends of environment, this report links the state of environment with the health impacts as WHO identifies that almost 99 percent of the global population resides in areas exceeding WHO thresholds for health protection.

Punjab at a Glance

Punjab, is the most populous province in Pakistan, with a total population of 127.6 million. Urban population of Punjab has reached 40.70% as compared to 31.3% in 1998. As the economic hub of the Pakistan the province experiences employment growth rate higher than the national average while also leading in human development indicators and prosperity. About 56% of the total geographical area of Punjab is cultivated, which is mainly attributed to its rich, fertile alluvial soils and extensive irrigation system. Land use of the Punjab is shared by forests area (0.476 Mha), cultivated areas (12.58 Mha), areas not available for cultivation (3.016 Mha), cropped area (17.14 Mha) and cultivable waste land (1.458 Mha). Punjab contributes about 39% (17,026 MW) of total energy mix of the country. Whereas, it is making rapid advancements towards solarization, with all major solar power plants located in the province. The manufacturing sector contributes around 20% in total economic output of the country with total 32,258 manufacturing industries mostly clustered in large metropolises such as Lahore, Gujranwala, Faisalabad, Sialkot, Sargodha, Mianwali, Jhang, Khushab and Chakwal. The major mineral production is of argillaceous clay, coal, limestone, rock salt and silica sand. Livestock plays an important role in the uplift of the rural economy with a 14.36% share in the National GDP and 62.68% contribution in Agricultural GDP. Rich diversity of flora and fauna in the province includes the species of international importance for conservation. There are more than 350 protected forests, 5 National Parks, 36 wildlife sanctuaries, and 23 Game Reserves in Punjab. As per the Punjab Multiple Indicator Cluster Survey (MICS) 2018, about 98% of the population has access to improved source of drinking water. Tap water is available to 18.8%, motorized pumps to 37.5% and 25.3% population uses hand pumps. Total 80.1% of the population is living in households using improved sanitation facilities, which is higher in urban (92.8%) as compared to rural areas (72. 8%). Rapid urbanization and a growing population in Punjab necessitate enhanced services across various sectors, including water supply, sewerage, drinking water availability, solid waste management, and sanitation. Efforts have been made by authorized bodies to provide access to safe drinking water, sanitation, and hygiene (WASH), Education, and employment as these are the fundamental rights for good health, welfare, and productivity of the state.

Air Quality

EPA Punjab conducted one day ambient air quality monitoring in 9 Divisional HQs of Punjab during August 17-30, 2023 and reported that all divisional HQs had $PM_{2.5}$ concentrations higher than the PEQS value. AQMS monitoring of air quality at multiple locations in Lahore showed highest AQI-$PM_{2.5}$ value in January, while the minimum AQI-$PM_{2.5}$ was measured in September. Compared to 2022, Lahore saw an increase in the number of days with good air quality and a decrease in unhealthy days in 2023. However, urban residents still endured 113 days (out of the 318 monitoring days) of poor to hazardous air quality. Overall air AQI-$PM_{2.5}$ based quality for Lahore and the 9 divisional HQs of Punjab was rated as 'Moderate'. Satellite based monitoring of atmospheric trace gases by SUPARCO observed that major areas in and around districts Lahore, Kasur, Sheikhupura, Nankana Sahib, Faisalabad, Okara, Gujranwala and Multan were the major hotspots of air pollution. However, in comparison to the year 2022, a decrease in concentrations of city hotspots is observed in 2023. Compliance monitoring of industrial effluents of 232 industrial units revealed that most of the units violated at least one of the PEQs permissible limits. Vehicle Inspection during 2023 indicated that about 68% of vehicles passed the safety inspections fit (road worthy). Government of the Punjab is striving hard to provide clean air to the inhabitants of Punjab. Initiatives are being taken at sectoral and cross sectoral level to control air pollution in the province including enhanced setup for air quality monitoring, strict enforcement of pollution control laws, tree plantations, induction of electric buses, climate smart agriculture and water management, and design and construction of net zero energy buildings.

Water Quality

Water is a resource that affects all facets of development and is connected to almost all Sustainable Development Goals (SDGs). Indus Basin Irrigation System (IBIS) is the largest contiguous irrigation system in the world irrigating 18 million hectares of land. Water scarcity in Pakistan has become so intense that per capita availability of water in Pakistan has been reduced from more than 5000 m^3 in 1951 to 1100 m^3 in 2005 and is expected to further decline by 800 m^3 till 2025. The current water storage capacity in Pakistan is only for 30 days as compared to the lowest requirement of 120 days internationally. The proliferating population, rapid urbanization coupled with improved living standards, unplanned industrialization and poor agricultural practices including ineffective irrigation methods and chemical runoff are the main drivers of water scarcity and pollution in the province. EPA divisional labs monitored the surface water quality for rivers, canals and drains in Lahore, Sheikhupura and Faisalabad. Overall quality assessment rating for monitored Rivers and Canals was 'Moderate' and 'Very Poor' for drains. Groundwater quality was assessed at three key sources i.e., receiving sources, distribution systems and consumer endpoints based on data provide by the Irrigation Department, WASAs and SP&IU, respectively. The groundwater quality for irrigation purpose was found fit for only 58% of the samples, while water quality within distribution networks of WASAs were rated 'Moderate'. At the consumer end the water quality of urban and rural unfiltered water was found 'Poor', while urban filtered except DG khan was rated as 'Good' and rural filtered as 'Poor'. Most of the industrial units were found non-compliant with parameters such as BOD (95.7%), COD (94.4%), Sulfide (91%), temperature (84.4%) and TSS (81.7%). Leather and tanning industry, textile mills, sugar mills, protein factories and paper and bard mills were identified as the main polluters. Implementing efficient water management practices, recycling and conservation measures are crucial to prevent water pollution and promote sustainable water usage.

Soil Quality

Soil quality assessment was carried out in nine divisions of Punjab namely Faisalabad, Lahore, Sahiwal, Multan, DG Khan, Bahawalpur, Sargodha, Rawalpindi and Gujranwala. Samples were collected from urban, industrial, agriculture, and effluent irrigated lands and were tested for physico-chemical properties. The assessment revealed that soils in Punjab had mainly around neutral pH except for the DG Khan Division with slightly alkaline urban, industrial and agriculture soils. The land irrigated with treated and untreated industrial effluents has caused alkalinity in the soil of Multan Division. Electrical conductivity values indicate non-saline conditions in all tested soil samples. Rawalpindi division stands out with strongly sodic agriculture soil, while Lahore and Bahawalpur had sodic soils in lands irrigated with industrial effluents. Punjab has fertile soils with adequate levels of nitrogen, potassium, iron, and phosphorus in various divisions. Zinc concentrations are also satisfactory. Notably, sodium levels are elevated in Sargodha, calcium in Sahiwal, and magnesium in Rawalpindi's land irrigated industrial effluents. Heavy metal based Pollution Load Index (PLI) showed moderately polluted soil types in all areas of 9 divisions with Rawalpindi and Multan divisions having highest PLI values (2.3). Regular monitoring of soil quality along with adoption of sustainable agriculture practices can help in sustaining agricultural productivity, mitigating sodicity, and preserving the overall health of Punjab's soils. Punjab Agriculture Department is striving for improved research and development as well as the enhanced soil quality monitoring and spreading education and awareness across Punjab. Several initiatives have been taken by the Department from use of GIS-Remote Sensing technology to provision of nutrient analysis facility to the farmers and mitigating the emerging issues of pesticide residues to name a few.

Climate Change

The world is experiencing a climate emergency. GHG emissions from agriculture sector alone accounts for 46% of total GHG emissions in Pakistan. The particulate matter contributes 23% of the total emissions in Punjab, with industrial sector being the major contributing source. Temperature and precipitation data collected from Pakistan Meteorological Department (PMD) The climatic showed that March-July 2023 were cooler than the normal average temperatures of Punjab for these months, despite of the fact that the overall mean temperature in the country remained 0.51°C above normal. Highest temperature during 2023 was recorded as 46.6°C in Noorpur Thal, District Khushab on June 22, whereas the highest rainfall in 24-hours was recorded by meteorological station at Lahore airport, measuring 226 mm on June 26. Indus tributaries of Punjab are under water stress and the average annual availability of all the rivers that comprise the Indus River System's flows for canal withdrawals fell from 145.20 to 124.90 MAF between 1976 and 2020. During 2023, Districts Bahawalnagar, Bahawalpur, Lodhran, Kasur, Vehari, Okara, Pakpattan and Multan were affected by urban flooding from August, 17 to September, 30. In the afflicted areas, the floods damaged 467 villages/basti/mozas, almost 24,000 homes, and 545,270 acres of farmed land. Due to floods/torrential rains not only crop yield has affected but also province has experienced a remarkable increase in disease outbreaks like dengue and cholera in 2023. Government of the Punjab is well sensitized about the risks and consequences related to climate change and is taking crucial initiatives in terms of climate change mitigation, adaptation, resilience and climate finance. An Environment and Climate Change Cell has been established in Planning and Development Board Punjab, working on climate related actions and financing. The cell is assisting P&D Board in the process of getting accredited for Green Climate

Fund (GCF). Government is also developing linkages between the provincial climate actions and the international obligations related to climate adaptation and mitigation.

Environmental Performance of Wastewater Treatment Facilities and Solid Waste Management Facilities

There are 434 industrial wastewater treatment plants In Punjab, encompassing primary, secondary, and tertiary facilities. However, these plants are insufficient to handle the considerable pollution loads. The limited number of wastewater treatment plants not only compromises aquatic ecosystems but also impacts trade opportunities with other countries. Optimizing resource utilization and treating waste before discharge into water bodies or land is crucial for maintaining trade ties. Performance of industrial wastewater treatment plants was assessed on a scale ranging from 'very poor' to 'very good' on the basis of tested parameters and PEQS compliance before and after treatment. Results revealed that the textile, sugar, and paper and pulp industries have 'very poor' performance in terms of wastewater treatment facilities. In Punjab, the generation of Municipal Solid Waste (MSW) ranges from 115 tons/day in DG Khan to 5000 tons/day in Lahore. MSW generation rates are higher in large metropolises, characterized by high waste production, rapid population growth, and predominantly urban lifestyles. The study area for performance assessment of solid waste management facilities was scaled up from the four districts in SOE Report 2022 to 09 divisional headquarters for SOE Report 2023. The study area included districts Lahore, Gujranwala, Sahiwal, Sargodha, Rawalpindi, Faisalabad, Multan, Bahawalpur, and DG Khan. The types of waste selected for the study were municipal solid waste and hospital waste, whereas the types of SWMFs included the MSW landfill/dumping sites and public/private hospital waste incinerators. Air, soil, and leachate were monitored from MSW landfills/dumping sites, whereas public and private incinerators were assessed for stack emissions and ash. In leachate, concentration of BOD, COD and TSS was found higher than the prescribed limits. While all soil parameters assessed except EC in some divisions (Rawalpindi, Multan and Sahiwal) were in acceptable limits. The ambient air monitoring at landfill sites revealed concentration of suspended particulate matter and $PM_{2.5}$ exceeding prescribed limits in most of the divisions. The analysis of ash content of private and public incineration facilities revealed high percentage of unburnt carbon and detection of lead, chromium and copper in some samples. Punjab's average MSW collection is poor and is 50% below the optimal level of 75%. In overall assessment waste collection, waste disposal, and waste-to-energy were ranked as 'Poor', while waste recycling was ranked as 'Moderate'. To effectively manage solid waste, additional technical and financial resources are necessary, along with adoption of integrated solid waste management practices and strengthening policies framework.

Measures taken to control Environmental pollution

Environmental sustainability can be achieved with the cooperation of all stakeholders, including public and private sectors, government agencies, and local communities. EPD Punjab has significantly improved its pollution control and environmental protection services in 2023. EPD Punjab is enhancing its sectoral regime by integrating business laws related to climate change. The EPCCD Green Building is the nation's first office building in the public sector and a landmark project in Punjab that aims to assure sustainable site development, water conservation, energy efficiency, green compliance in material selection, and improved indoor environmental quality. The Punjab Clean Air Policy was approved by the government in April 2023. On June 7, 2023, the Punjab Environmental Protection notified the smog prevention and control rules. The policy

outlines standard operating requirements for brick kilns, industrial units, resource recovery units, and pyrolysis plants in order to prevent these units from contributing to air pollution. Apart from the plastic management policy, the Punjab government has enforced rules on the manufacturing and consumption of single-use plastics. EPCCD has also installed nine more AQMS under DLI-2 in the Lahore Division, and work is currently on to build 21 more stations in other divisions. Moreover, work for the installation of 15 Water Quality Monitoring Stations (WQMSs) at Punjab's principal water bodies has been given to foreign consulting firms. During 2023, the EPA has effectively carried out 125 stack emissions inspections and 1000 industrial effluent examinations. EPA Punjab's anti-smog teams sealed 5970 air-polluting industrial sources during these inspections, while the units breaking the PEQS were fined PKR 467 million. In 2023, 255,497 dengue inspections were carried out resulting in removal of 266 dengue larvae, issuance of 3528 notices, lodging 232 FIRs and 19,321 source removals. EPA Punjab also enhanced its hospital waste management cell in which 1334 junkyards were inspected. During these inspections, 60 kilograms of hospital waste was confiscated by EPA Punjab, sealing 35 units engaged in illegal handling and storage of hospital waste. A total of 328,428 trees were planted throughout Punjab. The department envisions more stakeholder collaborations coupled with planned institutional, policy, monitoring, and regulatory improvements as means of further strengthening environmental governance in the province.

Environmental Complaints

EPCCD Punjab actively addresses environmental complaints through a formalized Grievance Redressal Mechanism (GRM) that operates through an efficient, responsive and accessible complaint handling system. Complaints pertaining to various environmental aspects, such as air pollution, noise pollution and improper waste management, etc., can be filed through a range of channels, including in-person visits to offices such as the Chief Minister's Office, Chief Secretary's Office, and relevant district authorities, as well as online platforms like the Prime Minister's Delivery Unit and Chief Secretary's complaint cell. Additionally, complaints can be submitted by mail or post directly to the concerned office. Upon receiving a complaint, the process of screening and assessment begins to determine the required action. The nature of action may vary depending on the type of complaint, ranging from filing FIRs to sealing units. In 2023, a total of 907 complaints were received throughout the province, with the highest number of complaints originating from Faisalabad. Most of these complaints were related to air pollution, followed by noise pollution and others. Out of the 907 registered complaints, 552 were successfully resolved, 83 units were sealed, and 42 FIRs were filed due to non-compliance with the Punjab Environmental Protection Act of 1997.

Environmental Action Plan

The environmental action plan (EAP) 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 resulting from human activities, conserve natural resources, and promote environmentally friendly practices. The 2022 State of Environment Report introduced an Environmental Action Plan with 11 interventions and 71 sub-interventions, fixing responsibilities and timelines. It identified, short-term (CY-23), medium-term (CY-24), and long-term (CY-25) measures required to be taken by the EPCCD and other stakeholders. In CY-23, significant achievements (in terms of initiated or completed) were made in the legislative, citizen engagement, industry regulation, vehicular emissions control,

monitoring enhancements, sustainable green financing, fugitive dust mitigation, and remodelling environmental governance interventions. EAP 2023 is also a three years plan starting from CY-24 and ending at CY-26. Two new interventions (Air and Climate Change) have been added along with some new sub-interventions. A dashboard will be set-up for monitoring of Environmental Action Plan by EPCCD, and focal persons will be designated for collaboration with relevant organizations.

CHAPTER 1 INTRODUCTION

1 BACKGROUND

1.1 Mainstay

Punjab Environmental Protection Act, 1997, mandates the Environmental Protection Agency (EPA) Punjab for the publication of an annual report on State of the Punjab's Environment, henceforth referred as the SOE Report. This is the second report in the series after the first one published in 2022[1]. In addition to the Act ibid, the SOE Report also derives its origin from the Disbursement Linked Indicator (DLI–III) of the Punjab Green Development Program (PGDP), a World Bank assisted Program, aimed at strengthening environmental governance and to promote green investments in the Punjab. This program is being implemented by the Environment Protection and Climate Change Department (EPCCD) Punjab and other implementing departments including the Industries, Commerce and Investment, Energy, Transport and Finance Departments and Planning and Development Board, Government of the Punjab.

DLI-III of PGDP "Environmental Information Disclosure and citizen engagement" identifies that EPCCD's annual SOE report shall provide environmental quality data and information on actions taken to reduce pollution and strengthen environmental governance. Incorporation of feedback solicited during public consultations, would be a major achievement to translate the Government's willingness into concrete actions. This will reflect both the EPCCD's increased capacity to collect and analyze environmental quality data and progress on transparency and citizen engagement for environmental management.

1.2 State of the Environment Report 2022

SOE Report 2022 provided a comprehensive assessment of the environment, including the ambient air, industrial emissions, surface and ground water, soil, wastewater treatment plants and solid waste management facilities. It aimed at informing the policymakers, stakeholders, and the general public about the environmental conditions prevailing in the province, their implications for human health and deciding way forward through an environmental action plan. In addition to discoursing the environmental profile of the Punjab, the SOE Report also highlighted a number of environmental challenges faced by the province during 2022. A DPSIR framework was used to postulate a chain of causal links beginning with 'driving forces' (economic sectors, human activities) and progressing through 'pressures' (emissions, waste), 'states' (physical, chemical, and biological), 'impacts' (on ecosystems, human health and functions), and 'responses' (prioritization, target setting, indicators). The main findings of the SOE Report 2022 for each sector are presented in Figure 1-1.

[1] Available at https://epd.punjab.gov.pk/system/files/Report%202022-hi-res%20%284%29.pdf

Quick Overview of SOE Report 2022

Air Quality

- Good or satisfactory AQI ($PM_{2.5}$) was observed only for 17 out of the total 309 monitored days in District Lahore.
- Satellite data revealed that Lahore, Kasur, Sheikhupura, Nankana Sahib, Faisalabad, and Gujranwala are among the hotspots of CO, SO_2, and NO_2 emissions.
- Vehicular and industrial emissions were identified as the main contributors in the deteriorating air quality of Punjab.
- Quality assessment of ambient air of Lahore, divisional headquarters and industrial stack emissions was rated as 'poor', 'moderate' and 'very poor' respectively.

Water Quality

- Population growth, rapid urbanization, industrialization, over-extraction and climatic variability are the key pressures on water resources.
- Bacterial contamination is found in drinking water of most districts of the Punjab, including Multan, Rawalpindi, Sargodha, Sheikhupura and Lahore.
- Organic loads are resulting in high Biological Oxygen Demand (BOD) in the rivers.
- Major contributors of industrial effluents include textile factories, sugar mills and leather tanneries.
- The overall quality of water in rivers was rated as 'moderate' (for irrigation purposes) and 'very poor' for drains due to high pollution loads.

Soil Quality

- In Punjab 56% of total geographical area is cultivated, which is mainly attributed to its rich, fertile alluvial soils.
- The overall quality of various types of soils in Punjab in terms of salinity (EC mS/cm) is rated as 'Good', 'Moderate', and 'Poor' for agriculture, urban and industrial soils, respectively.
- Fertility (Zn, Fe, Mn) and heavy metal (Ni, Cr, Cu, Pb) content of all soil types are rated as 'Good'.

Performance of Industrial Wastewater Treatment and Solid Waste Management Facilities

- EPA identified, 392 industrial wastewater treatment plants (primary, secondary, and tertiary) in 2022.
- Very poor' performance efficiency of wastewater treatment facilities installed in sugar and paper mills.
- There is only one environmentally approved landfill site in Punjab located at Lakhodair area Lahore.
- In rest of the districts municipal waste is dumped at open sites without proper landfill.

Measures Taken to Control Pollution

- EPA Punjab launched the anti-smog campaign as a preemptive measure to minimize air pollution.
- 705,650 trees were planted under the supervision of EPA field offices across Punjab in collaboration with multiple stakeholders.
- EPD Punjab established a Health Advisory System for Critical Air Pollution Events targeting vulnerable population groups.
- EPA Punjab inspected 2169 public and private hospitals to check the implementation of Punjab Hospital Waste Management Rules (2014) and action was taken against the non-compliant hospitals.
- Major regulatory and institutional reforms in Punjab for strengthening environmental governance in the province (accomplished/in pipeline) by EPD Punjab, are establishment of missing environmental quality standards, revision of existing standards and development of industry-specific environmental quality standards, Punjab Review of IEE and EIA Regulations (2022), Plastic Management Strategy, Regulations' on the production and consumption of single-use plastics and Punjab Climate Change Policy.

Environmental Complaint Redressal

- EPA has received a total of 1091 complaints from 36 districts across Punjab.
- Faisalabad remained at top (116) while Lahore remained second with 99 in receiving highest number of registered complaints. Out of which 63% complaints were resolved.
- Almost 47% of the complaints were related to air pollution showing public concerns towards clean air.

Environmental Action Plan

- SOE Report 2022 provided an Environmental Action Plan, with distinct roles, responsibilities and timeline.

Figure 1-1: Overview of SOE Report 2022

2 PURPOSE OF THE REPORT

Punjab's State of the Environment Report 2023 aims to provide an insight on the prevailing environmental conditions with updated sets of data and issues in the Province, remedial measures taken by the EPCCD Punjab and other relevant departments, along with the way forward for environmental protection and conservation.

3 APPROACH AND METHODOLOGY

The formulation of SOE Report is an intricate process, comprising multiple steps. The section below provides the approach and methodology adopted for the compilation of the SOE Report 2023.

3.1 Approach

The SOE Report 2023 is a product of state and trends of environmental quality indicators, assessed from primary and secondary environmental quality data analysis and a series of thorough consultations and collaborations among multiple stakeholders. The report focuses on:

i. Providing comprehensive assessment of the state of environment in Punjab
ii. Showcasing the environmental trends in the Province in comparison with previous years, to continue the process of environmental reporting initiated in 2022.
iii. Depicting the impacts of prevailing state of environment on human health and well-being.
iv. Engaging stakeholders, public and experts in environmental reporting to ensure informed environmental decision- and policy-making

SOE Report 2023 has been framed by following the Drivers, Pressures, State, Impact and Response (DPSIR) approach (explained in detail in section 1.6.3.), keeping it in line with the SOE Report 2022. The DPSIR approach:

a. Identifies main drivers directly or indirectly influencing environmental quality and sustainability.
b. Describes the 'pressures' in form of spatio-temporal change in environment, using the qualitative and quantitative data.
c. Analyses the 'state' of environment subsequent to such changes derived from the environmental pressures.
d. Evaluates the environmental and health impacts of the state of environment.
e. Highlights the policy measures and actions taken in response to the changing environment.

3.2 Methodology

The methodology adopted for the formulation of the report was as follows:

i. Developing the content

The content of SOE Report 2023 has been developed by the Strategic Planning and Implementation Unit, constituted under EPCCD Punjab for execution of PGDP. The

authors developed the content in line with the structure and sequence of information unanimously agreed upon at Program Appraisal stage of PGDP. External experts were engaged for environmental monitoring, laboratory analyses and data interpretations for soil, drinking (tap) water quality and environmental performance of solid waste management facilities. Literature and secondary data sources were also reviewed to align the primary data with existing studies, research, policies, laws and regulations.

ii. Review and recommendations

A committee, comprising technical experts in the subject matter, was notified by the EPCCD Punjab for periodic review of the draft report and to provide recommendations for improvement to the authors.

iii. Inter-departmental coordination

Concerned provincial departments were approached to link all relevant sectors with the state and trends of the environment. Sectoral data pertaining to 'environment' was graciously provided by the stakeholder departments for incorporation in the SOE Report.

iv. Editing and designing

The report has been edited by external resources with a vast experience in editorship. The editor has professionally edited, proof read and designed the final report. Efforts have been made to present the report findings in a presentable and comprehensive manner.

Figure 1-2: Methodology adopted for SOE 2023

4 STAKEHOLDER CONSULTATIONS

To engage all the relevant stakeholders and public in environmental reporting, three public hearings were conducted in different districts during formulation of SOE Report 2023; with the first hearing on table of contents in Lahore, second on draft report in Faisalabad and third on the draft report in Multan. The hearings had a fair representation from provincial and federal government departments/attached departments, non-government organizations (NGOs), academia, civil society organizations (CSOs), chambers of commerce and industry, youth and general public.

Figure 14-3: Stakeholder consultations

The response and feedback from the participants and subsequent response thereon is detailed as **Annexure A**.

5 WHAT'S NEW IN THE REPORT?

Though using the same approach and methodology in its formulation, SOE Report 2023 has been improved in light of comments and feedback from concerned stakeholders as well as the lessons learnt and gaps identified in the previous SOE Report. Some of key features that distinguish the current report from SOE Report 2022 are given in Figure 1-4

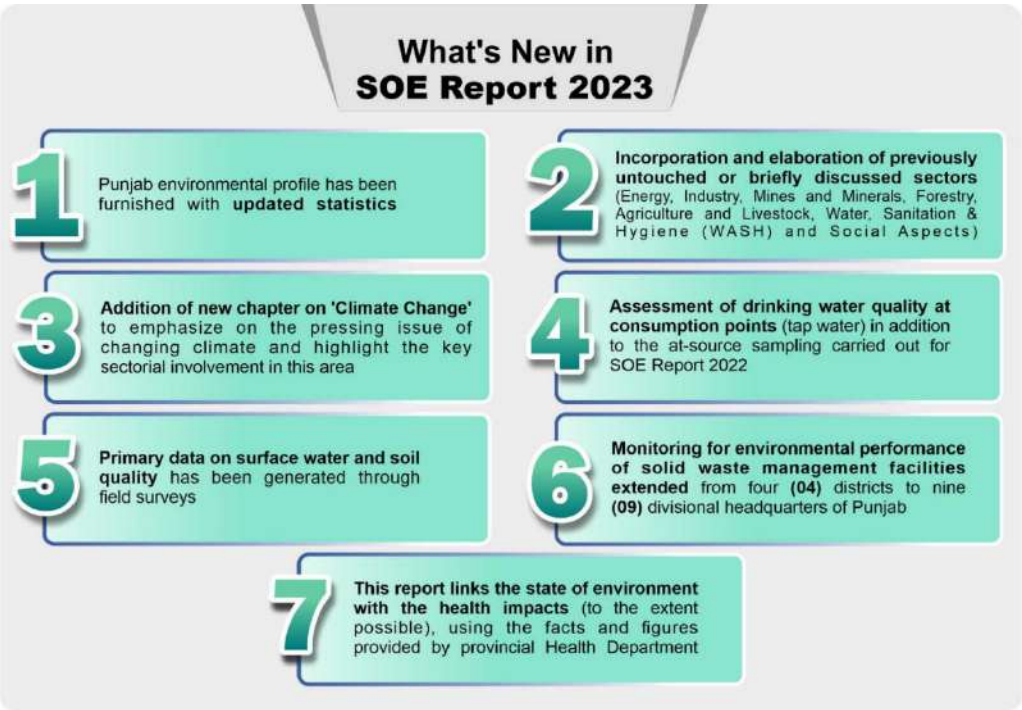


Figure 1-4: Key features of SOE Report 2023

6 READER'S GUIDE

6.1 Components and Indicators

The SOE Report 2023 retains the basic structure used last year, based on seven (07) broad components enlisted below:

i. Assessment of air, surface water, groundwater and soil quality based on available monitoring data
ii. Assessment of pollution sources along with a list of pollutants and their intensity that add to air, water and soil pollution
iii. Assessment of environmental performance of solid waste management and waste water treatment facilities
iv. Suitable course of action adopted to inhibit pollution and revamp the quality of environment.
v. Summarizing the details of environmental complaints received, categorized by nature of the issue and appropriate actions taken accordingly
vi. Public opinion and EPD's responses on the report
vii. Annual Environmental Action Plan

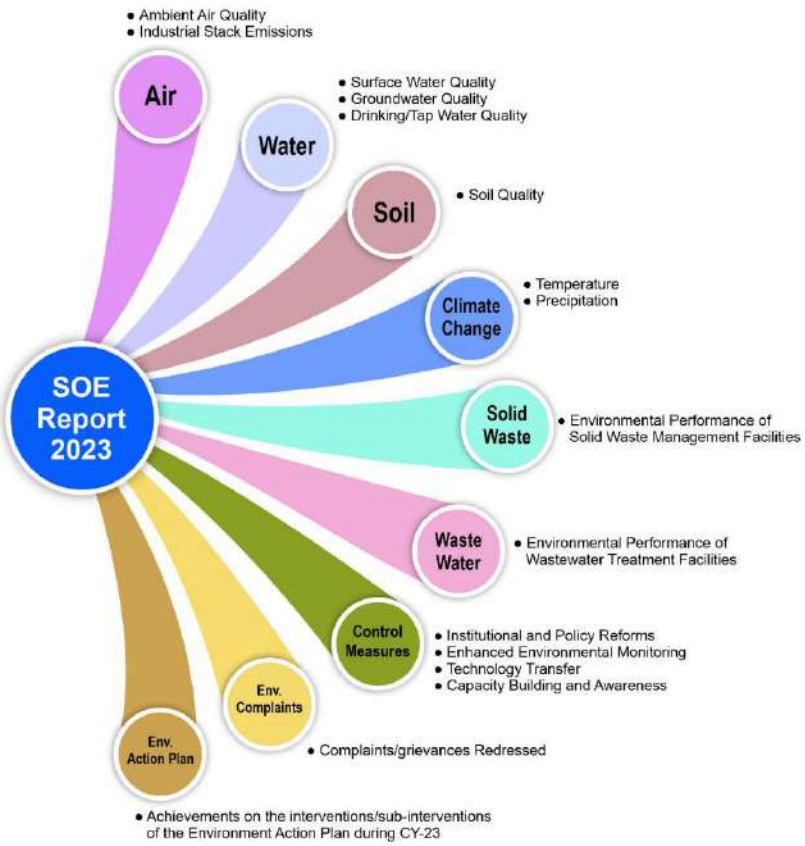


Figure 1-5: Components and indicators of SOE Report 2023

Components along with their respective indicators are shown in Figure 1-2 while component-wise detail of data streams is given in Annexure B.

6.2 Drivers, Pressures, State, Impacts and Response (DPSIR)

The environmental indicators identified for the SOE Report 2023 have been assessed by using DPSIR framework (Figure 1-6). The indicators identified for reporting, are mainly the physical (abiotic) components of the environment.

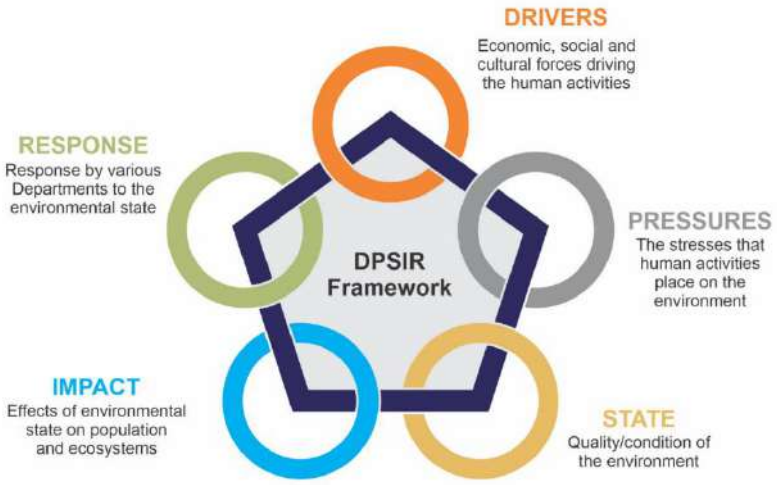


Figure 1-6: DPSIR Framework

The drivers and pressures on the identified components of environment are somehow uniform and are described as follows:

A. Drivers

Some common drivers behind the remarkable change in the state of environmental indicators, in Punjab, are:

i. Population upsurge, with high population density, especially in urban settings
ii. Climate change and variability
iii. Prompt urbanization, leading to horizontal expansion of cities
iv. Infrastructure expansion (road and bridge networks, highways, public and private vehicles, service institutes, commercial areas, etc.)
v. Escalating industrialization both in manufacturing sector and the small – medium enterprises, pertaining to increasing demand of goods and services
vi. Unsustainable values, attitudes and lifestyles

B. Pressures

These drivers exert certain pressures on the environmental indicators, for instance:

i. Burden on natural resources due to over-extraction and exploitation
ii. Emissions, effluents and wastes (environmental pollution)
iii. Land-use Change

The state, impacts and responses are given indicator-wise, in respective sections.

6.3 Indicator Ranking

Figure 1-7 presents an environmental quality assessment rating scale which has been used in this report to rate air, water, soil quality and performance of wastewater treatment and solid waste management in Punjab following the pattern of SOE Report 2022.

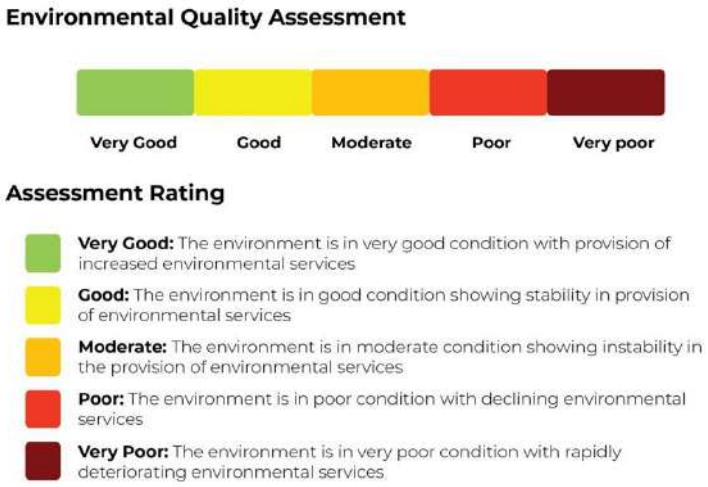


Figure 1-7: Environmental Quality Assessment Scale

7 LIMITATIONS IN REPORTING

In light of the lessons learnt from the publication of SOE Report 2022, data acquisition has been facilitated by enhanced and timely coordination with stakeholder departments and developing online portals for regular uploading of environmental data by EPA Punjab. However, it is good to make the process of reporting more transparent by explicitly narrating the limitations experienced while reporting. These are as follows:

Heterogeneity of data: The limitation pertaining to heterogeneity of data still prevailed for the SOE Report 2023 as for pervious report. The data is scattered and heterogeneous both spatially and temporally, challenging the all-inclusive, quantified representation of linkages between the state of environment and its health and economic impacts.

Limited scope of monitoring: District – wise monitoring of data, covering whole province is still a major gap in reporting, pertaining to limited available resources.

CHAPTER 2 PUNJAB AT A GLANCE

Key Findings

Total population of Punjab has approached 127.6 million people in 2023 with 40.70% population living in urban areas, as compared to 31.3% reported in 1998.

Employment growth rate is higher in Punjab than the national level. Informal (non-agricultural) sector employment accounted 44.3 % for the largest share of total employment in the province

Land use in Punjab comprises around 0.476 Mha of forest area 3.016 Mha area not available for cultivation, 1.458 Mha cultivable waste land, 12.585 Mha cultivated area and 17.140 Mha cropped area of the country.

There are more than 350 protected forests in Punjab. There are total 5 National Parks, 36 wildlife sanctuaries, and 23 Game Reserves in the Province.

Pakistan's total energy mix (by fuel) is reported to be 43,775 MW, out of which 17,026 is Punjab's share.

There is 30,000 hundred metric tons/year production of limestone in Punjab, followed by argillaceous clay, which is above 59,000 hundred metric tons.

The share of Punjab in Pakistan's livestock population is 60%

As of 2023, a total of 32,258 manufacturing industries are located in Punjab, mainly including the textiles, construction material, glass, furniture and grain mill production units

Women are almost half of the population in Punjab but their representation in public sector is not adequate.

As per the Punjab Multiple Indicator Cluster Survey (MICS) 2018, about 98% of the population has access to improved source of drinking water. Tap water is available to 18.8%, motorized pumps to 37.5% and 25.3% population uses hand pumps.

Total 80.1% of the population is living in households using improved sanitation facilities, which is higher in urban (92.8%) as compared to rural areas (72. 8%).

Punjab province has been remained at top in comparison to other provinces in Pakistan pertaining to higher human development indicators and prosperity

1 PUNJAB AT GLANCE

SOE Report 2022 has presented key features of the environmental profile of Punjab. The current section provides updated facts, figures and statistics about different sectors with a value addition of the information related to some additional sectors e.g. energy and social sector, identified on the basis of comments and feedback on the previous report.

1.1 Demography

In a lapse of five years (2017-2023), Punjab has maintained its status of being most populous province of the country with its total population approaching 127.6 million people in 2023 (Figure 2-1). The urban population is also gradually increasing in Punjab with 40.70% population living in urban areas in 2023 as compared to 31.3% reported in 1998. Lahore division stands as the most populous division of Punjab with a population of 22.8 million), followed by Gujranwala division with 18.8 million inhabitants[2] (Figure 2-2).

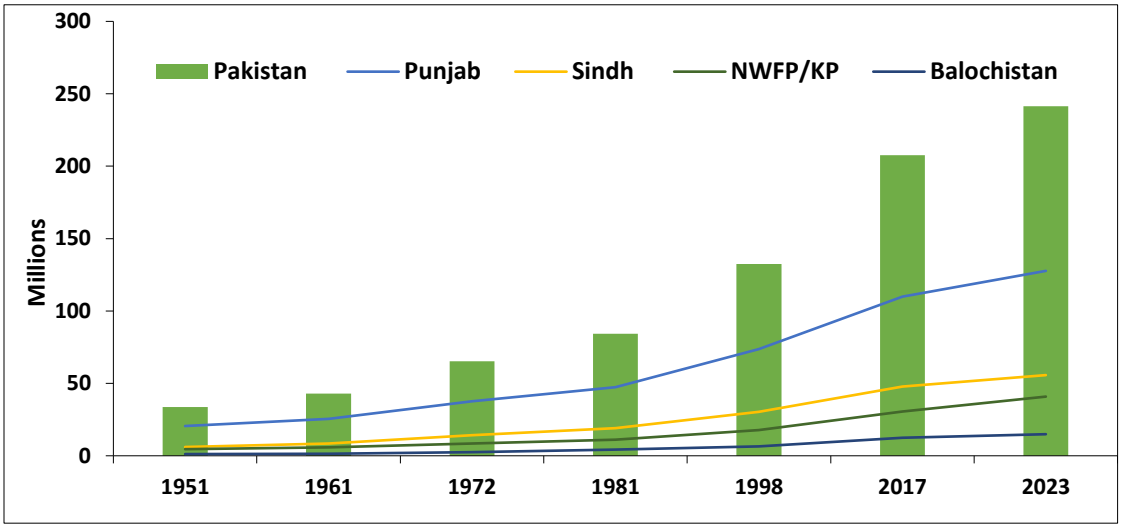


Figure 2-1: Population Growth Rates in the provinces of Pakistan

[2] Pakistan Population Census 2023, Pakistan Bureau of Statistics

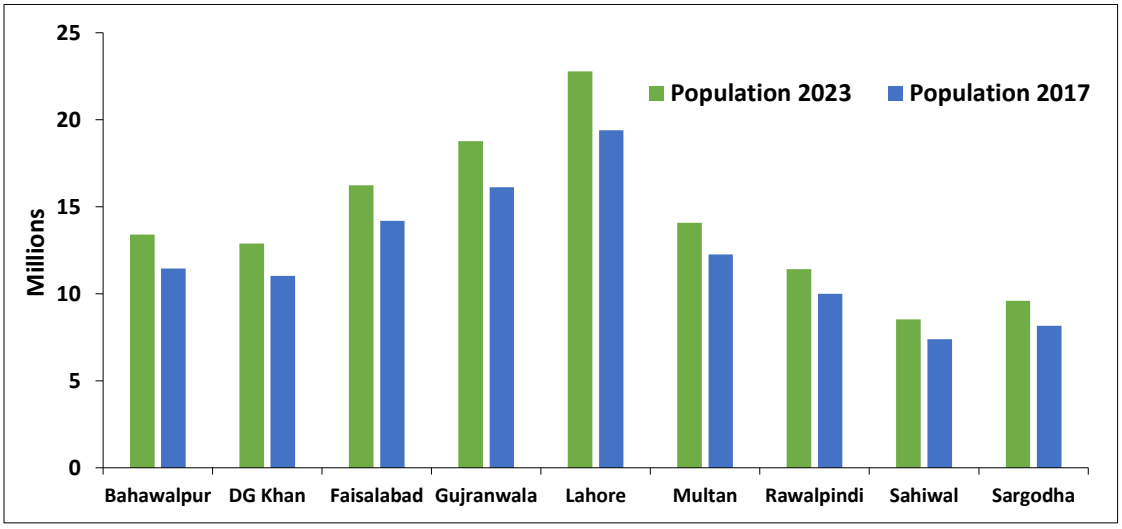


Figure 2-2: Division-wise population of Punjab (2017 and 2023)

1.2 Land use

According to the latest available statistics, Punjab comprises around 0.476 Mha of forest area, 17.14 Mha of cropped area, 3.016 Mha area not available for cultivation, 1.458 Mha cultivable waste land and 12.58 Mha cultivated area[3]. The comparison of land use statistics from 2016 to 2020 indicates a relatively uniform pattern (Figure 2-3).

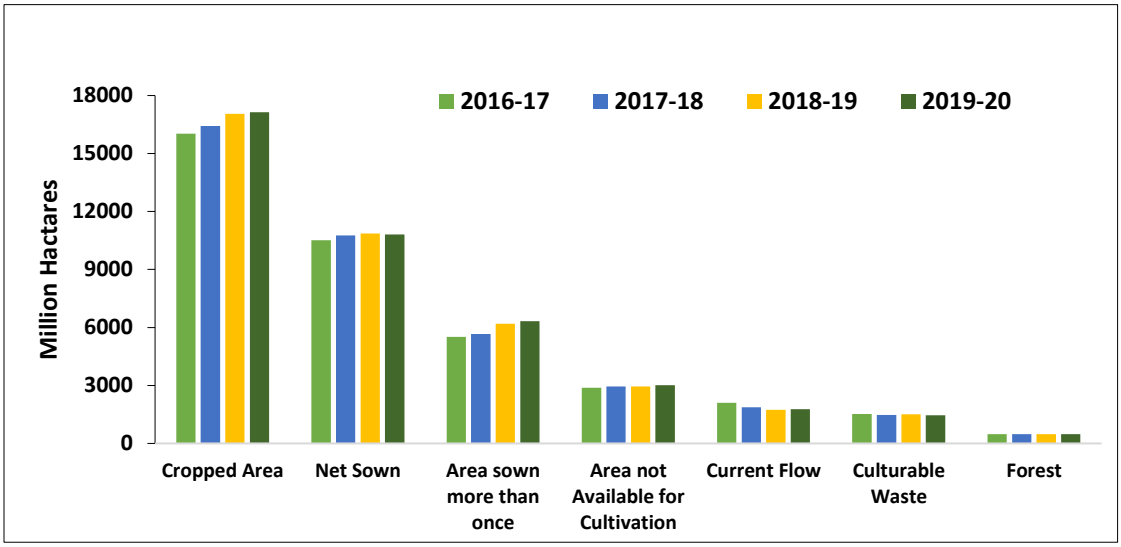


Figure 2-3: Land-use in Punjab (2016-2020)

[3] Punjab Bureau of Statistics

Definitions of the terms used in the Land Utilization Statistics:

i) **Total Area Reported** means the total physical area of the village/deh, tehsil or district etc. It includes cultivated area (net area sown + current fallow), culturable waste, unculturable land and forest area.

ii) **Forest Area** means the area of any land classed or administered as forest under any legal enactment dealing with forests. Any cultivated area which may exist within such forest should be excluded and shown under the heading cultivated area.

iii) **Total Cropped Area** means the sum total of area sown during Rabi and Kharif seasons during a given year including Zaid Kharif and Zaid Rabi.

iv) **Not Available for Cultivation** means the land absolutely barren, roads, canals, tanks, beds of rivers, torrents and ravines, sites of villages, houses, hills, mountains, sand dunes and all land devoted to uses alien to agriculture.

v) **Culturable Waste** means all cultivable land not actually cultivated. It should include all grazing and other land not included under forest.

vi) **Cultivated Area** means the land currently being used for agricultural purposes, including land under crops, orchards as well as current fallow. It is the area net sown plus current fallow.

vii) **Current Fallow** means the part of the cultivated area which has not been used for cropping during the year under reference but for which the total vacant period does not exceed three crop seasons. The land remaining vacant for more than three successive seasons should be shown under the head 'cultivable waste'

viii) **Area Sown** means the area which has been sown at least once in a year. It will include area under crops, fruit, vegetables etc. ix) Area Sown More than once means the difference between the total cropped Area and net sown i.e. the difference between (iii) and (viii).

On average the cultivated area remains considerably higher than the uncultivated area in the province (Figure 2-).

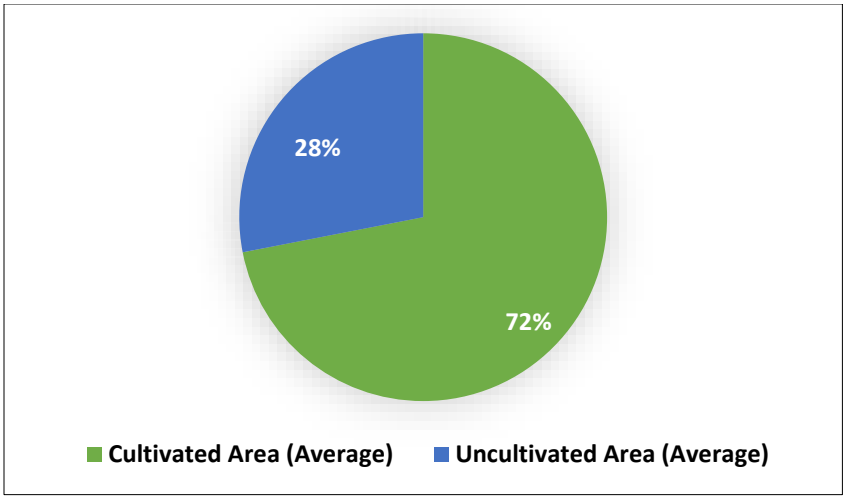


Figure 2-4: Percentage of cultivated and uncultivated area in Punjab

The rangelands provide several direct and indirect ecosystem services, including the dairy products, medicinal products and conservation of soil and water. Rangelands in Punjab roughly cover 8.28 million hectares [4]. These rangelands generally fall in Pothohar, Thal, DG Khan and

[4] UN Food and Agriculture Organization (FAO), Rangelands of Pakistan Current status, threats and potential, 2016

Cholistan areas. About 412,800 farmers residing on boundaries of these rangelands are directly benefited by grazing their animals[5].

1.3 Energy

Like Pakistan, the energy mix of Punjab comprises of Thermal, Nuclear, Hydel, Solar, and Bagasse based power production, with thermal power contributing most (74%) in its total energy mix[6] (Figure 2-5).

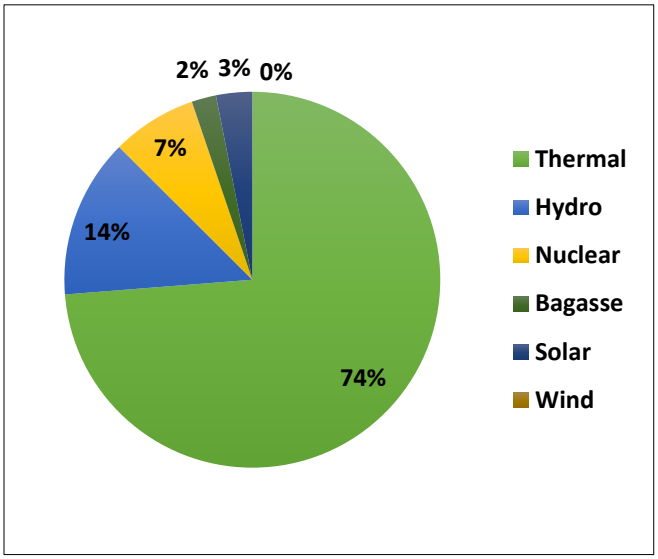


Figure 2-5: Punjab's Energy Mix

Total energy mix (by fuel) of Pakistan is reported to be 43,775 MW, out of which Punjab contributes 17,026 MW (Figure 2-6).

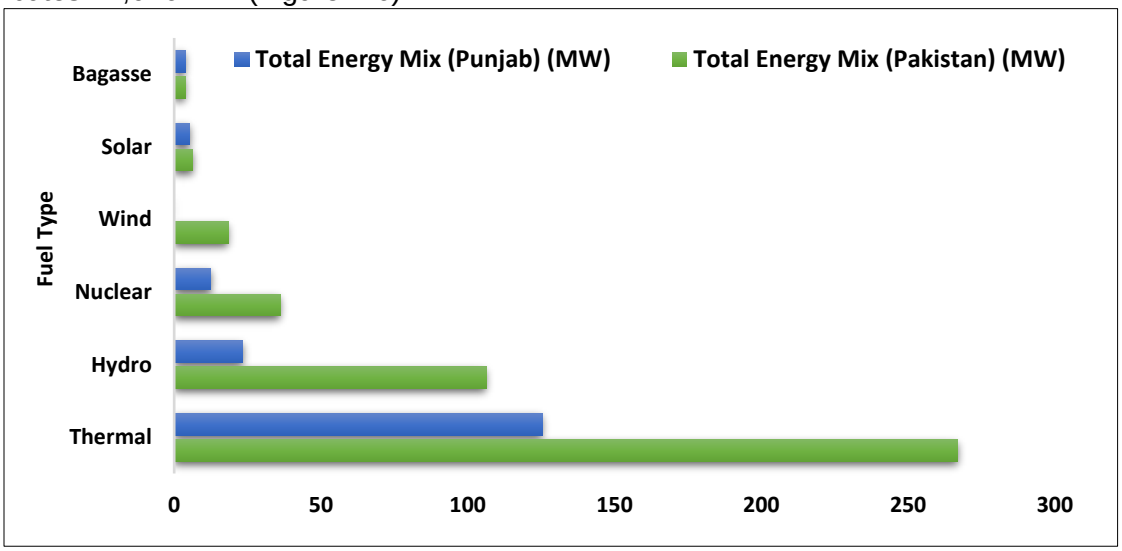


Figure 2-6: Punjab's Energy Mix (by fuel) and its contribution in National Energy Mix (MW)

[5] Forestry, Wildlife and Fisheries Department (2022)
[6] Energy Department, Government of the Punjab

About 62% of total power plants in Pakistan are located in Punjab province, with major proportion comprising of thermal power plants, followed by hydropower plants (Figure 2-7**Error! Reference source not found.**).

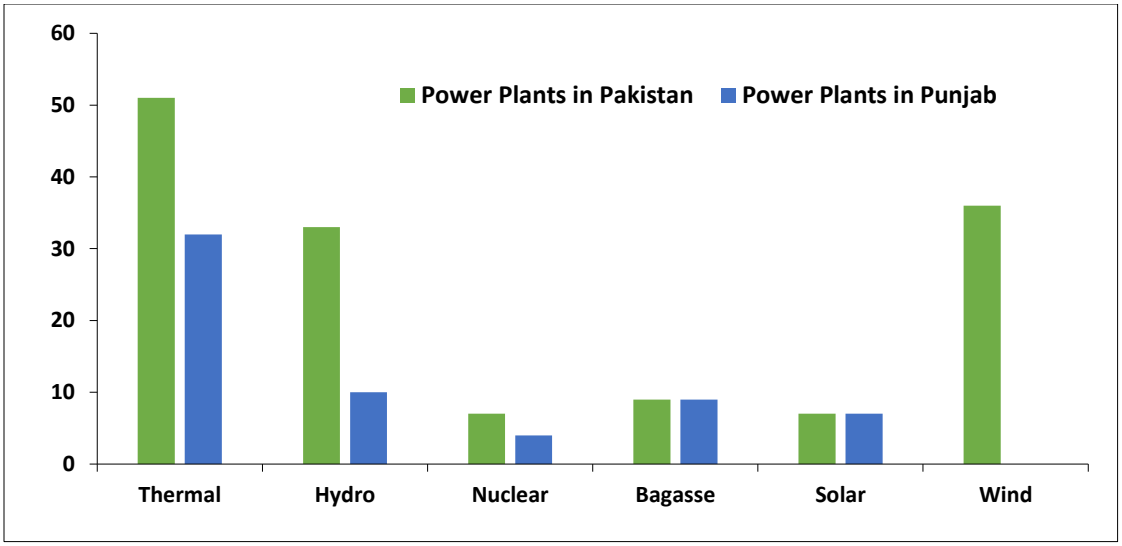


Figure 2-7: Power Plants in Punjab (by fuel)

The province is making advancements towards solarization at a rapid pace. So far, all the major solar power plants of the country are located in Punjab (Table 2-1)[7]. However, there is need to further enhance the dependency on renewable fuels and explore further options for renewable energy production such as wind power in the province. As reported by the Energy Department, Government of the Punjab, Punjab Energy Efficiency and Conservation Agency is executing solarization of public sector institutes, with a total solar potential of 19 MW, with an estimated GHG reduction of 9390 MT $CO_{2eq.}$ Furthermore, around 82,000 lights and 38,000 fans have been retrofitted in public sector institutes. Solarization and retrofitting is also underway in public hospitals.

Table 2-1: Power Plants located in Punjab along with dependable capacity (2022)[8]

Fuel	Power Station	Place of Power Station	Dependable capacity (MW) (June 2022)
Hydel	Ghazi Barotha	Ghazi Barotha	1450
	Rasal	Rasal	22
	Chashma	Chashma	184
	Jinnah Hydel	Mianwali	96
	Shadiwal	Shadiwal	14
	Chichoki Mallian	Sheikhupura	13
	Nandipur	Gujranwala	14
	Renala	Renala	1
	Marala Hydro (PPDCL)	Sialkot	8

[7] State of Industry Report (2022), NEPRA
[8] State of Industry Report (2022), NEPRA

Thermal	TPS Muzaffargarh	Muzaffargarh	1085
	Saba Power	Farooqabad	123
	GTPS Faisalabad	Faisalabad	114
	TPS Nandipur	Nandipur	411
	Lal Pir Power	Mehmood Kot	350
	Pak Gen.Power	Mehmood Kot	350
	Altern Energy	Fateh Jang	0
	Fauji Kabirwala	Kabirwala	151
	Japan Power	Raiwind	0
	KAPCO	Kot Addu	1345
	Kohinoor Energy	Raiwind	124
	Rousch Power	Sidhnai	395
	Southern Electric	Raiwind	0
	Attock Gen	Attock Morgah	156
	Atlas Power	Sheikhupura	214
	Saif Power	Sahiwal	204
	Orient Power	Balloki	203
	Nishat Power	Kasur	195
	Nishat Chunian	Kasur	196
	Sapphire Electric	Muridke	202
	Halmore Power	Bhikki	197
	Narowal Energy	Narowal	214
	Liberty Power Tech	Faisalabad	196
	Davis Energen	Jhang	0
	Huaneng Shandong Ruyi (Sahiwal Imported Coal)	Sahiwal	1243
	QATPL (Bhikki)	Bhikki	1163
	NPPMCL (Haveil Bahadur shah)	HBS	1181
	NPPMCL (Balloki)	Balloki	1172
	Reshma Power	Raiwind	0
	Gulf Powergen	Gujranwala	0
	Punjab Thermal Power Pvt. Ltd	Trimmu	1263
Nuclear	CHASNUPP - I	Chashma	301
	CHASNUPP - II	Chashma	315
	CHASNUPP - III	Chashma	315
	CHASNUPP - IV	Chashma	315
Solar	Quaid-e-Azam Solar Power	Bahawalpur	100
	Apolo Solar Development	Bahawalpur	100
	Best Green Energy	Bahawalpur	100
	Christ Energy	Bahawalpur	100
	AJ Power	Khushab	12
	Harappa Solar	Sahiwal	18
	Zhenfa Pakistan New Energy Company Ltd.	Layyah	100

Biomass Power Projects	JamalDin Wali II	RYK	24
	JamalDin Wali III	RYK	24
	RYK Mills	RYK, Punjab	25
	Chiniot Power	Chiniot Punjab	63
	Fatima Energy	Muzaffargarh	45
	Hamza Sugar Mill	RYK	15
	The Thal Industrial Corporation	Layyah	25
	Almoiz Industries	Mianwali	36
	Chanar Energy	Faisalabad	22

1.4 Forests and Biodiversity

Punjab has a diverse network of Subtropical Dry Scrub Forests, Tropical Dry Thorn Forests, Tropical Dry Broadleaved Forest and Subtropical Pine Forests situated in the Subtropical Sub-Himalayan and temperate regions to the south of tropical Indus plains. Punjab Forest Department reports the state of forest in terms of the total area planted, plantable blank, un-plantable blank, total blank and the area needing revenue verification. On the basis of this categorization, the latest available map of forests in Punjab for the year 2021 given in Figure 2-8, shows that 778,306 acres of land in Punjab is planted, whereas 337,792 acres of plantable land is lying blank.

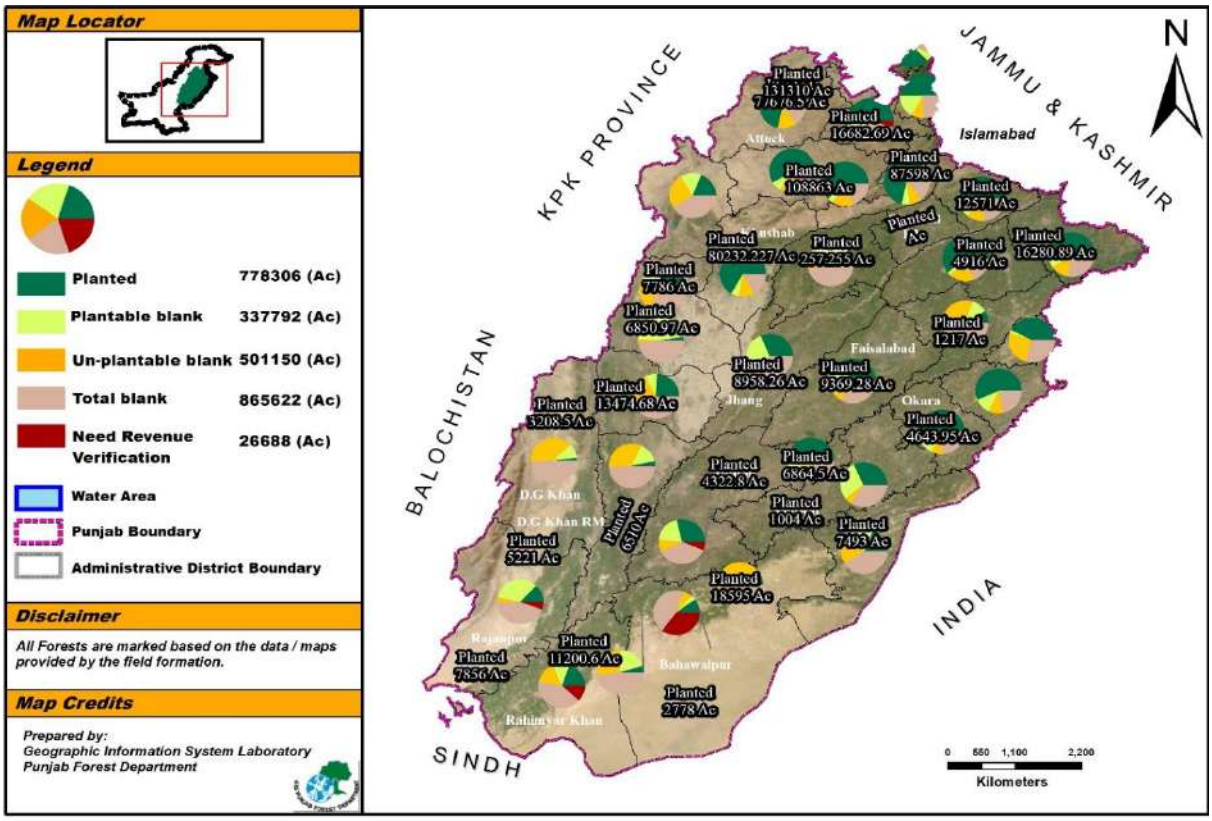


Figure 2-8: Forest Map of Punjab (2021)

The periodic (2013-21) change in forest area based on above categories depicts a gradual increase in total planted area in the province, however the total unplanted/blank area is quite higher than the planted area (.)[9]. Punjab has more than 350 protected forests, covering an area of around 560,000 acres of land[10].

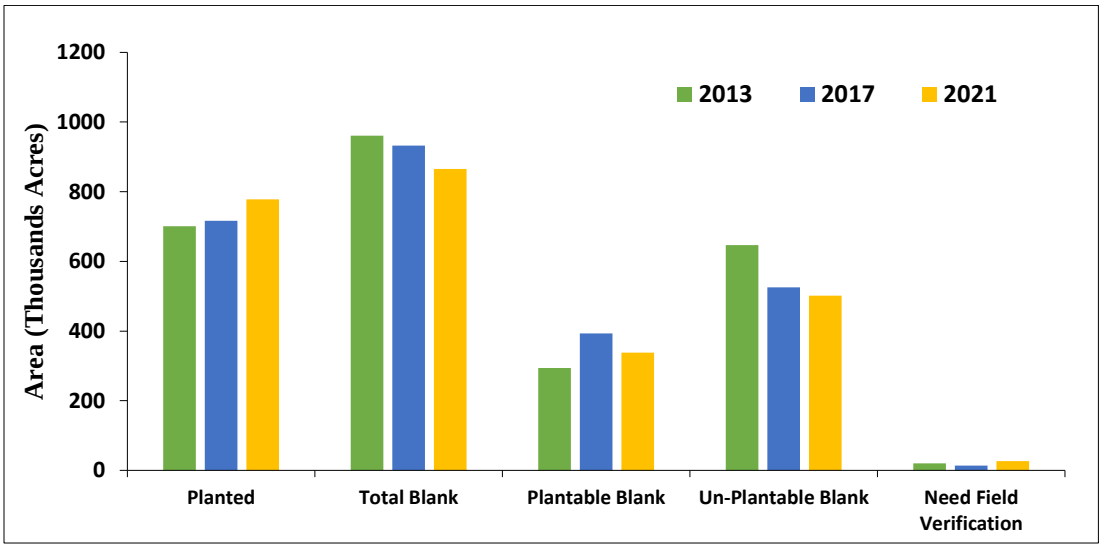


Figure 2-9: Forest Cover Change in Punjab

The flora and fauna in Punjab is diversely distributed on the basis of topography and geography of the province. In sub-tropical Chir Pine forests of the northern region *Pinus roxburghii* (Chir) forms practically the entire forest canopy. The other coniferous species are *Pinus wallichiana*, *Cedrus deodara*, *Picea smithiana* and *Abies pindrow*, including broad leaf species of *Quercus*. The riverine flora ('Belas') include *Acacia nilotica, Dalbergia sissoo* and other species of deciduous plants. Scrub forests are dominated by *Acacia modesta and Olea ferruginea.* The desert area of Cholistan supports thorn forest species including *Prosopis cineraria, Capparis decidua, Salvadora oleoides, Tamarix aphylla* and *Zizyphus jujube,* etc.

The relative abundance of wildlife species is declining globally. It has been reported that there has been a 69% decline in average relative abundance of wildlife globally, with 55% decline reported in Asia and Pacific[11], the region wherein the province of Punjab falls. Deforestation, overgrazing by livestock and land use change are the major drivers of biodiversity loss. Some of the key wildlife species in Pakistan including the Punjab have been listed as vulnerable (VU) or endangered (EN) globally by International Union for Conservation of Nature[12]. Whereas species like Chinkara, Blackbuck, Barking Deer, Indian Monitor Lizard, Cheetal, Neel Gaye, Indian Hog Deer are high priority conservation species due to alarming decline in their population at local levels.

[9] Punjab Forest Department
[10] Forests, Wildlife and Fisheries Department, Government of the Punjab
[11] WWF (2022) Living Planet Report 2022 – Building a nature positive society. Almond, R.E.A., Grooten, M., Juffe Bignoli, D. & Petersen, T. (Eds). WWF, Gland, Switzerland.
[12] Wildlife and Parks Department, Government of the Punjab

Table 2-2: -List of Endangered Species in Punjab

Sr No.	Name	IUCN Status	Date Assessed
1.	Asiatic Black Bear	VU	17 March 2016
2.	Black Partridge	VU	11 August 2021
3.	Common Leopard	VU	23 October 2022
4.	Fishing Cat	VU	21 June 2016
5.	Goral	NT	14 January 2020
6.	Great Indian Bustard	CR	17 August 2018
7.	Hog Deer	EN	03 December 2014
8.	Honey Badger	NT	28 February 2015
9.	Houbara Bustard*	VU	05 April 2023
10.	Indian Pangolin	EN	10 May 2019
11.	Indus River Dolphin	EN	01 August 2021
12.	Panther	VU	11 July 2015
13.	Punjab Urial	VU	16 March 2020
14.	Sambar Deer	VU	17 November 2014
15.	See-see Partridge	VU	01 October 2016
16.	Smooth Coated Otter	VU	21 January 2020
17.	Striped Hyaena	VU	02 October 2014
18.	White Rumped Vulture	CR	07 July 2021
*** Migratory, IUNC (International Union for Conservation of Nature)**			

The total area of high conservation priority in Punjab is estimated to be around 63,695 km², accounting for 29.72% of its landmass. Additionally, there are 120,788 km² (56.35%) designated with a moderate conservation value, and 28,870 km² (13.93%) with a low conservation priority. The protected area within Punjab comprises merely 1.03% of its total area[13]. There are total 5 National Parks, 36 wildlife sanctuaries, and 23 Game Reserves in the Province[14]. Moreover, Chashma Barrage, Taunsa Barrage and Uchhali Complex are recognized Ramsar Sites in Punjab. Under the Punjab Protection (Preservation, Conservation and Management) Act, special permission is mandated for any developmental activities within wildlife sanctuaries and national parks.

In the context of wildlife conservation, a network of *in-situ* and *ex-situ* conservation sites have been established throughout the Province.

[13] Punjab Spatial Strategy, 2047
[14] Wildlife and Parks Department, Government of the Punjab

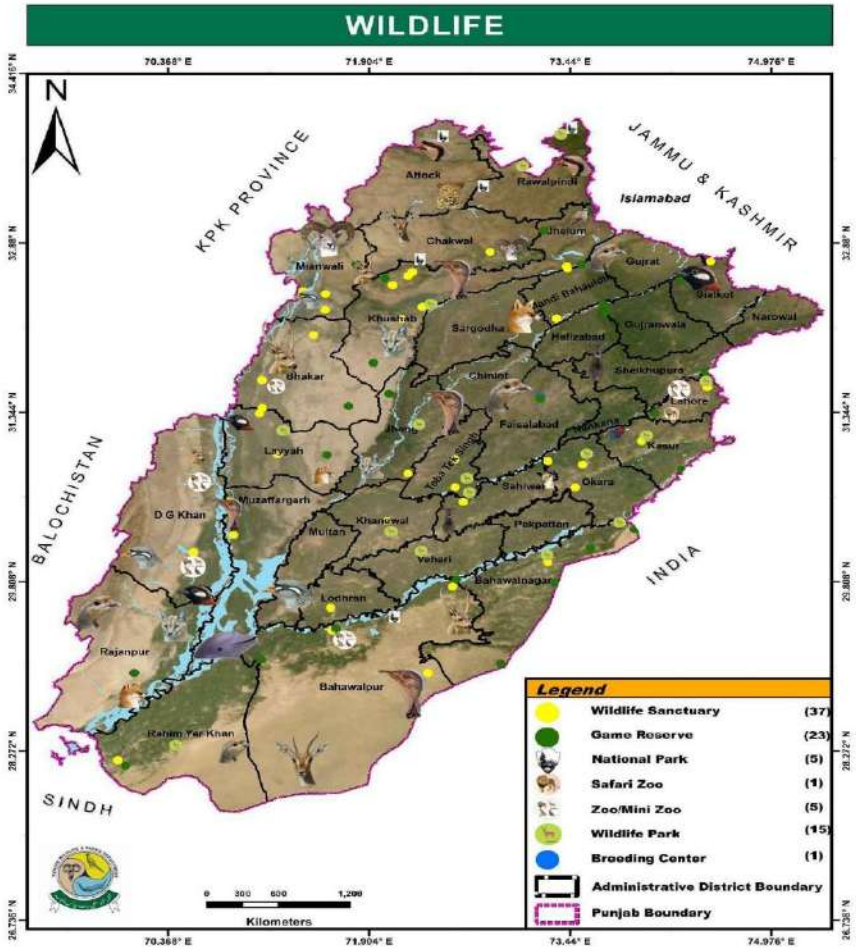


Figure 2-10: Wildlife Conservation Facilities in Punjab Pakistan

1.5 Transport

In Punjab, the common modes of transport range from heavy transport vehicles (trucks, buses, trolleys, etc.) to low transport vehicles (rickshaw, taxi, vans, cars) and two-wheelers (motorbikes, bicycles, etc.). Roads and Railways are common modes of inter-city transportation. The major metropolises including Lahore, Multan and Rawalpindi have mass transit systems in place. In some rural areas, animal-based transport is also common. Transport and communication sector contributes 58.2% in national sectoral value[15]

1.6 Mines and Minerals

In Punjab, the major mineral production is of argillaceous clay, coal, limestone, rock salt, silica sand. The year-wise (2017-2022) data on the mineral production indicates more than 30,000 hundred metric tons/year production of limestone in Punjab, followed by argillaceous clay, which is above 59,000 hundred metric tons. On a logarithmic scale, the extraction of limestone has remained maximum among other minerals as reported during 2017-2022.

[15] Punjab Growth Strategy 2018-2023 (2018)

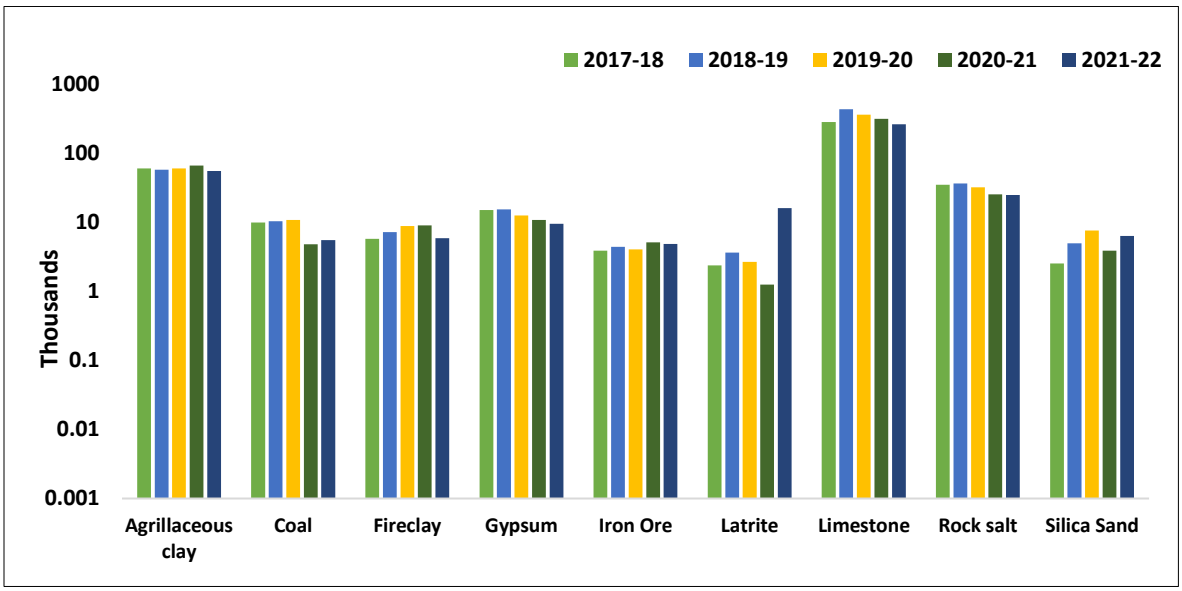


Figure 2-11: Mineral Production in Punjab from 2017 - 2022 (Logarithmic Scale)

Although mining and mineral production is a key economic sector, it has remarkable impacts on environmental and ecological resources. A recent study conducted in District Chakwal confirms high levels of contamination in soil and underground water. The soil and water were found contaminated with high levels of Total dissolved solids (TDS), salts and heavy metals, attributed by both the saline and acidic mine drainage, in and around the coal mines[16].

1.7 Agriculture and Livestock

Most of the total cropped area in Punjab is covered by wheat crop (46%), followed by rice (16%) and others[17].The statistics further reveal that agriculture is a major water-dependent sector, as 89% of sown area is irrigated through various sources of surface and groundwater. Canals and tube-wells are the main source of irrigation in Punjab[18].

[16] Muneeb, A., 2021, Status of Soil And Water Pollution At The Largest Coal Mining Area Of Punjab, Pakistan, Fresenius Environmental Bulletin 30(01):441-447 (https://www.researchgate.net/publication/358285867_STATUS_OF_SOIL_AND_WATER_POLLUTION_AT_THE_LARGEST_COAL_MINING_AREA_OF_PUNJAB_PAKISTAN)

[17] Punjab Bureau of Statistics

[18] Statistical Book of Punjab 2023 (Pg. 72)

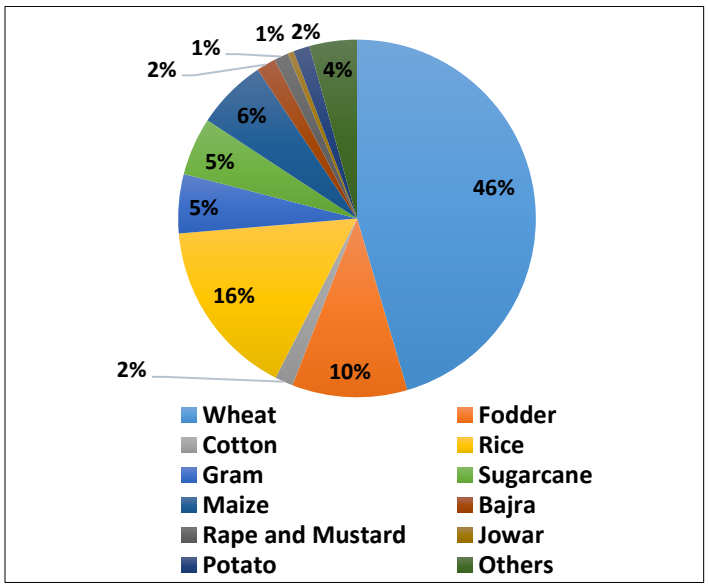


Figure 2-12: Crop-wise distribution of cropped area in Punjab

Livestock plays an important role in the uplift of the rural economy with a 14.36% share in the National GDP and 62.68% contribution in Agricultural GDP. Livestock is also a major economic sector of Punjab. The share of Punjab in Pakistan's livestock population is 60%[19].

1.8 Industry

Punjab is known for its rapid industrialization. Punjab is an economic center of Pakistan, with main industrial hubs clustered in its large metropolises such as Lahore, Gujranwala, Faisalabad, Sialkot, Sargodha, Mianwali, Jhang, Khushab and Chakwal. Faisalabad is the main point of industrial activity in the province, followed by Lahore[20].

The manufacturing sector contributes around 20% in total economic output of the country[21]. As of 2023, a total of 32,258 manufacturing industries are located in Punjab, mainly including the textiles, construction material, glass, furniture and grain mill production units[22].

1.9 Water, Sanitation and Hygiene (WASH)

Access to safe drinking water, sanitation and hygiene (WASH) is a fundamental right for good health, welfare and productivity and is widely recognized as a human right[23] as implicit under Article 9 of the Constitution of Pakistan, "No person shall be deprived of life or liberty, save in accordance with the law." United Nations General Assembly, on 28 July 2010, through Resolution 64/292, explicitly recognized the human right to water and sanitation and acknowledged that clean drinking water and sanitation are essential to the realization of all human rights.

[19] Livestock Department, Government of the Punjab
[20] Census for Manufacturing Industry (CMI) (2015-2016)
[21] Punjab Board of Investment and Trade (PBIT) (http://www.pbit.gop.pk/manufacturing)
[22] Bureau of Statistics, Government of the Punjab
[23] The human rights to water and sanitation were explicitly recognized by the UN General Assembly and Human Rights Council in 2010 and in 2015. Punjab Multiple Indicator Cluster Survey 2017-18

Rapid urbanization and a growing population in Punjab will continue to increase demands for sectors (Health, Education, Agriculture & Industry) and sub-sector services (water supply and sewerage issues, drinking water availability, solid waste management, sanitation and hygiene etc.). As per the Punjab Multiple Indicator Cluster Survey (MICS) 2018, about 98% of the population has access to improved source of drinking water. Tap water is available to 18.8%, motorized pumps to 37.5% and 25.3% population uses hand pumps. Around 63.8% of households are without *E. coli* contamination in drinking water (66.6% in rural areas and 60.8% in urban areas). Total 80.1% of the population is living in households using improved sanitation facilities, which is higher in urban (92.8%) as compared to rural areas (72. 8%).

As per the MICS 2018, it was observed that about 98.3% of the households had a specific place for hand washing, while only 1.7% households could not indicate a specific place where household members usually washed their hands. Among households where a place for hand washing was observed, almost 92.1% had both water and soap (or another cleansing agent) present at the specific place, and this was higher in urban (96.7%) as compared to rural areas (89.4%)[24].

1.10 Social Sector

1.10.1 Gender

Women are almost half of the population in Punjab but their representation in national assembly is only 20% of total 341 members while in Punjab out of 27 resolutions passed, only 4 were led by female MPAs. Similarly, women are 40% on gazette seats. Their under representation is not only restricted to these sectors but gender gap also persists in economic participation and opportunities as well that is responsible for widening socio-economic disparities as female Labor Force Participation (LFP) in Punjab is 27.8% as compared to 74.2% male LFP[25].

1.10.2 Employment

Employment growth rate is higher in Punjab than the national level.[26] As per Labour Force survey 2020-21, numbers of employed persons in Pakistan increased from 64.03 million in 2018-19 to 67.25 million in 2020-21. In Punjab it is increased from 38.21 million in 2018-19 to 39.07 million in 2020-21. But at national level the change is more significant in rural areas from 42.9 million in 2018-19 to 45.70 million in 2020-21 than in urban areas where it was just 21.10 to 21.55 million during the same timeframe. At provincial level employment numbers increased more 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 2-3).

[24] Punjab Growth Strategy, 2023
[25] Gender parity report 2022
[26] Punjab Growth Strategy, 2023

Table 2-3: Employment- Pakistan and Punjab

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
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

1.10.3 Inequality and Poverty

Punjab province has remained at the top in comparison to other provinces in Pakistan pertaining to higher human development indicators and prosperity. However, there are very sharp regional disparities found within the province. Employing a multidimensional measure of poverty[27], which considers different factors as income levels, education attainment, health and standards of living, it becomes evident that the rural areas of the province are more deprived as compared to the urban areas i.e., 6.3% of the population in urban areas can be considered poor under this multidimensional index while the incidence soars to 43.7% in rural areas.[28] Information on growth and poverty patterns of Punjab shows that by decrease of 1% in the inequality ratio will reduce multidimensional poverty by almost 0.4%[29].

Starting from 1998-99 to 2018-19, there is continuous decline in poverty rate across Punjab (**Error! Reference source not found.**) due to two possible reasons, (i) periods of high economic growth translated into poverty reduction, (ii) successful implementation of traditional and modern programs for alleviating poverty.[30]

[27] Multidimensional poverty index is a common tool to assess severity and patterns of poverty in a region.
[28] Punjab Education Sector Plan 2019/20 – 2023/2024
[29] Punjab Growth Strategy, 2023
[30] Poverty Trend in Pakistan -A Glimpse from Last Two Decades, Pakistan Institute of Development Economic (PIDE), Poverty Trend in Pakistan, published by 2021.

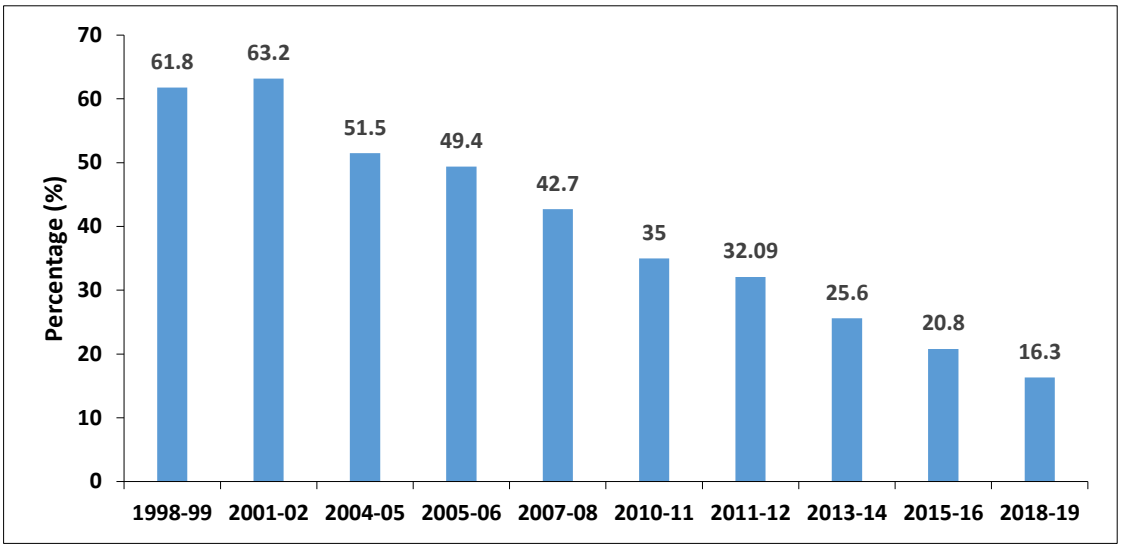


Figure 2-13: Poverty Trends in Punjab

However, it is worth mentioning that Southern Punjab has remained the most deprived zone relative to Central and Northern Punjab (Table 2-4)[31].

Table 2-4: Division/region wise incidence of poverty, 2017-18 (%)

Division	Incidence of poverty	Region	Incidence of poverty
DG Khan Division	52.25	Southern Punjab	42.03
Bahawalpur Division	42.66		
Multan Division	32.27		
Sargodha Division	30.36	Northern Punjab	18.98
Sahiwal Division	32.62		
Faisalabad Division	23.96		
Gujranwala Division	11.55	Central Punjab	26.12
Lahore Division	16.21		
Rawalpindi Division	9.91		

1.10.4 Child Labour

Definition of child labour is described in two categories; one is involvement in economic activities and other is household chores based on different age groups.[32] However, they are classified as child laborers if they are either too young to work or are involved in any activity which may compromise their physical, social, mental, or educational development.[33] In Punjab, 15% of children aged 5 to 17, 8% of those in 5 to 11 years and 28% between 15 to 17 years are involved in child labor. A major share of child labour is of boys than girls and more children are from rural areas as compared to urban areas. A

[31] Punjab Growth strategy 2023

[36],[33] MICS-2018

disproportionate share of children who married at age of 15 and 18 years either did not attend school or are uneducated.[34]

The Punjab Restriction on Employment of Children Act, 2016 is to prohibit the employment of children and restrict the employment of adolescents in certain occupations and processes. The Education Credential Assessment (ECA) defines a child to mean a person who has not completed his/her fourteenth year of age. The ECA states that no child shall be employed or permitted to work in any of the occupations (such as transport sector, railways, construction, and ports) or in any workshop wherein any of the processes defined in the act is carried out.[35]

1.10.5 Education

Education is one of the fundamental factors for increasing the productivity and enhancing the employment creation. Punjab has a young population; more than one-fourth of the total provincial population is of school going age. There are two demographic characteristics that make education planning in Punjab complex. The first: most of the 110 million people living in this province (63.3%) reside in rural areas. The second: internal migration is very significant.[36]

During the last five years, Punjab has shown substantial progress in school participation, but disparities by gender, location and socioeconomic status persist, and children are less likely to continue beyond primary school. About 25% of the population of Punjab is of school-going age and 10.5 million children of school age (5-16 years) are out of school children (OOSC) in Punjab despite in the expansion of public and private schools. It is important to mention that 54% of the total OOSC aged 5-9 years majorly reside in the eight districts: Rahim Yar Khan, Dera Ghazi Khan, Rajanpur, Muzaffargarh, Multan, Bahawalnagar, Faisalabad and Lahore. Many of the OOSC are in hard-to-reach areas and special efforts will be required to facilitate them with learning opportunities.[37]

Table 2-5 shows that districts in southern Punjab with 48.5% of adult literacy rate lag in all key education indicators as compared to the rest of the Punjab with 61.9%. The overall adult literacy is much lower in the region.

Table 2-5: Status of Literacy in Punjab

Indicator		Rest of Punjab	Southern Punjab
Adult literacy rate %		61.9	48.5
Youth literacy %	Male	74.6	62
	Female	63.4	43.6
Student teacher ratio		23.9	26.4
Teacher per school (No.)		8.64	6.88
Enrolment per school (No.)		201.25	181.7
Out of school children (%)	Primary	28.9	44.4
	Lower secondary	16.1	31
	Upper secondary	48.7	63.8

[34] Pakistan (Punjab) Education Fact Sheets I 2022
[35] MICS-2018
[36] Punjab Education Sector Plan 2019/20 – 2023/2024
[37] Punjab Education Sector Plan 2019/20 – 2023/2024

Table 2-6 provides the total and gender wise rural and urban literacy rates in Pakistan and Punjab. Data shows that there is a slight increase in total literacy rate in Pakistan (62.4 to 62.8%) and Punjab (66.1-66.3) from years 2018-19 to 2020-21. Literacy rates in both males and females of rural areas in Punjab have increased marginally but for females in the urban areas they remained constant over specified timeframe (74.3%).

Table 2-6: Literacy Rates in Punjab compared to Pakistan

Area		Literacy Rate(%) (10 Years and Above)[38]					
		2018-19			2020-21		
		Total	Male	Female	Total	Male	Female
Pakistan	Total	62.4	73.0	51.5	62.8	73.4	51.9
	Rural	53.7	67.1	40.4	54.0	67.2	40.8
	Urban	76.1	82.2	69.7	77.3	83.5	70.8
Punjab	Total	66.1	74.3	58.1	66.3	74.2	58.4
	Rural	58.5	69.2	48.4	58.8	69.0	48.9
	Urban	78.3	82.2	74.3	78.5	82.5	74.3

1.10.6 Health and Nutrition

Improved healthcare service delivery can play vital role in bringing socio-economic sustainability and reducing poverty. Progressive and efficient health sector have potential to enhance human capital development and accelerate the economic growth. Therefore, upgradation in healthcare service delivery backs economic growth and progress and as a result development of both sectors can be achieved[39]. The health system across Punjab has improved significantly in the last decade because of the focused approach, allocation of resources and effective monitoring by the government. Despite improvements in health system, the health and nutrition indicators in the southern region of Punjab are still alarming due to issues such as low literacy rate, poverty and poor infrastructure.[40] However, Punjab demonstrates better nutrition outcomes as compared to other provinces.

While Punjab's stunting and underweight rates showed some improvement over the past two decades, wasting rates have been on the rise since 2021, indicating a long-term nutritional problem. As per MICS Survey comparison from 2011 and 2018, acute malnutrition, known as 'wasting' (15.1% in MICS 2011 and 7.5% in MICS-2018) is partly caused by arid conditions and occasional droughts in some areas. It is more broadly a manifestation of poverty, inadequate care and feeding practices, food insecurity (quantity, quality and diversity), unhygienic conditions including access to safe drinking water, and lack of timely and affordable health care. Stunting is associated with increased risk of illness and death, poor cognitive development, lower educational attainment and diminished life-long income generation potential.[41] Underweight, a type of chronic malnutrition (32.6% reported in MICS 2011 and 21.2% in MICS 2018) is mainly caused by low intake of food/nutrients over long periods, repeated illness/infections, eating disorders,

[38] Pakistan Labour Force Survey 2020-21
[39] Punjab Growth Strategy, 2023
[40] Provincial Nutrition Response Plan for COVID-19,
[41] Policy Brief: Highlights of Malnutrition in Punjab Province by world bank

digestive problems like inflammatory bowel disease and thyroid disease etc. High burden of underweight children is common in some southern districts of Punjab.[42]

Evidence shows that investing in nutrition can contribute to sustainable and equitable growth, improve school attainment by at least one year, increase wages by 5-50 percent and boost gross domestic product by 4-11 percent in Asia and Africa. Success in tackling malnutrition relies on cross-sectoral action plans encompassing at the very least health, food, agriculture, poverty and water and sanitation sectors. Provincial strategizing must be supported with federal coordination through the development of a national nutrition policy, funding commitments under Medium Term Budgetary Framework and links with key federal programs. Nutrition advocacy, community education, defining of affordable interventions, technical capacity building at districts and interim progress monitoring are key areas for investment in Punjab.[43]

[42] Scaling Up Nutrition (SUN) Provincial Unit Planning and Development Board Government of Punjab
[43] Policy Brief: Highlights of Malnutrition in Punjab Province by world bank

CHAPTER 3 AIR QUALITY

KEY FINDINGS

- The overall AQI $PM_{2.5}$ based ambient air quality in Lahore for the year 2023 and in all other 9 divisional headquarters of Punjab is rated as 'moderate'.
- Number of days of good air quality with respect to AQI $PM_{2.5}$ in Lahore have increased from 17 in 2022 to 75 in 2023.
- The highest concentration of $PM_{2.5}$ in Lahore was reported in January (373 µg/m^3) while the lowest value was recorded in September 10.5 µg/m^3.
- All 9 divisional headquarters had $PM_{2.5}$ concentrations higher than the PEQS value with Rawalpindi having the least and Multan having approximately 04 times higher concentration than PEQS on the particular monitoring day.
- About 67% Public Service Vehicles (PSVs) tested during December 18, 2023 to January 1, 2023 were declared fit (road worthy).
- Lahore district alone accounts for 27.18 % of the total registered vehicles in the province and remained at the top.
- Based on 232 industrial stack emission inspections carried out by Environmental Laboratories of EPA Punjab during 2023, compliance monitoring shows brick kilns, oil, fat, and vegetable ghee processing units, flour mills, petroleum refineries, pharmaceutical facilities, plastics manufacturing plants, pyrolysis operations, protein factories, and wood product manufacturing industries to be rated as 'Very poor', while, paints and dyes factories and thermal power generation plants are rated as 'Poor' on the basis of monitored parameters.
- Thermal power plants, cement factories, and textile mills are primary NO_x emitters, while SO_2 surpass limits in power plants; multiple industries emit excessive CO, whereas all the industries inspected except sugar mills had the smoke emissions exceeding the prescribed PEQs limits.
- Government of the Punjab is striving hard for providing clean air to the inhabitants of Punjab. Various government departments are actively taking measures to control increasing air pollution at their various tiers.

1 OVERVIEW

Air is the first component of environment defined in the Punjab Environmental Protection Act 1997 (Amended 2012)[44]. The quality of air determines the quality of human life. Pakistan is experiencing an increase in air pollution attributed to the population growth, urbanization, industrial expansion, burgeoning economic development, inadequate regulatory policies, road dust and vehicles with weak emission control measures. Moreover, elevated concentration of pollutants and smog generation during the winter season are attributed to meteorological conditions such as low wind speed, limited air dispersion and temperature inversion.

Punjab Environmental Quality Standards for Ambient Air, 2016 provide permissible/acceptable concentration levels in ambient air and their methods of measurement. Currently, Environment Protection and Climate Change Department (EPCCD) has a limited setup of fixed Air Quality Monitoring Stations (AQMS) in Punjab. However, the availability of a mobile air quality monitoring station facilitates in measuring concentration of pollutants in areas lacking fixed AQMS.

2 ENVIRONMENT

2.1 Ambient Air Quality and AQI

Ambient air refers to the atmospheric air in its natural state comprising what surrounds us and what we breathe. Elevated levels of air pollutants such as, particulate matter, exhaust gases, smoke, dust particles, odour, light, electromagnetic radiation, heat, fumes, hazardous substances and radioactive materials lead to a decline in the overall quality of ambient air.

The Air Quality Index (AQI) is a numerical scale used to determine the level of air pollution in a specific location and it is calculated based on criteria air pollutants such as particulate matter ($PM_{2.5}$ and PM_{10}), sulphur dioxide (SO_2), Nitrogen dioxide (NO_2), carbon monoxide (CO), ozone (O_3) and Lead (Pb). The daily value of Air Quality Index (AQI) is disseminated through official website of EPCCD[45]. Table 3-1 provides colour illustration of AQI values and required public response levels[46].

Table 3-1: AQI categories, colour illustration and required response level

AQI	AQI Category	Colour Code & Response Level
0-50	Good	Prevention
51-100	Satisfactory	
101-150	Moderate	Preparedness
151-200	Unhealthy for sensitive group	Alert
201-300	Unhealthy	Warning
301-400	Very Unhealthy	Emergency
401-500+	Hazardous	Severe

[44] Under section 2 (x) of the Act *ibid*
[45] https://epd.punjab.gov.pk/aqi
[46] https://epd.punjab.gov.pk/system/files/Health%20Advisory%20Notification_0.pdf

2.2 Overview of air quality in the nine divisional headquarters of Punjab (Excluding Lahore)

Ambient air quality monitoring was carried out in 09 Divisional HQs by EPA Punjab on a single day at each city during August 17-30, 2023 through mobile air quality monitoring station. Figure 3-1 shows that all Divisional HQs had $PM_{2.5}$ concentrations higher than the PEQS value (15 µg/m^3) with Rawalpindi having the least and Multan with the highest concentration (approximately 04 times higher than the standard value) on the particular monitoring day.

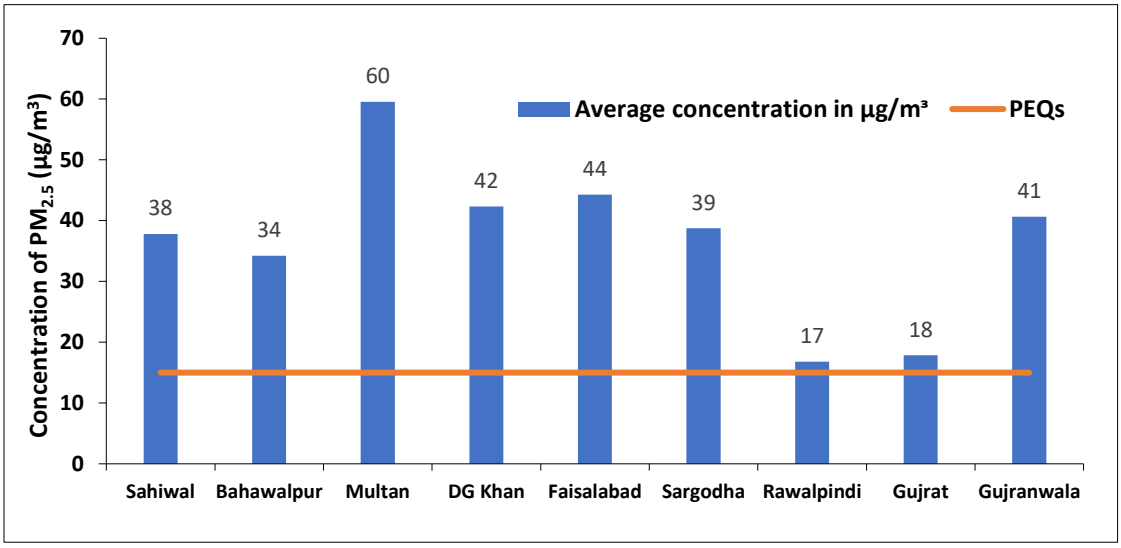


Figure 3-1: Monitoring of ambient air quality at 09 divisional HQs

Figure 3-2 shows the geographic distribution of the monitoring sites across the 09 divisional headquarters along with AQI values (based on $PM_{2.5}$) that were satisfactory for Rawalpindi (55), Gujrat (58) and Bahawalpur (97) only while all other divisional headquarters showed moderate values with highest in Multan (135).

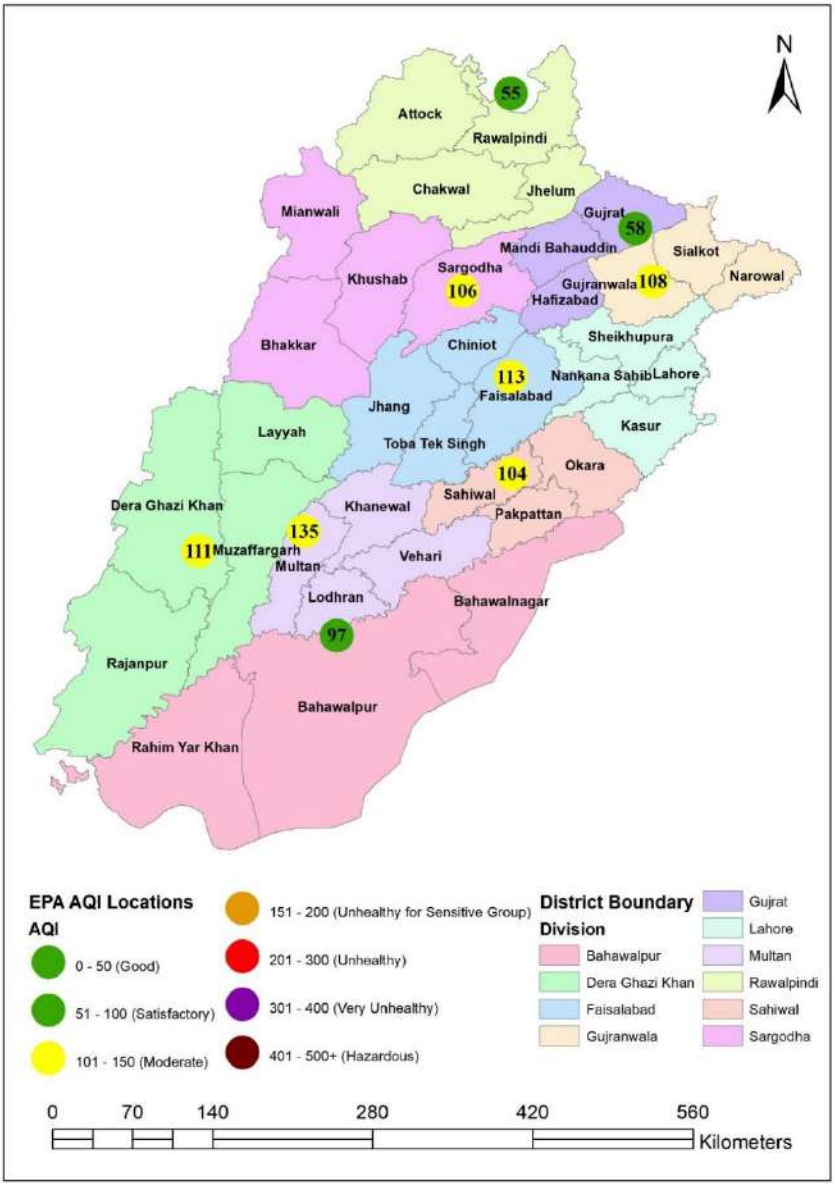


Figure 3-2: Ambient air quality monitoring of 09 Divisional HQs (AQI-$PM_{2.5}$)

2.3 Air quality of Lahore

In 2023, the concentration of $PM_{2.5}$ was monitored at multiple locations in Lahore using a mobile air quality monitoring station (Figure 3-3). Highest concentration of $PM_{2.5}$ (373 µg/m^3) was noted in January with corresponding AQI value of 427, while the minimum concentration of $PM_{2.5}$ (11 µg/m^3) and AQI (35) were measured in September (*Figure 3-4*). On an average, concentration of $PM_{2.5}$ (78.49 µg/m^3) has remained five times higher than the standard value with moderate AQI value (143).

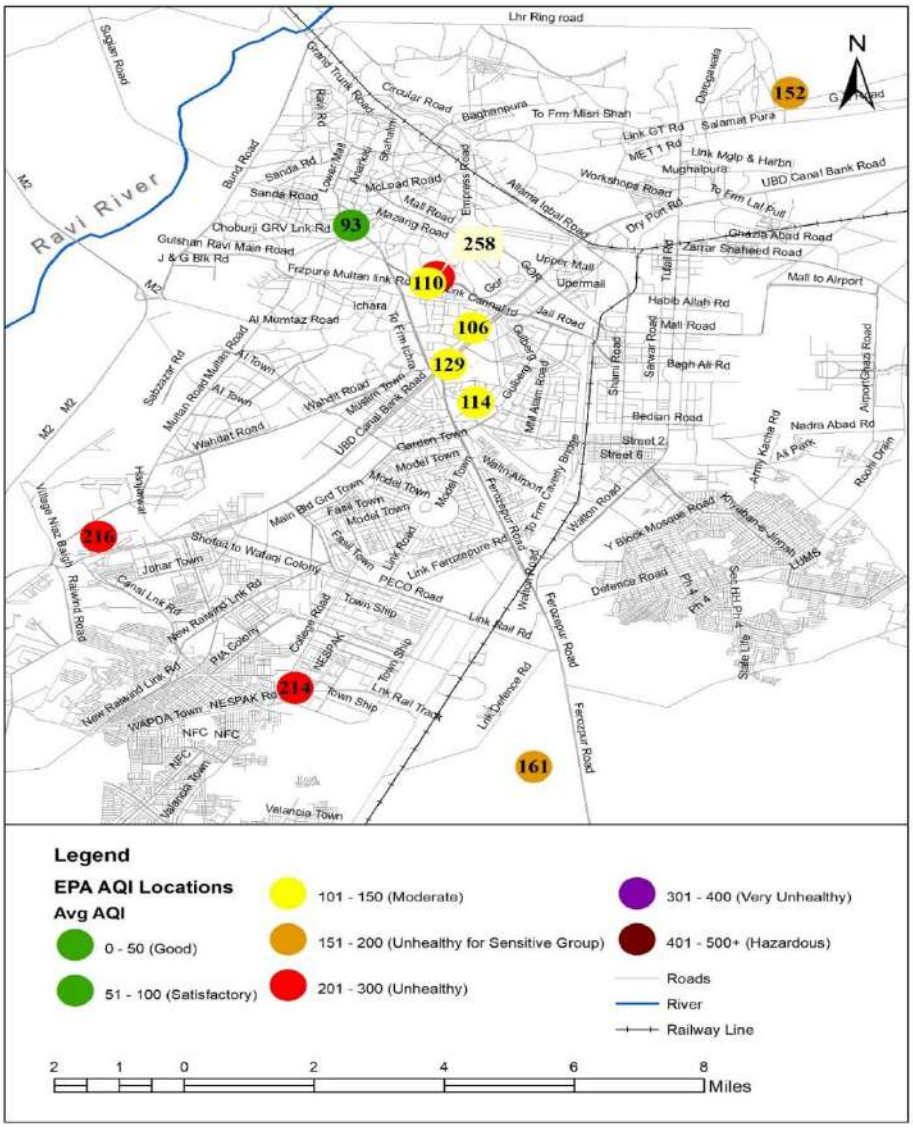


Figure 3-03: Monitoring of AQI-$PM_{2.5}$ at various locations in Lahore

For the years 2022 and 2023, the value of AQI on the same dates is presented in *Figure 3-4*.

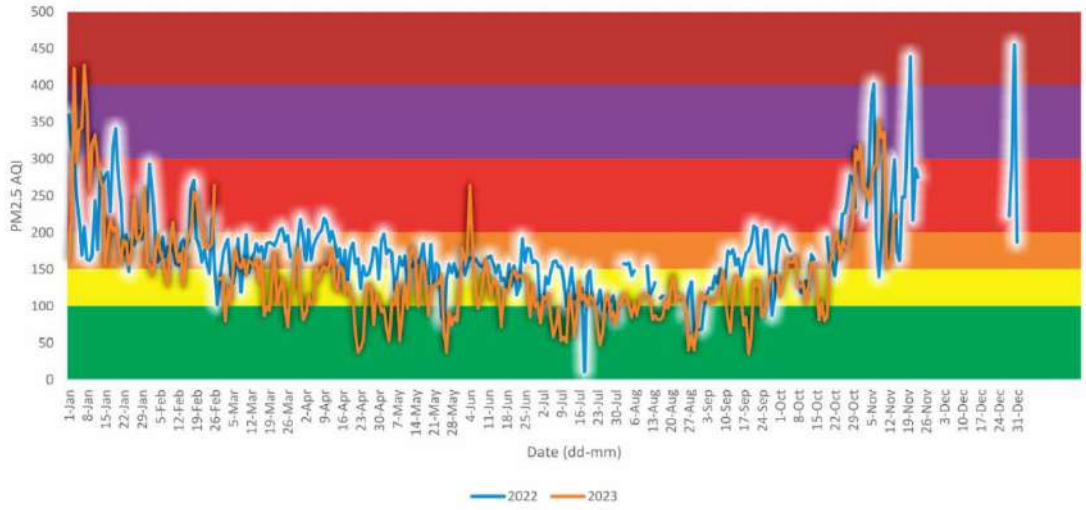


Figure 3-04: Comparison between AQI-$PM_{2.5}$ values of Lahore in 2022 and 2023

The trend analysis of the annual average $PM_{2.5}$ concentration during 2019 and 2023, as monitored by the Air Quality Monitoring System (AQMS) installed at the US Consulate in Lahore, indicates that the values consistently exceeded the standard PEQs threshold (*Figure 3-5*).

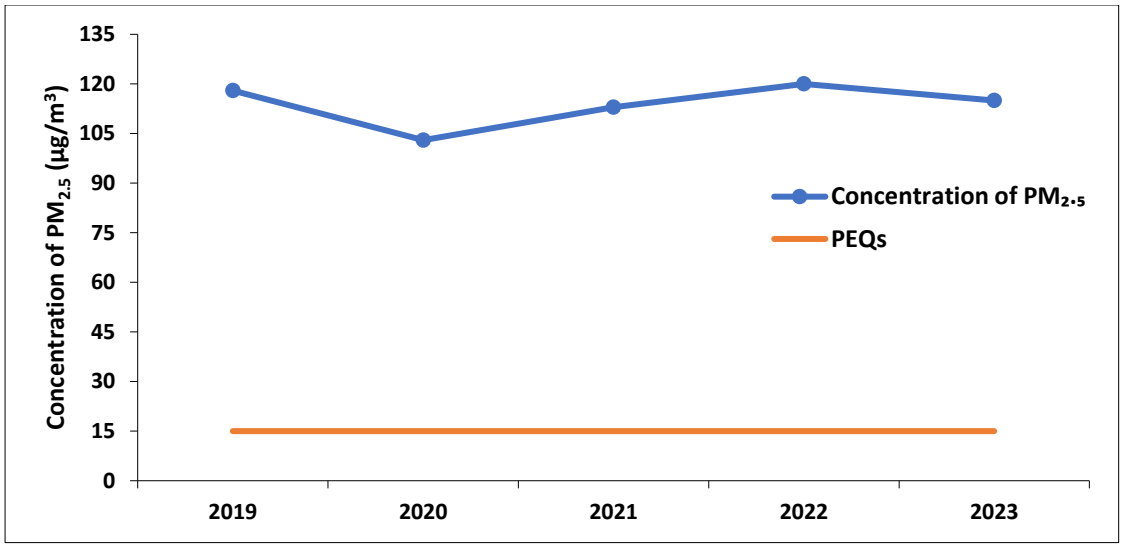


Figure 30-5: Measurement of Concentration of $PM_{2.5}$ from 2019 to 2023

Figure 3-6 shows that the numbers of days of good air quality with respect to AQI $PM_{2.5}$ value in Lahore have been increased from 17 in 2022 to 75 in 2023, while numbers of days of unhealthy air have been reduced from 154 in 2022 to 71 in 2023. But still the urbanites experienced 113 days of unhealthy-hazardous air quality.

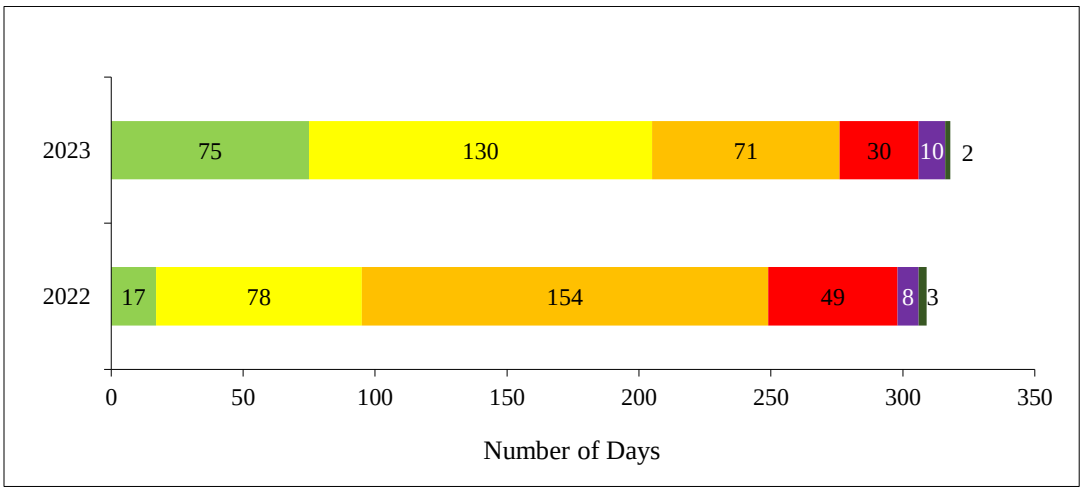


Figure 3-6: Number of days with respect to AQI ($PM_{2.5}$) air quality in Lahore in 2022 and 2023

2.4 Satellite based monitoring of atmospheric trace gases

The annual average concentrations of two major atmospheric trace gases viz. Carbon monoxide (CO) and Nitrogen dioxide (NO_2) measured by TROPOMI sensor on-board Sentinel-5P satellite during 2022 and 2023 over the Punjab are shown in Figures 3-7 and 3-8. These figures show the total column annual average pollutant concentrations and their hotspots (areas of high concentrations) in the Punjab.

Figure *3-7*3-7 shows that the total column annual average CO concentration ranged from 27 mmol/m^2 to 43 mmol/m^2. The major hotspots in 2023 were observed in and around districts Lahore, Kasur, Sheikhupura, Nankana Sahib, Faisalabad, Okara, Gujranwala and Multan. In comparison to 2022, higher concentrations of CO in central and southern Punjab and significant increase in urban areas are observed in 2023. Relatively lower concentrations are observed in Potohar and arid districts and southern parts of the province.

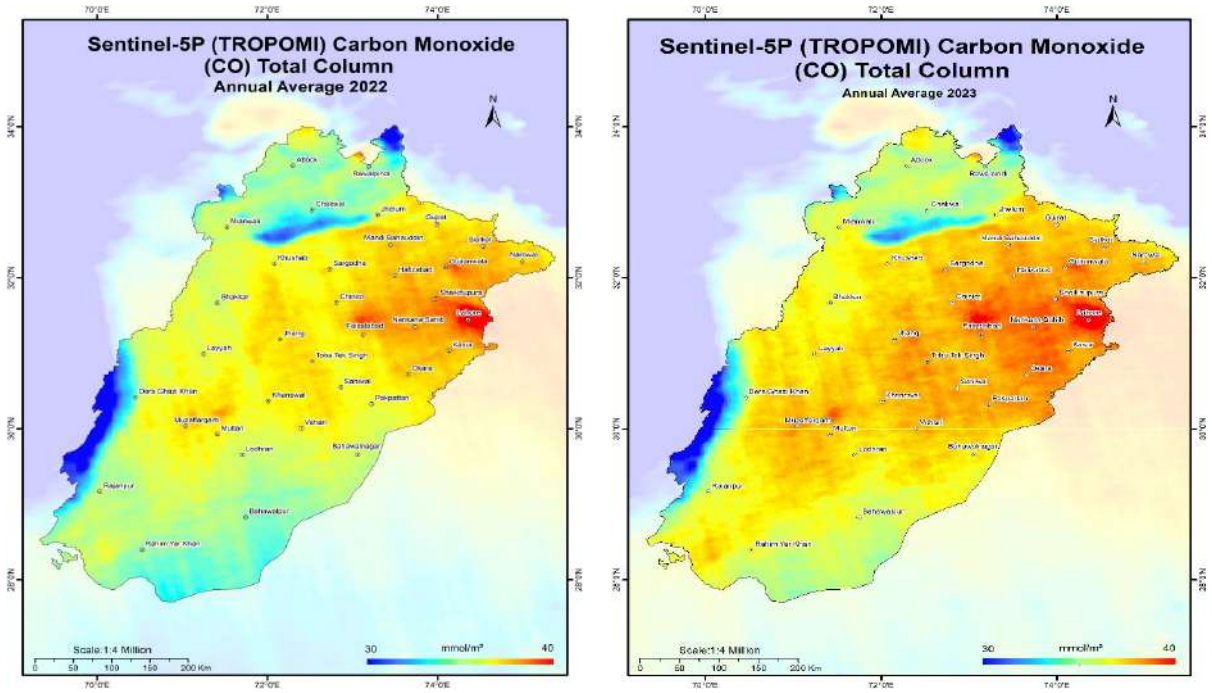


Figure 3-7: Annual averaged concentration of CO (mmol/m²) during years 2022 and 2023

Error! Reference source not found.3-8 shows that the annual averaged tropospheric column nitrogen dioxide (NO_2) concentration ranged from 13 µmol/m² to 133 µmol/m² in 2023. The major hotspots were observed in districts Lahore, Kasur, Sheikhupura, Faisalabad, Gujranwala, Mianwali, Multan and Rawalpindi. Vehicular emissions are the main source of this atmospheric trace gas, as is evident from its city and urban hotspots. In comparison to the last year (2022), a decrease in its concentration has been observed in the city hotspots during 2023. Overall, relatively lower concentrations are observed in the southern parts of the province.

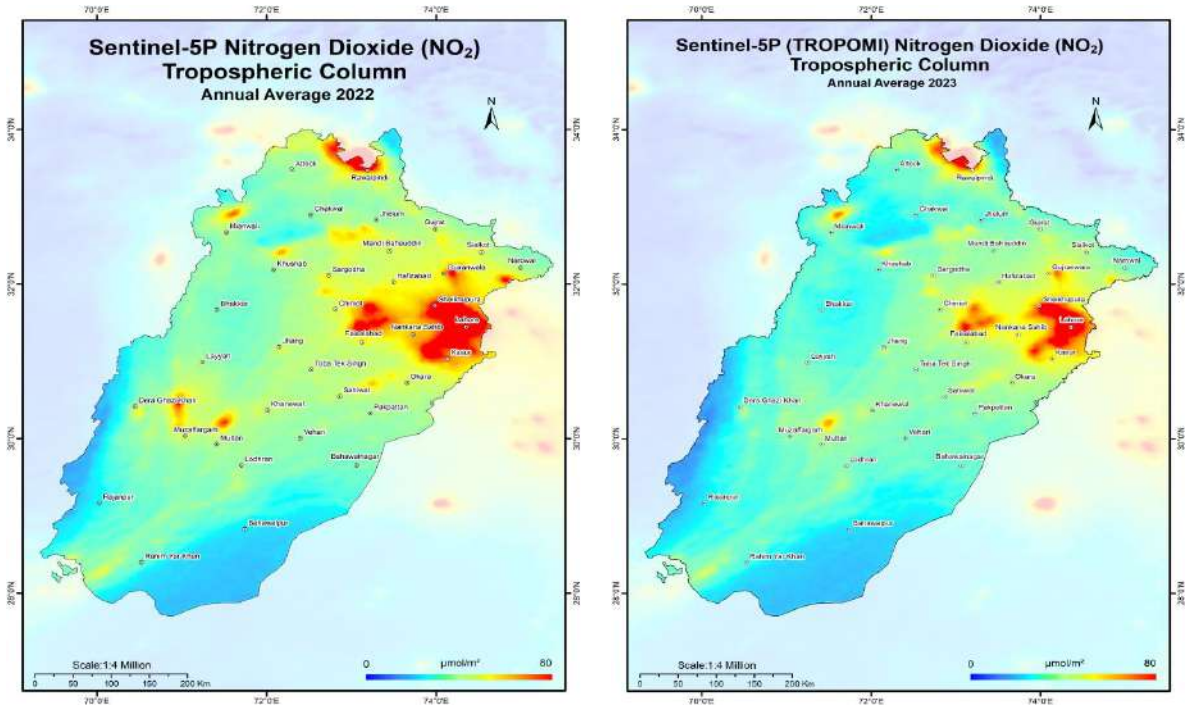


Figure 3-8: Annual averaged concentration of NO_2 (µmol/m²) during years 2022 and 2023

2.5 Industrial Monitoring and Vehicle Inspection

Industrial and vehicular emissions are among the main sources of air pollution in the Punjab. Industrial emission monitoring is being carried out by the Environmental Protection Agency Punjab, whereas vehicular monitoring is being carried out by the Transport Department through a public-private partnership. Details are given below:

2.5.1 Industrial stack emission monitoring

In 2023, Environmental Laboratories of EPA Punjab conducted a total of 232 industrial inspections[47] to monitor the compliance with "The Punjab Environmental Quality Standards for industrial gaseous emissions, 2016"[48]. These standards include the parameters such as smoke, particulate matter, hydrogen chloride, chlorine, hydrogen fluoride, hydrogen

[47] This data has been entered by EPA laboratories on the module of "Chemical Analysis Report (CAR)" at dashboard https://idm.pgdp.pk/ tikk 08th January, 2024.

[48] https://epd.punjab.gov.pk/system/files/NOTIFICATION_REGARDING_THE_PUNJAB_ENVIRONMENTAL_QUALITY_STANDARDS_FOR_INDUSTRIAL_GASEOUS_EMISSIONS%20%281%29.pdf

sulphide, sulphur oxides, carbon monoxide, oxides of nitrogen and heavy metals. The standard values are provided in mg/Nm^3, except for Smoke, which is measured on the Ringelmann Scale or equivalent number. The monitoring of gaseous emissions was conducted mainly in industries such as brick kilns, textiles furnaces, paper and paperboard, cement plants, paints and dyes, foods, oil and fats and vegetable ghee, chemical projects and sugar mills. Industry wise results of oxides of nitrogen, sulphur dioxide, particulate matter, carbon monoxide and smoke are given in Figures 3-9 to 3-13.

The analysis of the monitoring results revealed that:

- Thermal power generation plants, tobacco processing, cement plants and textile mills are the main contributors of NO_x emissions. However, thermal power generation is the only sector which exceeds the PEQs threshold (1200 mg/Nm^3).
- The concentration of SO_2 exceeds the prescribed PEQS limit (1700 mg/Nm^3) in thermal power generation plants. In contrast, emissions from chemical plants and textile mills, both considered high emitters, comply with the PEQs.
- Particulate matter monitoring indicates that only the wood products manufacturing sector exceeds the prescribed PEQS limits, set at 500 mg/Nm^3. However, furnaces (steel, iron, copper), cement plants, and waste disposal facilities are all within safe limits.
- Textile mills, paperboard mills, paints and dyes, wood products manufacturing, tobacco processing sugar mills, animal feed manufacturing units and power generation plants are emitting CO beyond the PEQs limits (800 mg/Nm^3).
- All the industries inspected except sugar mills had the smoke emissions more than the prescribed PEQs limits (40%).

Following is the industry-wise overview of pollutant concentration:

- The smoke emissions for the **brick kiln** had an average value of 58.3% on the Ringleman Scale which is 45% higher than the prescribed values of PEQS.
- In the **textile sector** the gaseous emissions had average values (mg/Nm^3) of NO_x (1019) and SO_2 (937) within the permissible limits of PEQS. Whereas, CO (6887 mg/Nm^3) and smoke (48.2%) exceeded 761% and 20.61% of the PEQS value, respectively.
- In **steel furnaces** gaseous emissions had an average value of particulate matter (342 mg/Nm^3) within the prescribed limits of PEQs. Whereas, the Smoke (52.6%) exceeded the PEQs value.
- In **paper and paper board mills**, the gaseous emissions had average values (mg/Nm^3) of NO_x (246) and SO_2 (4.26) within the permissible limits of PEQs. Whereas CO (5714 mg/Nm^3) and smoke (61.7%) exceeded the PEQs limits.
- In **cement plants** gaseous emissions had average values (mg/Nm^3) of PM (178), NO_x (1092), SO_2 (7.09) and CO (491) within the permissible limits of PEQs.
- In **Paints and dyes factories** gaseous emissions had average values (mg/Nm^3) of NO_x (371) and SO_2 (253) within the prescribed limits of PEQs. Whereas CO (3506 mg/Nm^3) and smoke (53.2%) exceeded the PEQS limits.
- In the **Food sector**, the gaseous emissions had average values (mg/Nm^3) of PM (436), NO_x (954) and SO_2 (1331) within the prescribed limits of PEQs. Whereas concentration of CO (3042 mg/Nm^3) exceeded 280% of the PEQs value.

- In **Chemical Projects** gaseous emissions had average values (mg/Nm^3) of NO_x (402), SO_2 (1328) and CO (25.32) within the permissible limits of PEQs. Whereas Smoke (50%) exceeded 25% of the PEQs value.
- In **Sugar mills** gaseous emissions had average values (mg/Nm^3) of NO_x (97.55), Sulphur dioxide (2.83 mg/Nm^3) and Smoke (34%) within the prescribed limits of PEQs. Whereas concentration of CO (1952 mg/Nm^3) exceeds 34% of the PEQs value.
- In **Thermal power generation power plants** gaseous emissions had an average value of CO (371 mg/Nm^3) within the prescribed limits of PEQs. Whereas NO_x (3580 mg/Nm^3) and SO_2 (2670 mg/Nm^3) exceeded the PEQS limits.

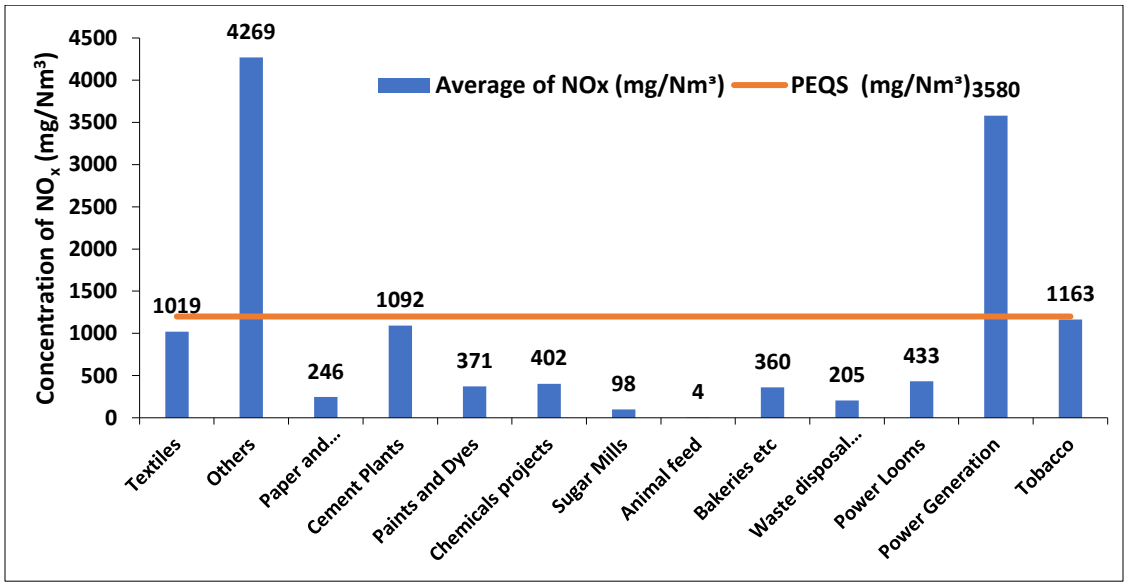


Figure 3-9: Average NO_X in stack emissions of various industries

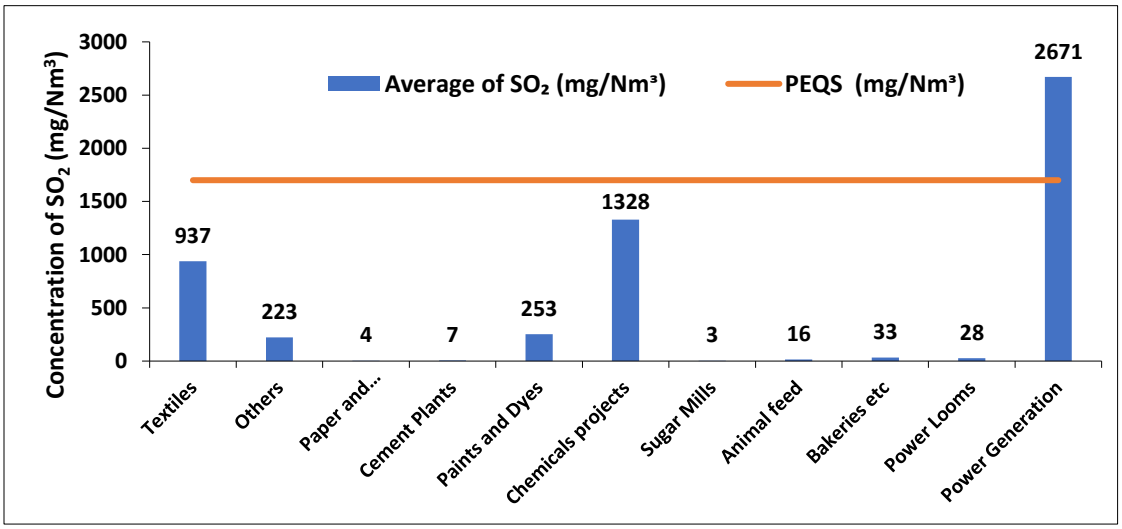


Figure 3-10: Average SO_2 in stack emissions of various industries

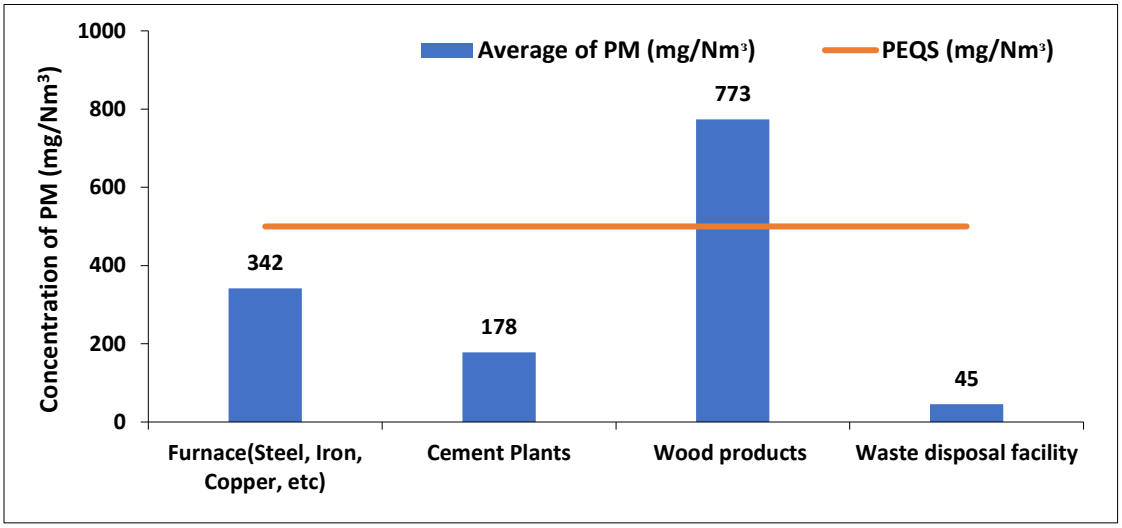


Figure 3-11: Average PM concentration in stack emissions of various industries

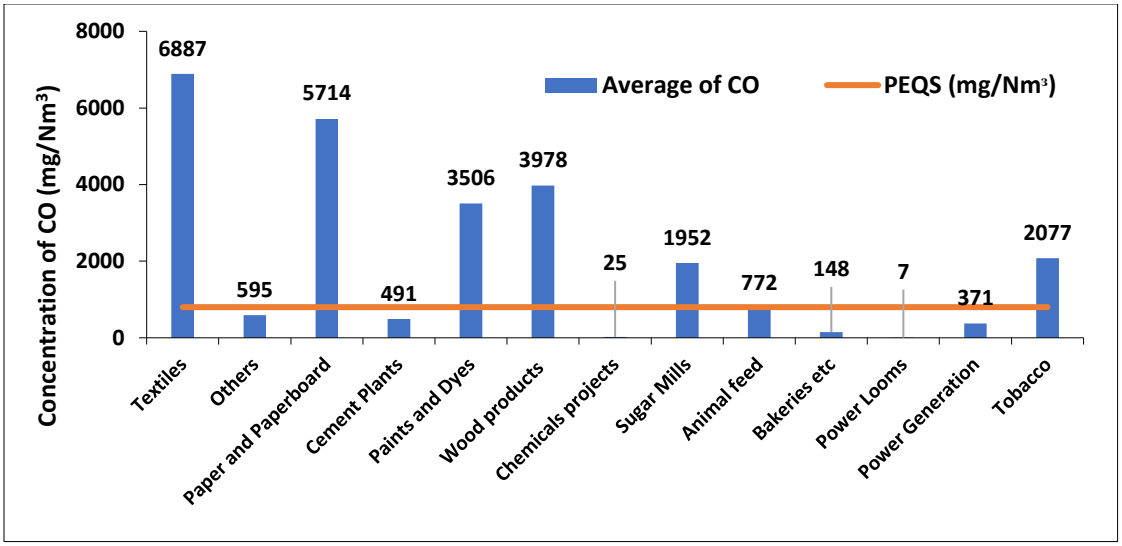


Figure 3-12: Average CO concentration in stack emissions of various industries

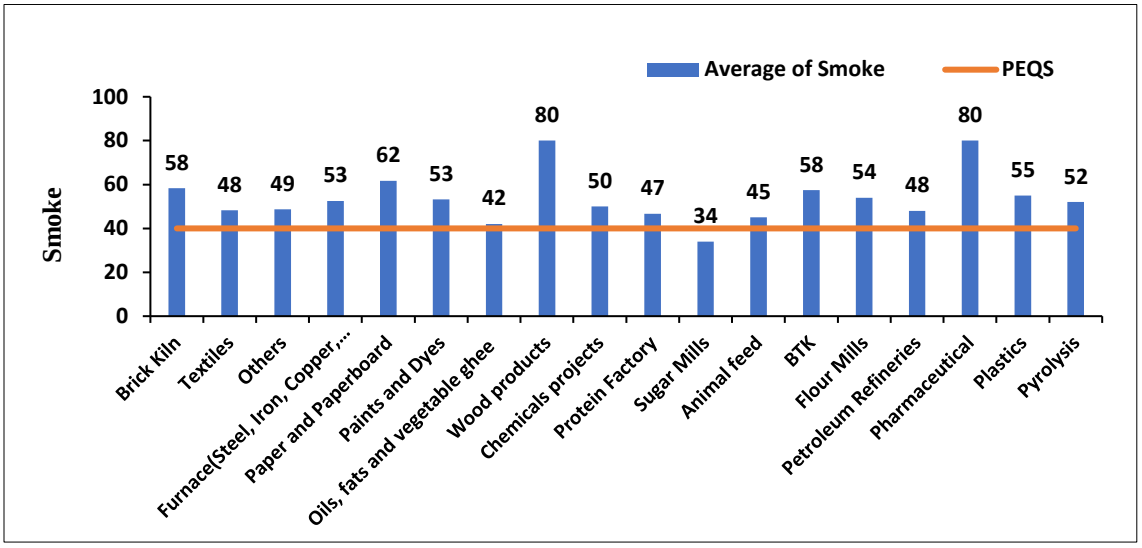


Figure 3-13: Average smoke produced by various industries

2.5.2 Vehicular Inspection

Approximately 17 million vehicles were registered between 2012 and 2023, comprising of motorcars, motorcycles, rickshaws, and commercial vehicles[49]. Notably, motorcycles alone accounted for 89% of this total (Figure 3-14). Percentage of registered motorcars steadily increased from 6.4% in 2012 to 9.9% in 2023, while percentage of Rickshaws declined from 1.5% to 1.2%. In terms of Compound Annual Growth Rate (CAGR), motorcycles, cars, rickshaws, and commercial vehicles exhibited values of 0.36%, 4.5%, -2.5% and 0.8%, respectively. These values indicate consistent increase for motorcycles and cars, a gradual decline for rickshaws, and a relatively stable presence for commercial vehicles. Lahore district accounted for 27.18% of the total registered vehicles, maintaining its position at the top.

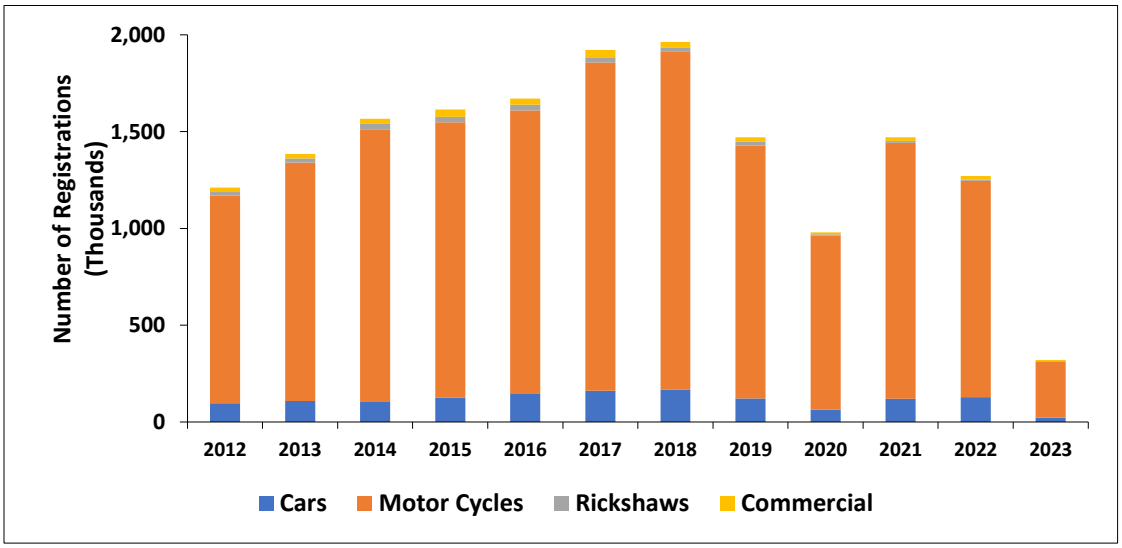


Figure 3-14:Year-wise registration of vehicles (2012 to 2023)

[49] Data from Transport Department.

The government of Punjab through the Transport Department has taken a revolutionary step in collaboration with Opus Inspection (Pvt.) Ltd. This step was taken in the field of Road Safety and Environmental Protection by introducing a modern and computerized Vehicle Inspection and Certification System (VICS) network. Under the system, all Public Service Vehicles (PSVs)[50] operating in Punjab are being regularly inspected for fitness. Such PSVs are awarded with a Fitness Certificate once it is confirmed that the vehicle is safe to operate on public roads and highways, and its noise and emission levels adhere to environmentally friendly limits.

From January 1, 2023 to December 18, 2023, a total of 0.2 million tests were conducted[51]. The average clearance rate was 67.7%, indicating that roughly two-thirds of vehicles are roadworthy (Figure 3-15). Passenger cars consistently maintained the highest monthly clearance rates throughout the year. Whereas, farm trucks and three-wheel vehicles consistently had the lowest monthly clearance rates. District-wise number of tests conducted versus PSVs cleared during 2023 is given in *Figure 3-16.* The type of PSVs-wise number of tests conducted versus vehicle is given in *Figure 3-17.*

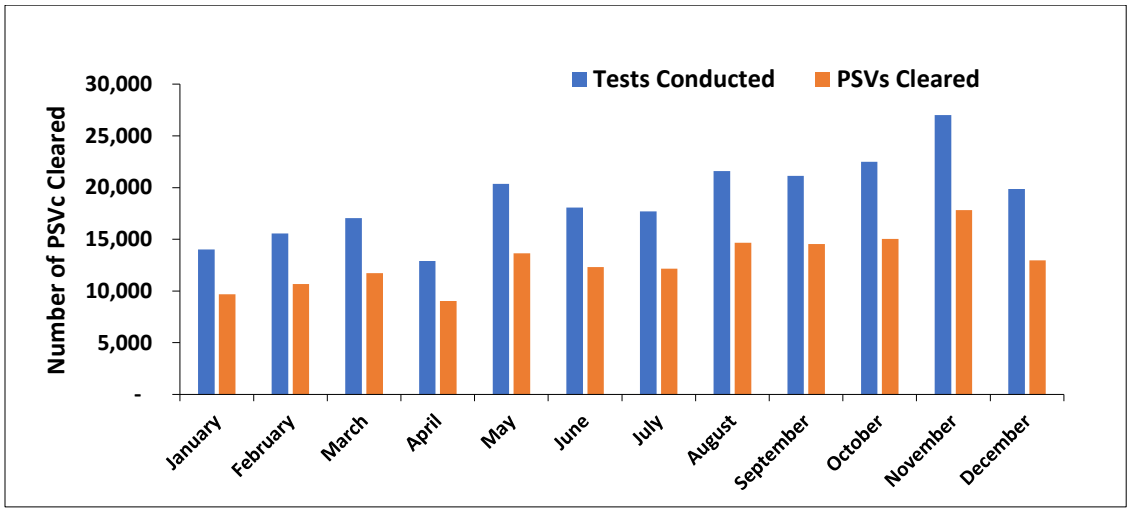


Figure 3-15: Number of tests conducted vs PSVs cleared during 2023

[50] It includes "***Bus, Farm Truck, Panel Van, Passenger Car, Pickup Truck, Station Wagon, Three-Wheel Vehicle, Tow Truck, Truck***"

[51] Data as obtained from VICS through Transport Department.

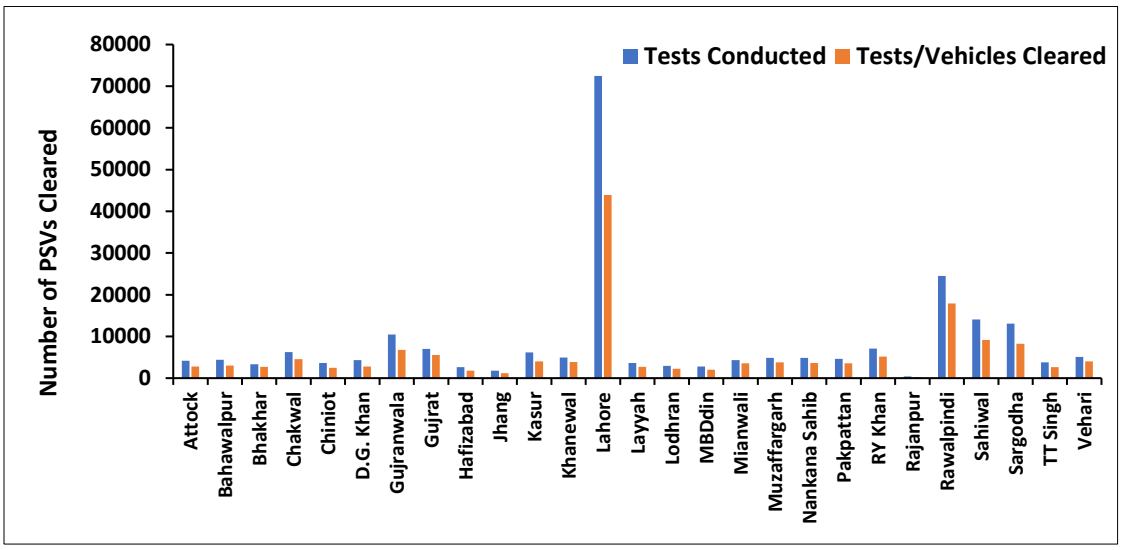


Figure 3-16: District-wise number of tests conducted vs PSVs cleared during 2023

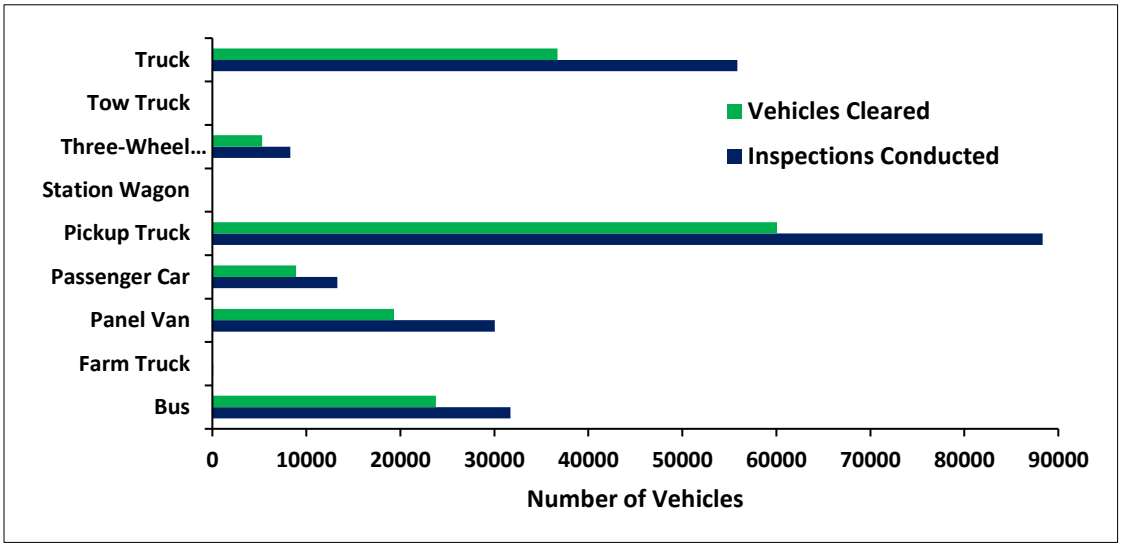


Figure 3-17:Types of PSVs and inspection/vehicles cleared during 2023

2.6 OVERALL ASSESSMENT

The overall air quality of Punjab HQs based on AQI $PM_{2.5}$ values is rated as 'Moderate' with a stable trend from previous year. However, in Lahore city the Air quality is still 'Poor', despite of the fact that there is a positive trend observed in 2023 with an increase in the number of days with 'good/satisfactory' AQI $PM_{2.5}$ values and a decrease in the number of unhealthy days. The concentrations of most pollutants, including smoke, carbon monoxide, and NO_x exceed permissible limits in stack emissions of many industries. Industry-wise rating for the stack emissions for the monitored parameters shows that brick kilns, oil, fat, and vegetable ghee processing units, flour mills, petroleum refineries, pharmaceutical facilities, plastics manufacturing plants, pyrolysis operations, protein factories, and wood product manufacturing industries have 'Very poor', while, paints and dyes factories and thermal power generation plants have 'Poor' compliance of the PEQS.

Ambient Air Quality Assessment

Assessment: Overall Punjab Divisional Headquarters (AQI $PM_{2.5}$)

Overall quality: Moderate

Assessment: Lahore (AQI $PM_{2.5}$)

Overall quality: Moderate

Industrial Stack Emissions Assessment

Assessment: Brick Kilns; Oil, Fat and Vegetable Ghee; Flour Mills; Petroleum Refineries; Pharmaceutical; Plastics; Pyrolysis; Protein Factory (Smoke)

Overall quality: Very Poor

Assessment: Textiles (CO, NO_x, SO_2 Smoke)

Overall quality: Moderate

Assessment: Steel Furnaces (CO, NO_x, SO_2 Smoke)

Overall quality: Good

Assessment: Paper and Paper Board Mills (CO, NO_x, SO_2 Smoke)

Overall quality: Moderate

Assessment: Cement Plants (CO, NO_x, SO_2 Smoke)

Overall quality: Very Good

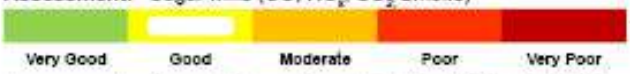
Assessment: Paints and Dyes Factories (CO, SO_2 Smoke)

Overall quality: Poor

Assessment: Chemical Projects (CO, NO_x, SO_2 Smoke)

Overall quality: Good

Assessment: Sugar Mills (CO, NO_x, SO_2 Smoke)



Overall quality: Good

Assessment: Thermal Power Generation Plants (CO, NO_x, SO_2 Smoke)

Overall quality: Poor

Assessment: Wood Products (CO, PM, Smoke)

Overall quality: Very Poor

Assessment: Others (CO, NO_x, SO_2 Smoke)

Overall quality: Poor

Assessment: Animal Feed (CO, NO_x, SO_2 Smoke)

Overall quality: Good

Assessment: Bakeries and Power Looms (CO, NO_x, SO_2,

Overall quality: Very Good

Assessment: Tobacco (CO, NO_x, SO_2,)

Overall quality: Good

3 MANAGEMENT

3.1 DPSIR Framework

Drivers

Punjab has almost 54.2% economic contribution to the national GDP and employs approximately 37.6 million people[52]. The drivers of poor air quality in Punjab are identified as follows:

a. **Population Growth:** Punjab is the most populous province of Pakistan. 128 million dwellers of Punjab constitute an overall 53% population count of the country. With an annual percentage average growth rate (2017-2023) of 2.53%, Punjab has a population density of 621.8 persons per Square Kilometre[53].
b. **Urbanization:** Urbanization is increasing at an unprecedented rate in Punjab. The urban proportion in Punjab is 40.70%[54].
c. **Industrialization**: The industries in Punjab significantly contribute to the GDP of the country. The industries are forced to run on 24/7 basis due to heavy demands which in turn result in emitting high volumes of air pollution.
d. **Poor Agricultural practices:** Punjab is a major producer of crops. In order to meet the increasing market demands (for wheat, rice, etc.), the farmers use conventional ways like stubble burning to sow the next crop in an expeditious manner without considering the environmental impacts of their activities.
e. **Increase in Vehicles:** Due to rapid urbanization, number of vehicles on roads in Punjab is increasing. Most of the vehicles run on fossil fuels, which release pollutants such as carbon monoxide, nitrogen oxides, and particulate matter into the air. Poor fuel quality and outdated engine technologies do not allow the clean burning of fossil fuels and cause vehicular pollution.
f. **Transboundary Pollution:** Stubble burning has been reported to be amongst the major contributors of air pollution especially for countries in Indo-Gangetic Plains. Therefore, the ambient air quality of Punjab has a direct linkage with the practices in the neighbouring countries.

Pressures

The above identified drivers pose a number of pressures on the air quality of the Punjab, which are explained as follows:

a. **Higher Greenhouse Gas Emissions (GHG):** Every driver exerts multiple pressures on the air quality. But, every driver, invariably results in a higher concentration of criteria pollutants especially particulate matter and the release of other GHG emissions.
b. **Industrial Emissions:** Industrial emissions exert multiple pressures on the ambient air quality including the release of criteria pollutants as well as greenhouse gas emissions. Criteria air pollutants have negative impacts on public health and the environment.
c. **Vehicular Emissions:** Air quality is exacerbated by adulterated fuel, lack of emission control devices such as catalytic converters/diesel particulate filters, low-efficiency engines, and poorly maintained vehicle fleets etc.

[52] https://punjab.gov.pk/system/files/PGS_2023.pdf
[53] https://www.pbs.gov.pk/sites/default/files/population/2023/Press%20Release.pdf
[54] https://www.pbs.gov.pk/sites/default/files/population/2023/Press%20Release.pdf

d. **Agriculture Related Emissions:** The activities like stubble burning, fertilization, cattle farming, rice paddies and the use of farm machinery and tube wells release a significant amount of particulate matter and other GHG emissions into the air contributing to poor air quality. Poor agricultural practices in Punjab are putting tremendous pressure on the ambient air quality.
e. **Dust Storms:** The hot summer temperatures ranging from 40-50°C, cause fine dust to rise into the atmosphere, forming dust clouds/storms that have a negative impact on air quality in the cities.

State

The state of the ambient air quality of the Punjab is as follows:

a. **Air Quality:** From 2019 to 2023, the air quality as measured at the US consulate at Lahore (near Shimla Hill) shows that annual $PM_{2.5}$ concentration is consistently more than 07 times higher than its PEQS value (15 µg/m^3). The average value of monitoring at various points in Lahore is 78.49 µg/m^3, which is 5.2% higher than the PEQS. At this concentration the corresponding AQI $PM_{2.5}$ value is 143 "Moderate". Amongst other divisional Headquarters, the highest concentration was recorded in Multan (approximately 04 times higher than the PEQS standards value) and lowest concentration was found for Rawalpindi (closest to the PEQS standard value).
b. **Higher values of industrial emissions**
Most of the industries monitored for stack emissions in 2023, showed higher emission levels and non-compliance with the PEQS thus polluting the environment.

c. **Vehicular Inspection:** During 2023, out of a total 227,684 PSVs tests conducted the average clearance rate was 67.75%, indicating that roughly only two-thirds of the vehicles passed the safety inspections and were road worthy.

Impacts

High concentration of criteria pollutants has serious health implications. For example, Carbon monoxide is a deadly gas that, even at low levels, can permanently damage the heart and brain, posing greater risks for those with heart or lung disease[55]. Ozone exposure can lead to respiratory issues, worsen lung diseases like asthma, and increase the frequency of asthma attacks[56]. Toxicity of lead is well-known, affecting various bodily systems[57], while nitrogen oxides can cause respiratory irritation and fluid build-up in the lungs, with high levels leading to severe throat and respiratory tissue damage[58]. Similarly, exposure to sulphur dioxide also results in respiratory difficulties, especially dangerous for children and can be immediately life-threatening at high concentrations[59]. Particulate matter poses diverse health risks including respiratory effects, heart diseases, diabetes, and neurological disorders in both children and adults[60].

[55] https://www.atsdr.cdc.gov/toxprofiles/tp201.pdf
[56] https://www.epa.gov/ground-level-ozone-pollution/health-effects-ozone-pollution
[57] https://www.atsdr.cdc.gov/toxprofiles/tp13.pdf
[58] https://www.atsdr.cdc.gov/toxfaqs/tfacts175.pdf
[59] https://www.atsdr.cdc.gov/toxprofiles/tp116.pdf
[60] https://www.atsdr.cdc.gov/pha-guidance/resources/ATSDR-Particulate-Matter-Guidance-508.pdf

District Health Information System (DHIS) is a mechanism of data collection, transmission, processing, analysis and information feedback to the first-level and secondary-level health care facilities in Punjab[61]. Data regarding disease prevalence of Asthma, Ischemic Heart disease and Hypertension for January 1, 2023 to September, 25 2023 gathered from Health Department shows that during the timeframe, 56% of patients were reported with hypertension, followed by asthma (32%) and ischemic heart disease (12%). Faisalabad, Rawalpindi, Gujranwala, Lahore and Multan have emerged as districts with a substantial overall health burden.

The overall number of ARI patients were highest in Lahore, followed by Faisalabad and Rawalpindi. Whereas, highest were in the 1–4-year age group, followed by the 5–14-year age group and 15–49-year age group. In the 50+ year age group the number of ARI patients were lowest. The results revealed that:

- Males are more likely to be exposed to risk factors for ARI, such as air pollution and second-hand smoke than females.
- Young children are more susceptible to ARI than adults because their immune systems are not fully developed.
- The number of ARI patients increased steadily from January to May 2023, before decreasing in June and July. It then increased again in August and September, before decreasing again in October-December. Figure 3-18 presents the district-wise number of OPD patients reported during 2023. Whereas, Figure 3-19 shows the month-wise distribution of number of patients reported during 2023.

  It is important to note that this data is only for OPD-ARI patients, which means that it does not include patients who were hospitalized for ARI. Additionally, the data does not include any information about the severity of the ARI cases.

[61] https://dghs.punjab.gov.pk/district_health

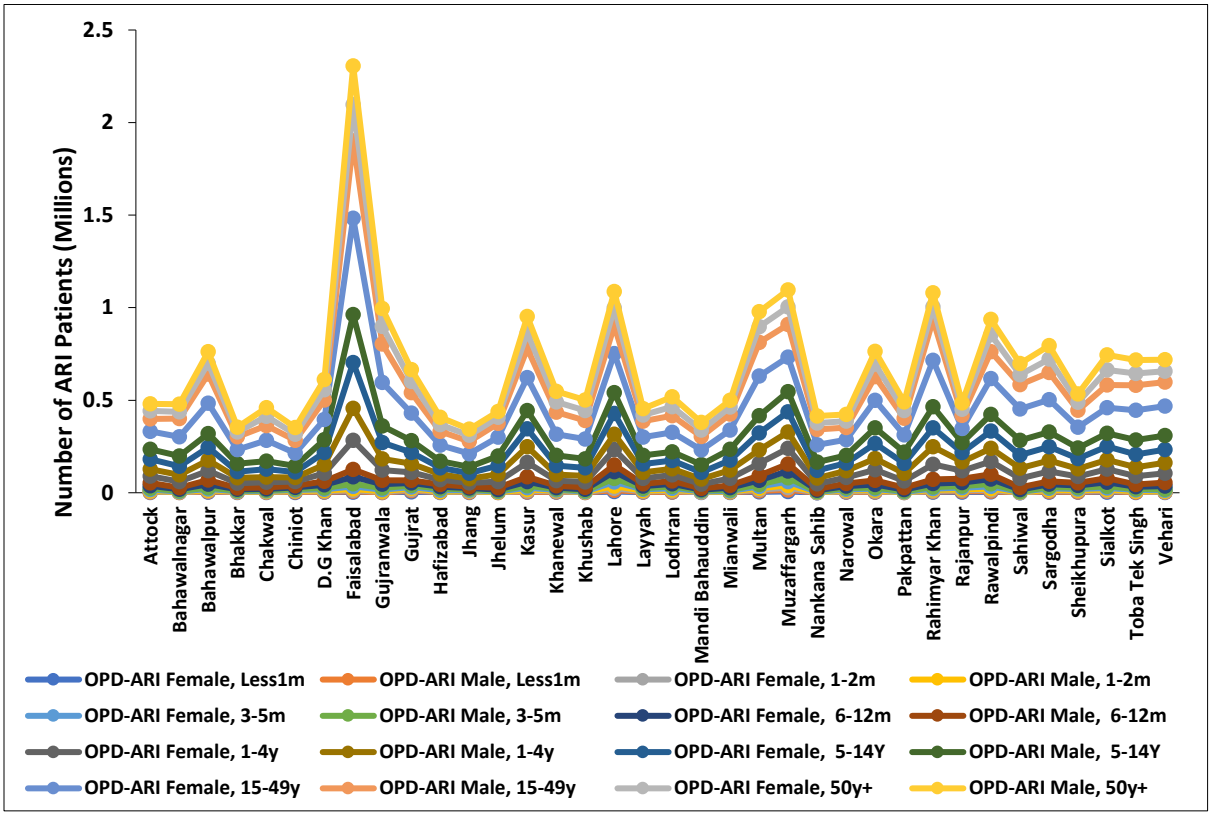


Figure 3-18: District-wise number of ARI patients during 2023

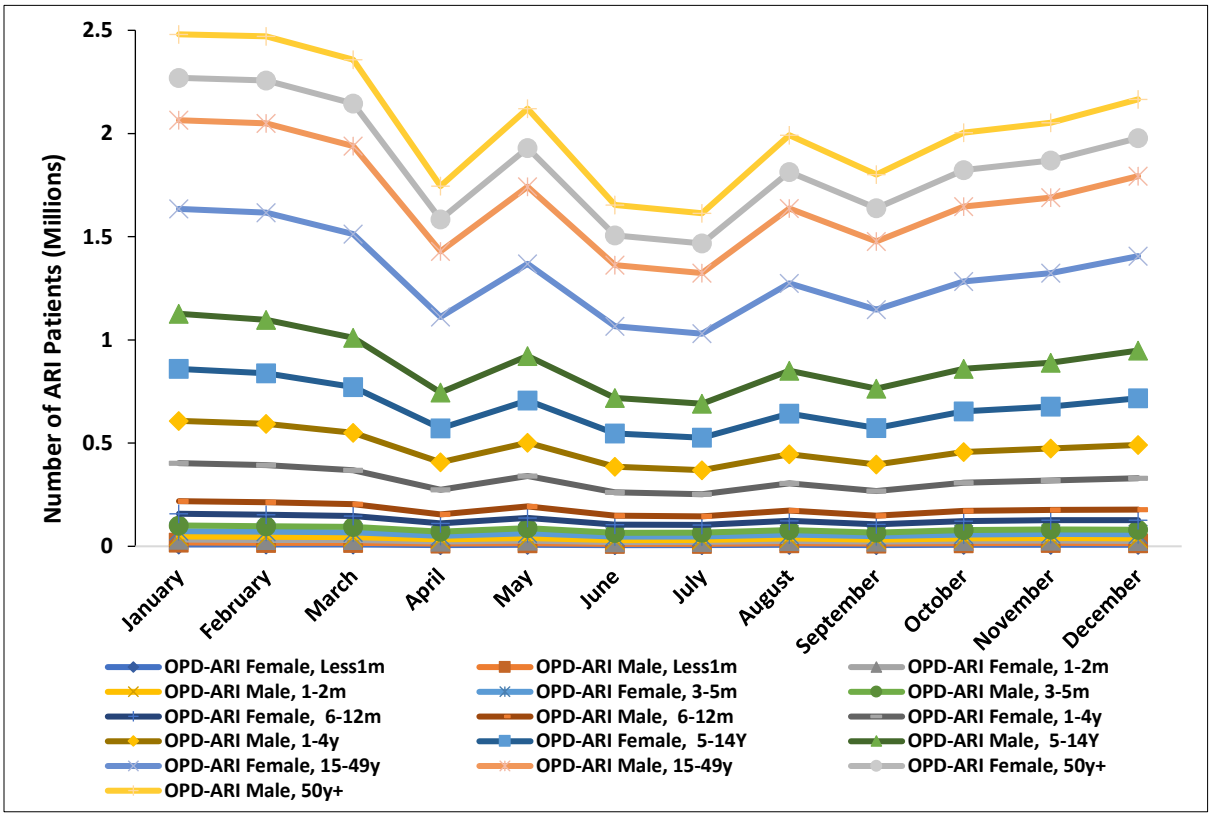


Figure 3-19: Month-wise ARI patients during 2023

Response

Government of the Punjab is striving hard to provide clean air to the inhabitants of Punjab. Various government departments are taking action for controlling air pollution at their various tiers. Details of initiatives of some government departments as mentioned in the Annual Development Program[62] are as follows:

- **Industries Commerce and Investment Department** is undertaking Establishment of Excellence Hub(s) in the field of Renewable Energy – (Kfw Development Bank, Germany Assisted Project in TEVTA Punjab); Demonstration Projects on Industries for Urban Centres, Relocation of Tannery Units to Sialkot Tannery Zone and its Operationalization (PGDP, DLI-7); Pilot/Demonstration Resource Efficiency and Cleaner Production Investments in key Industrial Sectors (PGDP, DLI-7); Infrastructure Development Work of Allama Iqbal Industrial City, Faisalabad-FIEDMC; Infrastructure Development (civil works) of Quaid-e-Azam Business Park (QABP) Sheikhupura; and Development of Bahawalpur Industrial Estate – PIEDMC
- **The Transport Department** is undertaking the Lahore Orange Line Metro Train Project; Punjab Digital Transport Governance; Induction of Eco-Friendly Buses in Cities of Punjab (DLI-6 PGDP); Consultancy Studies for Induction of Eco-Friendly Buses in Cities of Punjab; and Expansion of Inspection and Certification System for Motor Vehicles (DLI-6 PGDP)
- **Forest Wildlife & Fisheries Department** is undertaking the development of the National Park at Pabbi; Tree planting along ROW Ghazi Barotha Hydro Project; Establishment of Dargai Gill Forest Park; Solar Pumps in Depalpur Plantation; Afforestation along Vehari Burewala Road; Livelihood Improvement and Green Job Creation Through Ecosystem Restoration in Punjab; Ten Billion Tree Tsunami Programme (Phase-I) Up-Scaling of Green Pakistan Programme (Revised) in Attock, Bahawalnagar, Bahawalpur, Bhakkar, Chakwal, Chiniot, Dera Ghazi Khan, Faisalabad, Gujranwala, Jhang, Jhelum, Kasur, Khanewal, Khushab, Lahore, Layyah, Lodhran, Mianwali, Multan, Muzaffargarh, Nan kana Sahib, Narowal, Okara, Pakpattan, Rahim Yar Khan, Rajanpur, Rawalpindi, Sahiwal, Sargodha, Sheikhupura, Sialkot, Toba Tek Singh, Vehari. Apart from this various rehabilitation, digitization and strengthening activities are being carried out by the department.
- **Agriculture Department** is undertaking development of hybrid and OPVs in Vegetables Resilient to Climate Change; Promotion of Mechanized Agriculture for Increasing Crop Productivity; National Program for Improvement of Watercourses in Pakistan Phase-II; Punjab Resilient and Inclusive Agriculture Transformation (PRIAT; Transforming the Indus Basin with Climate Resilient Agriculture and Climate-Smart Water Management. Apart from these initiatives there are programs for productivity enhancement of wheat, sugarcane and rice.
- **Energy Department** is undertaking setting up Solar Tube wells in water logged areas of Punjab; Design and construction of net zero energy building (ACEIP , DLI-8); Energy Efficiency & Conservation Programme (PGDP, DLI-5) in Attock, Bahawalnagar ,Bahawalpur, Bhakkar, Chakwal, Chiniot, Dera Ghazi Khan, Faisalabad, Gujranwala,

[62] https://pnd.punjab.gov.pk/system/files/Dev%20Prgm%202023-24.pdf#overlay-context=D7fR0aHpE_n5Yix1C/3

Gujrat, Hafizabad, Jhang, Jhelum, Kasur, Khanewal, Khushab, Lahore, Layyah, Lodhran, Mandi Bahauddin, Mianwali, Multan, Muzaffargarh, Nankana Sahib, Narowal, Okara, Pakpattan, Rahim Yar Khan, Rajanpur, Rawalpindi, Sahiwal, Sargodha, Sheikhupura, Sialkot, Toba Tek Singh, Vehari; Punjab Ujala Program (Central Punjab) (ACEIP, DLI-1,2,3,4); Distribution of 1-Kw solar systems to poor population of Punjab based on BISP data; Development of renewable energy initiatives; Installation of biogas plant for Gujjar Colony; Installation of solar panels at the residences of Hon'ble Judges situated in GOR-I Lahore; establishment of waste to energy fund to meet financial viability gap for waste to energy projects in Punjab; Renewable energy development sector investment programme (REDSIP); Converting three cities of Punjab into solar smart cities in Gujranwala, Mianwali, Multan; Improvement of energy efficiency in WASA systems in Attock, Bahawalnagar, Bahawalpur, Bhakkar, Chakwal, Chiniot, Dera Ghazi Khan, Faisalabad, Gujranwala, Gujrat, Hafizabad, Jhang, Jhelum, Kasur, Khanewal, Khushab, Lahore, Layyah, Lodhran, Mandi Bahauddin, Mianwali, Multan, Muzaffargarh, Nankana Sahib, Narowal, Okara, Pakpattan, Rahim Yar Khan, Rajanpur, Rawalpindi, Sahiwal, Sargodha, Sheikhupura, Sialkot, Toba Tek Singh, Vehari; and solarization of Lahore High Court, Other residences in GOR-I Lahore, Basic Heath Units (Phase-II) (ACEIP, DLI-2,3), 100 Higher secondary schools in Punjab (ACEIP), 35 Tehsil Headquarter Hospitals and 100 Rural Health Care Centres and Installation of B.E.S.S, Schools for differently abled children, commissioners complexes, Public institutes (Phase-II), public sector building, Basic Health Units (Phase-I) (ACEIP, DLI-2,3), and Institutes of Cardiology in Faisalabad and Multan.

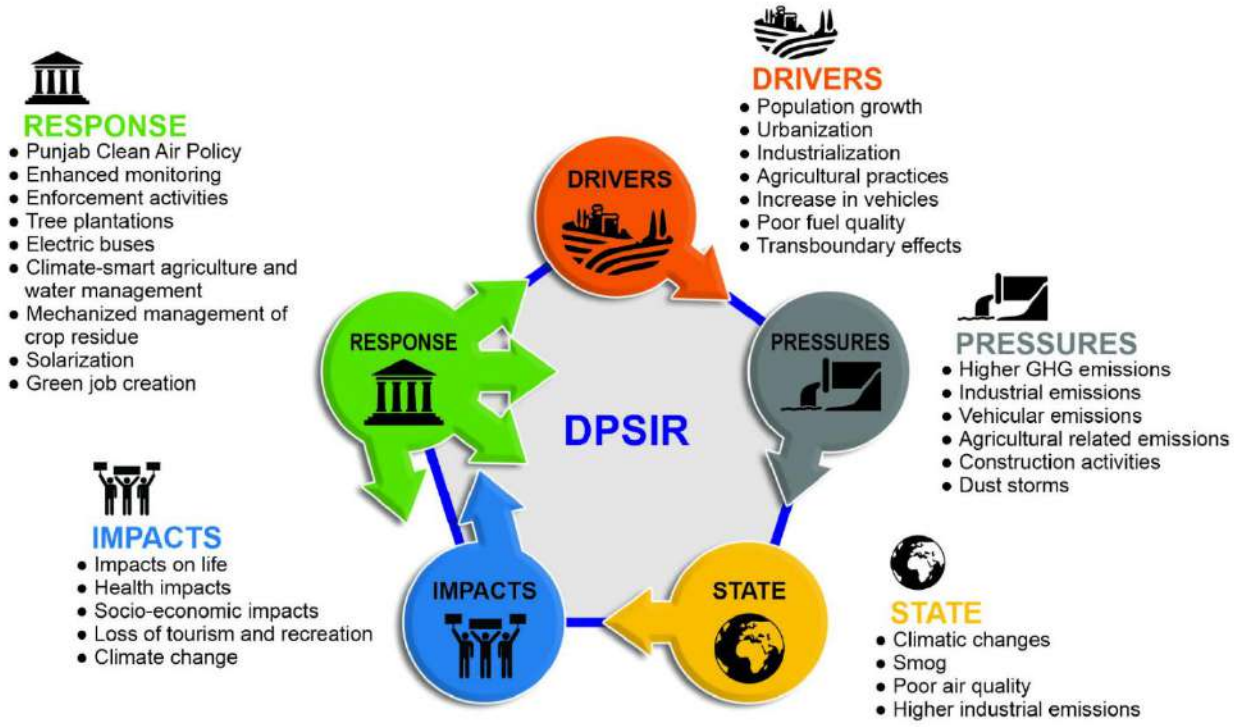


Figure 3-20: DPSIR framework for air quality in Punjab

4 THE WAY FORWARD

The recommendations given below are in addition to the earlier provided in the SOE Report, 2022. This will help in the building of the following:

Citizen Engagement: Establishment of web-based air portal and engage public, private and civil sectors in the development of joint policy framework to address air quality related environmental challenges. Effective participation of stakeholders and public-private sector cooperation in decision making-processes shall be carried out.

Strengthening of regulatory framework: EPCCD has notified the Punjab Clean Air Policy with phased action plan, now there is a need for implementation of the same to harness its fruits. It also requires the stern implementation of the Punjab Environmental Protection (Smog Prevention and Control) Rules, 2023. Further the clean air act is also a need of the hour.

Implementation of Key achievement: EPCCD has been able to get notified the Punjab Clean Air Policy (with phase Action Plan) and Health Advisory on the wake of critical air pollution. The implementation of these key documents will pave the way towards reduction in air pollution as well as improvement in quality of life.

Enhanced Air Quality monitoring with apportionment studies: To strengthen the capacity for measurement of air quality in 10 districts of Punjab, Environment Protection and Climate Change Department has signed contracts for 30 air quality monitoring stations on engineering procurement and construction mode. However, the apportionment studies have not been carried out due to certain limitations. EPCCD is committed to carry out the apportionment studies during 2024.

One City one solution: Every district in Punjab has some intrinsic characteristics and distinct practices in terms of agriculture, industries and vehicular pollution. Therefore, there is need to develop one district one solution. One solution cannot be fit for all. Area specific environmental action plans including pollution and dust control/urban dust management plan are required to be developed.

Industrial establishments: Comprehensive control of industrial establishments and reduced emission of multi pollutants, end of pipe particular matter remover, installation of continuous emission monitoring systems etc. are required. Development, implementation, and encouragement of techniques and technologies that prevent pollution at the source are the need of the time.

Vehicular Emissions: The recommendations for reducing vehicular emissions include, green transportation, standards, action plans and solutions, Road Engineering for removing traffic congestion in the major roads of the urban centres, increase in the counters of issuance/renewal of fitness certificates/route permits and deployment of the teams for checking vehicles plying on road without fitness certificates and route permits.

CHAPTER 4 WATER QUALITY

Key Findings

- In 2023, average flows across all rivers (Indus, Chenab, Kabul, and Jhelum) increased notably by 10.47% as compared to CY 2022. River Jhelum saw the most significant surge, with a remarkable 24.34% increase in flow.
- Surface water quality assessment rating for monitored Rivers and Canals was ‘Moderate’ and ‘Very Poor’ for drain.
- Groundwater monitoring by irrigation Department revealed that only 58% of tested groundwater sources were suitable for direct irrigation.
- Based on Water Quality Index, the overall quality of unfiltered water in both urban and rural areas was rated as ‘Poor’. Particularly, the urban areas of Faisalabad, Sargodha, and Bahawalpur and all assessed rural areas had water quality ‘unfit’ for drinking at consumer end.
- Filtered drinking water in urban areas is generally deemed suitable for consumption, except in DG Khan, where elevated levels of arsenic were detected.
- The majority of filtered drinking water sources in rural areas (except for Lahore and Rawalpindi), were found to be unsuitable for drinking purposes, mainly due to elevated arsenic levels.
- The assessment conducted by EPA laboratories indicated that only 0.8% of industrial units from the sampled group met the PEQS standards for all monitored parameters. Conversely, the remaining 99.2% of industrial units exceeded prescribed PEQs limits in at least one parameter.
- The leather and tanning industry, was identified as the most polluted and only sector where none of the PEQS limits were found to be in compliance.

1 OVERVIEW

Water is considered as the second most essential element for life, after oxygen. Water is a resource that affects all facets of development and is connected to almost all Sustainable Development Goals (SDGs). It is vital and basic to life itself, promotes ecological health, and propels economic progress. Indus River System (IRS) is primary source of water in Pakistan. The burgeoning human population along with escalating industrial activities, agricultural needs and improved living standards have intensified consumption of water resources. It has been estimated that per capita water availability in Pakistan has reduced from 5000 m^3 in 1951 to 1100 m^3 in 2005 and is expected to further decline by 800 m^3 till 2025[63]. The current storage capacity is inadequate as the three major water reservoirs in Pakistan, i.e. Mangla (1967), Tarbela (1978) and Chashma (1971), have a total designed capacity of 15.75 MAF, which has been reduced to 13.1 MAF due to sedimentation. These reservoirs can only save water requirement of for up to 30 days as compared to the internationally lowest water storage requirement of 120 days[64].

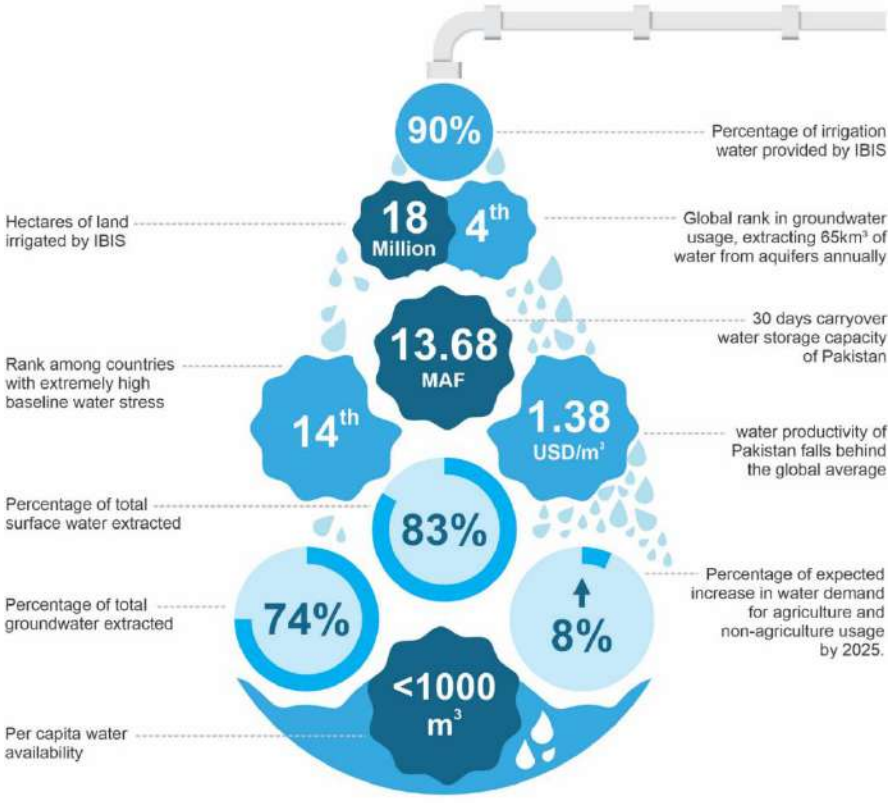


Figure 4-01: A snapshot of surface and groundwater supplies in Pakistan

63 Qureshi, R., & Ashraf, M. (2019). Water security issues of agriculture in Pakistan. PAS Islamabad Pak, 1, 41.

64 Ishaque, W., Mukhtar, M., & Tanvir, R. (2023). Pakistan's water resource management: Ensuring water security for sustainable development. *Frontiers in Environmental Science*, *11*, 1096747.

It is estimated that water shortfall of Pakistan will increase from 11% in 2004 to 31% by 2025, leading to an annual food shortage of almost 70 million tonnes[65]. According to a UNICEF report more than 10 million people living in Pakistan lack access to safe drinking water. The floods of 2022 severely damaged water systems in affected regions, leaving over 5.4 million individuals, including 2.5 million children dependent solely on polluted water from ponds and wells[66].

2 ENVIRONMENT

2.1 Surface Water Resources

Surface water is a vital resource, serving not only for irrigation needs but also as a crucial source for industrial and potable water supplies. Beyond its immediate usage, surface water plays a multifaceted role in sustaining ecosystems and facilitating the replenishment of underground aquifers. The Indus Basin Irrigation System (IBIS) is one of the largest contiguous irrigation systems in the world with a major portion situated in Punjab. Six major rivers – the Indus, Jhelum, Chenab, Ravi, Sutlej and Kabul – and their tributaries flow in the province (Figure 4-2).

2.1.1 Rivers

The Irrigation Department, Government of the Punjab, monitors the flows of rivers flowing in the province. Figure 4-3 shows average monthly flows for the four major rivers flowing in Punjab – Indus, Chenab, Kabul and Jhelum – as monitored at rim stations for the past two years (CY 2022 and CY 2023). Indus river had the highest average annual flow (4.9 MAF), nearly equivalent to the combined flows of the other three rivers, followed by the River Chenab (1.98 MAF). The highest flow for a particular month was observed for River Indus in July (13.98 MAF), whereas the lowest flow was observed for River Jhelum in December (0.32 MAF). The flow trajectories in CY 2023 generally remained same as CY 2022 for all rivers, with minor deviations. Notably, River Indus experienced deviations during May-September, River Chenab during June-July, River Jhelum during May-July, and River Kabul during April-September. Overall, there was a 10.47% increase in average flows across all four rivers in CY 2023 as compared to CY 2022, with River Jhelum recording the highest percentage increase (24.34%), followed by Chenab (11.37%), Indus (4.3%), and

[65] Ashraf, M. Water Scarcity in Pakistan: Issues and Options. Pakistan Council of Research in Water Resources (PCRWR). 2018.
[66] https://www.unicef.org/pakistan/press-releases/more-10-million-people-including-children-living-pakistans-flood-affected-areas

Kabul (1.87%). The maximum percentage decrease was observed in River Chenab (-59% in January) and Kabul (-56% in August), with the later reporting the highest decrease in average monthly flow for a specific month as compared to the previous year (-3.16 MAF in August).

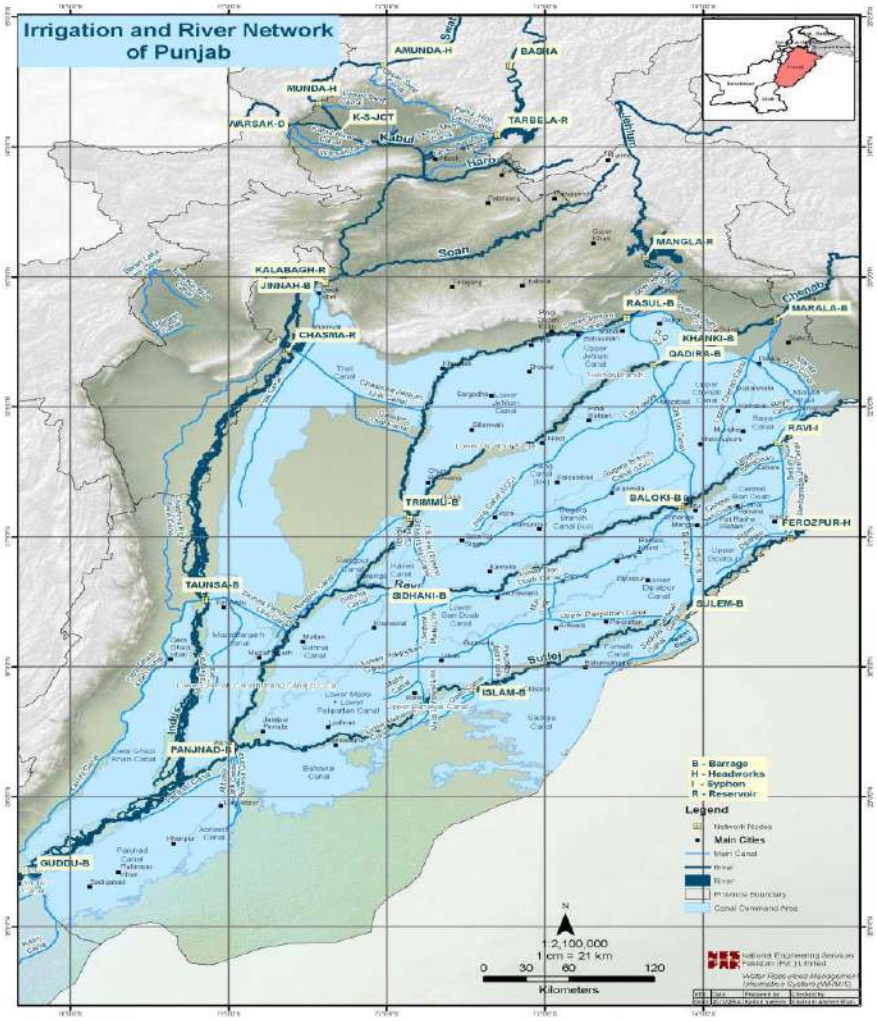


Figure 4-02: Irrigation and River Network of Punjab (Source: Irrigation Department, GoPb)

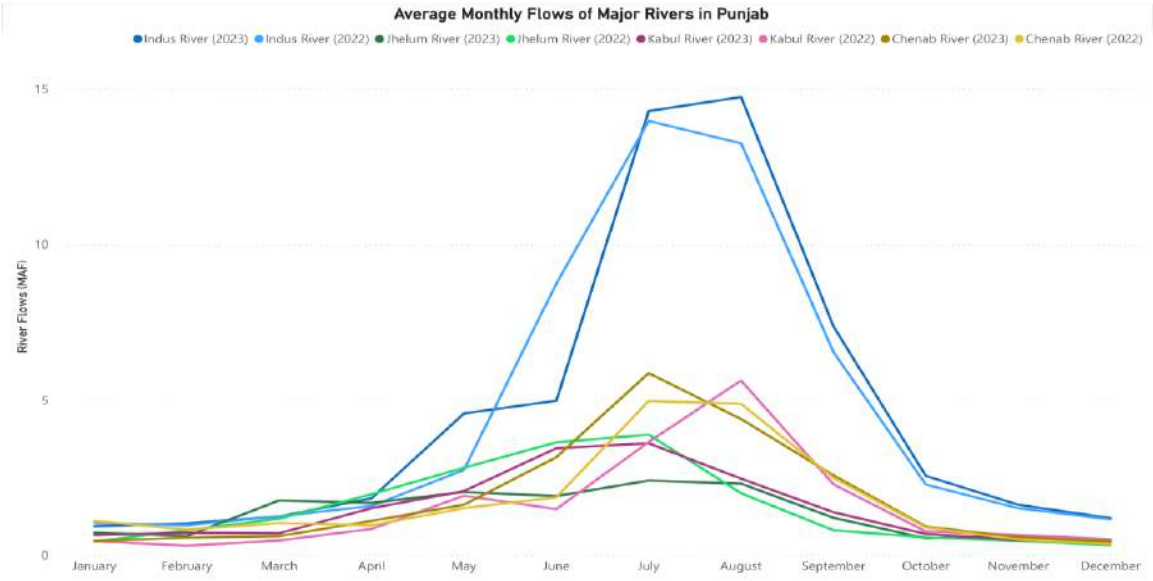


Figure 4-03: Average Monthly Flows of Major Rivers in Punjab – CY 2023 and CY 2022 (Source: Irrigation Department, GoPb)

2.1.2 Canals

Pakistan possesses one of the largest man-made contiguous canal systems in the world. Most of the canal network is situated in the province of Punjab. The Irrigation Department, has divided the provincial irrigation system into 8 operational zones for administration and management of the system. According to a working paper by PIDE, the provincial canal system delivers irrigation supplies to farmers through 51,990 outlets in its system of 24 main canals and distribution canals spanning over 22,700 km[67].

Major canal withdrawals occur at the two prime command zones in the north of Punjab, namely the Indus Zone and the JC Zone (Figure 4-4). Here, water is discharged into canals through two command centres (dams); Tarbela Command and Mangla Command. Figure 4.4 shows actual canal withdrawals for both Rabi 2022-23 (October 2022 through to March 2023) and Kharif 2023 (April to September 2023) periods. It is observed that despite monthly variability amongst both zones, the overall canal withdrawal was similar: Indus Zone contributed 20.35 MAF (49%) while JC Zone contributed 21.18 MAF (51%) over the entire period. It was further noted that the water withdrawals during the Kharif 2023 were about thrice the quantum of water withdrawals during the Rabi 2022-23 period.

[67] https://www.pide.org.pk/pdf/Rural/water_and_irrigation(Khalid_Riaz).pdf

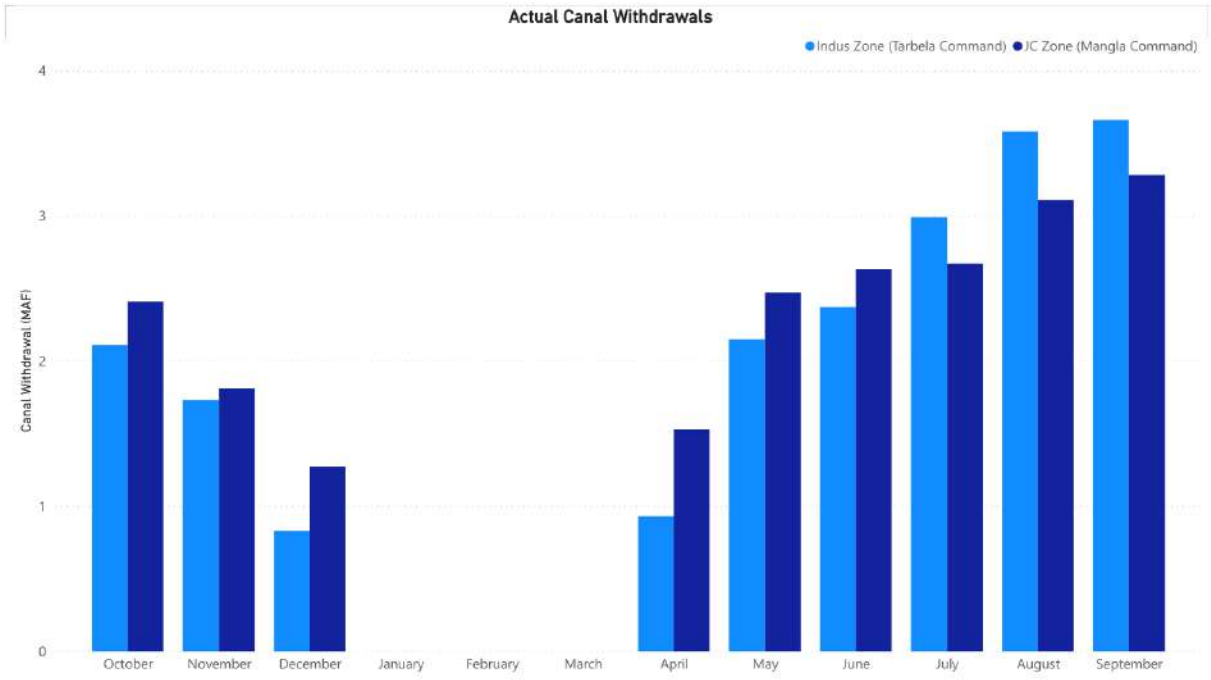


Figure 4-04: Actual canal withdrawals in Punjab [October 2022 – September 2023] (Source: Irrigation Department, GoPb)

2.2 Pollution Sources

Degradation of water quality is a result of several interrelated factors encompassing both anthropogenic and natural factors. Activities such as industrial/vehicular emissions, agricultural and biomass burning, as well as dust storms, contribute to air and soil pollution, subsequently impacting water quality. Key inorganic contaminants include heavy metals (such as arsenic, cadmium, lead, zinc, mercury, iron, manganese, nickel and copper) and toxic compounds and radicals (nitrates and fluorides). Heavy metals pose serious health risks, including the development of conditions such as cancer, melanosis, hyperkeratosis, peripheral vascular diseases, hypertension, and lung diseases[68]. Organic pollutants, including oil and pesticides, mostly enter water systems through agricultural runoffs[69]. Biological contaminants, normally emerging from domestic wastes especially faecal matter and hospital wastes, introduce harmful pathogens in the water bodies, leading to severe public health risks[70]. Widespread contamination is exacerbated by inadequate and improper sanitation, and disposal of untreated wastewater[71] in major water bodies, thereby affecting both urban and rural water sources.

[68] Noor, A. E., Fatima, R., Aslam, S., Hussain, A., un Nisa, Z., Khan, M., ... & Sillanpaa, M. (2024). Health risks assessment and source admeasurement of potentially dangerous heavy metals (Cu, Fe, and Ni) in rapidly growing urban settlement. *Environmental Research*, *242*, 117736.

[69] Sultan, M., Hamid, N., Junaid, M., Duan, J. J., & Pei, D. S. (2023). Organochlorine pesticides (OCPs) in freshwater resources of Pakistan: A review on occurrence, spatial distribution and associated human health and ecological risk assessment. *Ecotoxicology and Environmental Safety*, *249*, 114362.

[70] Fida, M., Li, P., Wang, Y., Alam, S. K., & Nsabimana, A. (2023). Water contamination and human health risks in Pakistan: a review. *Exposure and Health*, *15*(3), 619-639.

[71] Qazi, A. A., Ali, M., Farooq, Z., Latif, M., Naqvi, S. A. A., Iqbal, R., ... & Iqbal, M. A. (2023). Anthropogenic Activities and Water Quality: A Case of River Satluj, Pakistan: Water Quality of River Satluj. *Biological Sciences-PJSIR*, *66*(1), 74-80.

2.3 Surface Water Quality

Maintaining the quality of surface water is of utmost importance due to its significant impact on both aquatic ecosystems and human well-being. Rivers and other freshwater sources are highly vulnerable to pollution given their role in carrying off the industrial and municipal wastewater along with runoff from the agriculture fields. As the surface water quality deteriorates, its use for domestic, drinking, agriculture, industrial, recreation and other purposes is impaired.

Punjab, with approximately 70% of its land dedicated to agriculture, relies heavily on surface water for irrigation due to low rainfall in most of the areas. Thus, water scarcity and pollution could potentially impact agricultural productivity, posing threat to national food security. Inefficient water distribution networks, industrial discharge, inadequate domestic sewage treatment, agricultural runoff, and encroachment on water resources are some of the pressures faced by freshwater sources.

To assess the water quality of surface water bodies, EPA Divisional Labs monitored the surface water quality by key physico-chemical parameters such as pH, BOD, COD, TDS, TSS, Chloride, Sulphate and Sulphide. As irrigation is the major use of the surface water in Punjab, therefore its suitability for irrigation purposes was determined by using FAO Standards[72]. Samples from rivers, canals and drain were collected during the months of August and September. River water samples were collected from Ravi (Ravi Siphon, Shahdara Bridge, and at Saggian Bridge) and Chenab (near Chiniot). Canal water samples were collected at three points along the Lahore Canal (originating point, Jallo, Ferozepur Road Bridge and Thokar Niaz Baig), at two different locations along the Upper Chenab Canal in Sheikhupura and four samples from Jhang branch Chiniot and Faisalabad. Drain samples were collected from Jhang at two locations i.e., upstream and downstream of Rani Wah Drain (Figure 4-5).

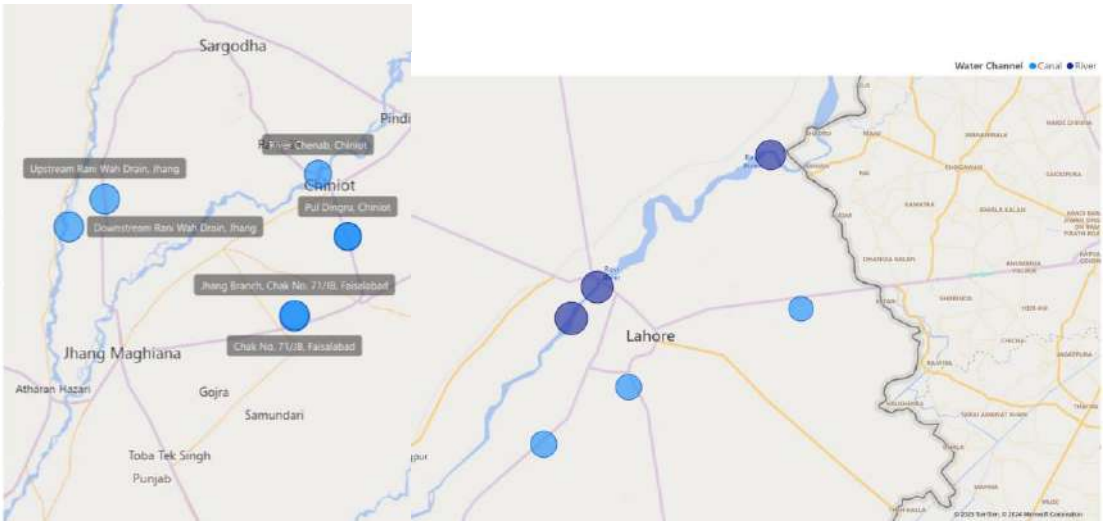


Figure 4-05: Monitoring points of surface water bodies in Lahore and Faisalabad (Source: EPA)

Results of the analyses are shown in Figures 4-6 to 4-8 and are described below in the relevant section.

[72] https://www.fao.org/3/t0234e/T0234E01.htm

2.3.1 Rivers

Mean pH and TDS (mg/l) of both Ravi and Chenab rivers were in FAO acceptable limits for irrigation water quality[73], while Cl^- concentration exceeded in both. Mean COD (mg/l) of Ravi (35) was higher than Chenab (22). TSS value of River Ravi (932) was much higher than Chenab (126). Results of other parameters (mg/l) i.e. for BOD (7.1), sulfate (30) and sulfide (0.26) were only reported for River Ravi.

2.3.2 Canals

All the samples were found to be within safe limits of pH. Jhang branch was found to have highest values of COD, TDS and Chloride followed by upper Chenab, Sheikhupura. Similarly, BOD, sulfate and sulfide was also found higher in upper Chenab than Lahore Canal. However, TSS value was found highest in Lahore Canal.

2.3.3 Drain

pH (9.4) and Cl^- (1083 mg/l) values were found exceeding the FAO limits, while TDS (79 mg/l) was within limit. Other monitored parameters (mg/l) were also found in high concentrations (COD 161 and TSS 2575).

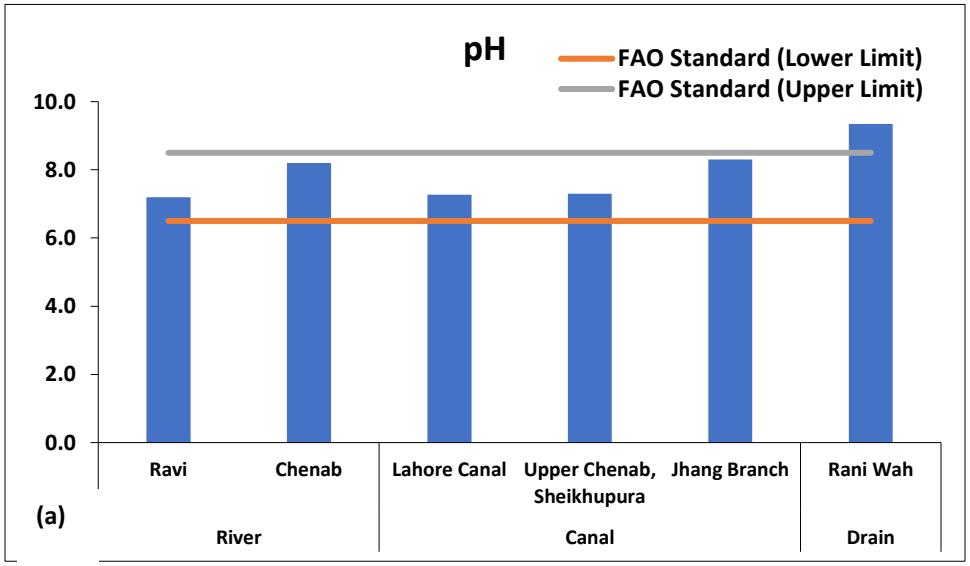


Figure 4-6: (a) pH of surface water bodies

[73] https://www.fao.org/3/t0234e/T0234E01.htm

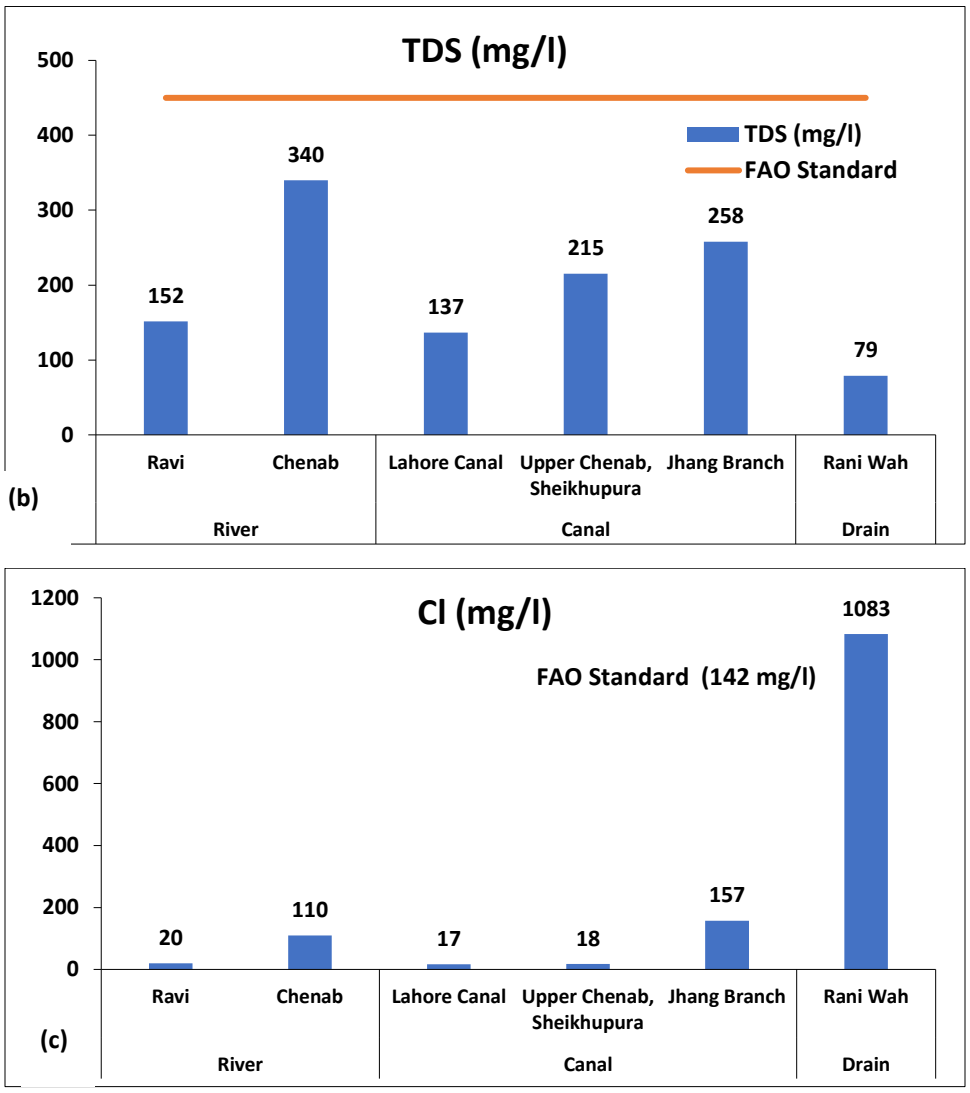


Figure 4-6: (b) TDS, (c) Chloride level in surface water bodies

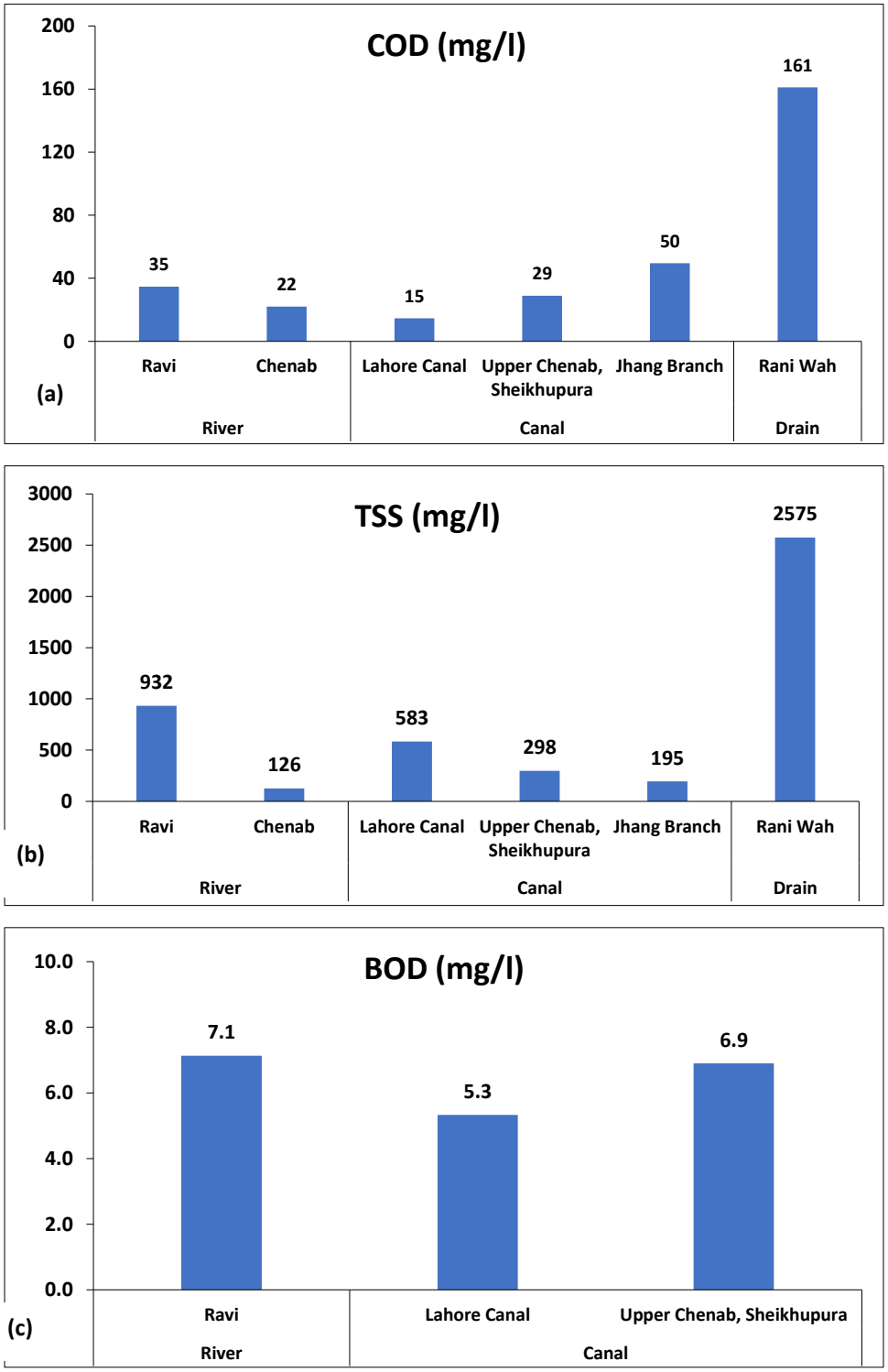


Figure 4-7: (a) COD, (b) TSS, (c) BOD level in surface water bodies

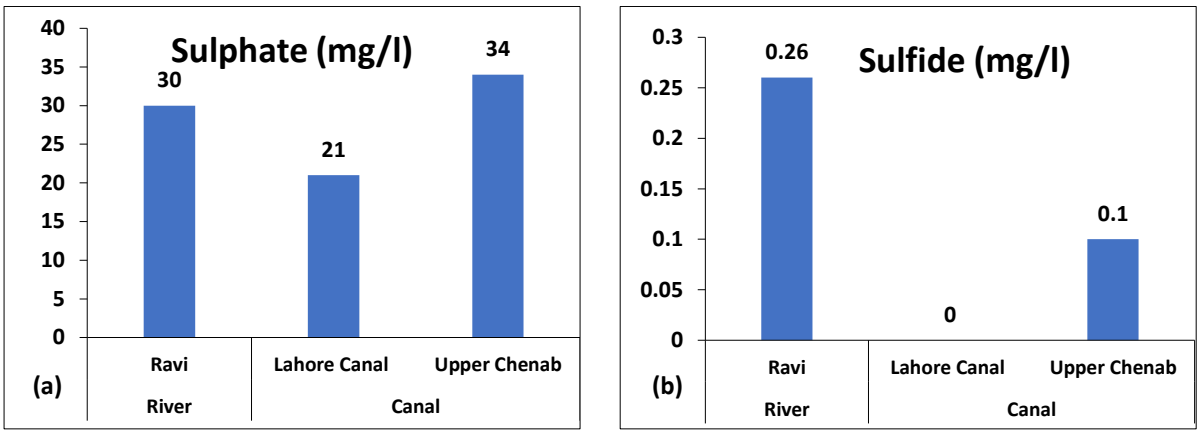


Figure 4-8: (a) Sulfate and (b) Sulfide level in surface water bodies

2.4 Ground/Drinking Water Resources

Access to safe and clean drinking water is a basic human right, and a fundamental tenet of public service provisioning. Groundwater plays a vital role in sustainable development as it provides around 25% to 40% of the world's drinking water. Only about 3% of water on earth is fresh water; of that, only about 1.2 % can be used as drinking water.[74] It is estimated that the quantity of groundwater in the province is being depleted at the rate of 2% per annum, whereas water output for irrigation, drinking and industrial use far exceeds the input recharge through surface water and precipitation. With increasing population, the pressures of water availability and quality have increased manifolds in recent times (Figure 4-9).[75]

2.5 Ground/Drinking Water Quality

Deterioration of drinking water quality is directly linked with adverse impacts on environmental, economic and social welfare of a nation. Extraction of deep ground water for drinking purpose is generally considered safe and free from contamination, but requires more economic cost and is a challenge for poor societies, and leads to lowering of water table. In Punjab, public drinking water is mainly provided by Provincial Water and Sanitation Agencies (WASAs) in large cities and by TMAs in smaller towns. Individual or community-based systems exist in other non-serviced locations. Water filtration plants have also been installed by WASAs/TMAs/NGOs, in some parts of major cities and in several rural villages, to provide clean drinking water to people.

[74] https://education.nationalgeographic.org/resource/earths-fresh-water/
[75] Ishaque, W., Mukhtar, M., & Tanvir, R. (2023). Pakistan's water resource management: Ensuring water security for sustainable development. Frontiers in Environmental Science, 11, 1096747.

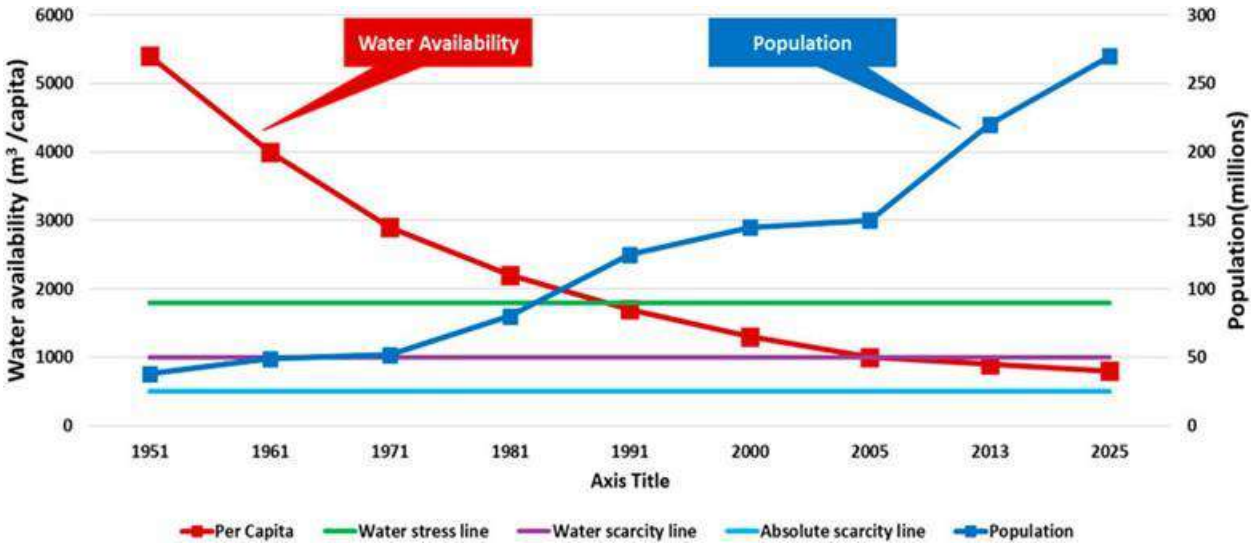


Figure 4-09: Pakistan's water availability and demand by 2025

For the purpose of this report, water quality assessments were conducted at three key sources i.e., receiving sources, distribution systems and consumer endpoints. Groundwater quality assessment by the Irrigation Department, focused on suitability for irrigation, especially near canal sources. The WASAs monitored the quality of groundwater within their distribution systems to gauge its suitability for drinking purposes. Whereas, the SP&IU team organized assessments of drinking water for checking fitness/quality compliance at the consumer end by testing water from taps and filtered sources throughout the province.

2.5.1 Irrigation Network Sources (Irrigation Department)

The Irrigation Department, surveyed the quality of groundwater for irrigation purposes throughout Punjab. The department has divided the province into 8 canal divisions, encompassing around 30 districts, on the basis of the provincial irrigation network. Various locations along the irrigation network were bored to collect samples for ground water quality assessment during pre-monsoon (June) and post-monsoon (October) months. The average boring depth of samples across all canal divisions was around 145 feet, and average screen length was reported to be around 93 feet. The average Natural Surface Elevation (NSL) was reported to be around 189 metres. The average discharge was stated as 1.93 Cs. Although this is normally an annual exercise undertaken by the department, data currently was only available for CY 2022 (correct at the time of preparation of this report and thereby such is being reported herein). The results of the assessment are expressed in terms of three chemical parameters, namely EC, SAR and RSC (The Irrigation Water Quality Standards and classification by WAPDA were used as standard)[76].

In terms of EC, both pre- and post-monsoon monitoring revealed small differences in values (Figure 4-10). Only 4 canal divisions complied with the EC standard limit, while the overall average level (1.57 dS/m) was slightly above the stipulated limit (1.5 dS/m). The overall average Sodium Adsorption Ratio (SAR) was 5.72 and the average pre-monsoon (5.79) and post-monsoon levels (5.65) were all significantly below the specified limit (10). Results

[76] Water and Power Development Authority, 1981.

of Residual Sodium Carbonate (RSC) revealed overall average (2.05 meq/L), pre-monsoon (2.15 meq/L) and post-monsoon (1.95 meq/L) levels were within the given threshold (Figure 4-12).

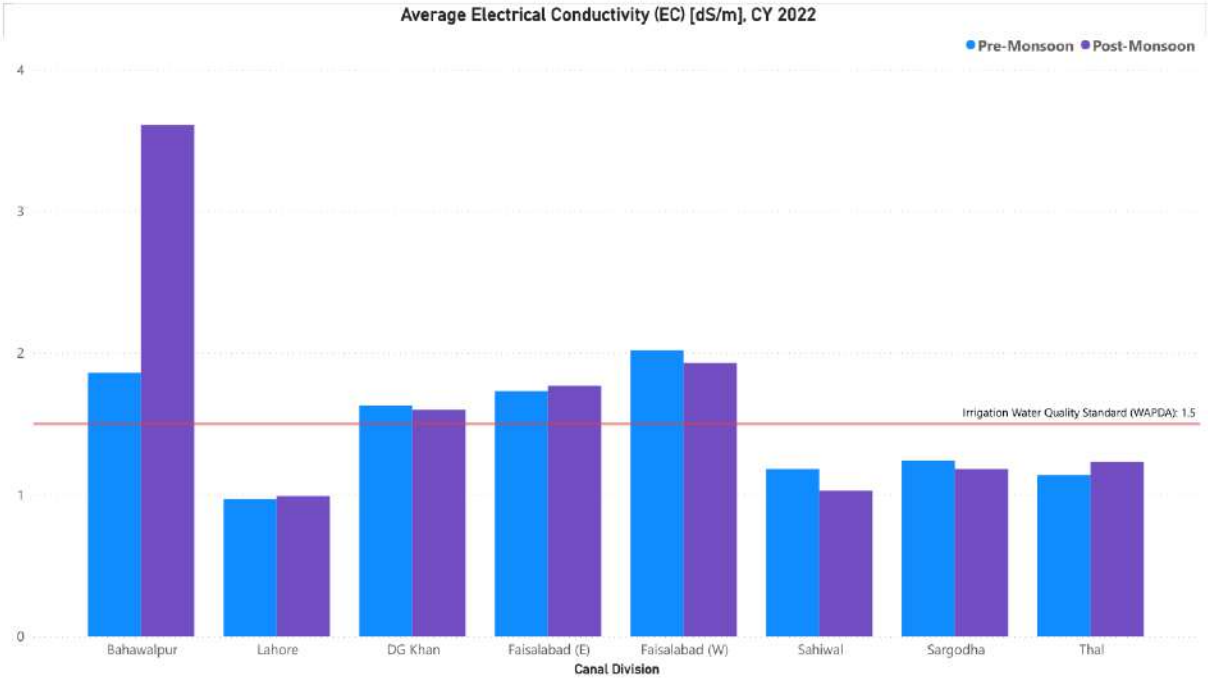


Figure 4-10: Average EC level in groundwater within the provincial irrigation network (Source: Irrigation Department, GoPb)

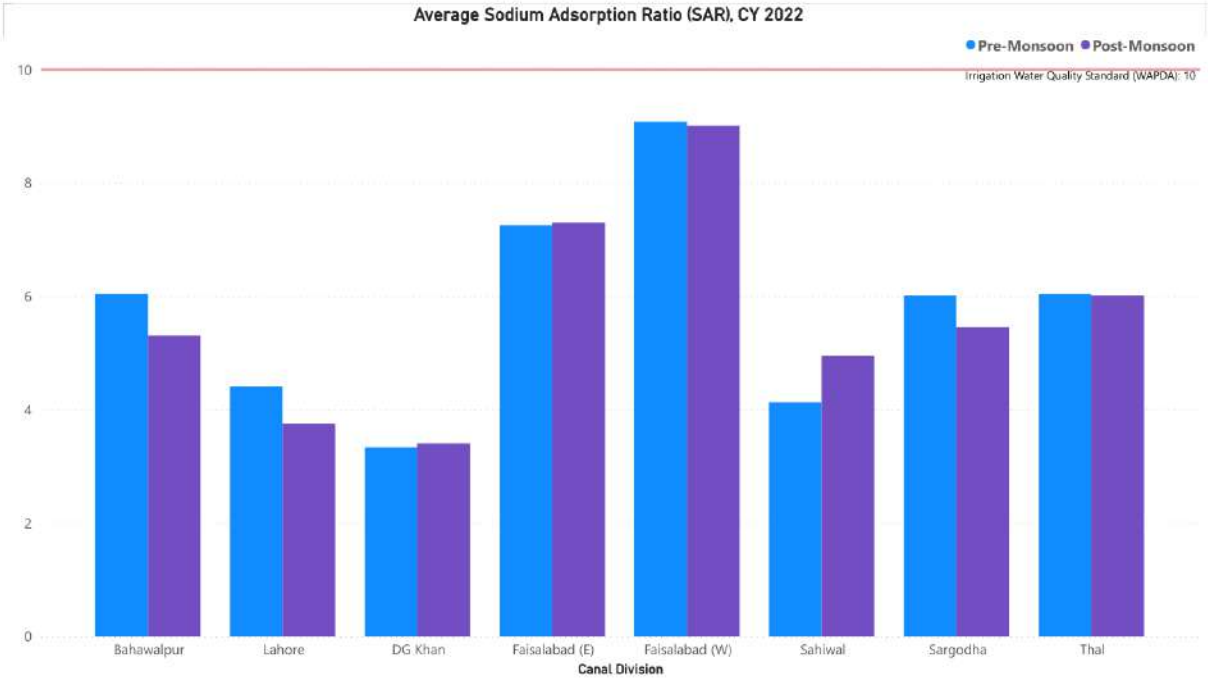


Figure 4-011: Average SAR level in groundwater within the provincial irrigation network (Source: Irrigation Department, GoPb)

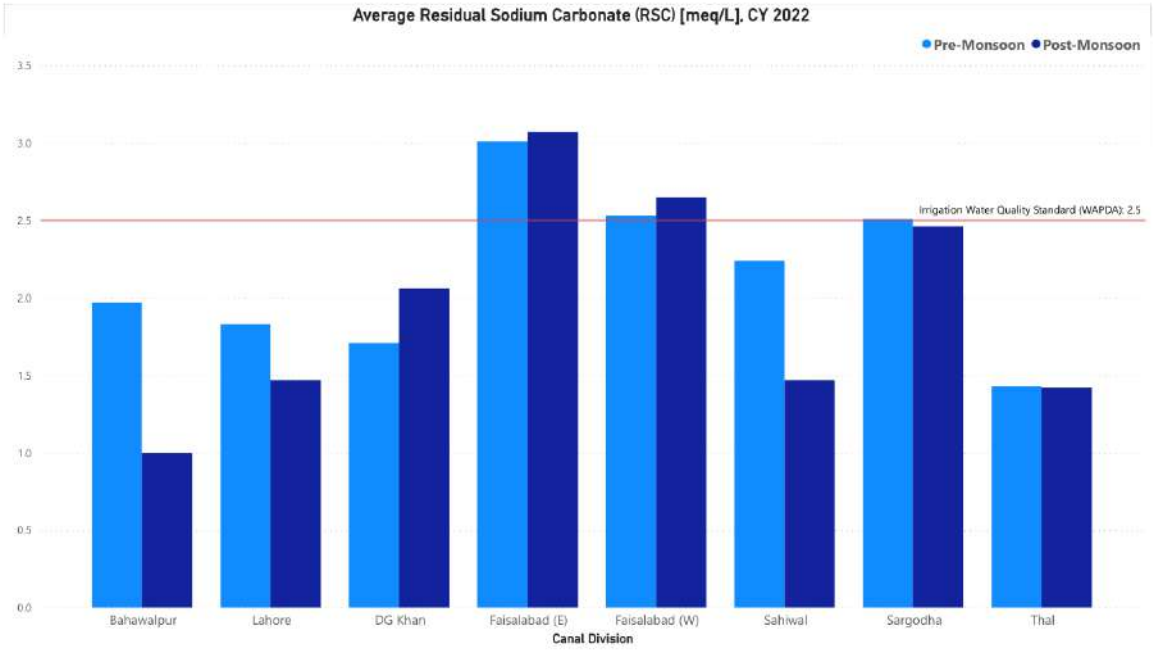


Figure 4-12: Average RSC level in groundwater within the provincial irrigation network (Source: Irrigation Department, GoPb)

Overall fitness level Groundwater quality in the areas of three divisional canals (Lahore, Sahiwal and Thal), was *usable* for irrigation purpose during both pre- and post-monsoon periods. Whereas, in three other divisional canal areas (DG Khan, Faisalabad West, and Sargodha), the water quality was *marginal* before and after the monsoon season. In Bahawalpur and Faisalabad East divisional canal areas water quality was *marginal* in the pre-monsoon period and became *hazardous* in the post-monsoon period. Groundwater monitoring revealed that only 58% of groundwater sources contained *usable water* which could be used directly for irrigation without dilution; the remaining groundwater sources either needed dilution with canal water or were deemed hazardous to be used for crop irrigation. Thal canal division had the highest fitness efficiency (≈80%), followed by Sahiwal (≈77%) and Lahore (76%) canal divisions (Figure 4-13). Both Faisalabad canal divisions were found to have the lowest fitness efficiency (collectively averaging 30%), followed by Bahawalpur canal division (40%).

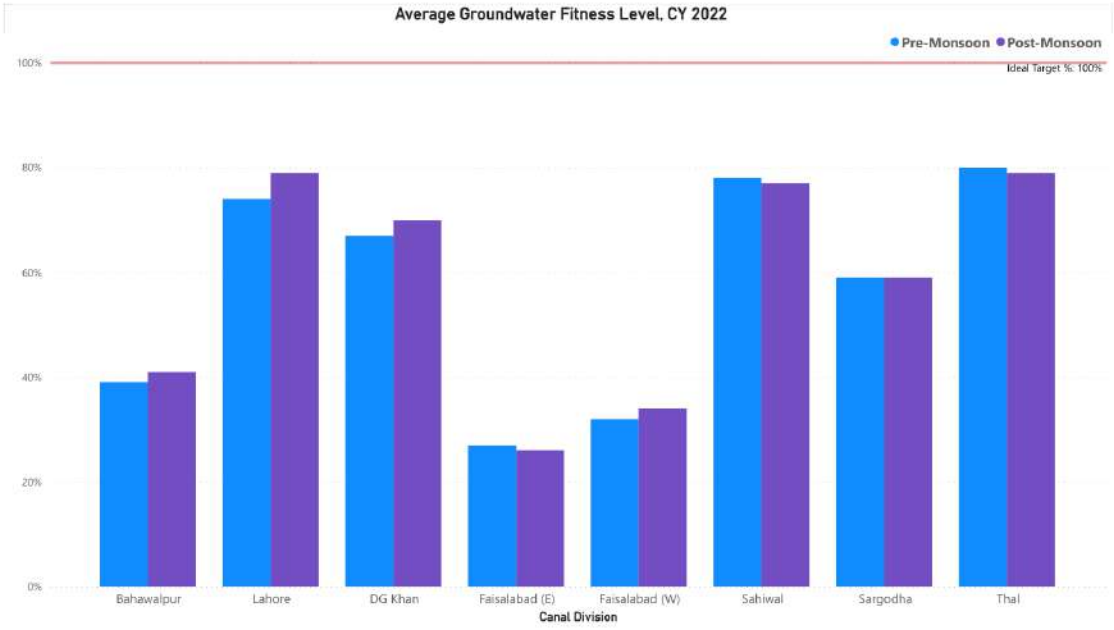


Figure 4-13: Average fitness level of groundwater in the provincial irrigation network (Source: Irrigation Department, GoPb, 2023)

2.5.2 Drinking Water Distribution System (Provincial Water and Sanitation Agencies)

Data from four WASAs (Lahore, Gujranwala, Faisalabad and Rawalpindi) was received and analysed. All the four WASAs, monitored and tested water within their distribution systems to ensure compliance with the physical, chemical and biological standards/guidelines.

Physical Characteristics: All of the four WASAs reported that more than 90% of the samples were in acceptable PEQS limits for physical characteristics including physical appearance (% clear), odour, taste, colour, EC, Turbidity, TDS and overall fitness level (Figure 4-12). In terms of pH all the WASAs reported that more than 98% of the assessed samples were in compliance to PEQs (Figure 4-14).

Chemical Contamination: In terms of residual chlorine level, applicable standards were in compliance range by all WASAs except in Lahore, where only 51% of the samples met the standard criteria throughout the year. In a number of cases, it was reported that there was no residual chlorine detected in the sample. This is somewhat alarming as chlorine is used as a disinfectant and absence of it within the distribution system can lead to introduction of biological contamination within the mass water supply network, with adverse health impacts.

Various other chemical parameters were reported varyingly by different WASAs. WASA Rawalpindi, for example, reported average **alkalinity** value (186 mg/L) within applicable standard limits.[77] Both WASA Rawalpindi and WASA Faisalabad reported annual average of total hardness within the PEQS limits[78]. All WASAs also reported on the overall chemical fitness of water for

[77] The Indian Standard "IS 10500 (2012): Drinking water [FAD 25: Drinking Water]" gives the maximum requirement (acceptable limit) for total alkalinity (as Calcium Carbonate) as 200 mg/L. The standard also provides for a permissible limit for alkalinity in water sample as 600 mg/L, which is to be employed in the absence of an alternate source.

[78] As Calcium Carbonate

each calendar month, based on the chemical parameters used for assessing the drinking water quality within their jurisdictions. All the WASAs reported average fitness score more than 98% implying that the drinking water supplied by WASA is largely free from chemical contaminations and suitable for consumption (Figure 4-16).

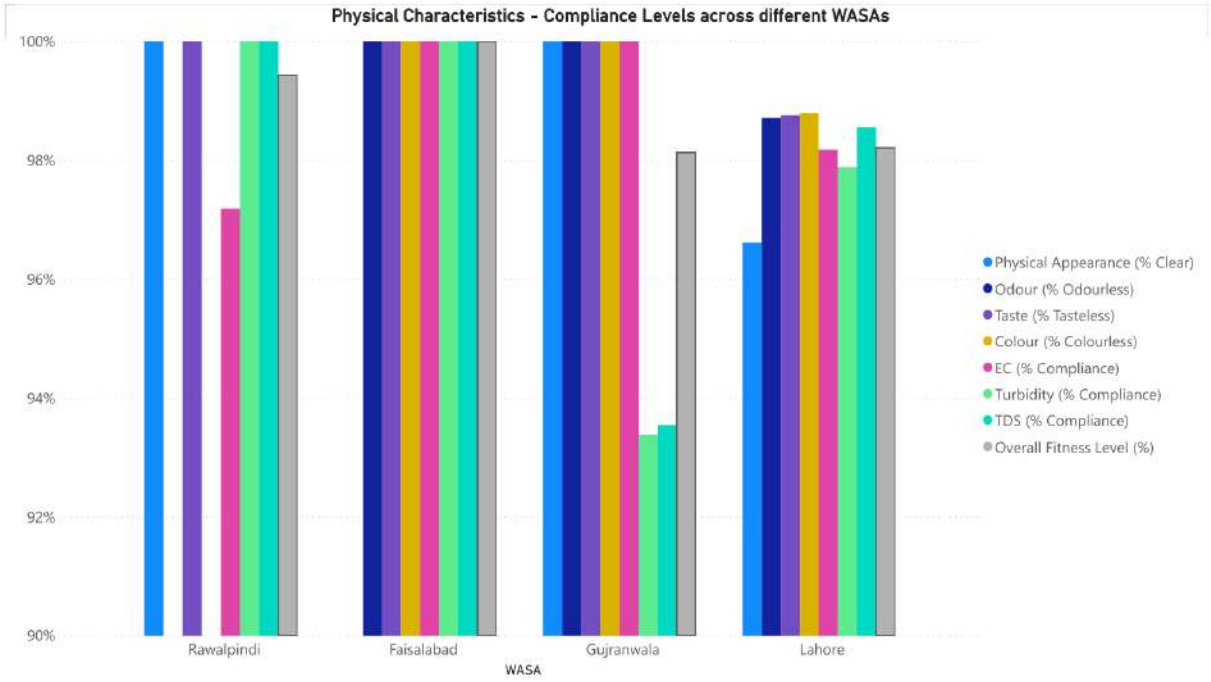


Figure 4-014: Compliance levels of physical characteristics across different WASAs (Source: WASAs, 2023)

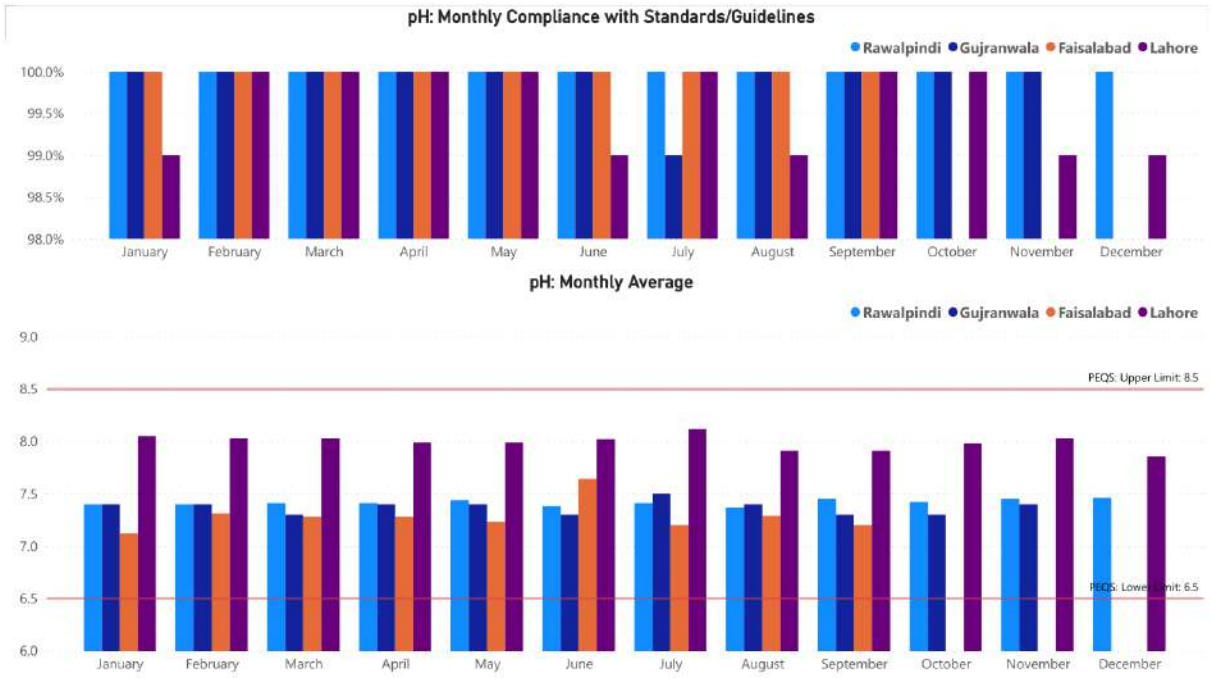


Figure 4-015: Monthly pH average and compliance levels (Source: WASAs, 2023)

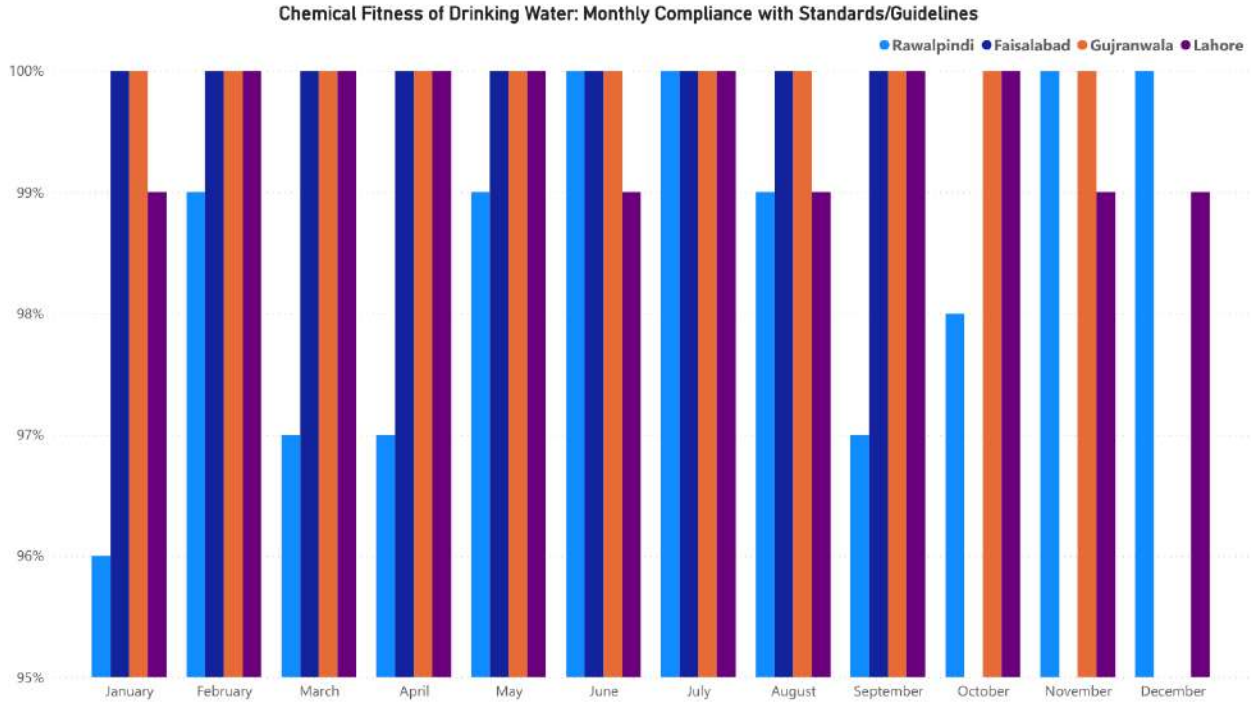


Figure 4-16: Chemical fitness of drinking water in distribution systems (Source: WASAs, 2023)

Biological Fitness: WASAs monitored the biological contamination of water by the presence or absence of *Escherichia Coli*, within their distribution networks (**Error! Reference source not found.**). *E Coli* is a type of faecal coliform bacteria usually present in the lower intestinal tracts of humans and some animals, it is excreted and may be washed into water bodies along with sewage, thereby contaminating them. It is important to monitor presence of *E. Coli*, as while most strains of the bacteria are harmless, some may cause severe illnesses like diarrhoea, urinary tract infections, respiratory illnesses and bloodstream infections. All four WASAs reported high levels of biological fitness (85%) in terms of average annual microbial (pathogenic) non-contamination, as depicted in **Error! Reference source not found.**8. Though there were monthly variabilities in biological fitness, especially evident in case of Lahore during late summer months; however, this was rectified by WASA Lahore after conducting a follow-up. The general trend for microbial fitness appeared to be increasing at the start of the year, dipping somewhat during summers and rising again in winters; perhaps this could be attributed to excess water washing into water bodies (along with contaminants) during and post the monsoon season.

Figure 4-017: Coliform bacteria (Source: Washington State Department of Health, 2022)

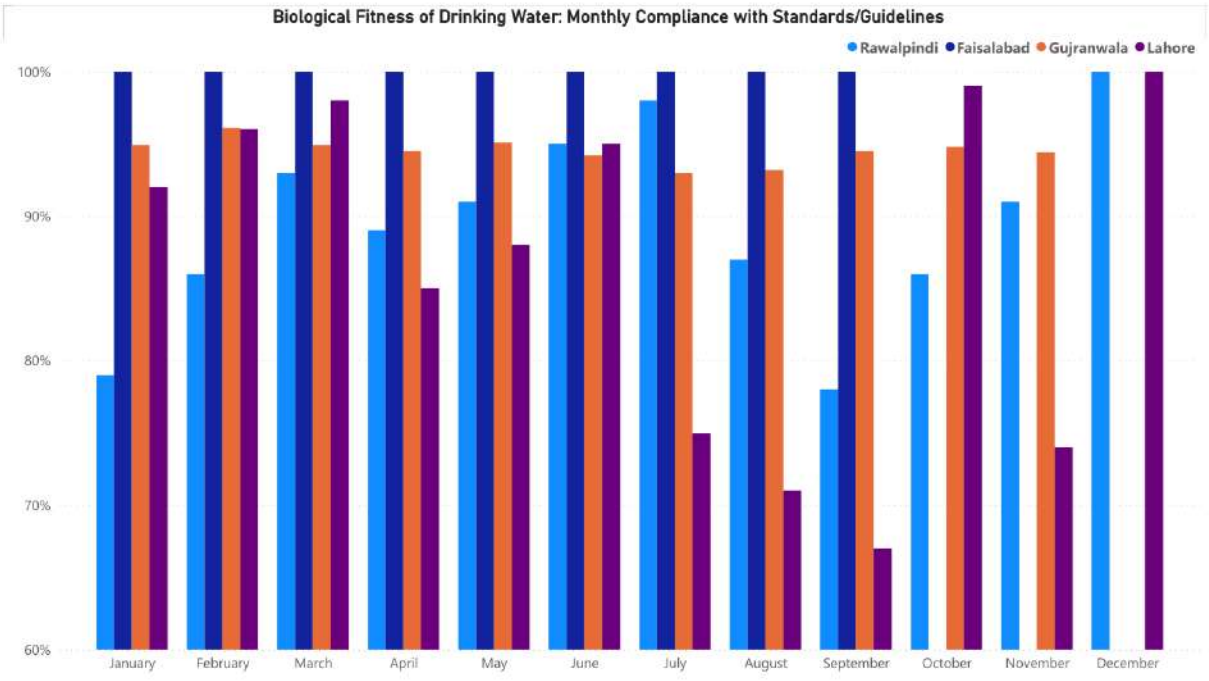


Figure 4-18: Biological fitness of drinking water in distribution systems (Source: WASAs, 2023)

Overall Fitness: The overall fitness was taken as a function of physical, chemical and biological fitness as reported by each WASA. According to the WASAs, they report the water samples to be fit only if they conform to all three fitness dimensions i.e., physical, chemical and biological. As narrated above, water in distribution systems was generally found to be physically and chemically fit in all four cases. Overall fitness levels reported by respective WASAs were generally higher and uniform over the months for Faisalabad and Gujranwala as compared to Rawalpindi and Lahore showing lower fitness and greater temporal variability, as shown in Figure 4-19.

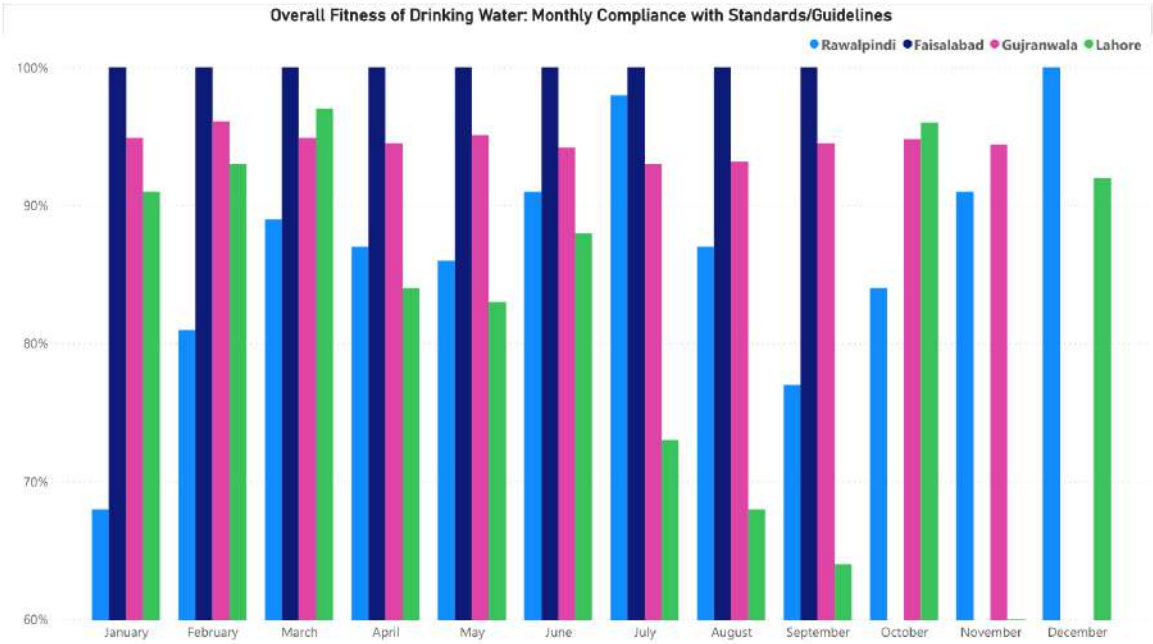


Figure 4-019: Overall fitness of drinking water in distribution systems (Source: WASAs, 2023)

WASA Lahore monitored the quality of water within its distribution system using the WASA Lahore Water Testing Laboratory to assess its suitability for drinking purposes. Initially, only 71.4% of the water samples met the criteria for drinking water quality based on tested parameters. Subsequently, WASA Lahore implemented follow-up remedial treatment measures at the sites where the water was deemed unfit. Upon re-evaluation, it was found that the fitness for drinking purposes had increased to around 98.5%, as shown in Figure 4-20.

Figure 4-20: Fitness of drinking water analysed before and after follow-up treatment in Lahore (Source: WASA Lahore, 2023)

2.5.3 Drinking Water Quality Assessment at Consumer End

Strategic Planning and Implementation Unit (SP&IU) organized assessments of water quality for drinking purpose at the consumer end in all nine divisions of the province. The team assessed the quality of water from public consumer facilities in both urban and rural areas across each division, evaluating water from both public filtered and unfiltered (tap) water supply systems. Three water samples from each of the consumer drinking water sources were taken, and assessed in environmental labs for fitness/quality compliance in each division for each supply system (filtered/unfiltered), and for each type of area (urban/rural).

Total 108 water samples were collected and assessed for their compliance with physical, chemical and biological dimensions. The physical parameters included colour, taste, odour, electrical conductivity, TDS and turbidity. The chemical parameters comprised of alkalinity, Arsenic, Bicarbonate, hardness, Calcium, Carbonate, Bicarbonate, Chloride, Magnesium, Nitrate-Nitrogen, pH, Potassium, Sodium and Sulphates. The biological parameters entailed checking for coliform presence in terms of Total Coliform, Faecal Coliform and *E. Coli*. These parameters were assessed for fitness in terms of their compliance with the PEQS limits; wherein PEQS limits were not present for a particular parameter, corresponding thresholds from WHO guidelines or USEPA standards for drinking water were used instead. The standards/guidelines used herein are reproduced in Annexure A-1.

In addition to individual fitness evaluation, Pollution Load Index (PLI) was calculated for each type of water source in all nine divisions as an index for estimation of contamination status of heavy metals present in drinking water samples. Moreover, Water Quality Index (WQI) of drinking water samples collected from urban and rural areas in all nine divisions was also computed. The WQI score obtained from the aforementioned fitness analyses categorized the drinking water into five classes as shown in Table 4-1: Drinking Water Quality Index (WQI) Thresholds.

Table 4-1: Drinking Water Quality Index (WQI) Thresholds

WQI	STATUS
0 to 25	Excellent
26 to 50	Good
51 to 75	Poor
76 to 100	Very Poor
>100	Unfit

The assessment of urban filtered and unfiltered drinking water quality involved collecting samples from each division. Laboratory analyses revealed that nearly all samples met the stipulated requirements of standards/guidelines for all physical, chemical, and biological parameters assessed. The only exception was arsenic monitoring in DG Khan, with a concentration of 5.9 mg/L, far exceeding the standard limits. The WQI rating indicated that Gujranwala division had the best rating score (26.8, Good), whilst Sargodha scored the worst rating (76.5, Very Poor). In terms of PLI, all samples were rated below 1, with Lahore recording the least PLI score (0.26) and DG Khan the highest (0.86). These analyses indicate that the filtered drinking water in selected urban areas was found to be *fit* for drinking purposes, except for DG Khan due to Arsenic excess.

In case of unfiltered drinking water at the consumer end all the physical parameters were found well within stipulated limits prescribed by relevant standards. However, EC values for four divisions (Faisalabad, Sargodha, Bahawalpur and DG Khan) and TDS levels for three divisions (Faisalabad, Sargodha and DG Khan) surpassed the limits. In terms of chemical fitness, lab testing for most parameters including hardness, bicarbonates, carbonates, chlorides, fluorides, nitrate-nitrogen, pH, potassium, sodium and sulphates were found in compliance with recommended threshold limits except few parameters exceeding limits in Faisalabad, Sahiwal and Sargodha divisions. However, the situation was particularly concerning for other chemical parameters. For example, arsenic levels exceeded the WHO guidelines (≤ 0.01 µg/L) in all collected samples, although samples from the Rawalpindi division (0.03 µg/L) complied with the

more lenient PEQS standard limit (≤ 0.05 µg/L). DG Khan (2.86 µg/L) had the highest arsenic level. Alkalinity limits for Faisalabad, Sargodha, Bahawalpur, and DG Khan exceeded WHO guidelines. In the context of biological contamination, no coliforms were indicated in any of the samples. The Water Quality Index (WQI) scores computed based on the aforementioned analyses revealed that the quality of tap water collected from urban sites in most divisions was categorized as poor. In particular, Faisalabad, Sargodha, and Bahawalpur were classified as unfit. The Pollution Load Index (PLI) was lowest in Lahore (0.43) and highest in DG Khan (0.89). These findings suggest that tap drinking water in urban areas at the selected sites is largely unfit for consumption without treatment.

The assessment results for rural filtered drinking water indicated that all samples conformed with the stipulated standard requirements for all tested physical quality parameters including colour, odour, taste, and turbidity; however, it was also noted that EC in DG Khan (1,393 µS/cm) and TDS in both Bahawalpur (990 mg/l) and DG Khan (920 mg/l) were quite close to the standard limits. In terms of chemical fitness, all samples conformed to the stated standard requirements for hardness, Carbonates, Bicarbonates, Chlorides, Fluorides, Nitrate-Nitrogen, pH, Potassium, Sodium and Sulphates parameters. Only two water samples, from Lahore and Rawalpindi, were found to comply with arsenic standard limit. Samples from Bahawalpur and DG Khan (testing at 6.43 µg/l and 2.59 µg/l respectively) had the highest reported Arsenic concentration. No coliforms were detected during biological fitness testing. Based on WQI of rural filtered water samples, most of the divisions categorized as *good,* while a few were classified as *poor*. However, in overall analysis, most of the filtered drinking water sources in rural areas (within the selected areas), except for Lahore and Rawalpindi, were deemed *unfit* for drinking purposes, primarily due to excess arsenic levels.

Compliance monitoring for rural unfiltered drinking (tap) water revealed that Bahawalpur was worst division, failing to meet 13 out of 21 tested parameters. In terms of physical quality fitness, all samples conformed to standard requirements for colour, taste and turbidity. While samples tested for odour in Bahawalpur reported objectionable results. EC and TDS compliance was found lacking in all divisions except for Rawalpindi, Gujranwala and Lahore. Bahawalpur was reported with the worst EC and TDS recordings.

Regarding chemical quality testing, all samples conformed to the limits specified by standards for Carbonates, Fluorides, Nitrate-Nitrogen and pH. However, standard limits for alkalinity were found in compliance in only two divisions (Gujranwala and Rawalpindi), whereas Bahawalpur and DG Khan reported the highest readings. Alarmingly, Arsenic was detected in all divisions, with Sargodha reporting the highest measurements. Bahawalpur failed to meet the standard limits for hardness, Bicarbonates, Potassium, Sodium and Sulphates. Monitoring in DG Khan also failed to comply with the standard requirements for Bicarbonates and Chlorides (whilst it was quite close to the prescribed limit for Sodium monitoring. Moreover, Bahawalpur and DG Khan were the only regions where biological quality standards were not met. The WQI rating of rural unfiltered (tap) water highlighted that water sources from Faisalabad, Sargodha, Bahawalpur and DG Khan divisions were categorized as *unfit*, while those from Lahore, Gujranwala, Multan, and Rawalpindi were designated to be *very poor*. The PLI values followed a similar pattern wherein majority of the divisions, Lahore, Gujranwala, Faisalabad, Sargodha, Bahawalpur and DG Khan crossed the threshold level of 1. These findings indicate that the tap drinking water in urban areas within the selected sites was found to be *unfit* for drinking purposes (without treatment), with high severity in Bahawalpur and DG Khan divisions.

Looking at the physical parameters in particular EC and TDS, it is evident from the Figure 4-19 that: (1) the filtered water sources are much better than the unfiltered ones (by an average factor of ≈2.8), and (2) the urban sources are much better than their rural counterparts (by an average factor of ≈1.4). Taken individually, for both of these factors, the values increase in the order: $urban\ filtered < rural\ filtered < urban\ unfiltered < rural\ unfiltered$. This is evident from average values for both the above-mentioned physical indicators, as displayed in Figure 4-21. For both these parameters, it can also be seen that – on average – only the rural unfiltered water sources exceed the stipulated standard limits; all the other three sources fall within the prescribed limits.

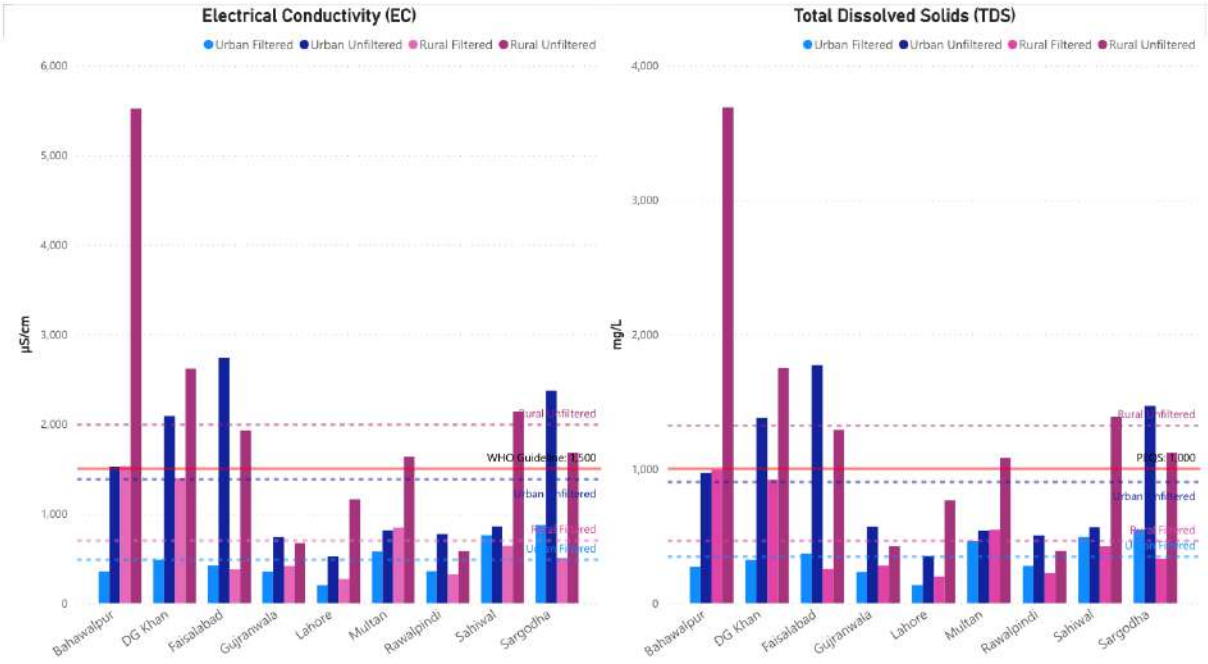


Figure 4-21: Physical parameters (EC and TDS) monitored in consumer end water samples

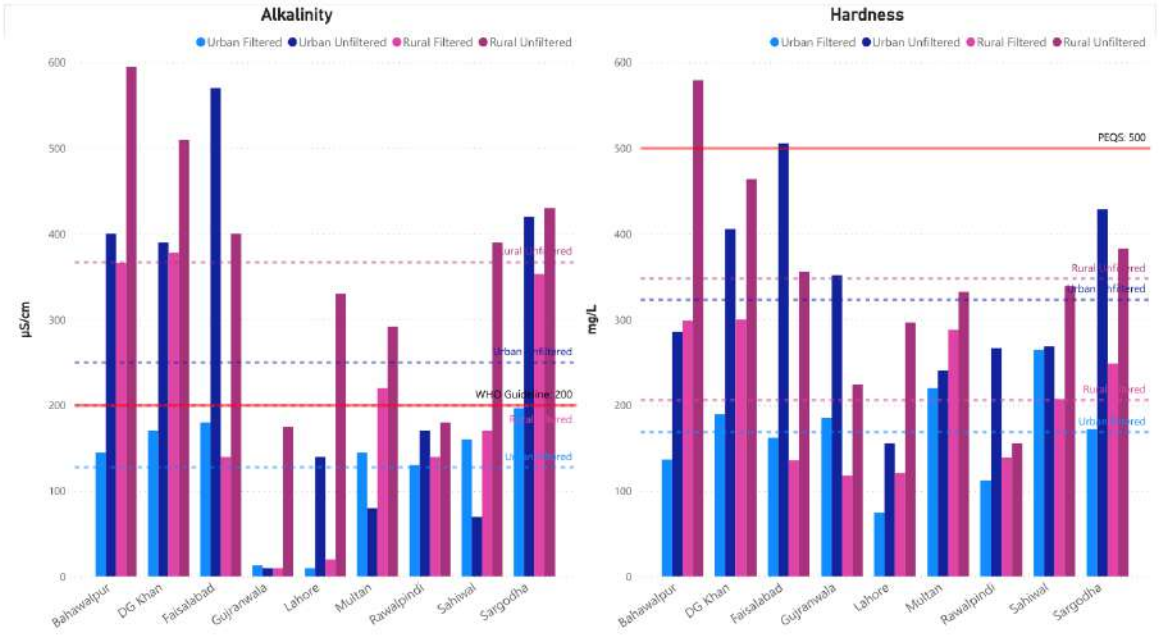


Figure 4-22: Chemical parameters (Alkalinity and Hardness) monitored in consumer end water samples

The **PLI**[79] values calculated from urban drinking water samples were less than the fitness threshold (<1) in all divisions, whereas exceeded in rural water sources in several divisions (**Error! Reference source not found.**3 and 4-25). In the case of urban water sources, Lahore division remained the best with the least PLI values (0.26 for filtered and 0.43 for unfiltered), while DG Khan fared the worst with the highest PLI rating scores (0.89 for filtered and 0.89 for unfiltered).

The WQI[80] computation analysis provided clear delineations regarding both absolute and relative fitness quality ratings of water sources amongst the selected sites in the province. In terms of urban filtered water, it was found that sources in Lahore, Gujranwala, Sahiwal, Multan, Rawalpindi, and DG Khan were ranked as *good* while those in Faisalabad, Sargodha, and Bahawalpur were categorized as *poor*. At the same time, WQI analysis for urban unfiltered (tap) water sources depicted that fitness of such sources in most of the divisions was rated as *poor* whilst the quality of corresponding sources in Faisalabad, Sargodha and Bahawalpur divisions ranked them in the *unfit* criteria. The current investigation also demonstrated that the quality of rural filtered water in most of the divisions was characterized in *good* category according to WQI analysis, whereas the same in Faisalabad, Sargodha, DG Khan and Bahawalpur divisions was graded in *poor* criteria. In the case of rural unfiltered (tap) water, the sources in Bahawalpur, Sargodha, Faisalabad, and DG Khan divisions were ranked in *unfit* category on the basis of WQI,

[79] The Pollution Load Index (PLI) is an index for estimation of contamination status of heavy metals present in drinking water samples. For this exercise, PLI was calculated from filtered/unfiltered (tap) water samples obtained from selected sites of urban and rural areas in Punjab. PLI is determined as follows:

$PLI = (CF_1 \times CF_2 \times CF_3 \times \cdots \times CF_n)/n$, where CF is the contamination factor given by the ratio of metal concentration in drinking water and background value of that metal, and n is the number of metals.

[80] The Water Quality Index (WQI) of drinking water samples was calculated as: $WQI = \sum_{i=1}^{i=n} w_i q_i$, where q_i is the quality rating scale for each assessed parameter in terms of its concentration versus standard limit (as a percentage) and w_i is the unit standard limit weight for that parameter.

while sources in Lahore, Gujranwala, Multan and Rawalpindi divisions were characterized in *poor* category.

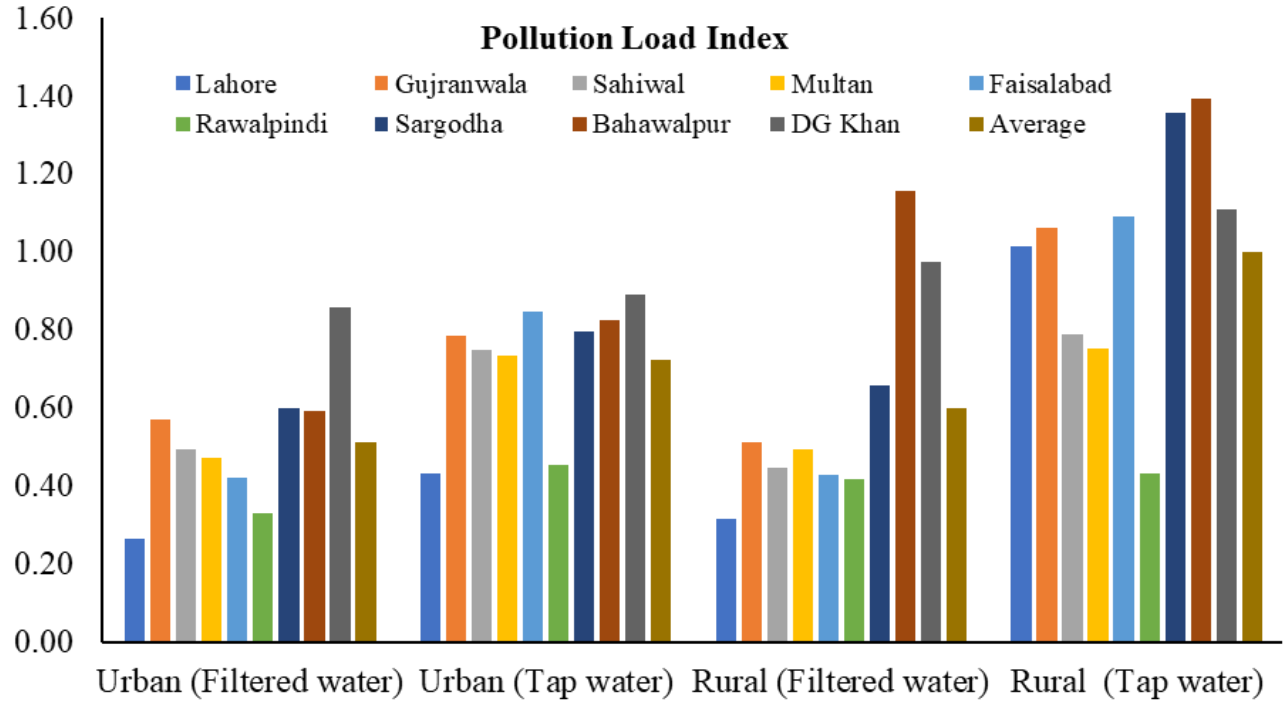


Figure 4-013: Pollution Load Index of filtered/unfiltered (tap) water collected from urban and rural areas in all nine divisions of Punjab

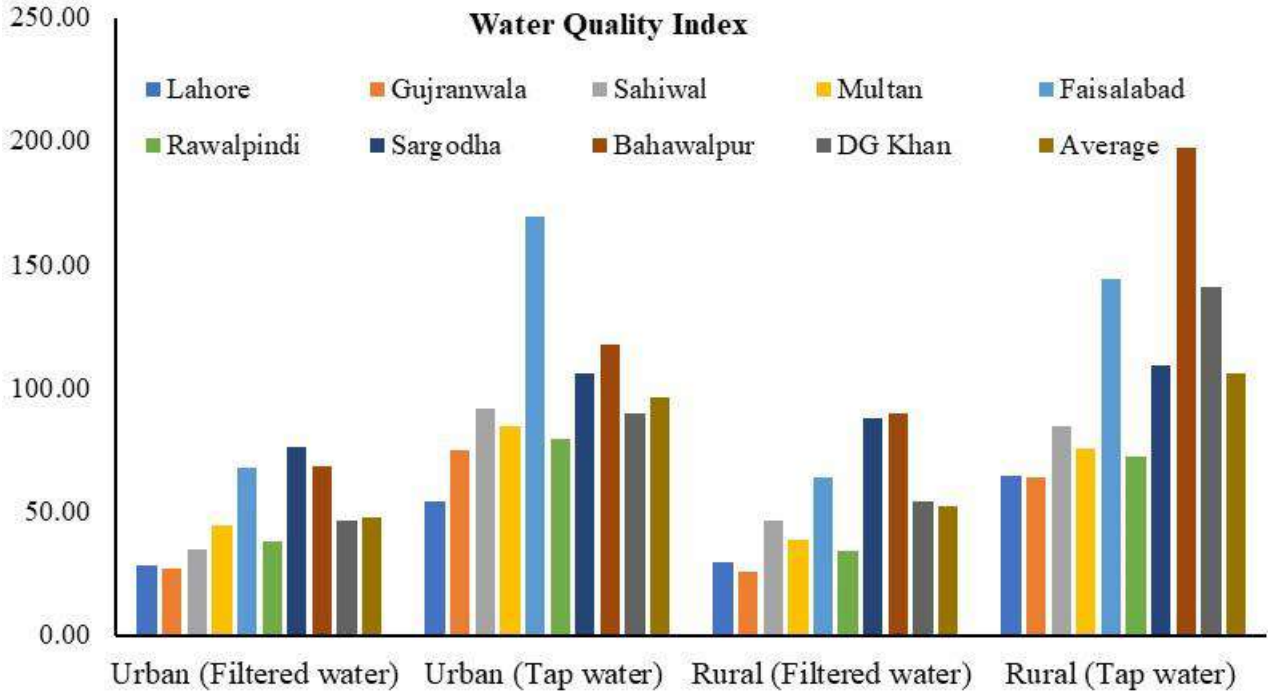


Figure 4-24: Water Quality Index (WQI) of filtered/unfiltered (tap) drinking water collected from the selected urban and rural areas in all nine divisions of Punjab

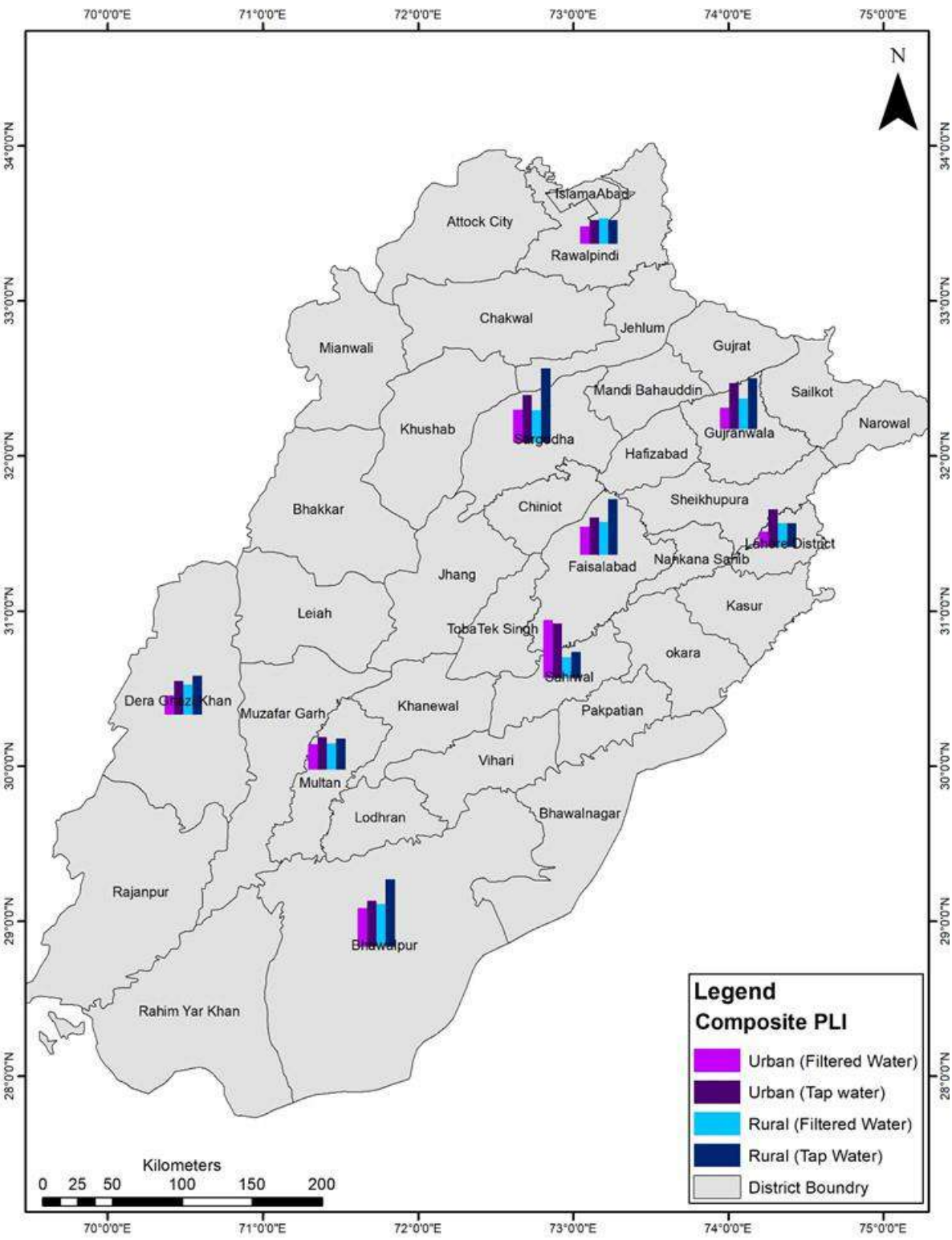


Figure 4-025: Composite Pollution Load Index (PLI) map of (filtered and unfiltered) drinking water collected from rural and urban areas in all divisions of Punjab

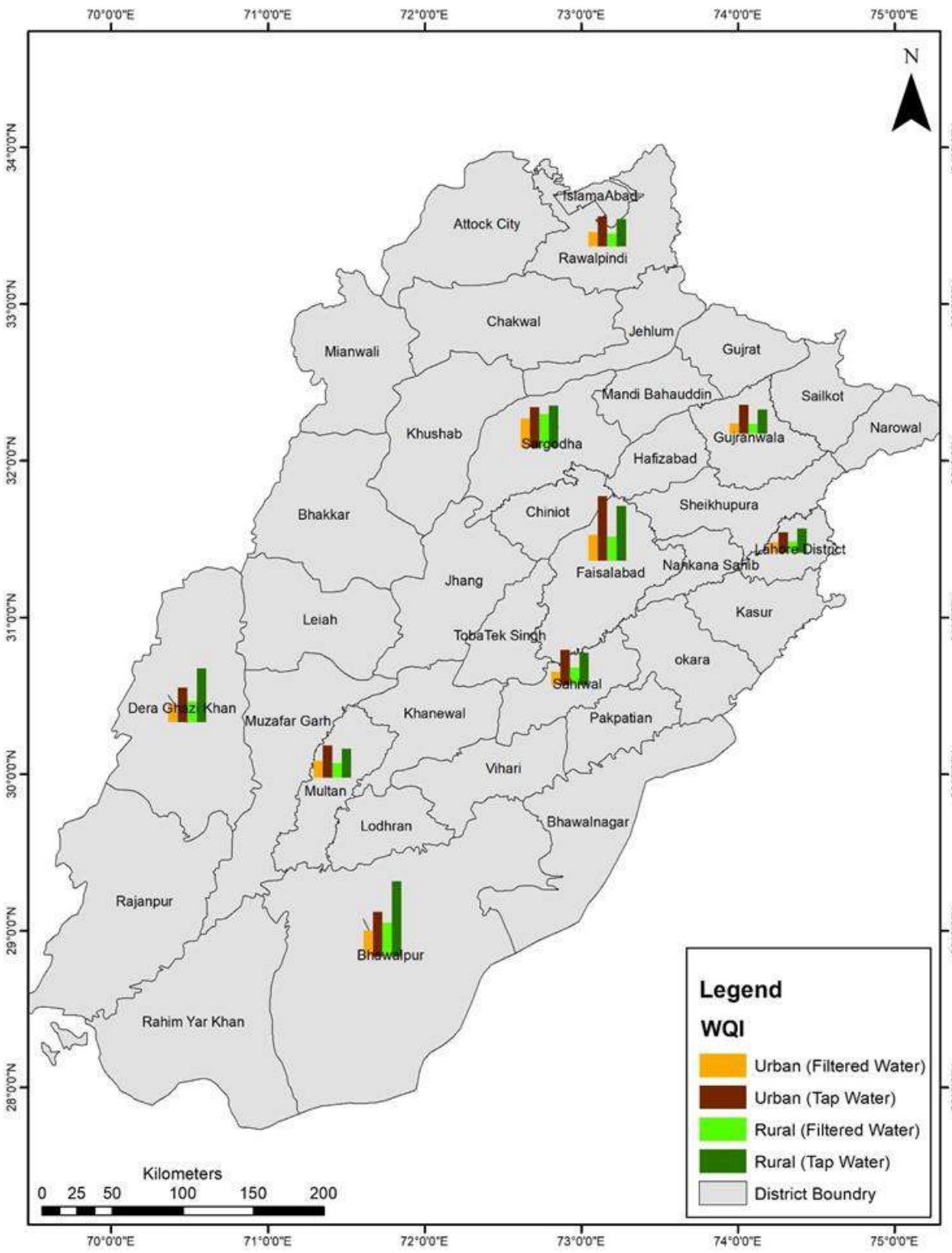


Figure 4-26: Composite Water Quality Index (WQI) map of filtered/unfiltered (tap) drinking water collected from the selected urban and rural areas in all nine divisions of Punjab

2.6 Industrial Pollution Loads

Industrial effluents are amongst the leading causes of water pollution along with agricultural runoffs and municipal wastewater/sewerage. With the prime intent to gauge compliance of environmental quality standards, 8 EPA laboratories in major districts conducted monitoring and assessment of industrial effluents/wastewater in 25 districts of the province. Samples were collected from 504 industrial units grouped into 36 industrial categories to monitor the quality of industrial effluents. Around half of the sampled industries were concentrated in 2 districts, namely Multan (26%) and Kasur (24%). Around a quarter of the industries sampled belong to the leather and tanning industry sector, followed by textiles (17%) and flour (14%) sectors; thereby, collectively these 3 sectors constitute over half of the industries sampled. A listing of the industry sectors sampled and district location, along with respective industrial unit counts, is appended herewith at Annexure C-2.

The assessment conducted by the EPA laboratories revealed that only 0.8% of industrial units from the sampled group comply with the PEQS standards for all the monitored parameters. Whereas the other 99.2% industrial units exceeded prescribed PEQs limits in at least one of the parameters[81]. Generally, 65.5% environmental standard breaches were reported in various parameters by the industrial units. Most of the industrial units were found non-compliant with parameters such as BOD (95.7%), COD (94.4%), Sulfide (91%), temperature (84.4%) and TSS (81.7%). Figures 4-27- 4-34 illustrate the results of industrial effluent monitoring, wherein the most polluting industrial sector for a particular parameter on basis of sectoral average (the outlier) is displayed separately from the rest of the sectors.

The leather and tanning industry was identified as the most polluted and only industrial sector where none of the PEQS limits were found to be complied with parameters assessed. The difference with PEQs limits was even starker in case of COD, Chloride, TSS and TDS wherein the average concentrations for this sector exceeded industry concentration averages by at least a factor of ≈3.5 times. The other main pollution causing industries included protein manufacturing, pesticides, textiles, sugar mills, mining, and paper industries.

The average concentration of COD (1,778 mg/l) was found 12 times higher than the prescribed PEQs threshold. Only 5.6% of the industries were found within prescribed limits. The leather and tanning industry sector having the highest COD (5,849 mg/l) exceeded the PEQS limit by a factor of 39. Whereas, effluent from protein and pesticide manufacturing factories had the COD concentrations exceeding the PEQS limit by factors of 10.3 and 9.8 respectively (Figure 4-27). The concentration of sulfide was not in compliance with PEQs limits (< 1.0 mg/l) in 36% of the industrial units assessed, while the effluent from sugar mills had the highest concentration of sulfide (290 times the PEQS limit) followed by the leather and tanning industry sector (55 times the PEQS limit). The average industry Sulfide monitoring evaluation was found to be 20.6 times the PEQS limit (Figure 4-28).

[81] PEQS limits for this section refer to the “Punjab Environmental Quality Standards for Municipal and Liquid Industrial Effluents” as notified by the Government of the Punjab on August 12, 2016. They can be assessed on the EPCCD website at <https://epd.punjab.gov.pk/peqs>.

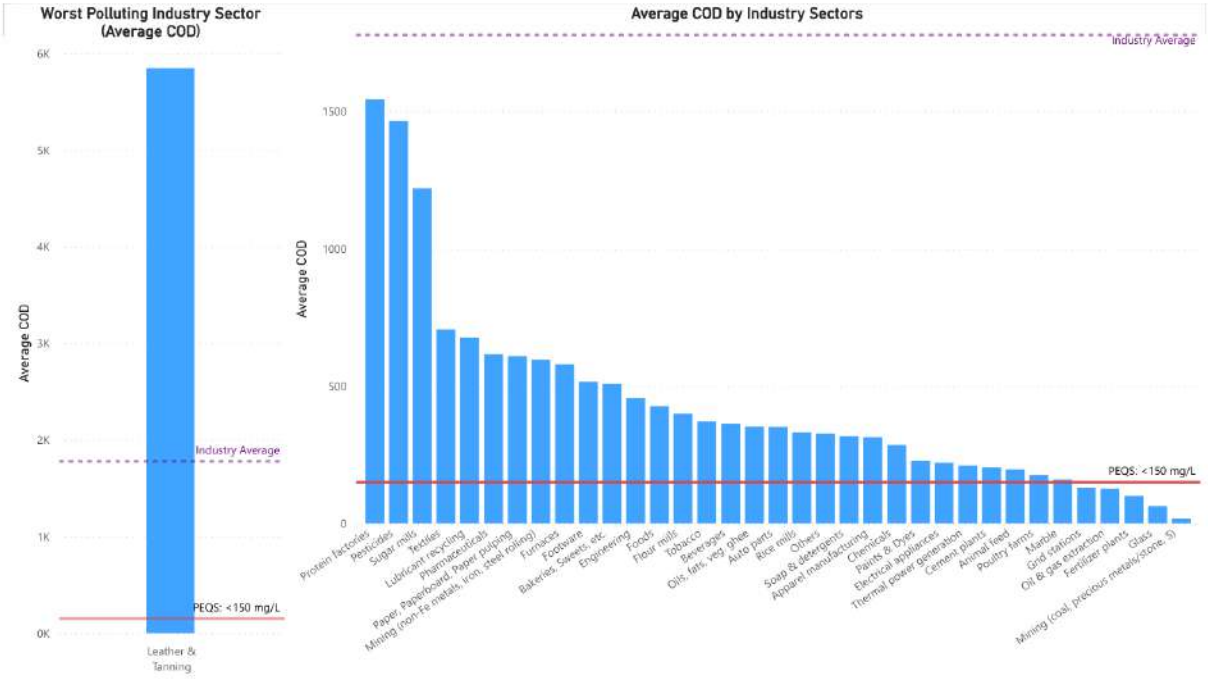


Figure 4-27: Average concentration of COD monitoring for sampled industrial units (Source: EPA, 2023)

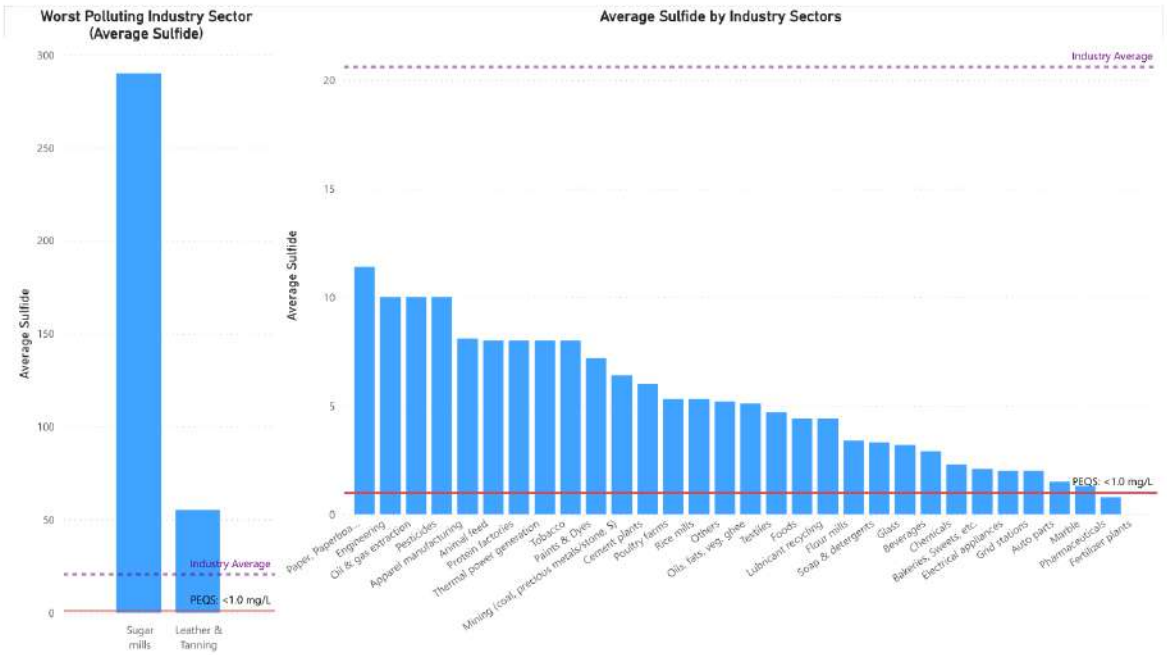


Figure 4-28: Average concentrations of sulfide monitored across sampled industrial sectors (Source: EPA, 2023)

The sulfate concentration exceeded PEQS (< 600 mg/l) in 39% of the industrial units across 12 industry sectors (Figure 4-29). Leather & tanning industry had the highest concentration of sulfate (1,869 mg/l), followed by mining (947 mg/l) and marble sectors (936 mg/l). Similarly, 38% of the industrial units belonging to 16 industrial sectors had chloride concentration more

than PEQs (< 1,000 mg/l). Figure 4-30 shows that the leather and tanning industry sector had the highest concentration of chloride (average of 12,662 mg/l) followed by lubricant recycling industry.

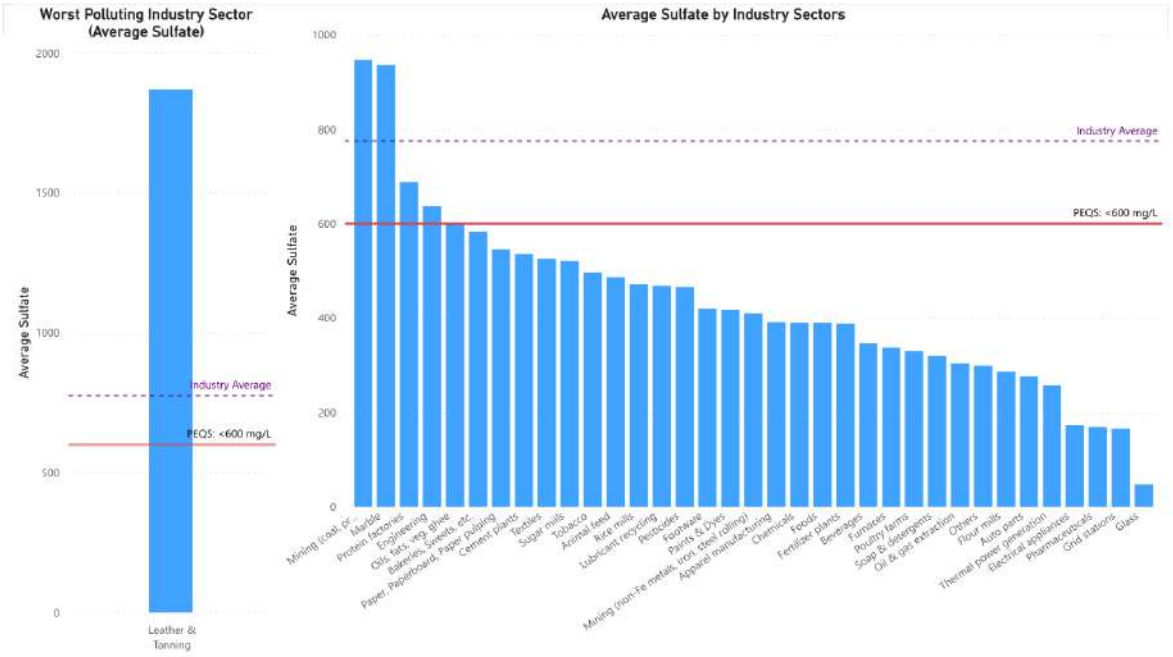


Figure 4-029: Average Sulfate monitoring for sampled industrial sectors (Source: EPA, 2023)

PEQS limits (< 200 mg/l) were majorly non-conformed in the case of TSS monitoring, with 81.3% of the industrial units failing to meet the compliance standards (Figure 4-31). The average industry TSS (1,548.3 mg/l) was found to exceed the PEQS limit threshold at a factor of 7.7. The leather & tanning industries (average: 5,442 mg/l; 27.21 times the PEQS limit) and protein factories (average: 3,245 mg/l; 16.23 times the PEQS limit) were the prime perpetrators, with concentration limits exceeding industry averages by more than twice (351% and 210% of the industry averages, respectively). The former sector including the most TSS polluting industrial unit with the discharge assessment of 96,155 mg/l (480.8 times the PEQS limit; 62.1 times the industry average).

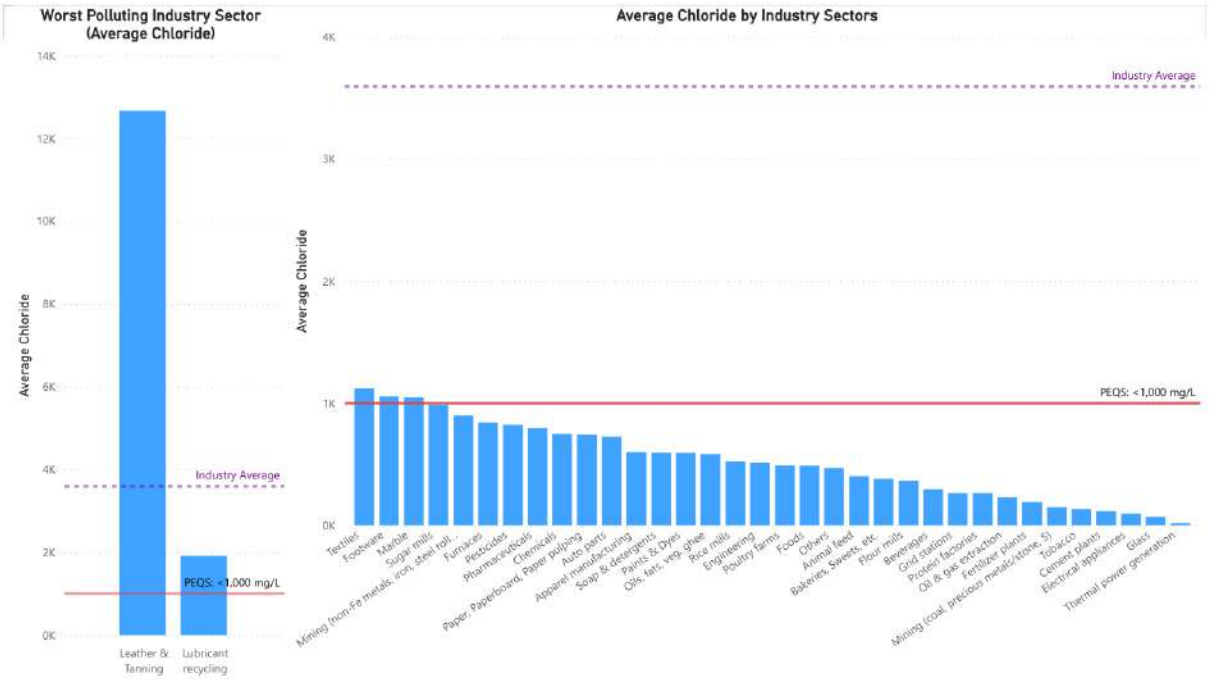


Figure 4-30: Average Chloride monitoring for sampled industrial sectors (Source: EPA, 2023)

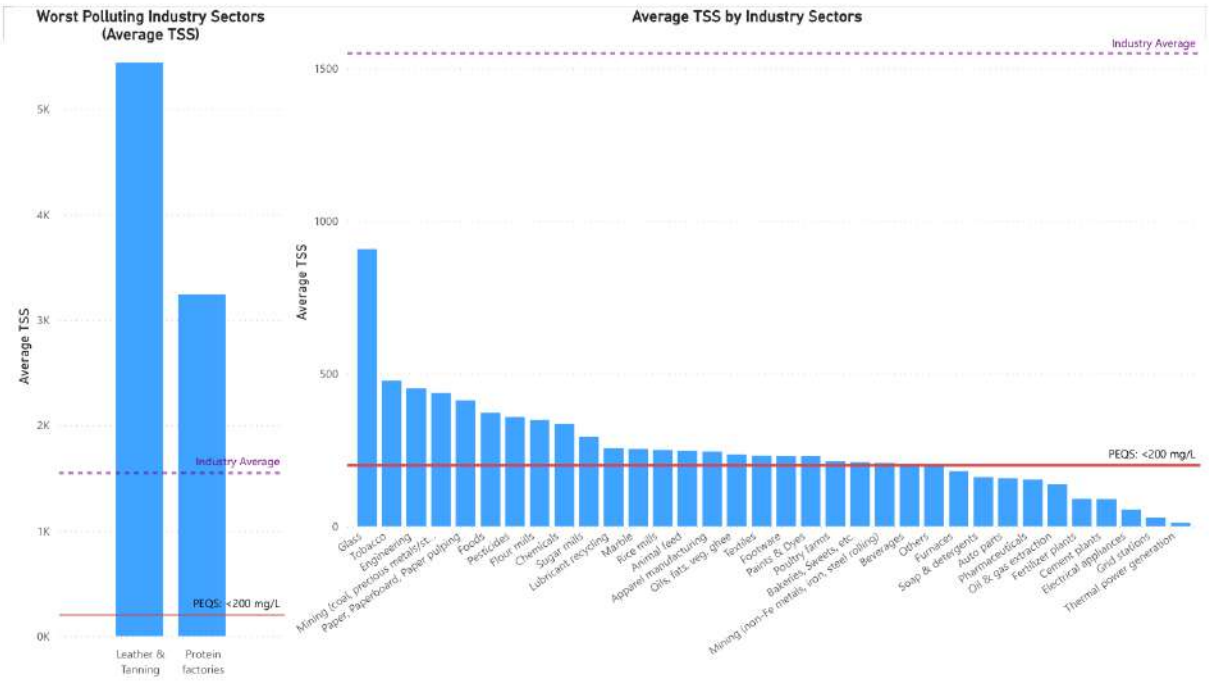


Figure 4-31: Average TSS monitoring for sampled industrial sectors (Source: EPA, 2023)

About 42% (21 industrial sectors) of the industrial units exceeded the PEQS limits for TDS (3,500 mg/l). There were only 2 industrial units out of 504 that comply with stricter USEPA Limits (500 mg/l). The effluent from leather and tanning industry sector showed the highest concentration of TDS (Figure 4-32).

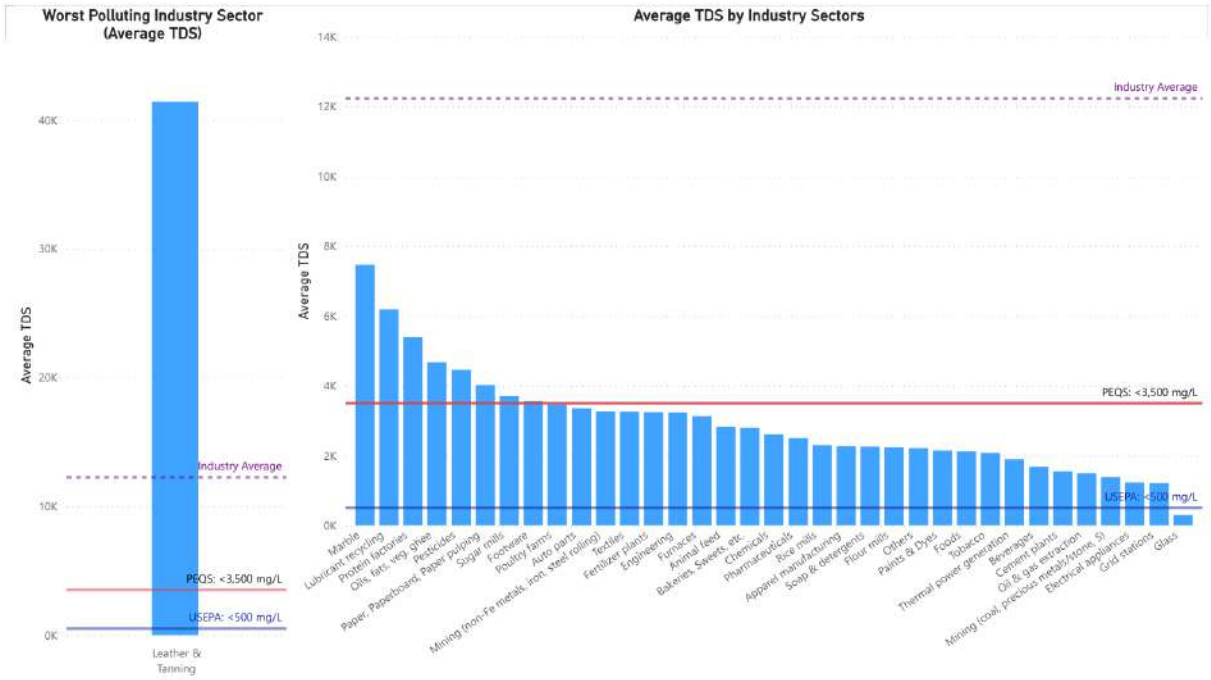


Figure 4-032: Average TDS monitoring for sampled industrial sectors (Source: EPA, 2023)

BOD (Biochemical Oxygen Demand) is a crucial parameter in monitoring water quality, indicating the amount of oxygen required by aquatic organisms for their survival and overall health. Nearly 40% of industrial units across 20 sectors failed to meet the PEQS limit threshold of 80 mg/l. The average industry monitoring rating, at 1,921 mg/l, exceeded this threshold by a staggering 24 times. Once again, the leather and tanning sector emerged as the primary source of pollution, with its average BOD discharge of 3,015 mg/l surpassing the PEQS limit by 37.7 times and exceeding the industry average by 1.57 times.

pH is a key water quality indicator, with PEQS recommended limits of 6-9. It was found that about 60.3% of the sampled industrial units did not comply however, the average pH value (6.8) was well within the recommended limits. The food industry sector was with the highest pH (11.1), while the lowest pH (1.5) was recorded for a unit within the leather and tanning industry (Figure 4-34).

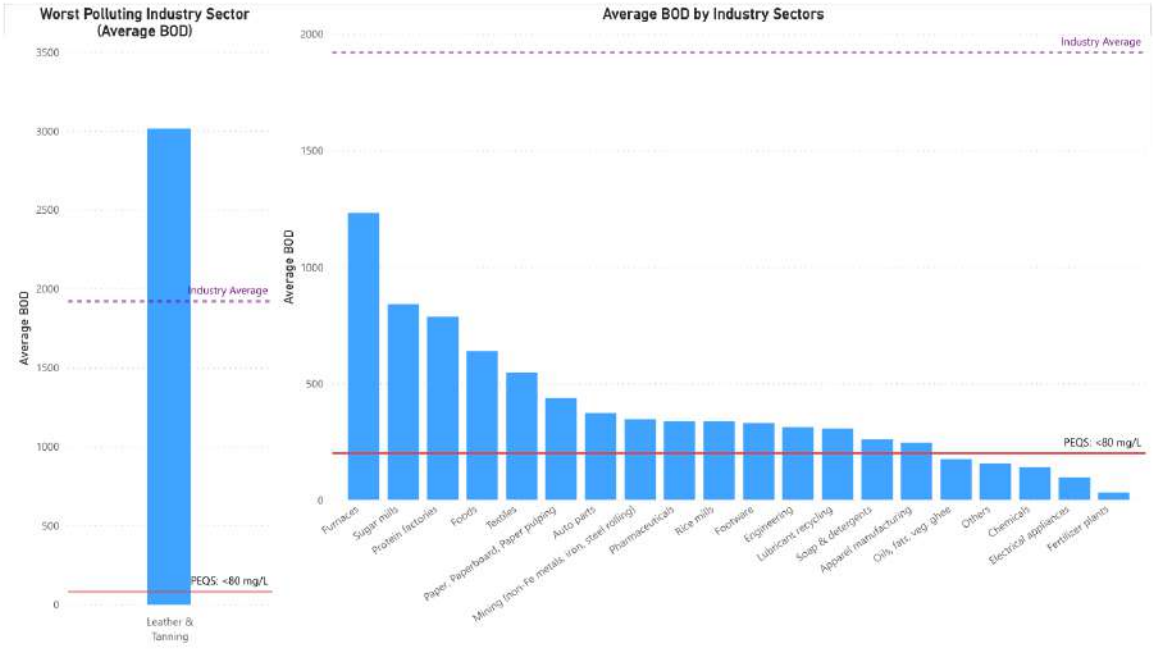


Figure 4-033: Average BOD monitoring for sampled industrial sectors (Source: EPA, 2023)

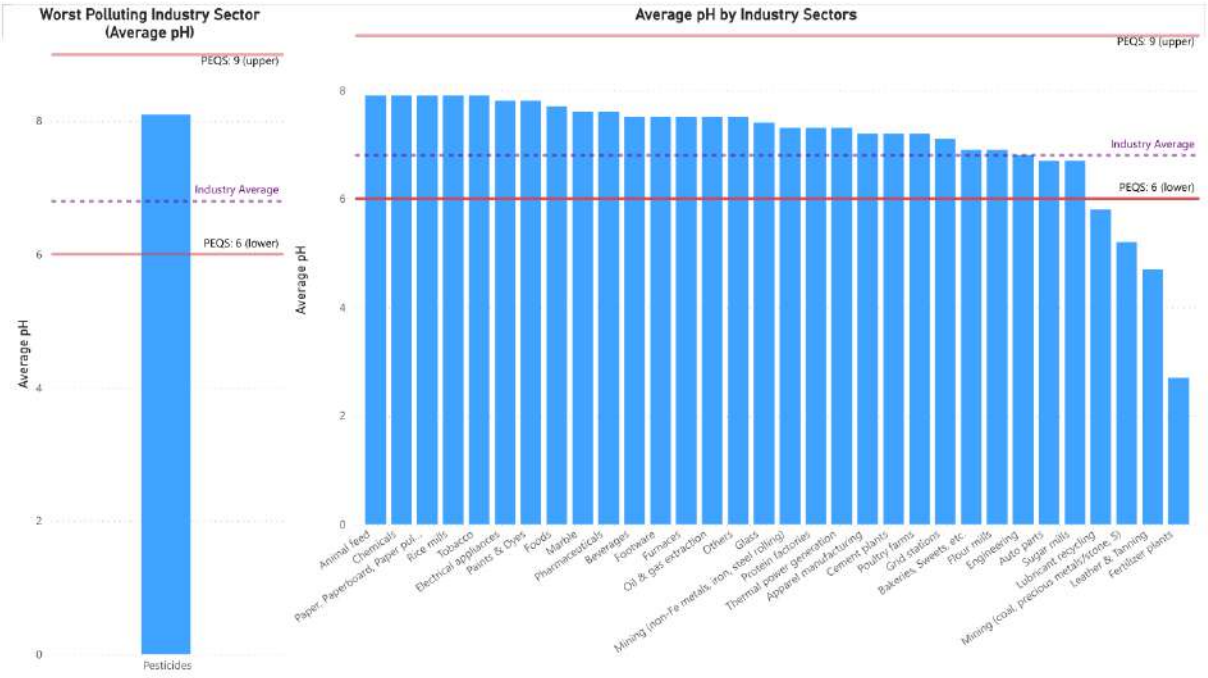
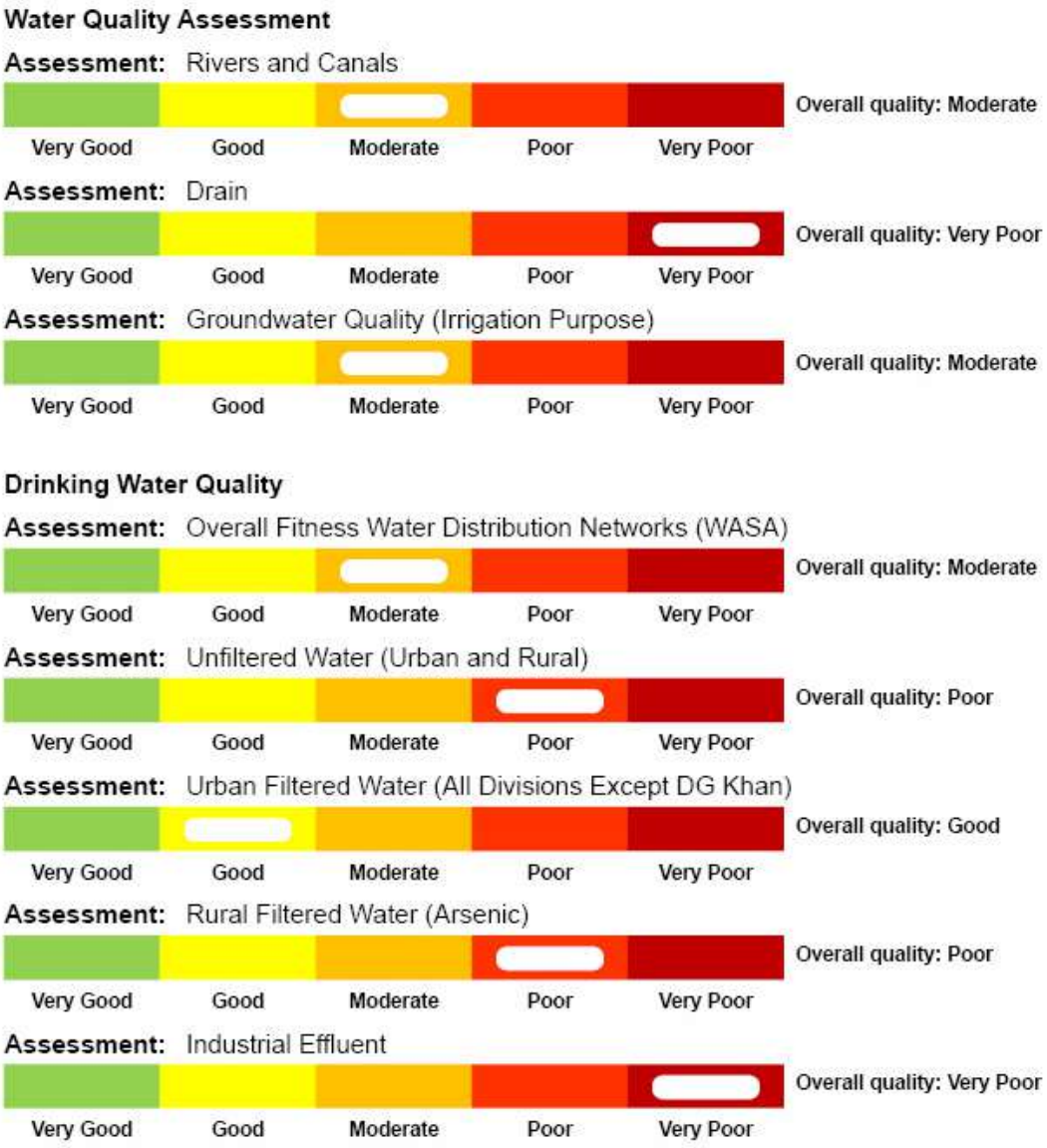


Figure 4-34: Average pH monitoring for sampled industrial sectors (Source: EPA, 2023)

2.7 Overall Assessment

The overall quality of surface water in rivers and canals was found ‘Moderate’, while of drain it was rated as ‘Very Poor’. Overall groundwater quality for irrigation was rated ‘Moderate’ Quality of urban filtered drinking water was rated ‘Good’ while both unfiltered urban and rural waters were

'Poor' and unfit for drinking along with rural filtered water having high Arsenic content. Industrial effluents exceeding most of the PEQS limits for monitored parameters were rated as 'Very Poor'.



3 MANAGEMENT

DPSIR Framework

The DPSIR Framework for water resource management system in Punjab (Figure4-37) identifies the challenges and requisite responses as follows:

Drivers

The proliferating population growth and rapid urbanization coupled with improved living standards of citizens has intensified the water demand in the province. Unplanned industrialization has resulted in the discharge of pollutants into water bodies, contaminating water sources and reducing their quality. Poor agricultural practices including ineffective irrigation methods and

chemical runoff has not only placed the pressure on water availability but has also deteriorated its quality. Transboundary pollution due to shared discharge in many rivers has also contributed to the water pollution in the province. Furthermore, the distribution and availability of water are disrupted by weather patterns altered by climate change, placing further strain on already vulnerable water sources.

Pressures

Inappropriate agricultural and industrial practices contribute to resource wastage, ultimately impacting per capita water availability. Polluting factors, notably untreated sewage from municipal sources, untreated industrial effluents, and agricultural runoffs, further strain freshwater resources. Industries discharge significant volumes of effluents into nearby water bodies, significantly deteriorating their overall quality. Moreover, siltation and increased sediment load in dams has reduced the water storage capacity of dams.

State

In Punjab, river and canal water quality is moderate. Groundwater for irrigation is moderate, with only 58% samples meeting EC, SAR, and RSC standards of irrigation water quality. Distribution system water is also moderate in fitness (majorly because of biological contamination), urban filtered drinking water is good (except DG Khan), while rural filtered water is poor in quality (high Arsenic). Unfiltered drinking water both urban and rural have poor quality and are unfit for drinking. Industrial effluents exceed most limits, and are rated very poor.

Impacts

Per capita water availability in Punjab is declining and soon the province will touch water severe scarcity level. The current water stress level has already put pressure on food and water security in Punjab. Compounded with these factors, the level of water pollution has increased burden of disease in the province. The nation is fighting with these challenges which are affecting their health and socioeconomic wellbeing.

A USAID study undertaken in Kasur district found that 87% of the health-related costs in the region were directly attributable towards water quality aspects. Including these and other activities, there are high observable socioeconomic impacts and losses owing to water quality and unavailability issues, thereby disturbing almost all aspects of life and livelihoods.

Limited or no access to clean and safe drinking water can have significant and far-reaching impacts on health, socioeconomic conditions, and the environment. Some of the key amongst them are listed below:

Health Impacts: Contaminated water is a breeding ground for waterborne pathogens such as bacteria, viruses and other parasites, thereby resulting in high incidence of waterborne diseases. Diseases like cholera, typhoid, hepatitis, dysentery and various gastrointestinal and blood-related infections are often linked to the consumption of unsafe water. Exposure to heavy metals through water is known to cause various diseases in humans such as kidney pathology, respiratory problems, cancers and neurological disorders. Poor water quality can contribute to malnutrition, especially in children. Moreover, diarrheal diseases resulting from contaminated water can lead to nutrient loss and hinder the absorption of essential nutrients, thereby impacting seriously health.

The District Health Information System (DHIS) – a healthcare monitoring program implemented by DGHS – is *a mechanism of data collection, transmission, processing, analysis and information*

feedback to the first level care facilities and secondary level health care facilities (in all districts of the province). It provides a baseline data for district planning implementation and monitoring on major indicators of disease pattern, preventive services and physical resources."[82] DHIS is aimed at provision of KPI analyses to the department and healthcare administrators throughout the province, facilitating them in performance evaluation, problem resolution and policymaking regarding healthcare provision. Data from public healthcare facilities throughout the province regarding OPD walk-in patients[83] for waterborne diseases (including diarrhoea, cholera, gastroenteritis, typhoid and other related infections) for CY 2023 was collated and analysed for impacts, for the purposes of this report. Monthly and district-wise monitoring enumerations are depicted in Figure 4-35 and Figure 4-36. It can be seen that, generally, the 15-49 y age group reported the most patients throughout the year and across all districts in the province, followed by 5-14 y and 1-4 y age groups. The least number of OPD patients belonged to less than one month, 1-2 m and 3-5 m age groups (perhaps, this may be due to the fact that such patients were covered in separate paediatric OPDs and wards). Most OPD patients visited public healthcare facilities in the Lahore district, followed by Faisalabad, Muzaffargarh and Gujranwala districts. It was also noted that there were slight gender disparities amongst different age groups, with close to an even split in overall numbers. May, closely followed by August, were the most 'infection-reporting' months, whereas the least number of patients visited OPDs in December and January.

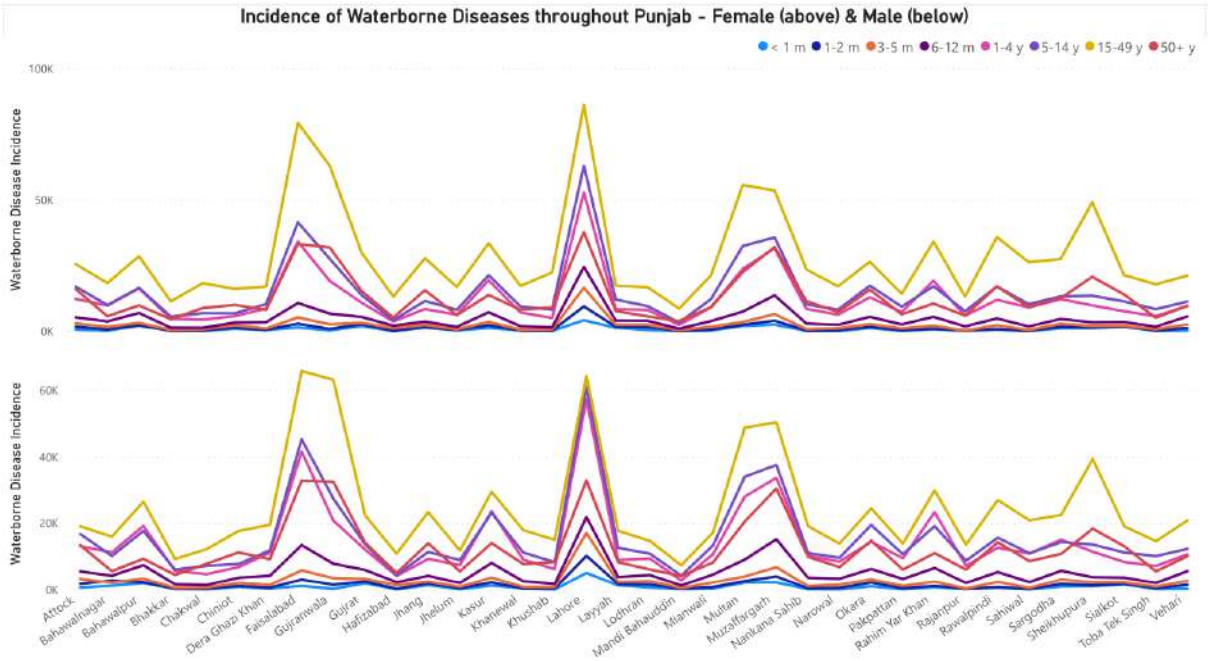


Figure 4-35: Incidence of waterborne diseases in Punjab (Source: DGHS, Punjab, 2023)

[82] https://dghs.punjab.gov.pk/district_health

[83] This data merely relates the number of patients visiting OPDs for waterborne diseases, and does not delineate on the final diagnosis, severity of disease, outcome of visit and next course of action. Moreover, this does not include data for hospitalizations, either post of without going to OPD.

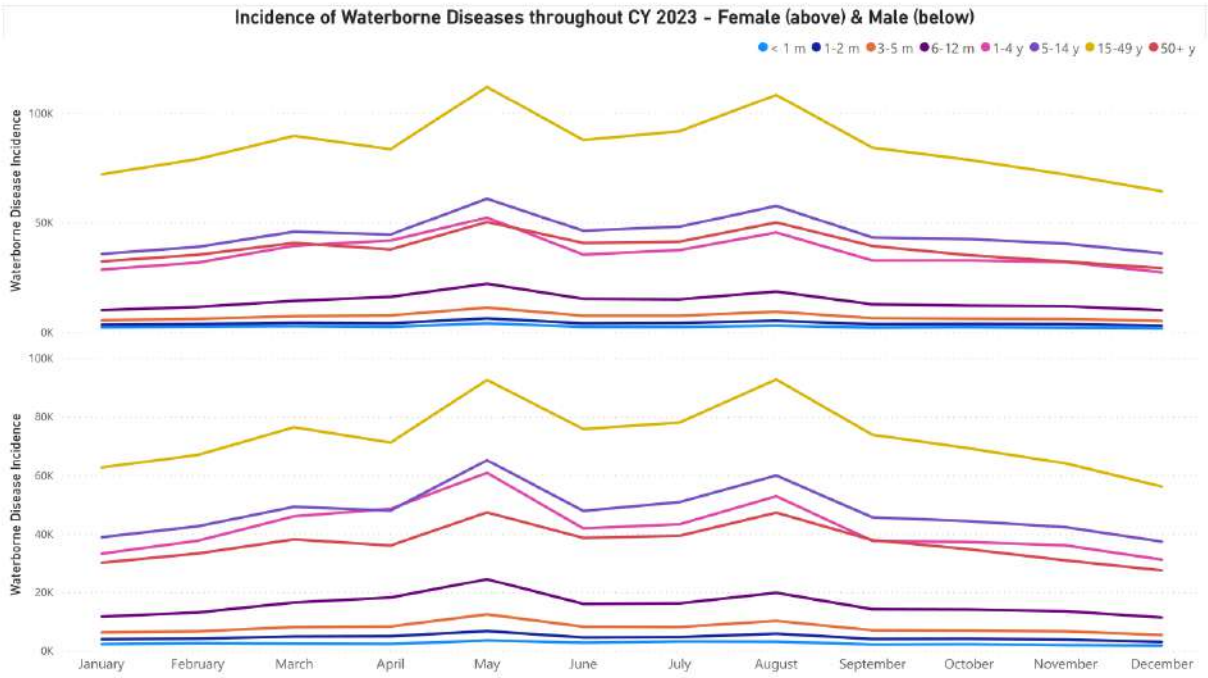


Figure 4-036: Incidence of waterborne diseases during CY 2023 (Source: DGHS, Punjab, 2023)

- **Socioeconomic Impacts:** Poor water quality and scarcity significantly inflate healthcare costs, as treating waterborne diseases places a heavy burden on healthcare systems. This not only results in increased medical expenses but also reduces productivity due to illness. Individuals afflicted by waterborne illnesses may experience a sharp decrease in work or school attendance, mobility and productivity, leading to long-term economic consequences for affected communities. Given that unsafe drinking water is commonly linked with impoverished and undereducated communities, the economic strain of waterborne diseases can perpetuate a vicious cycle of poverty, diverting resources from income-generating activities to address health issues.
- **Environmental Impacts:** Unsafe disposal of industrial and municipal wastes can contaminate groundwater, a vital source of water for drinking and irrigation use. Groundwater contamination can persist for long periods and is challenging to remediate. Furthermore, unabated discharge of pollutants into water sources can seriously harm aquatic ecosystems. Besides humans and land-based animals, such contaminants may affect all aquatic life, thereby disrupting balance of the ecosystem and impacting biodiversity. Agricultural runoff containing mostly toxic pollutants from contaminated water can lead to soil degradation, which, in turn, affects crop yields and dwindles agricultural productivity.
- **Social and Cultural Impacts:** In some cases, communities with limited access to safe and clean water may be forced to displace from their ancestral homes and relocate in search of better water sources. Such migration can lead to social disruption and the loss of traditional ways of life. Water quality and access issues may also lead to widening of gender disparities, as women and children are often disproportionately affected by lack of access to safe water.

Response

Punjab is rapidly approaching water stress due to its dense population and intensive use of water in agriculture, presenting serious challenges in terms of water quality, availability, and access.

Addressing unsafe drinking water requires a holistic approach that considers health, socioeconomic, and environmental factors. Global initiatives targeting sustainable development goals aim to enhance water quality and accessibility. Urgent proactive measures in legal and policy domains are crucial for effective water resource management in Punjab. Implementing appropriate legal frameworks can safeguard water resources and combat pollution, while improving water management practices can reduce environmental costs.

Based on results of 364 water samples collected by LG&CD Department of Punjab (90% samples contaminated with bacteria and arsenic) Chief Minister reinvigorated the "Clean Drinking Water for All Project," installing 307 purification plants to ensure safe water for residents of Bahawalpur, Lahore, Okara, and Kasur.

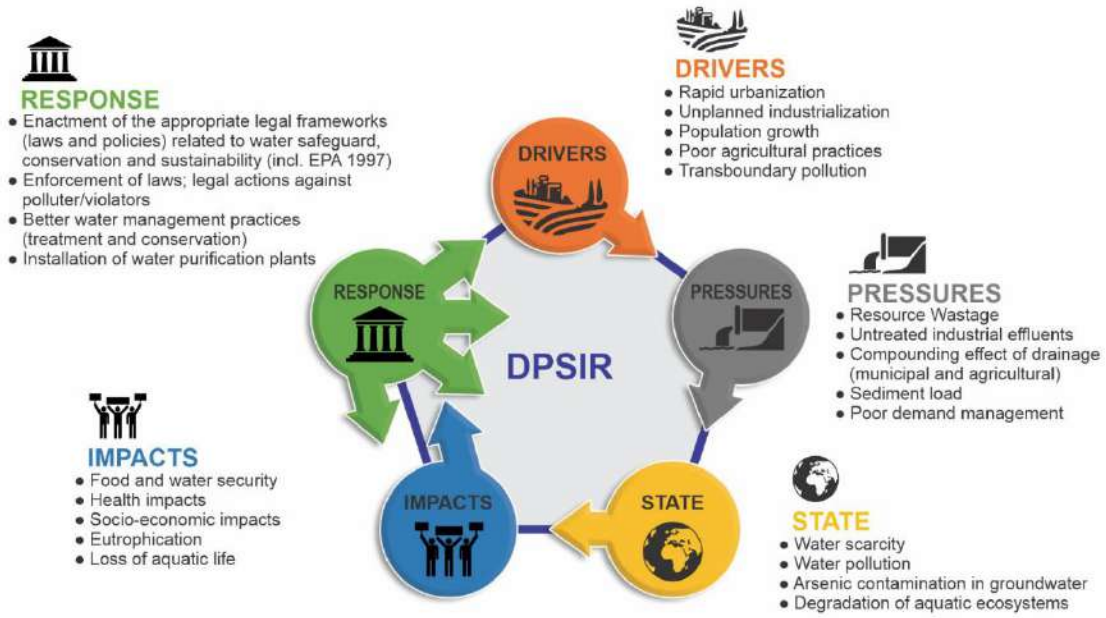


Figure 4-37: DPSIR framework of water quality in Punjab

4 WAY FORWARD

Water quality and security are crucial across various dimensions including household, economic, urban, environmental, and resilience to water-related disasters underscoring their paramount importance. Findings of this report will serve as a valuable resource for policymakers, environmental agencies, researchers and other environmental stakeholders to offer insights into the current state-of-affairs regarding water resources within the province. By highlighting key environmental indicators and potential concerns, the assessment aims to inform strategic decision-making, policy formulation and sustainable resource management practices. Following are some recommendations for addressing the challenges related to water quality:

Strengthening Regulatory Framework: Strengthening of relevant regulatory framework, enactment of 'missing laws' related to environment and establishment of enforcement mechanisms are crucial to monitor and control pollution from industrial effluents, agricultural runoff, and other sources. The government may address the key issue of water quality through

enactment and promulgation of appropriate, legal covenants and policies aimed at safeguarding water quality, and ensuring its conservation and sustainability.

Water Monitoring System: Survey and identification of all point and non-point pollution sources causing ground, surface and drinking water contamination should be undertaken as a priority with the core intent of mitigating them. The public sector should institute and maintain baseline data on both quantity and quality of all surface, ground and drinking water resources in the province.

There should be establishment of drinking water quality testing labs and recruitment of relevant human resource at each divisional headquarter in order to monitor and publish water quality status on monthly and yearly basis.

Integrated Water Resource Management, Governance and Stewardship: Implement integrated water resource management approaches that consider the interconnectedness of surface and groundwater systems. Develop coordinated strategies for watershed management, land-use planning, and water allocation to ensure sustainable utilization of water resources while protecting water quality.

Investment in Water Infrastructure: Upgrade and expand water treatment facilities to ensure that water supplied for domestic, agricultural, and industrial purposes meets quality standards. Laying down new water supply infrastructure and replacement of fractured and broken waste water and drinking water networks on priority basis. The sewage/effluent carrying lines should be separated from drinking water supply lines to avoid mixing of waste water with clean water. There should be advance water purification/filtration plants at each union council and village level to provide safe, healthy, pure, safe and clean drinkable water.

Promotion of Sustainable Agriculture: Encourage the adoption of sustainable agricultural practices aimed at reducing reliance on chemical fertilizers and pesticides, thereby mitigating the potential contamination of groundwater and surface water reservoirs. Promote precision irrigation techniques and the use of organic farming methods to reduce water pollution and preserve soil health.

Community Engagement and Awareness: Raise awareness among communities about the importance of water conservation and pollution prevention. Empower local stakeholders, including farmers, industries, and households, to actively participate in water management initiatives and adopt practices that promote water quality improvement.

Research and Innovation: Support research and innovation in water treatment technologies, pollution monitoring techniques, and sustainable water management practices. Collaborate with academic institutions, research organizations, and industry partners to develop cost-effective solutions for addressing water quality challenges in Punjab.

Assessment and monitoring of health risks associated with water borne-diseases: Assessment and monitoring of health risks associated with water borne diseases (diarrhoea, giardiasis, dysentery, typhoid fever, *E. Coli* infection, and salmonellosis, hepatitis and cholera etc.) in public consuming poor quality drinking water

Revision of PEQS: It is imperative to undertake revision of Punjab Environmental Quality Standards for drinking and industrial effluents in line with international, WHO and USEPA environmental standards. Moreover, quality standards for surface water should be designed on priority basis.

Geo-mapping and geo tagging of water resources: Undertaking geo-mapping and geo-tagging initiatives for groundwater, surface water, and drinking water quality and quantity is crucial.

Figure 4-38: Key dimensions of national water security

CHAPTER 5 SOIL QUALITY

KEY FINDINGS

- Soil is a complex system that is formed by the weathered rocks. It is critical in supporting plant growth by providing structural support, nutrients and water.
- The overall quality assessment based on the tested samples of all soil types from nine divisions of Punjab in terms of pH and salinity (mS/cm) is rated as ‘Good’.
- The sodicity levels varied among soil types. Sodicity of agriculture and effluent irrigated land is rated as ‘Poor’ while it is ‘Moderate’ for urban and industrial soils.
- Fertility status for Nitrogen, Potassium and Iron in all soil types is ‘Good’ whereas level of Phosphorus is ‘Moderate’. Level of Zinc in agriculture soils and land irrigated with effluents is also rated as ‘Good’ while it is ‘Moderate’ for urban and industrial soils in Punjab.
- Heavy metal contents (Pb, As, Cd, Hg and Se) of all soil types in Punjab were within permissible limits but on the basis of secondary data on heavy metal contamination reporting in Punjab the overall soil quality is rated as ‘Moderate’.
- Pollution Load Index (PLI) showed moderately polluted soil types in all areas of 9 divisions, thus requiring remedial and management measures. Rawalpindi and Multan divisions had highest PLI values (2.3).
- Adopting soil health management systems, diverse crop rotations, and no-till/strip-till cropping systems for improving soil quality are recommended for Punjab.

1. OVERVIEW

The term ‘Soil” originates from the Latin word “Solum” meaning ‘floor’. Soil is the loose surface material that covers land. It consists of inorganic particles and organic matter. Soil is usually formed by the deposition of weathered rocks. Other factors such as leaching and microbial activity along with weathering process make a whole range of different soil types. Each type has particular strengths and weaknesses for agricultural production.

Soils vary greatly in their chemical and physical properties. It is a complex system and its diverse physiochemical properties are potentially prone to significant changes, depending upon environmental, geological[84] and anthropogenic factors. Soil provides the structural support to plants and also provides them essential nutrients. Good soil structure contributes to soil and plant health allowing water and air movement through the soil profile. Soil stores water for plant growth and also supports soil microbial and animal activities.

Soil is an essential medium, required for vegetation growth that acts as a nutrient and water reservoir, enabling plant growth. Plants require 12 essential nutrients for growth including six macro-nutrients i.e., Potassium (K), Calcium (Ca), Magnesium (Mg), Nitrogen (N), Sulfur (S) and Phosphorous (P). The physiochemical characteristics of soil such as infiltration and water-holding capacity, temperature, pH, organic matter, nutrient content and aggregation determine the subsequent soil processes including the erosion, drainage, salinity and fertility.

Soil types and quality vary in Punjab, owing to various factors such as topography, climate and geological formations. The primary soil types found in Punjab include alluvial soils which are formed by the deposition of sediments carried by rivers, especially the Indus River. Alluvial soils in Punjab are also found such as in Lahore which are generally fertile and good for a wide range of crops. Certain areas in Punjab contain clayey soil texture, which can retain water for longer period. While clayey soil is fertile, proper drainage is essential to prevent waterlogging. Some areas in Punjab especially south Punjab, show sandy soil which is good for drainage but may require more frequent irrigation due to its lower water retention capacity. Many areas in Punjab experience issues with soil salinity or alkalinity which impacts fertility. Effective soil management practices are essential to address these challenges. It is important to understand that the distribution of soil types varies within different districts and regions of Punjab. Local variations may occur, impacting agricultural practices and the choice of crops. Conducting soil tests is a common practice for farmers and experts to analyze soil characteristics accurately and make informed decisions regarding crop selection and soil management.

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2 ENVIRONMENT

2.1 Sampling and Monitoring Plan

A comprehensive soil quality assessment was conducted for all the nine divisional headquarters of the Punjab province. The survey involved the collection of soil samples from distinct categories, namely urban, industrial, agricultural areas, and lands irrigated with treated and untreated industrial effluent. In total, 108 soil samples were meticulously collected across the study area.

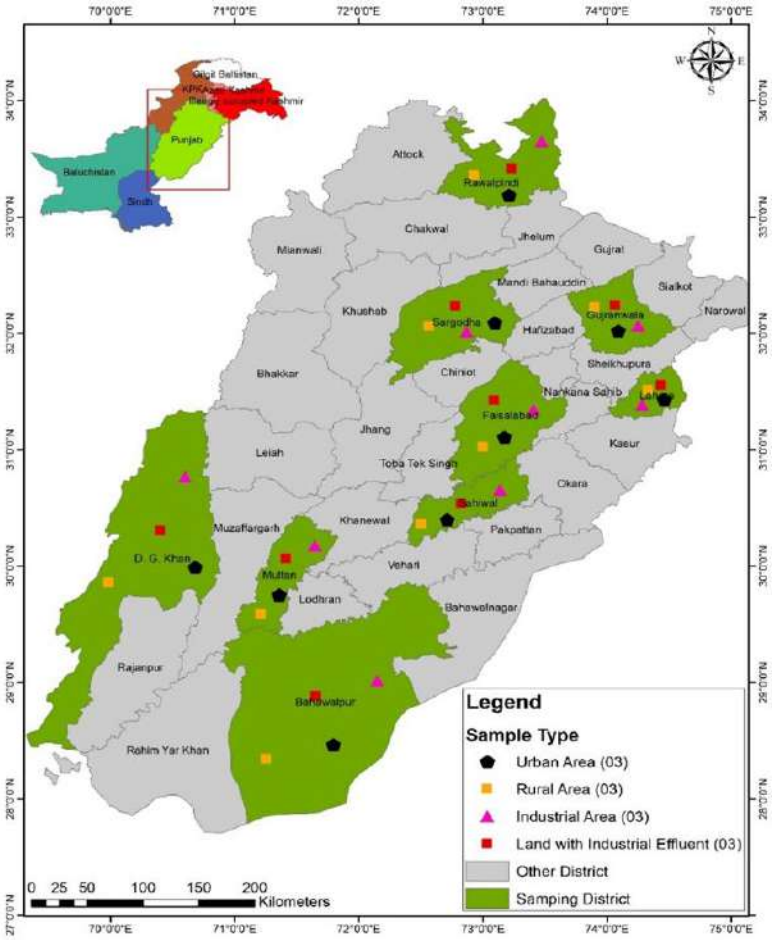

Figure 5-1: Sampling & Monitoring Plan (Soil Quality)

The sampling procedures are provided in detail as Annexure D.

Before the survey, data about the industries generating treated and untreated effluent was collected so that sampling could be done efficiently by saving resources. GPS devices were used to get the coordinates of each sampling site across the selected nine divisional headquarters to spatially represent locations on the map.

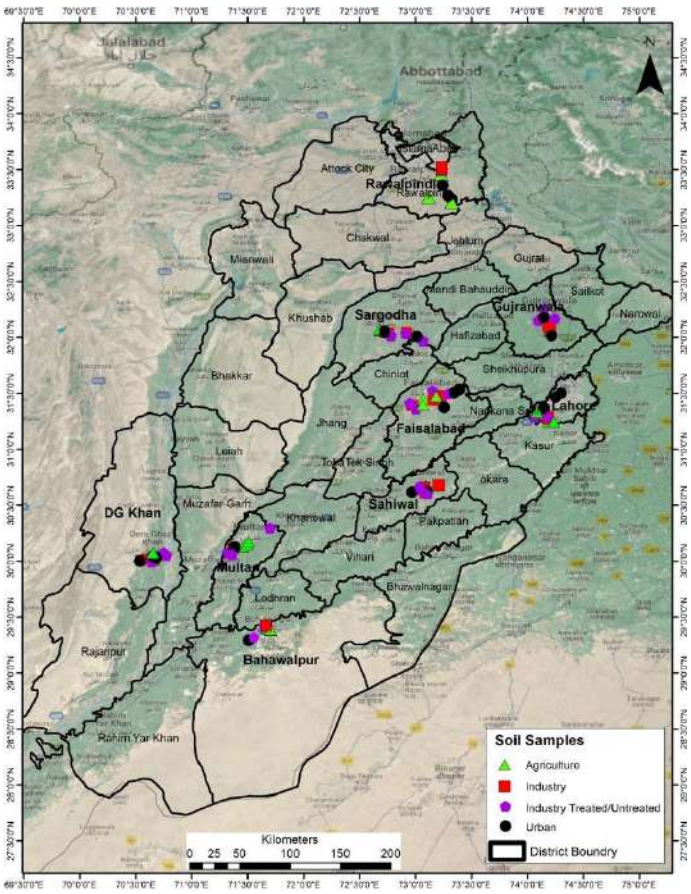

Figure 5-2: Soil Quality Sampling Locations

2.2 Description of the study area

2.2.1 Lahore Division

Lahore, culturally rich and one of the developed cities of Punjab, is located at latitude 31° 20′ and 31° 50′ N and longitudes 74° 05′ and 74° 37′ E covering an area of 1772 km^2. The Ravi River flows on the northern side of Lahore whereas Lahore Canal begins at the Bambawali-Ravi-Bedian (BRB) Canal that runs through the east of the city. Lahore consists of nine towns namely; Ravi, Samnabad, Data Gunjbakhsh, Aziz Bhatti, Nishtar, Shalimar, Wagah, Iqbal and Gulberg along with cantonment area[85]. There is a complex geological structure beneath Lahore that is made up of bedrock formations, unconsolidated sediments, and layers of alluvial deposits. In Lahore, silty clay loam, sandy loam, and clay loam are the most common soil types. The composition of these soil types varies depending on the zone[86]. The climate of this city is semi-arid[87].

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[87]Haider, R., Yasar, A., & Tabinda, A. B. (2017). Urban Emission Patterns at a Semi-Arid Site in Lahore, Pakistan. *Polish Journal of Environmental Studies, 26*(1).

2.2.2 Gujranwala Division

Gujranwala is present in the north of Lahore in Punjab located at 31° 51′ to 32° 24′ N and 73° 46′ to 74° 30′ E[88]. District Gujranwala has a total land area of 3,622 km^2. Chenab River flows through the northern part of Gujranwala and Gujarat. The Upper and lower Chenab Canals serve as a major source of irrigation water for Gujranwala and surrounding areas. Climatically Gujranwala is a semi-arid district with hot environment. In summer, temperature varies between 27 to 40˚C while 5 to 19 ˚C in winter season. In the coldest times of the year (November until February), the average low temperature can reach 7˚C[89]. Around 872 mm of annual rainfall is received by this district[90]. Gujranwala soil is a blend of various soil types namely; silty clay loam (67.7%), sandy loam (4.15%), sandy clay loam (13%), silty loam (9.41%) and loam (1.4%)[91].

2.2.3 Sahiwal Division

Sahiwal is located approximately between 30° 02′ to 30°40′ N and 72° 20′ to 73° 06′ E[92]. Chichawatni and Sahiwal City are the two sub districts that make up the Sahiwal District. The district is known for its renowned buffalo cattle breed. The rivers Sutlej and Ravi provide water for irrigation in this area making the land fertile. Sahiwal is a productive area, with the Sutlej and Chenab rivers flowing through it on opposite sides. This region's principal crops are sugarcane, wheat, rice, cotton, and fodder. Climatically, the district is significantly semi-arid (dry and hot[93]) with temperature varying between 38 to 48°C and sporadic highs of 55°C. The hottest months are May, June, and July. December and January are the coldest months, with average lows of 5 to 22°C. With 150 to 300 mm of annual rainfall, it features extensive agriculture as well as a few natural forest reserves[94].

2.2.4 Multan Division

Multan, the fifth largest city in Pakistan, is located at latitudes 29° 22' and 30° 45' N and longitudes 71° 04' and 72° 04' 55" E covering an area of 3721 km^2. The district comprises of four tehsils: Multan Cantonment, Multan Sadar, Shujabad, and Jalalpur Pirwala (District office, Multan). Multan experiences extreme weather with summer temperatures averaging 49˚C while 1°C in

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winter. The district receives an annual precipitation of 127 mm[95]. It is a very fertile land with plain topography and an extensive network of rivers, canals, and water channels. Multan is located in a bend created by five rivers of central Pakistan. It is built on a mound east of the Chenab River. The majority of its terrain is composed of low, alluvial plains created by the sediment deposits in the river[96].

2.2.5 Faisalabad Division

The latitude and longitude of Faisalabad City are 30° 42′ to 31°47 N and 72° 40′ to 73° 40′ E, respectively[13.] The district is spread over 5,856 km^2 in Punjab's fertile region at an elevation of 186 meters (610 feet) above sea level[97]. Faisalabad experiences hot, muggy summers and cool, dry winters due to its semi-arid climate. A combination of valleys, isolated depressions, and high ground are features of its topography. Rich alluvial loess soils with calcareous properties are the specialty of Faisalabad, making the area highly productive for agriculture[98]. Faisalabad is surrounded by the two main rivers of Punjab; Chenab River towards the north and Ravi River towards the south. The entire district lies in the Rechna Doab (the area between Ravi River and Chenab). The major canal system of the Faisalabad Division comprises of the Lower Chenab Canal and its associated administrative circle.

2.2.6 Rawalpindi Division

Rawalpindi, is the fourth largest city in Pakistan, located at 33° 24′ N latitude and longitude 72° 59′ E, in the Pothohar plateau. It covers an area of 5,285 km^2 with an elevation of 300 to 2790 m[99]. There are seven sub-divisions (tehsils) of Rawalpindi namely; Kotli Sattian, Taxila, Gujjar Khan, Rawalpindi, Kahutta, Murree and Kallar Syedan. Erosion is a significant factor in the plateau[100] and the variable topography has hills in the north while plain areas in the south[101]. Koppen Geiger climate system classifies this district as humid sub-tropical. This district receives an average precipitation of about 1255 mm; however, the mean temperature is around 21°C[102]. The primary source of water for domestic and agriculture purposes is the Simly Dam and Soan River. Moreover, river Koran supply water to Rawal dam and is a major source for drinking

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purpose in Rawalpindi city and cantonment areas. The most common soil types are loamy and clayey soils with varied fertility levels. The district's location can affect the specific characteristics of the soil. For instance, research has revealed that The Gujar Khan region's soils are typically loamy and have moderate fertility[103]. The Kahuta area's soils are composed of deeper layers of sandy loam and upper layers of sandy clay loam[104].

2.2.7 Sargodha Division

Sargodha city is encircled with agricultural lands and is present on the floodplain of the Jhelum River. It has a variety of landscapes, such as the Salt Range Mountains to the south and the Potohar Plateau to the north. Geographically, the district is located at 31° 34' N to 32° 36' N latitude and 72°10' E to 73°18' E longitude[105]. The climate is hot and semi-arid with an average temperature of 24°C and 410 mm of annual precipitation[106]. The alluvial soil here is deposited by Indus River and its off-shooting streams. This region's soil also contains a moderate amount of sand, clay, gravel, and silt, collectively making up the alluvial formation[107]. The Lower Jhelum Canal is one of the major water channels in Sargodha supplying irrigation water. It is a branch canal of the Upper Jhelum Canal originating from the Jhelum River. The Main Branch Canal is also an important water channel in Sargodha. It originates from the Upper Jhelum Canal and supplies water for irrigation to various areas in Sargodha and neighboring regions.

2.2.8 Bahawalpur Division

Bahawalpur, a city in the south of Punjab, famous for carpets, embroidery and pottery is situated between latitudes 29° 22' N and longitude is 71° 37' E at an elevation of 152 m[108]. The climate of Bahawalpur district is harsh, with hot summers (48°C) and cold dry winters (7°C) receiving annually 150-200 mm precipitation in Monsoon season making the area arid. The district is physically separated into three separate physiographic strata: the plain area, the desert area, and the riverine area. The Cholistan desert occupies more than two thirds of the district's total area[109].

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The soil of this ancient district consists of sandy clay loam texture with 33% clay[110]. The Abbasia canal is one of the major water channels in Bahawalpur. It comes from the Sutlej River and serves as a significant source of irrigation water for the agricultural lands in the region. The Eastern and Western Sadiqia Canals (branches of Abbasia canal) are source of irrigation water in Bahawalpur

2.2.9 DG Khan Division

Dera Ghazi Khan is located in Punjab's southwest zone, at the base of the Koh-e-Suleiman Mountain range (also known as the Suleiman Range)[111]. From a geographic standpoint, DG Khan district occupies 13,740 km^2, making it the third largest district in the province of Punjab. The city area, which spans approximately 100 km^2 (10,000 hectare), is located between 30° and 30° 05' 28'' N latitude and 73° 35' 33'' to 73° 41' 41'' E longitude. The climate of study area is classified as an arid zone receiving 150 mm mean annual precipitation, primarily as monsoon (during July-August). There is a significant difference in average temperature between cold-mild winter and hot summer, ranging from 13 to 50°C. The topography is progressively more elevated to the west and features a level city center. The city includes alluvial plains as well as piedmont which are arid regions receiving little rainfall. Its piedmont zone is situated at a high altitude. The majority of the area is rocky and is made up of sandstone, which ranges in color from light grey to dark grey, with fine to coarse grains and limonitic coloring in some areas. Despite being at a lower elevation, the composition of alluvial shows that it is made up of more than just water, organic matter, and minerals; instead, it is derived from a variety of parent materials[112]. DG Khan is located in the floodplain of the Indus River. DG Khan canal originates from the Taunsa Barrage, which is located on the Indus River. The barrage regulates the flow of the river and diverts water into various canals, including the DG Khan.

2.3 Soil Quality

The soil quality was tested for 14 parameters i.e., pH, Electrical Conductivity, SAR, Cadmium, Lead, Arsenic, Mercury, Selenium, Zinc, Iron, Magnesium, Sodium, Potassium, Nitrogen and Phosphorus. The results were compared with international soil quality standards for heavy metals[113]. For soil salinity Water and Power Development Authority classification[114] was used and for fertility assessment standards referred in International Center for Agricultural Research in the Dry Areas were used[115].

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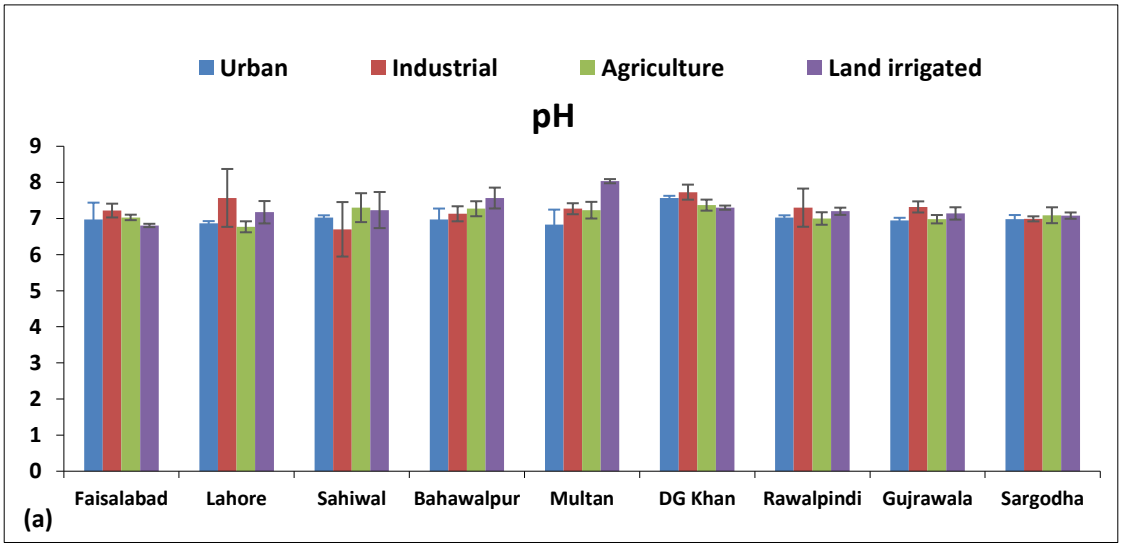
2.3.1 Soil Salinity and Sodicity

Figure 5-1a shows that pH for all soil types varied between 6.7 to 8. The urban soils in all divisions had relatively neutral pH values except DG Khan Division (7.6) with slightly alkaline urban soil. Soil pH remained slightly alkaline for industrial soils of Lahore (7.6) and DG Khan (7.7) divisions. with maximum (8) in case of land irrigated with in Multan. pH values of agriculture soils of all divisions were also around neutral. Comparatively higher pH value (in alkaline range) was recorded in the lands irrigated with wastewater in Multan Division (8).

When tested for soil Electrical Conductivity values (mS/cm), all soil types across selected divisions in Punjab were found to be non-saline with low salt concentrations. Comparatively higher levels of EC (but non-saline) were recorded for urban, industrial and agriculture soils of Multan division and land i irrigated of Sahiwal division (Figure 5-1b).

Sodium adsorption ratio values of all soil types ranged from 5-55 showing the presence of non-sodic to strongly sodic soil types. The urban soils of Lahore, Sahiwal and Multan divisions were non-sodic, while they were slightly sodic for Faisalabad, DG Khan and Sargodha and moderately sodic for Gujranwala and Rawalpindi. All industrial soil types were either slightly or moderately sodic except for Multan where value of sodium adsorption ratio was 5 so soil was categorized as non-sodic. SAR levels were strongly sodic for agriculture soils of Lahore (46) and Rawalpindi (54) and for Lahore (55) and Bahawalpur (49) divisions' lands irrigated with industrial effluent. Rest all the soil samples in these two categories were even slightly or strongly sodic (Figure 5-3c).

The level of Sodium was significantly high in the urban, industrial, agriculture and irrigated soils of Sargodha division while comparatively low levels were recorded in urban soil of Sahiwal, industrial soil of Rawalpindi, agriculture soil of Gujranwala and land irrigated of Faisalabad divisions (Annexure D).



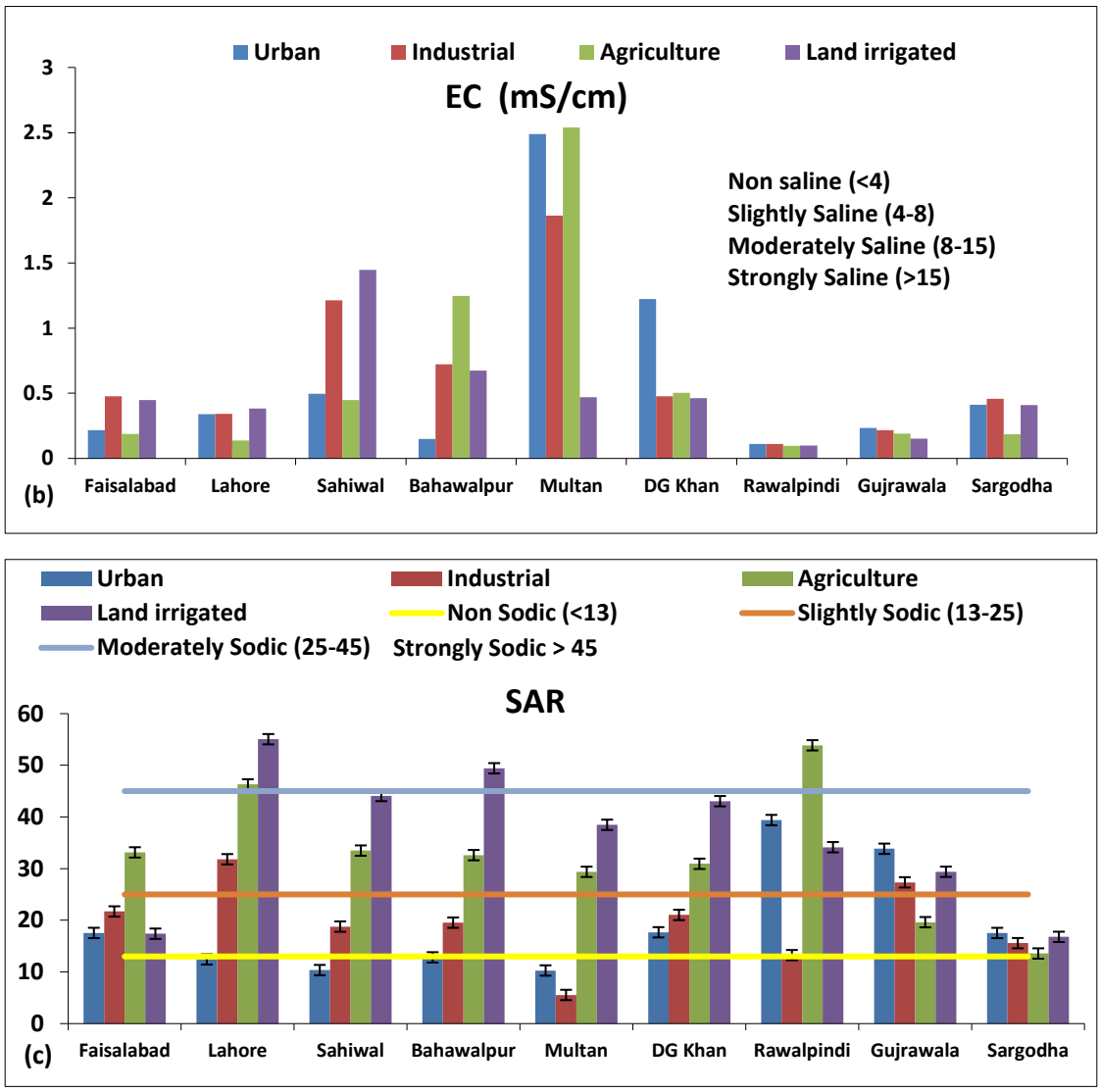


Figure 5-3: pH (a), EC (b) and SAR (c) in four soil types of selected divisions in Punjab

2.3.2 Soil Fertility

The level of nitrogen in all soil types were found to be adequate with maximum nitrogen concentration found in urban soils of Sahiwal, industrial soil of DG Khan, agriculture soil of Sargodha and irrigated land of Rawalpindi divisions (Figure 5-4a).

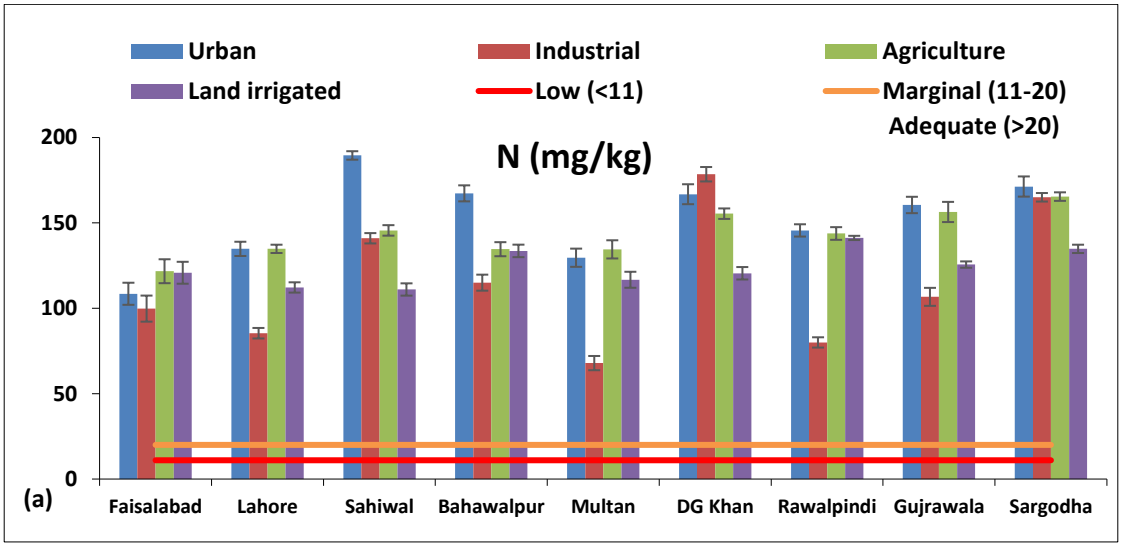
Phosphorus deficiency was observed in the soils of industrial areas of some divisions of Punjab e.g. Rawalpindi, Bahawalpur and Gujranwala while it was marginal for other three soil types. Concentration of phosphorus was marginal in all soil types of Sahiwal and Multan divisions. Adequate levels of phosphorus were recorded in some soil types of the selected divisions with highest in agriculture soil of DG Khan and land irrigated with effluent in Sargodha division (Figure 5-4b).

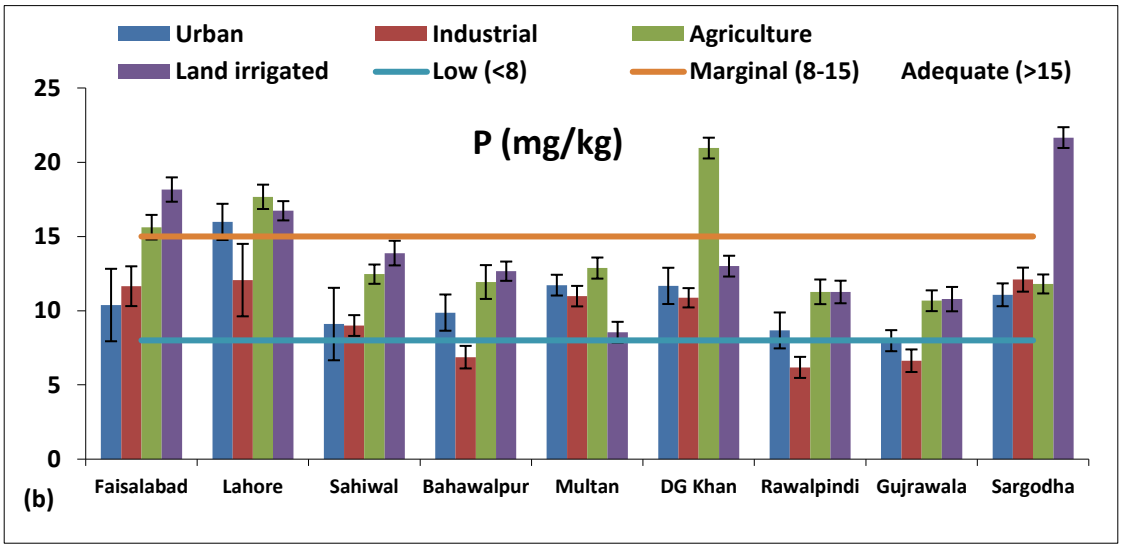
The concentration of Potassium in all soil types across the selected nine divisions in Punjab was found to be adequate. Comparatively highest Potassium levels were present in lands irrigated with effluent in Bahawalpur, agriculture soil of Gujranwala and DG Khan and in urban and industrial soils of Sahiwal divisions (Figure 5-4c).

Agriculture soils of Punjab have adequate levels of Zinc. The concentration of Zinc is also adequate in industrial soil and irrigated land of Bahawalpur, DG Khan, Gujranwala and Sargodha divisions. Marginal levels of zinc were found in urban soils of six out of nine selected divisions while Zinc deficiency was recorded in irrigated land of Faisalabad, industrial soil of Lahore and Rawalpindi and urban soils of Rawalpindi and Sargodha divisions (Figure 5-5a).

The selected soil types across the nine divisions had adequate levels of Iron with maximum levels reported in irrigated land of Faisalabad, agriculture and urban soils of Lahore and industrial soil of DG Khan (Figure 5-5b).

The level of Calcium (Ca) was comparatively higher in urban soils of Multan, industrial and agriculture soils of Sahiwal and irrigated land of Faisalabad division. Comparatively low level of Ca was recorded for urban and agriculture soils of Rawalpindi, industrial soil of Faisalabad and irrigated land of Bahawalpur divisions. Level of Magnesium (Mg) was highest in urban, industrial and effluent treated lands of Rawalpindi and agriculture soils of Bahawalpur division while comparatively low levels of Mg were reported for urban and industrial soils of Sahiwal, agriculture soil of Lahore and effluent treated land of Faisalabad divisions (Annexure D).





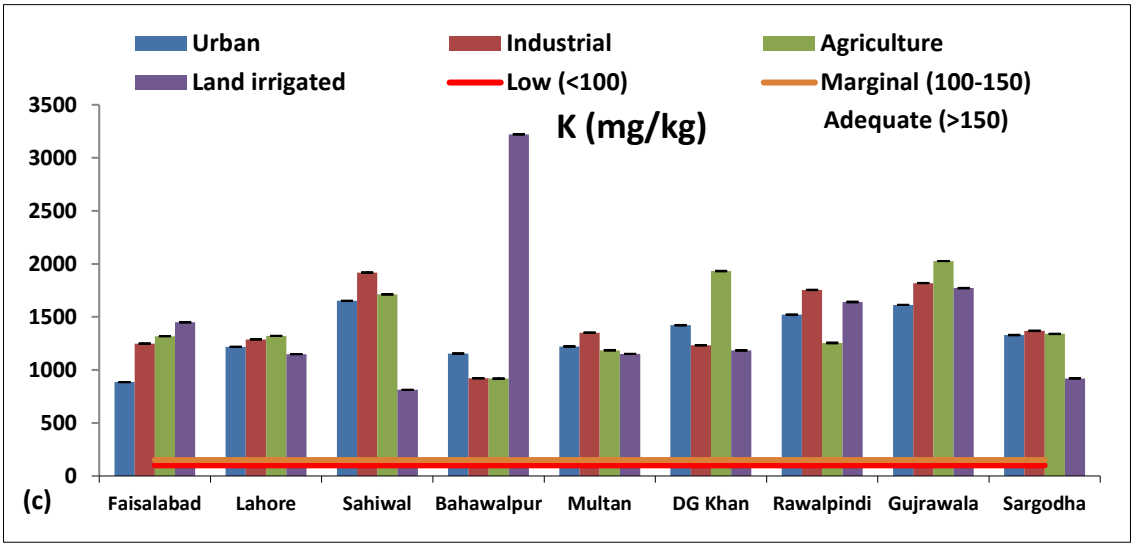


Figure 5-4 Nitrogen (a), Phosphorus (b), Potassium (c) in four soil types of selected divisions in Punjab

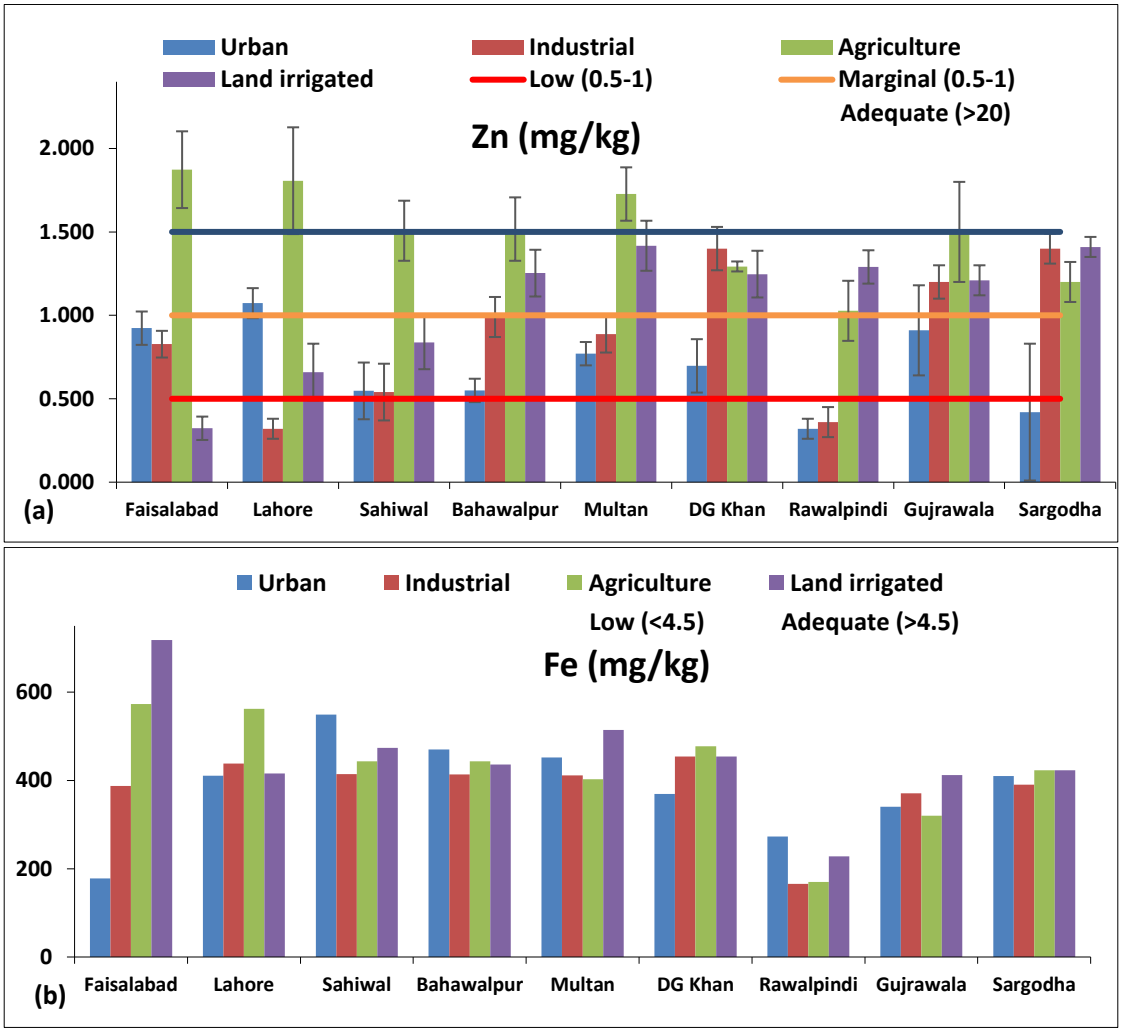


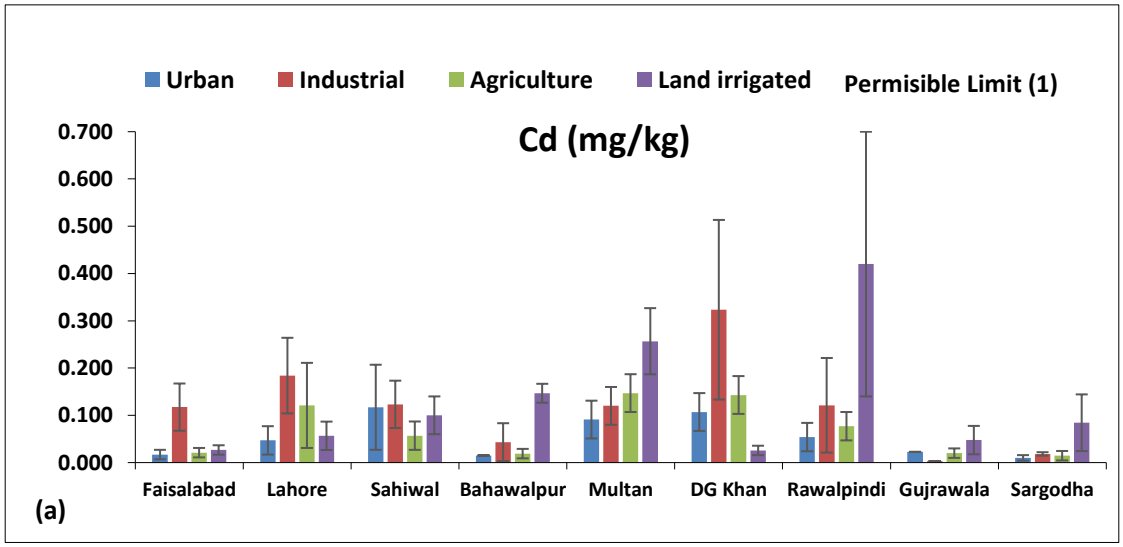
Figure 5-5 Zinc (a) and Iron (b)in four soil types of selected divisions in Punjab

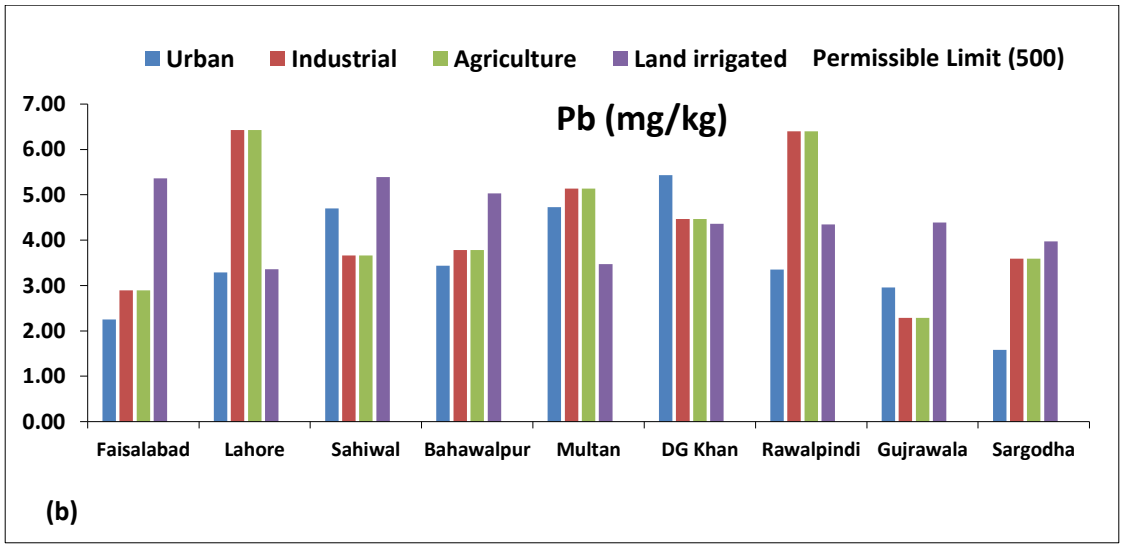
2.3.3. Heavy Metals

The concentration of heavy metals (mg/kg) in all soil types of Punjab were found within the permissible limits set by International Standards. Cadmium (Cd) concentration was comparatively higher in the effluent irrigated land of Multan and Rawalpindi, industrial and urban soils of DG Khan and agriculture soils of Multan division (Figure 5-6a).

Comparatively higher concentration of Lead (Pb) was found in urban soils of Sahiwal, Multan and DG Khan, industrial and agriculture soils of Lahore and effluent irrigated land of Faisalabad division (Figure 5-6b).

Arsenic (As) levels were also within the permissible limits. Comparatively higher levels of As were recorded for urban soils of DG Khan, industrial soils and effluent irrigated land of Multan and agriculture soils of Bahawalpur division (Figure 5-6c). Mercury (Hg) and Selenium (Se) were not detected in any of the soils of selected divisions of Punjab (Annexure D).





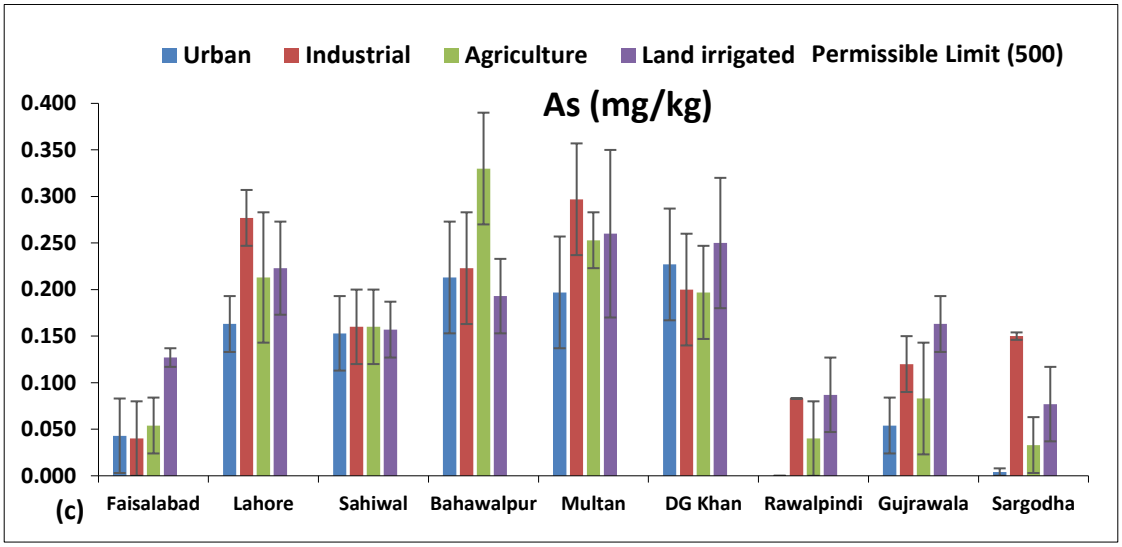


Figure 5-6 Cadmium (a), Lead (b), Arsenic (c) levels in various soil types in Punjab

Though the primary data revealed that the heavy metal concentrations were within the permissible limits set by International Standards, the secondary data and literature confirms the heavy metal contamination at different locations in Punjab, particularly the ones irrigated with industrial wastewater. In a study[116] conducted in DG Khan District of South Punjab, the soils and vegetable/crops irrigated with the industrial effluents exhibited that although the heavy metal levels in the soils were within permissible limits, the transfer of heavy metals from soil to plants was quite evident in the study area. Chromium, nickel, lead and manganese were exceeding the FAO/WHO acceptable limits, posing serious threats to the consumers of the contaminated crops which included the tomato, brinjal, red corn and apple etc. Similarly, the soils and groundwater of District Kasur were found contaminated with chromium, iron, nickel, cadmium, lead, zinc, cobalt and manganese. The soils were found particularly contaminated with chromium (in a range of 1970 to 2980 mg/kg), which was relatable to the presence of leather tanneries in Kasur[117]. In another study in Kasur Cr concentration was found to be 724 mg/kg in soils attributed to the presence of tannery industries[118].

Heavy metal contamination has been a significant environmental issue in various regions, including Punjab. Industrial activities, agricultural practices, and improper waste disposal can contribute to the accumulation of heavy metals in soil, water, and air. Some common heavy metals of concern include lead, nickel, cadmium, mercury, and arsenic. Industrial water used for the irrigation purpose has increased and is further expected to increase in the future because of insufficient wastewater treatment facilities and increased industrialization in Punjab. The areas of

[116] Atta MI, Zehra SS, Dai D-Q, Ali H, Naveed K, Ali I, Sarwar M, Ali B, Iqbal R, Bawazeer S, Abdel-Hameed UK and Ali I (2023) Amassing of heavy metals in soils, vegetables and crop plants irrigated with wastewater: Health risk assessment of heavy metals in Dera Ghazi Khan, Punjab, Pakistan. Front. Plant Sci. 13:1080635. doi:10.3389/fpls.2022.1080635

[117] Afzal, M; Shabir, G; Iqbal, S; Mustafa, T; Khan, QM; Khalid, ZM (2014) Assessment of Heavy Metal Contamination in Soil and Groundwater at Leather Industrial Area of Kasur, Pakistan http://dx.doi.org/10.1002/clen.201100715

[118] Riaz, M., Yasmeen, T., Arif, M. S., Ashraf, M. A., Hussain, Q., Shahzad, S. M., et al. (2019). Variations in morphological and physiological traits of wheat regulated by chromium species in long-term tannery effluent irrigated soils. Chemosphere, 222, 891–903.

central Punjab near the industrial zones are found to be contaminated with heavy metals like Ni, Cu, Cr, Cd and Pb. A study conducted at Faisalabad has reported accumulation of Pb above the recommended levels in plants and soils being irrigated by the city effluents. Furthermore, the industrial zones of Lahore, Sheikhupura and Kala Shah Kaku indicated soil and water contamination of heavy metals in their respective areas[119]. Among heavy metals Arsenic concentration was found to be very high (43.9 mg/kg) in soils of Khushab[120]. Rawalpindi soils have also been found to be contaminated with cadmium and chromium. In addition, the electroplating and tannery industries are found to contain toxic metals such as Ni, Cr, As, Hg, Pb etc.[121]. Soils of Faisalabad city have been reported to contain toxic heavy metals like Pb, Cu and Ni. In district Sargodha, the highest level of Cd in the soils was found to be 6.74 mg/Kg and this higher values of Cd in soil suggested the possible risk of Cd entering into food chain which was reflected in the Cd accumulation by the forage crops in the range of 1.14 to 4.20 mg/kg[122].

Metal contaminants like Pb, Cd, Zn and Cu are mobile in nature and are found in engines, tiers and petrol of vehicles. Toxic metals are accumulated in top soils and vegetation near the road ecosystem. Countryside areas of Pakistan are connected through road channels and thus the soil of such areas is accumulated with heavy metal toxicants. Studies have shown heavy metal contamination of different water sources, soils and vegetables in Rawalpindi area where Zn, Pb, Ni, Cd and Cr concentrations in soils decreased with the increase in distance from Islamabad-KallarKahar, KalarKahar-Lilla and Lilla-Lahore (M2). Atmospheric depositions also increase the level of heavy metals contamination of these vegetables at the market sites during transport and marketing[123].

The soils contaminated with heavy metals not only affect the plants and human consumers, but also affect the grazing and fodder-fed animals. The same was confirmed through a study[124] conducted on the heavy metal contamination of fodder crops in District Sargodha, where the chromium accumulation was revealed in the blood of buffalos fed by the fodder crops contaminated by this metal. More surprisingly, the crops were irrigated with municipal wastewater confirming the fact that using municipal or industrial wastewater increases the probability of heavy metal contamination in the receiving soils and plants.

[119] Lone, M. I., Aslam, R and Khan, K. S. 2000. Water quality and soil contamination in some industrial areas of Pakistan. Pak. J. Social Sci. 18: 1-6.
[120] Khan, Z. I., Ahmad, K., Akram, N. A., Mehmood, N., & Yasmeen, S. (2017). Heavy metal contamination in water, soil and a potential vegetable garlic (Allium sativum L.) in Punjab Pakistan. Pakistan Journal of Botany, 49, 547–552.
[121] Farid, G., Sarwar, N., Saifullah, A.A., Ghafoor, A. and Rehman, M., 2015. Heavy metals (Cd, Ni and Pb) contamination of soils, plants and waters in Madina town of Faisalabad metropolitan and preparation of GIS based maps. Adv Crop Sci Tech, 4(2), 693-706.
[122] Khan, Z.I., Ashraf, M., Ahmad, K. and Akram, N.A., 2011. A study on the transfer of cadmium from soil to pasture under semi-arid conditions in Sargodha, Pakistan. Biological trace element research, 142, 143-147.
[123] Ahmad, S.S. and Erum, S., 2010. Integrated assessment of heavy metals pollution along motorway M-2. Soil and Environment, 29(2), 110-116.
[124] Ghazzal M, Hussain MI, Khan ZI, Habib ur Rahman M, El-Habeeb AA, Yang H-H. Chromium Poisoning in Buffaloes in the Vicinity of Contaminated Pastureland, Punjab, Pakistan. *Sustainability*. 2022; 14(22):15095. https://doi.org/10.3390/su142215095

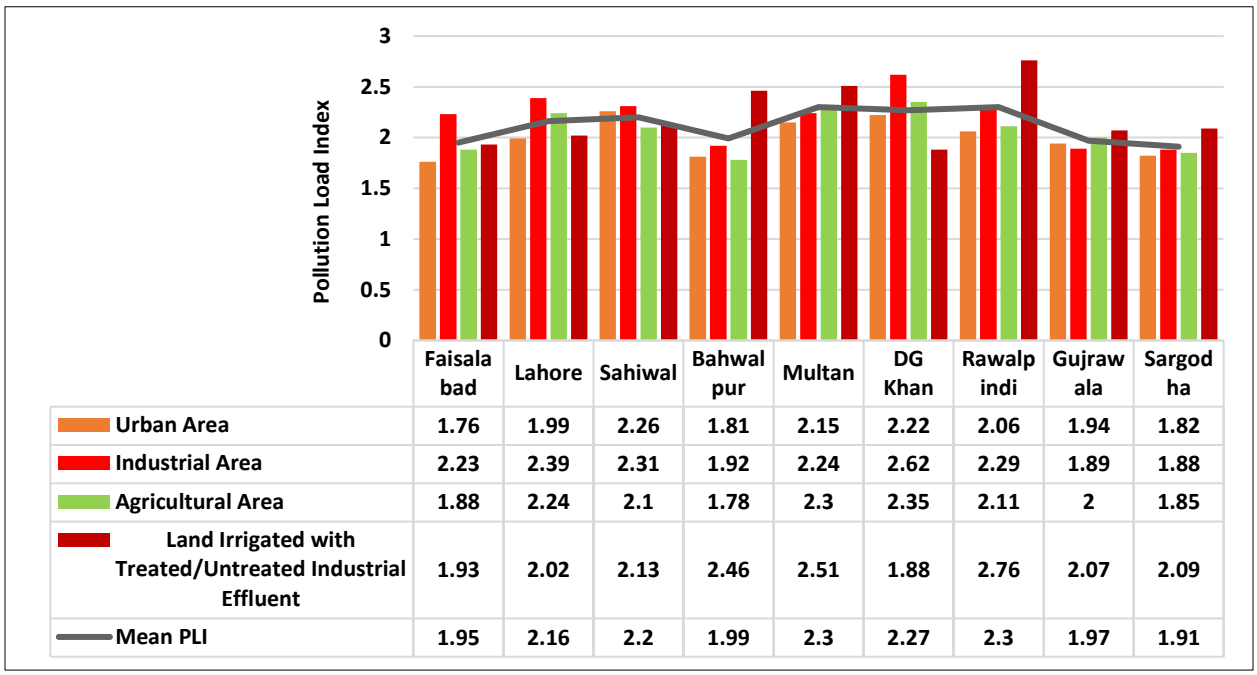
2.3.4. Pollution Load Index

Pollution load index (PLI) was calculated (Eq. 1) for various divisions of Punjab[125]. The PLI can be measured via a scale from 1 to 6: 0 = none; 1 = none to medium; 2 = moderate; 3 = moderate to strong; 4 = strongly polluted; 5 strong to very strong; 6 = very[31]. In this study, it was observed that all the divisions showed PLI = > 1 thus showing medium to moderate polluted soils in all divisions of Punjab (Figure5-7).

$$PLI = (CF1 \times CF2 \ldots \times CFn)^{1/n} \quad (1)$$

Where CF is the contamination factor and n is the number of metals.

The highest PLI was obtained in Rawalpindi and Multan followed by DG Khan and Sahiwal divisions while comparatively lowest in Sargodha.



	Faisalabad	Lahore	Sahiwal	Bahwalpur	Multan	DG Khan	Rawalpindi	Gujranwala	Sargodha
Urban Area	1.76	1.99	2.26	1.81	2.15	2.22	2.06	1.94	1.82
Industrial Area	2.23	2.39	2.31	1.92	2.24	2.62	2.29	1.89	1.88
Agricultural Area	1.88	2.24	2.1	1.78	2.3	2.35	2.11	2	1.85
Land Irrigated with Treated/Untreated Industrial Effluent	1.93	2.02	2.13	2.46	2.51	1.88	2.76	2.07	2.09
Mean PLI	1.95	2.16	2.2	1.99	2.3	2.27	2.3	1.97	1.91

Figure 5-7 Pollution Load Index (PLI) of soil samples collected from various divisions of Punjab

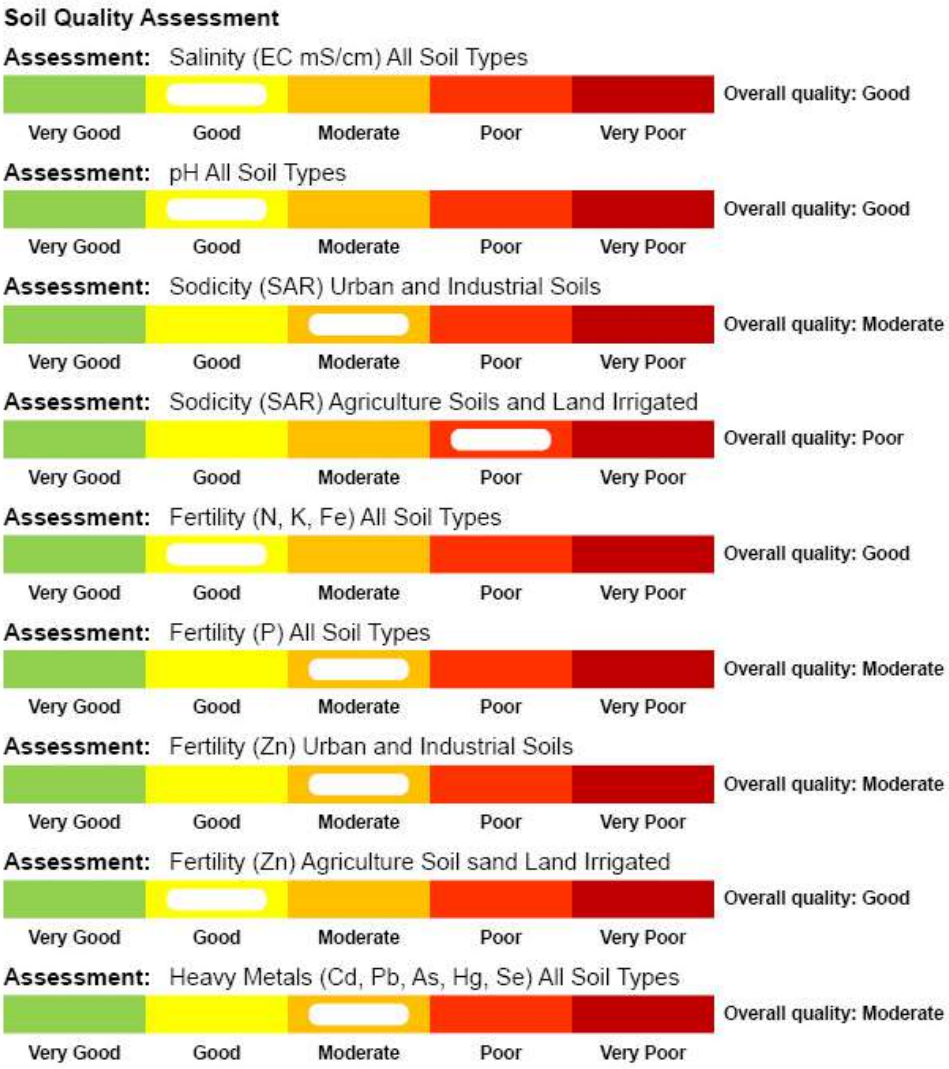
2.3.5 Overall Quality Assessment

Soil quality is the capacity of a typical type of soil to sustainably function, in an ecosystem (natural or managed), in order to support the productivity and habitats. It is pertinent to mention here that the soil quality assessment in this report is based on the results of the samples collected and analyzed particularly for the sake of this report. As the sample size was limited so it might not be representative for the whole of the region particularly in case of heavy metals where secondary

[125]Tomlinson, D.L., Wilson, J.G., Harris, C.R. and Jeffrey, D.W.(1980). Problems in the assessment of heavy-metal levels in estuaries and the formation of a pollution index. *Helgoländer meeresuntersuchungen*, 33, 566-575.

data shows presence of contaminated soils especially in the industrial and effluent irrigated lands in Punjab.

The overall quality assessment of all soil types of selected nine divisions of Punjab in terms of pH and salinity (mS/cm) is rated as ‘Good’. The sodicity levels varied among soil types. Sodicity of agriculture and effluent irrigated land is rated as ‘Poor’ while it is ‘Moderate’ for urban and industrial soils. Fertility status for Nitrogen, Potassium and Iron in all soil types is ‘Good’ whereas level of Phosphorus is ‘Moderate’. Level of Zinc in agriculture soils and land irrigated with effluents is also rated as ‘Good’ while it is ‘Moderate’ for urban and industrial soils in Punjab. Heavy metal contents based on primary and secondary data of all soil types in Punjab are rated as ‘Moderate’ based on the prescribed limits available for each of the indicator parameters. Higher SAR values show a higher level of sodium. Excess sodium can cause soil dispersion and breakdown of clay particles thus negatively affecting soil structure. Soil particles are dispersed reducing soil infiltration and permeability which could lead to poor water movement within soil causing waterlogging issues. Although lead concentration was within permissible limit but trend showed that the concentration might increase in future due to extensive use of wastewater for irrigation, pesticides and fertilizers.



3 MANAGEMENT

Soil has an important role in maintaining ecosystem health which is essential for the survival of living organisms. Being an agriculture backbone of country's economy, joint efforts must be taken by all public and private sectors to maintain and preserve soil quality in Punjab. Thus, collaboration between farmers, government bodies and agricultural experts are essential for the success of soil quality management initiatives.

3.1 Soil Salinity and Waterlogging

Soil salinity is defined as the concentration of various salts in the soil. The major salts which trigger the salinity problem include potassium nitrate, magnesium sulfate, sodium chloride and sodium bicarbonate. Sodium chloride is the major salt among all which is responsible for the salinity. Salinity originates from various sources. Anthropogenic sources include land development and agriculture[126]. Agriculture practices and industries discharge effluents which have high quantity of salts. Excess irrigation causes a rise in groundwater table. Salinity is usually found where an old traditional irrigation system is used. It largely impacts vegetation and the groundwater quality. The solutions to salinity are expensive and time taking. Industrial effluents should be regularly monitored to avoid water and soil salinity.

Water-logged soil is defined as water-saturated soil. Waterlogging leads to salinity which affects agricultural soils. Waterlogging and salinity restrict crop production. These problems arise due to unsustainable crop production practices in Pakistan. The Indus River Basin is affected by salinity and waterlogging due to inadequate water management techniques, water seepage from canals and subsurface drainage, etc. The quality of the groundwater used for irrigation is not good. Environmental problems such as salinity and waterlogging can be devastating for productive lands. Excess water and increased concentration of salts are hazardous for soil health and biota. Waterlogging and salinity problems can be potential threats to food security in Pakistan.

Reports reveal that about 7,044,000 acres of agricultural land in Punjab has become unproductive because of waterlogging and salinity while fruits, grains and vegetables are being cultivated on 36,700,000 acres of land. In saline lands i.e. both irrigated and non-irrigated, surface water is very rare and available groundwater is mostly saline or brackish. This saline groundwater when used for irrigation purposes can further cause salinity in soils which restricts the agricultural production and damages the quality of agricultural land. This issue has become a serious threat to the sustainability of irrigated agricultural land particularly in the Punjab province, wherein nearly more than 50 percent of the pumped groundwater is saline thus is a potential threat for the irrigated soils[127]. Waterlogging and salinity are strongly interconnected problems in various parts of Punjab, and pose substantial challenges to the agriculture sector. The use of extensive irrigation is common through canal water and groundwater which can contribute to both waterlogging and salinity. Insufficient drainage

[126] Thal Doab, Chaj Doab, Rachna Doab and Bari Doab Pakistan Council of Research in Water Resources. (2019). Annual Abridged Report 2021-2022, Institute of Soil Chemistry and Environmental Sciences, Ayub Agricultural Research Institute, Faisalabad.

[127] Thal Government of Punjab (GOP). 2009. Groundwater Monitoring in Punjab, Directorate of land Reclamation , Irrigation Department, Lahore.

worsens the situation, and stagnant water leads to accumulation of salts in soil thus increasing salinity levels in soil. The management of groundwater table is very important and if the groundwater table is relatively high, this can result in waterlogging, and occurrence of salts in groundwater leading to salinity problems. Efforts by government, agricultural sector, and local farmers are important for implementing sustainable solutions to address both waterlogging and salinity problems in Punjab. This could involve various practices such as improved drainage and irrigation practices, use of salt-tolerant crops and soil management methods.

3.2 Soil Fertility and use of Agrochemicals

The organic matter in the soil, which consists of animal and plant material at various stages of decomposition, plays a significant role in soil fertility. Organic matter not just provides nutrients but has significant role in enhancing soil water retention capacity, soil porosity, recycling of fertilizers and flourishing of soil organisms. Thus, soil rich in organic matter causes enhanced crop yields when cultivated. In Punjab, 61% of the total geographical land area is successfully cultivated due to its fertile alluvial plains and efficient irrigation system. A study in various districts of Muzaffargarh showed the deficiency of organic matter in 95% of the tested soils. Reports suggest that the cultivated land in various areas of Punjab has stayed stable over the past 40 years. However, since most of the plough able land in this province is already cultivated, fertilizers and pesticide usage are relatively higher with subsequent effects on soil quality.

3.3 Physical Properties of Soil

The physical and hydraulic characteristics of soil play an important role in its quality and fertility. The major districts lying in Potohar Plateau and Doabs include Rawalpindi, Jhelum, Chakwal, Mianwali, Khushab, Bhakkar, Layyah, Muzaffargarh, Gujrat, Mandi-bahauddin, Sargodha, Faisalabad, Gujranwala, Narowal, Sialkot, Nankana Sahib, Sheikhupura, Toba Tek Singh, Khanewal, Multan, Sahiwal, Okara, Kasur and Lahore.

However, as suggested by the secondary data collected from different sources, it is reported that soils in Punjab Pakistan are not very rich in organic matter, largely owing to harsh summer temperatures, intensive tillage and use of inorganic fertilizers[128,129]. A study showed that loam, silt loam and sandy loam are major soil textures in the Potohar region. The sandy texture decreases with the increasing depth. The major reason is again the large-scale erosion and rainfall in the region. The soil textures were noted as almost the same in the Doab region. However, texture varied with the depth because the washing down of top layers was reported in Potohar and a little in Doabs as the plains in Doabs are largely ploughed and are exposed to surface erosion. It was also reported that soil strata are more diverse in the Potohar region than Doabs [35].

3.4 DPSIR Framework

The DPSIR framework is described below:

[129]Punjab's State of the Environment Report. (2022). Environment Protection Department, Government of the Punjab, Pakistan

Drivers

Several factors affect the physicochemical properties of the soil notably environmental, topographic, and human-drivers. They also include:

- Rising food demand: Punjab is the most heavily populated province in Pakistan. Increased population raises demand for both food and agricultural goods, putting additional strains on soil resources.
- Urbanization: Punjab is considered one of the most urbanized areas in South Asia, and has been experiencing a steady, long-term shift of people to urban centers. Currently, around 36% of the population resides in urban Punjab. With the expansion of cities, the amount of waste generated has also increased. Unfortunately, improper disposal of this waste from both households and industries has put a burden on soil resources.
- Industrialization: Increasing industrialization in the province has also significantly affected soil quality, particularly in areas surrounding industrial clusters where discharges from industrial sites and waste management problems are more prevalent.
- Poor agricultural practices: Inappropriate use of pesticides and fertilizers, as well as irrigation of crops with contaminated water, can degrade soil quality.
- Topography: The topography of an area is a crucial factor in determining the soil characteristics. In Punjab, the Potwar and Doab regions have distinct differences in the physio-chemical properties of their soils. For example, the degree of soil erosion is much higher in the hilly lands of the Potwar region as compared to the plains of the Doabs.

Pressures

- Land Use Change: In Punjab, the majority of the land is used for agricultural purposes, but there is limited and inconsistent data on the land use change throughout the province. For instance, it has been reported that the area of vegetation in the Okara district has declined from 91.6% in 2002 to 89.3% in 2020, with an increase of 4.5% in the built-up area. A study carried out in Southern Punjab from 2000 to 2001 showed land use changes (water change by 1.02%, cropland by 2.63%, forest by 31.03%, settlement by 14.52%, and barren land by 12.87%).
- Livestock grazing: The Forest Department of the Government of Punjab is responsible for maintaining above 6 million rangelands. The Range Management Circle Lahore is responsible for managing rangelands in 12 districts across four range management divisions, which include Chakwal, DG Khan, Bahawalpur and Bhakkar. The primary goal of this management is to provide benefits to the local community. The rangelands are primarily located in the region of Thal, Potwar, and Cholistan. Approximately 400,000 farmers and grazers residing in the vicinity of these rangelands gain benefit directly from grazing around 1.2 million animals. However, to manage the stress on these pastures, rotational grazing is carried out continually throughout the year.
- Biomass Use: A theoretical and technical assessment of the potential for biomass-based energy generation in Punjab revealed that the technical potential for generating ethanol from agricultural biomass as a household or non-commercial source of energy has significantly reduced. Other sources also confirm the use of biomass for burning in rural households. The use of agricultural biomass, such as residues of crops, not only increases

moisture retention of soil but also prevents the loss of water from evapotranspiration, consequently improving soil quality.

- Overuse of Pesticides and Fertilizers: As Punjab is primarily an agricultural region, the soil here gets significant inputs of pesticides, fungicides, fertilizers and insecticides. A study in Punjab carried out in cotton fields revealed that farmers used 70% more pesticides to obtain higher yields of cotton, compared to other provinces[130].
- Faulty irrigation practices: Consistent use of contaminated water for irrigation can lead to enhanced salinity of soil and heavy metal contamination. Extensive use of fertilizers, flood irrigation systems and excessive tillage can also make land unsuitable for agricultural purposes.
- Heavy metals contaminants: In the province of Punjab high levels of contaminated soil, particularly with heavy metals, are resulting from uncontrolled industrialization and lack of appropriate management of waste and discharges from industrial operations.
- Climate change: Punjab is characterized as an arid and semi-arid region, with extreme summers and low humidity. Consequently, the province's agriculture system relies mainly on irrigation to ensure that crops receive sufficient water. The Southern Punjab region is known for its extreme climatic conditions and frequent droughts. The arid climate of this region promotes evapotranspiration, which leads to a significant reduction in the water and moisture content of soil. Moreover, extreme weather conditions in the province such as heavy rainfall and flooding have also resulted in soil erosion and unstable agricultural lands.
- Erosion: Erosion leads to the removal of the topsoil (rich in organic matter) and ultimately declines the productivity/fertility of the soil. Additionally, the eroded soil is washed away by water resulting in the deposition of sediments in the rivers and streams, which in turn hinders their smooth flow. Furthermore, sedimentation can cause floods and increase the level of turbidity in these freshwater resources, which has devastating impacts on aquatic life.

State

- Soil Pollution: Heavy metals are deposited in the soil through natural processes but various anthropogenic activities also contribute to this problem, such as improper waste disposal.
- Salinity: Increasing rates of evapotranspiration in arid or semi-arid regions result in high soil salinity due to salt accumulation over time. Moreover, salts are being added into soils through use of saline underground water and from industrial wastewater irrigation systems.
- Desertification: The possibility of desertification is high in areas where degradation of soil has been caused by excessive erosion, overgrazing and through various sources of pollution. Desertification can have significant and long-lasting effects on food security.
- Variable physio-hydraulic properties: Anthropogenic activities such as urbanization, farming on slopes, and practices that promote the process of erosion contribute to soil degradation.

[130] 10.1016/j.cropro.2014.10.013

Impacts

- Pollution load index, SAR and Na levels were found to be high in this study thus posing serious considerations and negative impacts on soil quality.
- Overall, the soils of the study area showed polluted state according to PLI which often causes decreased fertility, leading to less crop yields and resulting in food insecurity.
- Healthy soils usually provide a good support for a variety of plants, microbes and animals while polluted soil quality can substantially affect all segments of environment thus causing biodiversity loss. A lot of species rely on a specific type of soil environment for their survival and changes in soil quality can destroy their habitats.
- Soil is also considered as a natural filter removing various kinds of contaminants before reaching groundwater thus poor soil quality can result in leaching down of fertilizers, pesticides and toxic heavy metals and negatively impacting our aquatic ecosystems.
- Reduced plant cover due to poor soil quality results in soil erosion which can lead to destruction of valuable topsoil and affecting significantly both agricultural crop yields and water quality.
- Nutrient cycling is also very important to ensure the availability of nutrients to plants and various organisms in soils. Deteriorating soil quality can disturb cycling process causing nutrient imbalances/deficiencies thus affecting overall health of the ecosystems.
- Human health is also impacted by polluted soil and poor soil quality for example, nutritional content of edible crops grown on poor soils are low thus leading to nutritional deficiencies in diets of people relying on those crops.
- Specifically, high sodium concentration in soils can cause various harmful impacts on plant growth, soil quality and overall ecosystem health. The major impact is that high sodium concentration relative to other essential elements such as magnesium, calcium, and potassium can displace these ions from soil particles, causing breakdown of the soil aggregates and negatively impacting soil structure. This dispersal can result in the compacted and hard layers having poor water draining and infiltration rate. Poor water movement through the soil profile results in waterlogging and increased sodicity and salinity levels in the root zone. Soil fertility is therefore compromised and availability of essential nutrients is also disrupted leading to reduced microbial activity.

Response

- Tree plantation improves the soil structure and enhances its organic and nutrient contents. Forest Department is efficiently engaged in plantation activities, which also improves the soils health. Moreover. The Department is also developing multiple schemes for upgrading, rehabilitating and maintaining various reserve forests and national parks, thereby improving soil quality and stability. In agriculture sector, shift towards organic farming, sensible use of fertilizers, careful use of pesticides and zero tillage, are the key to improve soil fertility and quality.
- Agriculture Department is striving for improved research and development as well as the enhanced soil quality monitoring across Punjab. The relevant projects initiated by Agriculture Department during 2023 include the Upgradation of GIS-Remote Sensing Based Crops' Estimates & Strengthening of Area Frame Sampling Methodology in Punjab, Provision of Micronutrient Analysis Facility in District Soil and Water Testing Labs in Punjab, Mitigating the Emerging Issues of Pesticide Residues in Vegetables and Rice

through Capacity Building of Farmers and Extension Agents, Mapping of Soil Series in Selected Areas of Sargodha District under Citrus Orchards and Infrastructure Improvement of Soil Survey of the Punjab, Strengthening of GIS Labs of Soil Survey of Punjab to Evaluate the Impact of Human Interventions on Different Soil Series of Punjab.

- Agriculture Department is also spreading awareness about the best soil and crop management techniques. Moreover, the department is also providing education and extension services to farmers on soil health, conservation practices and sustainable agriculture.
- Work on rehabilitation of eroded, gullied land through soil conservation measures in hill torrents/barani areas of southern Punjab has also been carried out by agriculture department.

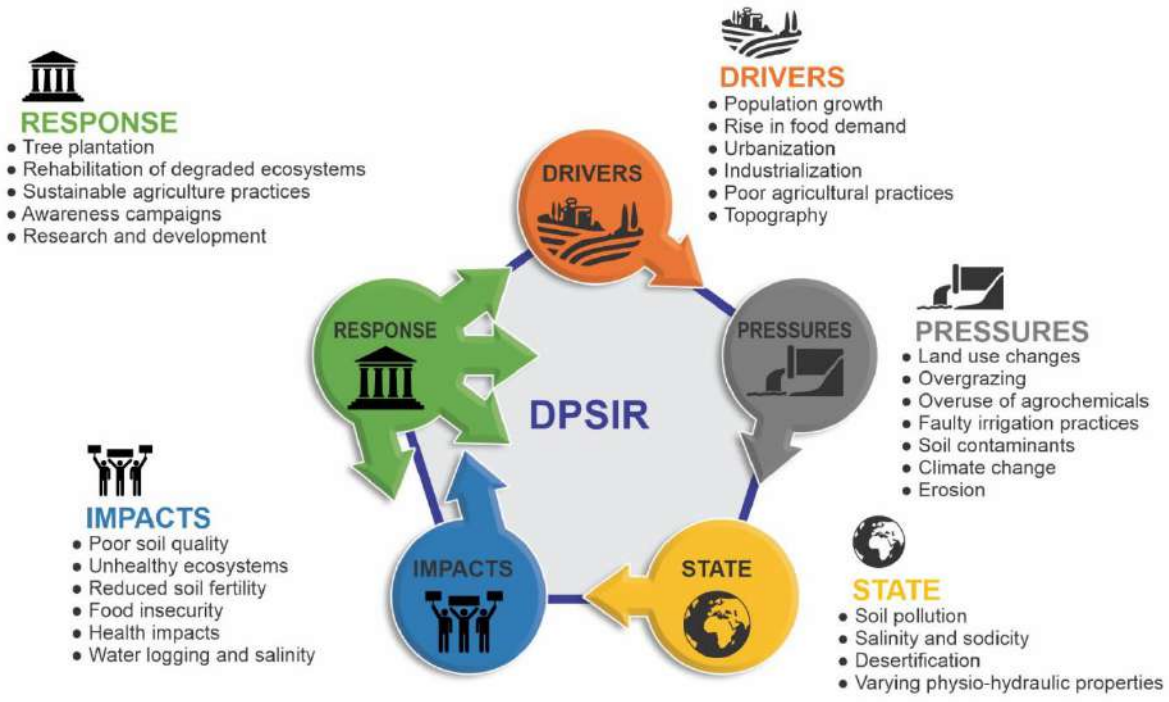


Figure 5-8: DPSIR framework of soil quality in Punjab

4 THE WAY FORWARD

There are different techniques and methods for improving soil quality as listed below

- **Adopting a soil health management system** can increase crop cover, and diverse crop rotations with high residue can also benefit the soils. Employing crop rotation helps retard pest and disease cycles while improving nutrient levels. Cover cropping reduces erosion and enhances organic matter and soil structure. Adopting organic farming techniques lessens the reliance on synthetic pesticides and fertilizers, improving biodiversity and microbial activity.
- **No-till/Strip-till cropping systems** should be used to reduce erosion and loss of top soil. Conservation tillage reduces soil disturbance, maintaining its structure and moisture retention.
- **Nutrient and grazing management** are important factors for marinating and improving soil quality. The overall analysis of different soils would be helpful for better management. Incorporating compost, biochar, or manures improve nutrient content and microbial activities of soils.
- **Comprehensive planning at the governmental level** is required for soil quality improvement. Policymakers should prioritize various sustainable land management activities, offering incentives for farmers to adopt conservation strategies such as cover cropping, crop rotation, and organic farming.
- **Government-led research studies** can support the development of advanced technologies and practices which enhance soil health. Regular soil testing is also crucial to develop specific strategies based on the soil's unique needs. Hence, there is an urgent need to mobilize public and private organizations to conduct research projects on soil quality assessment in Punjab province.
- **Investing in educational programs** for the farmers to raise awareness about sustainable soil management practices is important for ensuring healthy soils.
  Collaborative efforts with the research institutions, NGOs, and agricultural sectors can lead to a holistic approach to soil quality management, ensuring long-term productivity and health of agricultural lands. There is a need to establish monitoring systems to determine soil health and quality on regular basis at a national level. Moreover, local soil quality standards for soils must be developed at the national level.

CHAPTER 6 CLIMATE CHANGE

KEY FINDINGS

- Pakistan, is the 5th most vulnerable country to climate change.
- Agriculture sector accounts for 46% of GHG emissions in Pakistan.
- The particulate matter contributes 23% of the total emissions in Punjab, with industrial sector being the major contributing source.
- The climatic normal in Punjab (1991-2020) shows 17.1°C and 30.1°C to be the mean annual minimum and maximum temperatures, whereas the mean annual precipitation has been recorded as 49.8 mm.
- Cooler than normal average temperatures (1991-2020) were observed in Punjab during the months of March-July, 2023. However, the overall mean temperature recorded in the country were 0.51°C above normal.
- Highest temperature during 2023 was 46.6°C recorded in Noorpur Thal, District Khushab on June 22, whereas the highest rainfall in 24-hours was recorded by meteorological station at Lahore airport, measuring 226.0 mm on June 26.
- Punjab's Indus tributaries are under water stress. The average annual availability of all the rivers that comprise the Indus River System's flows for canal withdrawals fell from 145.20 to 124.90 MAF between 1976 and 2020.
- Around 863 million people have been impacted by the floods that have historically occurred between 1973 and 2022.
- The water levels on the Sutlej at the Ganda Singh Wala village gauging station were recorded to be highest in 35 years in August 2023.
- During 2023, Districts Bahawalnagar, Bahawalpur, Lodhran, Kasur, Vehari, Okara, Pakpattan and Multan were affected by urban flooding from August, 17 to September, 30.
- In the afflicted areas, the floods damaged 467 villages/basti/mozas, almost 24,000 homes, and 545,270 acres of farmed land.
- Kharif crops (cotton, sugarcane, rice, maize, moong, sesame, fodder and vegetables) have undergone production losses due to the floods/torrential rains during 2023.
- Punjab has experienced a remarkable increase in disease outbreaks like dengue and cholera (250 confirmed cholera cases from May 2022 to April 2023).
- Several initiatives have been taken by the government departments (Energy, Transport, Agriculture, Finance, Irrigation and Forest etc.) to combat climate change like policy reforms, solarization projects, electric buses, water conservation strategies and climate financing to name a few.

1 OVERVIEW

The world is experiencing a climate emergency. With each passing day we are moving closer to a precipitous decline brought on by our lack of readiness and protracted climate action. Saying that climate change is reshaping the global resource and resilience map wouldn't be an exaggeration. Average global variation in temperature is a key determinant of climate change. During 2023, the world has observed the hottest recorded summer, as NASA[131] has reported that the months of June, July, and August were 2.1°F (1.2 °C) hotter than the mean summer recorded temperatures between 1951-1980.

South Asian region, like rest of the globe is coming across a **"new climate normal"** along with the subsequently augmenting extreme weather events e.g., ranging from intensified heat waves to the devastating floods, with its disparate impacts on the vulnerable groups of population. More than half of this region has encountered several climate-driven extreme events during 2001-2021. It is projected that the estimated economic loss resulting from climate change for South Asian states are more than the global average of losses by about 7%, with Pakistan facing a potential loss of 10% by 2100[132].

2 ENVIRONMENT

2.1 Punjab's Climate Change Outlook

Punjab is the most populous province of Pakistan, which is the 5th most vulnerable country to climate change[133] and is facing serious threat of devastation from abrupt climatic events. The province is experiencing the climate induced challenges at an unprecedented rate. The manifestations of climate change in Punjab include increased riverine, flash, and urban flooding frequency and intensity, as well as heat waves. These events have multiple secondary effects on all vulnerable sectors, including but not limited to water resources, agriculture, health, and ecosystems.

Punjab's economy is primarily agrarian, but the industrial sector also makes a significant contribution. The province has a diverse agriculture system, attributing 51 million acres of cultivated land. The province has more than 3900 small and cottage industries, around 11500 textile units and more than 6000 food processing units[134]. The agriculture itself is a large contributor in increasing greenhouse gas (GHG) footprint of an area. According to Pakistan's national GHG inventory (2018), agriculture sector accounts for 46% of GHG emissions. The major GHG's emitted from agricultural sources are CO_2, N_2O and CH_4. The agricultural practices, including livestock rearing, stockpiling the animal dung, manure management, fertilizers, paddy fields, diesel-fueled irrigation sources, slash burning are main sources of GHGs to the atmosphere. Other sectors, including the transport, industry, energy and waste are also contributing in escalation of climate pollutants in the air.

Particulate matter is the most critical air pollutant in Punjab, that is responsible for the formation of smog which becomes more evident during winters due to thermal inversion. Soot or black carbon, is one of the particulate matter components that also contributes to

[131] https://www.nasa.gov/news-release/nasa-announces-summer-2023-hottest-on-record/
[132] Climate Change Action Plan 2021-2025 South Asia Roadmap (2021) The World Bank Group
[133] Un-Habitat Country Report Pakistan 2023
[134] Punjab in brief, Punjab Board of Investment and Trade (http://www.pbit.gop.pk/punjab-in-brief)

climate change. The black carbon's ability to absorb sunlight is widely known, and it could lead to atmospheric warming and consequent modifications in precipitation patterns[135]. According to the emissions inventory of Punjab[136], the particulate matter contributes 23% of the total emissions in Punjab, with industrial sector being the major contributing source. Though the 'emissions' side of climate change is at a rapid rise in the province, vulnerability, adaptation, institutional capacity and resilience remains at the top policy and strategy priority in context of climate action.

2.2 Weather Patterns and Climate Normals

As highlighted in SOE Report 2022, Punjab has a diverse climate, ranging from semi-arid to arid in the southern regions to cool and humid in the northern areas (north to the Salt Range). The climatic normal recorded from 1991-2020 depict that in Punjab, the mean annual minimum and maximum temperatures remained as 17.1°C and 30.1°C, respectively, whereas the mean annual precipitation has been recorded as 49.8 mm[137] (Figure 6-1).

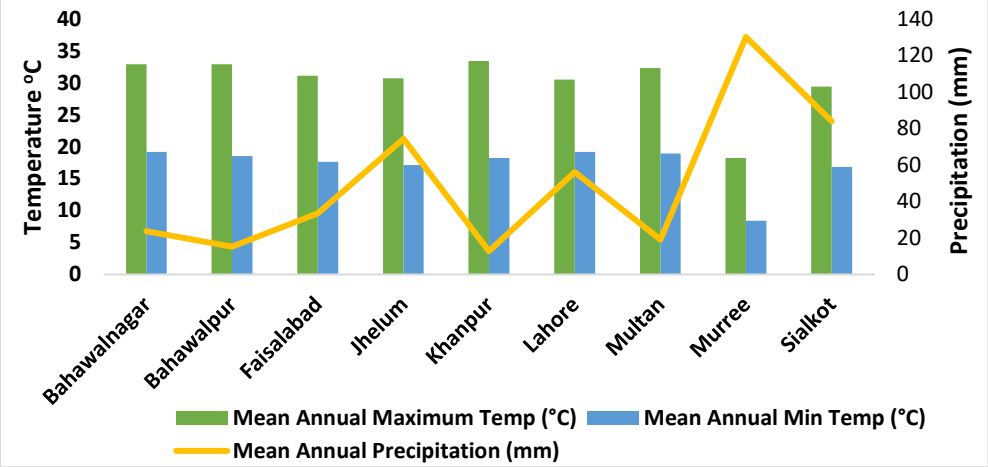


Figure 6-1: Climate Normals in Punjab (1991-2020)

During 1880s to 2020, the extreme records of minimum and maximum temperatures in Punjab show that the lowest minimum temperature has been recorded to be -12°C (in Northern Punjab), whereas, the highest maximum temperature has been recorded to be 50.8°C (in Southern Punjab)[138] (Figure 6-2). The wide gap between these temperature extremes depicts the high variability of temperatures across province.

[135] Black Carbon: A Science/Policy Primer John Bachmann I Vision Air Consulting, LLC I December 2009, Pew Center On Global Climate Change (https://www.c2es.org/wp-content/uploads/2009/12/black-carbon-primer.pdf)
[136] Air Pollution Emission Inventory of Punjab, Pakistan (1991-2020) Urban Sector Planning & Management Services Unit, Planning & Development Board, Government of the Punjab and SUPARCO
[137] Pakistan Meteorological Department (PMD)
[138] PMD

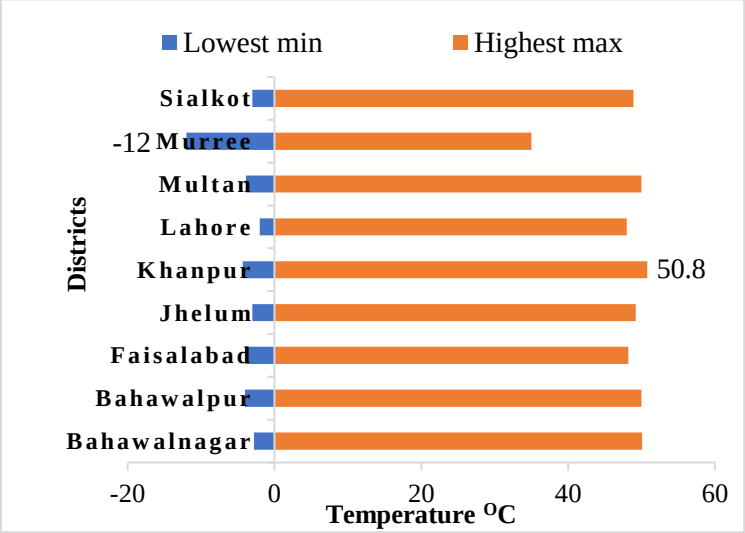


Figure 6-2: Extreme Temperature Records in Punjab (1880s to 2020)

2.3 Weather Anomalies-2023

i. Temperature

The world's hottest summer temperatures occurred in 2023. Summertime temperatures in the Indian Subcontinent and eastern Pakistan have been relatively lower this year, especially when compared to the surface air temperatures that were reported in the year, 2022 as depicted in Figure 6-3a & b.[139]

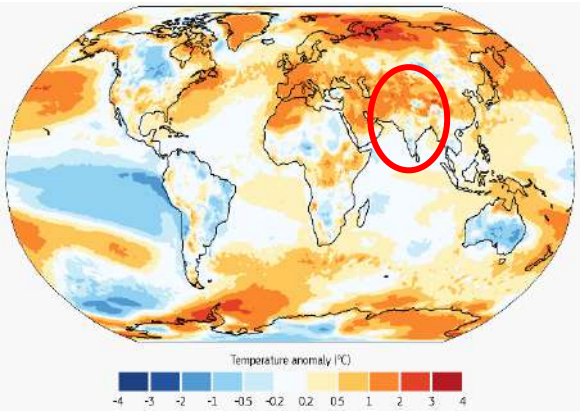


Figure 6-3a: Surface air temperature anomalies – 2022

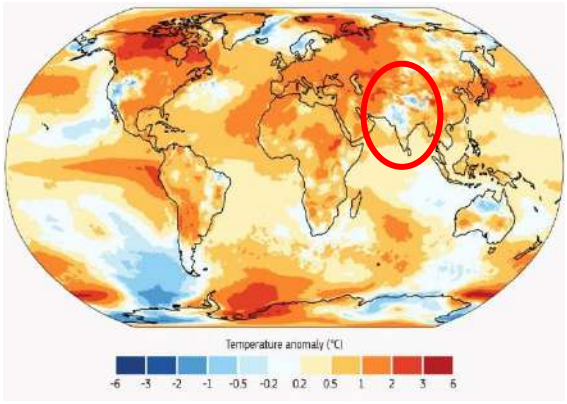


Figure 6-3b: Surface air temperature anomalies - 2023

It was reported that a strong storm of low air pressure that emerged in the continent's west drove humid winds from the Arabian Sea over the area caused a historically low temperature to occur in May of 2023 in India. This resulted in the dense clouds, reducing the sunlight along with the above-normal precipitation and a record colder temperature

[139] Copernicus Climate Change Service (*https://climate.copernicus.eu/global-climate-highlights-2023*)

reported by Indian Met stations[140]. The cooler than normal temperatures have also been observed in Punjab (eastern Pakistan) and the same is confirmed by Pakistan Meteorological Department (Figure 6-4). However, the overall mean temperature recorded in the country were 0.51°C above – normal[141].

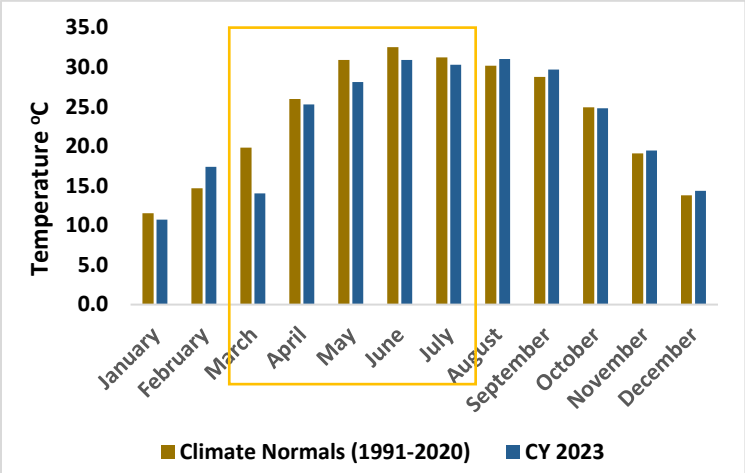


Figure 6-04: Comparison of Punjab's Mean Monthly Temperatures of Climate Normals (1991-2020) and CY 2023 (Recorded from 09 Met Stations)

It is pertinent to mention here that the cooler temperatures due to inter-annual variability do not refute the phenomena of global warming - led climate change. It cannot be inferred that global warming is occurring uniformly over all the regions on the Earth. Rather, it is just the average increase in global temperature that is recorded in context of climate change. The regional weather patterns keep varying, depending on several parameters including, but not limited to the local and regional atmospheric pressures, wind patterns, cloud density, solar radiation, geography and topography[142].

ii. Precipitation

Where on one hand, the temperatures remained cooler in the province, the precipitation patterns also showed remarkable anomalies round the year 2023 (Figure 6-5). Departure from normal remained higher for the months of May, October and November receiving higher while months of January, February, August and December received below average rainfall.

[140] https://www.theguardian.com/environment/2023/may/05/weather-tracker-unusually-chilly-start-may-india-us
[141] State of Pakistan's Climate – 2023, Pakistan Meteorological Department
[142] NOAA (2020) (https://www.climate.gov/news-features/climate-qa/does-global-warming-mean-it%E2%80%99s-warming-everywhere)

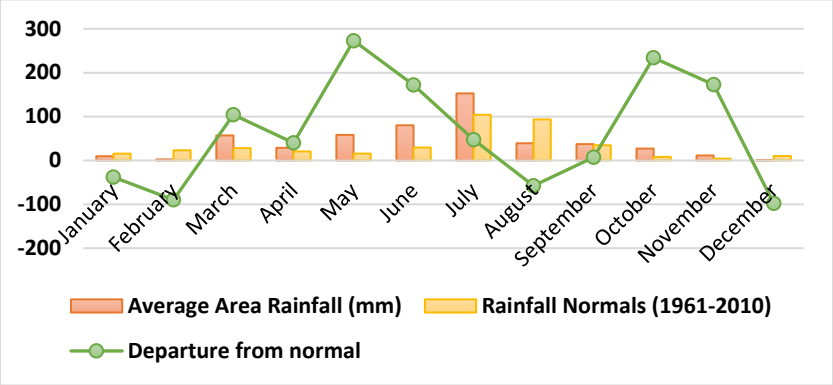


Figure 6-05: Rainfall Anomalies Recorded During - 2023

2.4 Extreme Weather Records - 2023

The highest temperature during 2023 was 46.6°C recorded in Noorpur Thal, District Khushab on June 22, whereas the highest rainfall in 24-hours was recorded by meteorological station at Lahore airport, measuring 226.0 mm on June 26. The extreme events recorded in Punjab during 2023 are detailed in Figure 6-6.

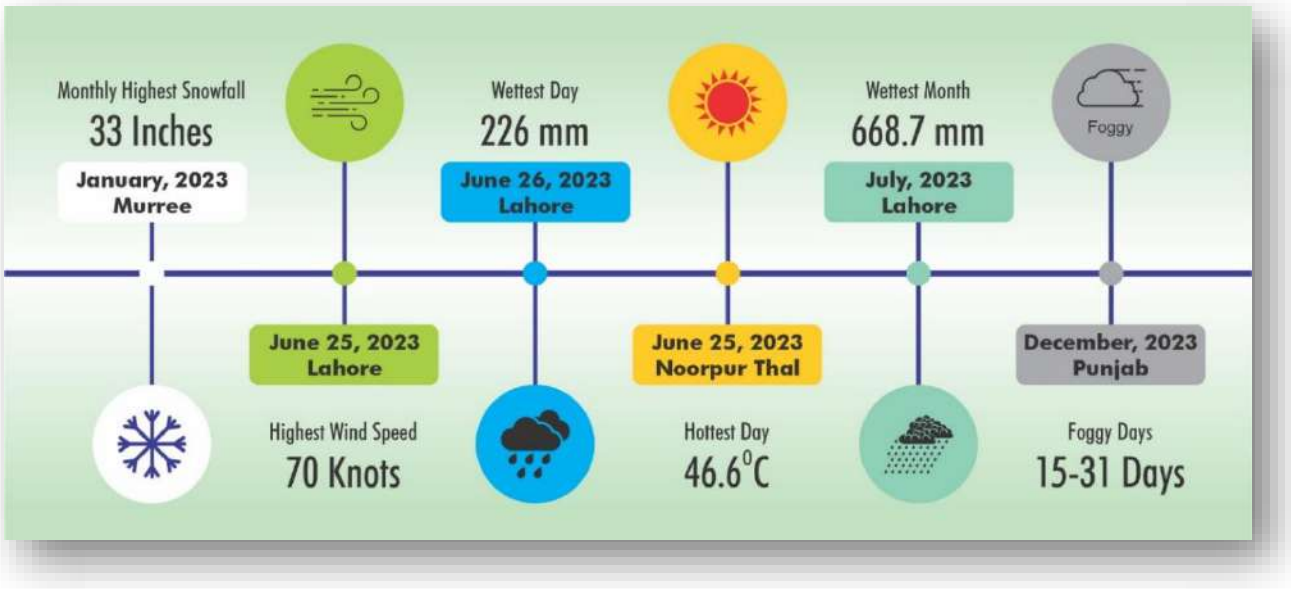


Figure 6-6: Extreme weather records in Punjab - 2023

2.5 Sectoral Impacts of Climate Change in Punjab

Climate change affects every sector of the economy in different ways. There is complex nexus between the climate change and its inter- and intra-sectoral implications. So far, no in-depth data is available with quantified impacts of climate change and its subsequent hazards on the economic sectors of Punjab. A glimpse of these impacts based on the available data is given below

2.5.1 Water Sector

Water sector is highly vulnerable to the impacts of climate change. Punjab is experiencing water-stress situation along Indus tributaries. Irrigation Department, Punjab reported that between 1976-2020 the average yearly availability of all the rivers that make up the Indus River System's flows for canal withdrawals decreased from 145.20 to 124.90 MAF. Out of the 37 large aquifers studied between 2003 and 2013, a study carried out by NASA found that Indus Basin aquifer was the second most overstressed and was being depleted at an alarming rate. This situation has led to a high pressure on groundwater resources of the province. Recent survey conducted by Punjab Irrigation Department, indicates that over abstraction has led to falling of groundwater to lower than critical limits in seven districts of Punjab including Lahore, Multan, Khanewal, Vehari, Lodhran, Pakpattan and Sahiwal. Percentage of area with unfit groundwater quality increased by 35%, 38% and 49% in the year 2010, 2014 and 2020, respectively. Recurring flood events caused major damages to irrigation and drainage infrastructure in the preceding years 2010 (River Indus), 2014 (River Chenab), 2022 (Hill torrents in DG khan & Rajanpur) and 2023 (Eastern rivers).

2.5.2 Agriculture and Livestock Sector

Farmers in districts Muzzaffargarh, D.G Khan and Faisalabad have reported rising challenges of food security due to climatic disasters (floods and droughts) followed by pest attack, rainfall, wind and hailstorms[143]. Consequent upon the Floods-2022, the Rabi season crops have shown higher yield, which has partly compensated the crop damages of the Kharif season, leading to an overall growth of agriculture sector to 1.55%. However, the growth rate reported in 2022-2023 was second lowest in the country since 2017 (**Error! Reference source not found.**-7)[144].

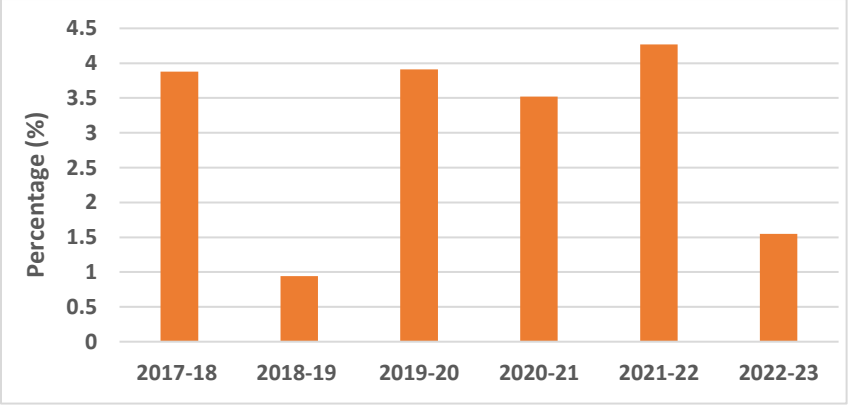


Figure 6-7: Agriculture Sector Growth Rates 2017-2023

[143] Civil Society Coalition for Climate Change (2018). Food Security and Challenges of Climate Change: A Case Study of Punjab, Pakistan

[144] Pakistan Economic Survey 2022-23 (Agriculture)

The kharif crops i.e., cotton, sugarcane, rice, maize, moong, sesame, fodder and vegetables have undergone production losses due to the floods/torrential rains during 2023[145] (Figure 6-8).

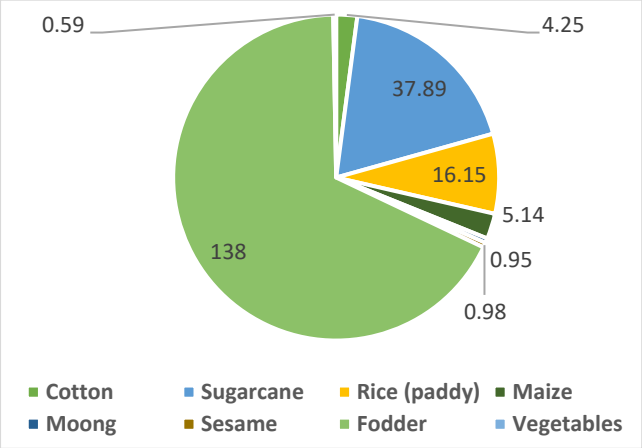
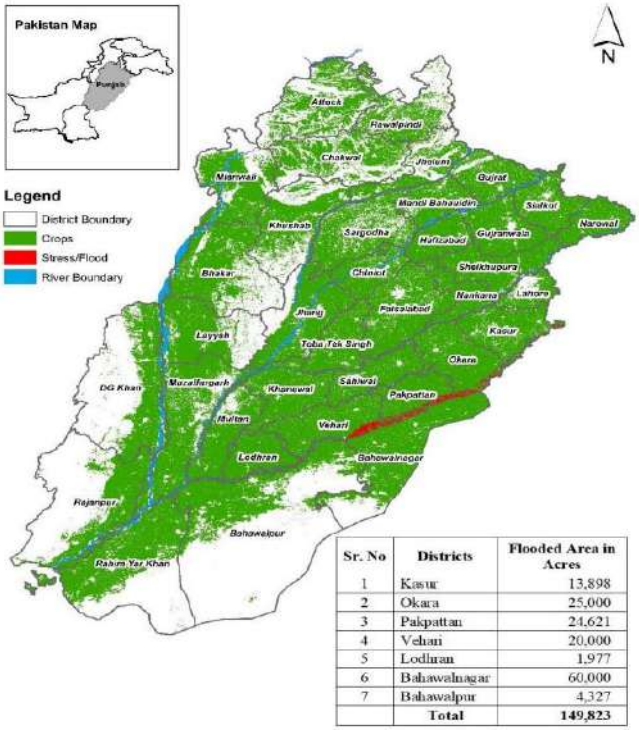


Figure 6-8: Production Loss of Kharif Crops from Floods/Rainfalls (000 Tons)

Unforeseen variability in weather patterns puts stress on the crop health and growth, which is calculated by the Normalized Difference Vegetation Index (NDVI). The stress map of crops (Figure 8)[146] indicates that severe stress was found on the crops cultivated in Kasur, Pakpattan, Okara, Vehari, Bahawalpur and Bahawalnagar districts due to flood water in River Sutlej, affecting an area of 60,000 acres. Floods of 2022 have had a devastating impact on the livestock as well. According to NDMA updates dated 18-11-2022, estimated 1,164,270 livestock heads perished due to 2022 floods with 205,106 (17.6%) in Punjab[147]. The sector has also been affected by the floods in 2023 as well, as discussed in upcoming section (6.3).

[145] Crop Reporting Services, Agriculture Department, Government of the Punjab
[146] Crop Reporting Services, Irrigation Department, Government of the Punjab
[147] Pakistan Economic Survey 2022-2023 (Agriculture)



Sr. No	Districts	Flooded Area in Acres
1	Kasur	13,898
2	Okara	25,000
3	Pakpattan	24,621
4	Vehari	20,000
5	Lodhran	1,977
6	Bahawalnagar	60,000
7	Bahawalpur	4,327
	Total	**149,823**

Figure 6-9: Stress Map of Crops, September 2023

2.5.3 Health Sector

Climate change poses threats to human health in both direct and indirect ways. The direct impacts arising from the climate change and its manifestations include illnesses, injuries and deaths resulting from heat/cold waves, forest fires, droughts, floods, storms, sky lightning, land sliding and other events. However, the indirect health effects of climate change stem from its effects on food production, the environment (air and water quality), the spread of infectious diseases, and the emergence of chronic illnesses and allergies.[148] During May 2022 to April 2023, about 250 cholera cases were confirmed in Punjab[149]. Out of cumulative total of 25,932 confirmed dengue cases in Pakistan during 2022, 6483 (29%) cases were reported from Punjab[150]. The disease patterns related to poor air quality and contaminated water are discussed in respective Chapters.

2.5.4 Urban Sector

According to certain urban development statistics for Punjab, the urban sector is highly vulnerable to climate change, which not only makes urban areas less able to adapt to extreme weather events and disasters but also increases their exposure, particularly to vulnerable populations. Some of the impacts are detailed below;

[148] 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)
[149] World Health Organization, Pakistan Floods Situation Report, Health Emergencies Program (Situation Overview), Issue No. 33, 19th May 2023
[150] World Health Organization, Disease Outbreak News (Dengue - Pakistan), October 2022

a. The population of Punjab has reached 127.6 million as per Population Census 2023 with an annual growth rate reported as 2.53%[151]. Cities have grown incredibly, which has resulted in changes in land use, unlawful encroachment, environmental issues, and incompatible service usage. Housing shortage is evident from Lahore's statistics where 3.4 persons are living per room, which is higher than India (2.7), Sri Lanka (2.2) and Turkey (1.3). There is a total backlog of nearly 400,000 units with annual demand of 78,000 houses per year[152]
b. Air pollution is on the rise in urban areas due to multiple factors, including environmental problems, inefficient energy use, a rapid increase in the number of vehicles, industrial activities without adequate air emission control, and the open burning of solid waste, including plastic. The Air Quality Index, (calculated on basis of $PM_{2.5}$ and PM_{10}) during smog season 2023 is continuously being recorded between unhealthy for sensitive groups (151-200) to very unhealthy (301-400) in Lahore[153].
c. Urban flooding due to heavy rainfalls has become a serious concern in the cities of Punjab. This occurs due to poor planning and inadequate drainage and infrastructure in the cities causing streets and low-lying areas to be submerged in water affecting mobility, and creating other issues to the residents.

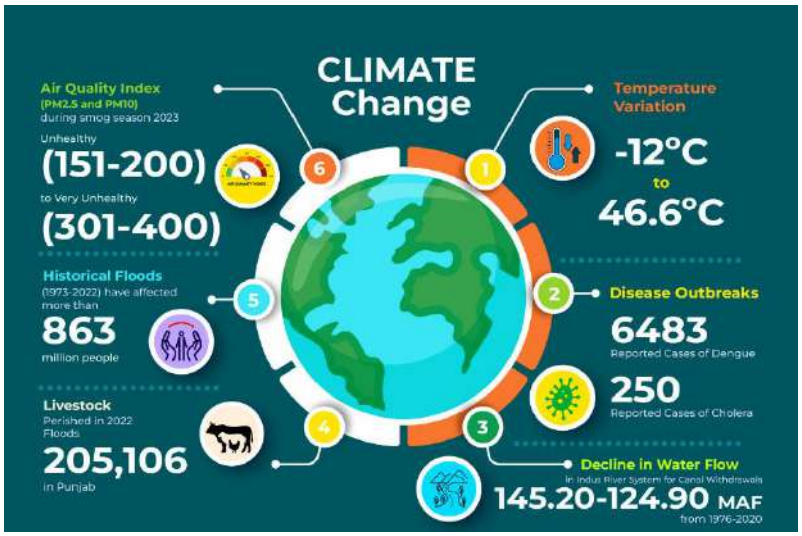


Figure 6-10: Sectoral impacts of climate change in Punjab

2.6 Loss and Damages

The extreme events arising from the changing climate have led to devastating loss and damages throughout the country, specifically during past few decades. An overview of the losses and damages brought on by extreme weather occurrences in Punjab province are shown below.

[151] Pakistan Population Census 2023
[152] Punjab Board of Investment and Trade (PBIT) (http://www.pbit.gop.pk/infrastructure)
[153] Environment Protection Department (EPD) Punjab (https://epd.punjab.gov.pk/index.php/aqi)

2.6.1 Floods

Punjab experiences flooding in Monsoon season, mostly due to torrential rains and hill torrents. During mid-June each year a monsoon system due to low depression originates in the Bay of Bengal, the northeastern segment of Indian Ocean. The system enters Punjab from India from the West or North West and then moves towards North. Punjab's rivers get substantial inflows due to the persistent, heavy rainfall in the northern mountain ranges. The summertime high glacier melt combined with these large inflows causes floods in Punjab's plains. In addition to the riverine floods, Punjab also experiences flash and urban flooding during the months of June-October. However, the intensity of flooding varies depending on the intensity and frequency of precipitation.

Since 1970's the floods have caused severe loss and damages to the infrastructure and human life. According to the Provincial Disaster Management Authority (PDMA) Punjab, the historical floods (1973-2022) have affected more than 863 million people in all. The loss and damages to the households, cropped area, livestock and human lives have also remained significant during these events (Figure 6-11). More than 3000 people have lost their lives during these floods[154] (Figure 6-12).

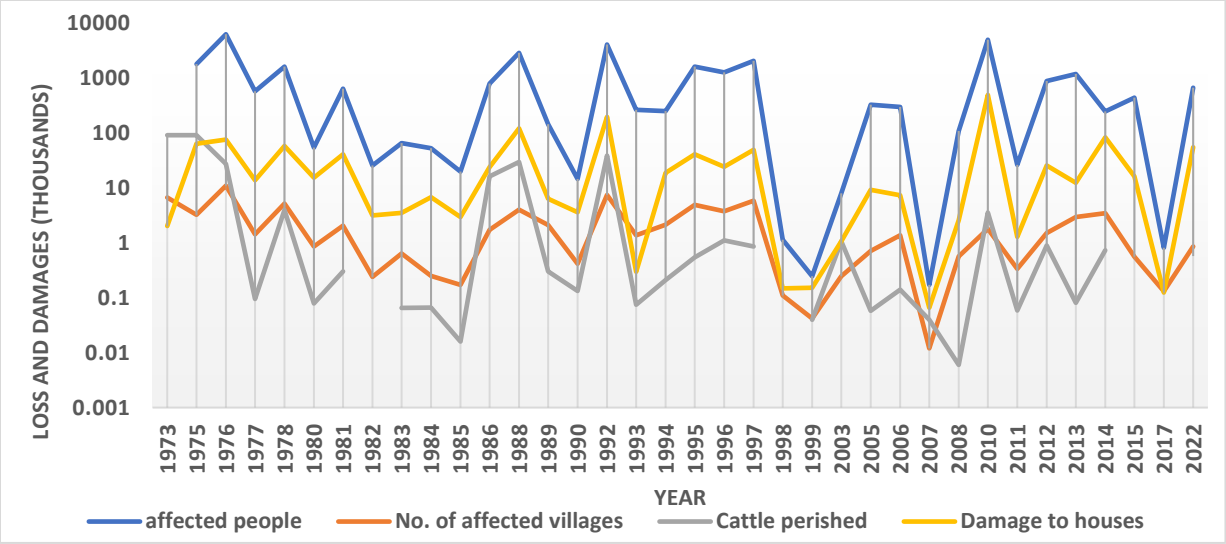


Figure 6-11: Loss and Damages in Punjab during Historic Floods (Logarithmic scale)

[154] PDMA, Punjab

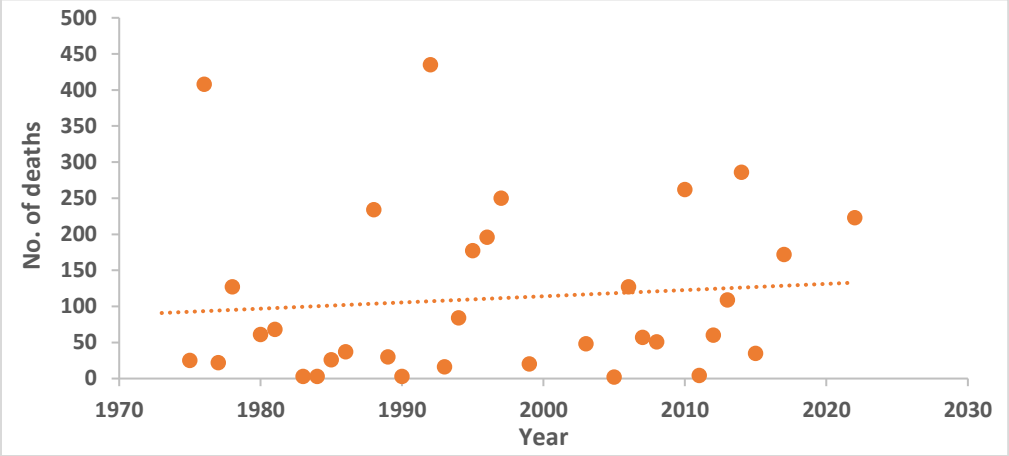


Figure 6-12: No. of deaths reported during historical floods in Punjab (1973-2022)

Most recently, Punjab has faced flooding along Sutlej River in August, 2023. The water levels on the Sutlej at the Ganda Singh Wala village gauging station, 7 km west of Ferozepur, were recorded to be highest in 35 years[155]. According to PDMA, flood season was observed from 17th of August, to 30th September during which Districts Bahawalnagar, Bahawalpur, Lodhran, Kasur, Vehari, Okara, Pakpattan and Multan were affected by urban flooding. The floods affected 467 villages/basti/mozas with more than 24,000 houses and 545,270 acres of cultivated land in the affected districts. Around 300,000 livestock was transported for rescue purposes, whereas 11 persons were reported injured and 10 reported dead as a result of these floods[156].

Torrential Rains and Thunderstorms

In addition to the floods, the torrential rains along with the thunderstorms also pose threat to human and animal lives as well as to the infrastructure. According to PDMA, during 2023 the torrential rains and thunderstorms have not only damaged the infrastructure (Figure 6-13**)** but have also resulted in more than 300 injuries and 124 deaths due to sky lightning, structural collapse and heat stroke events in different districts of Punjab.

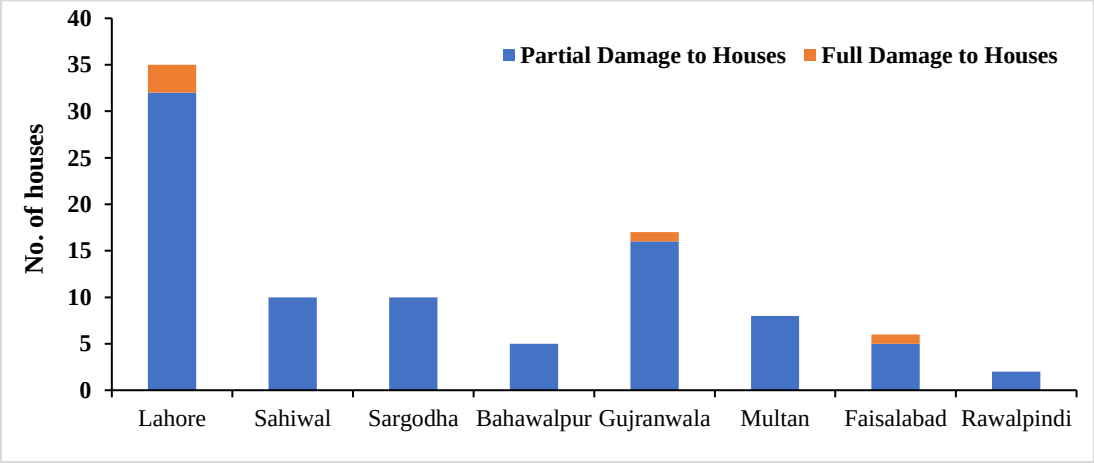
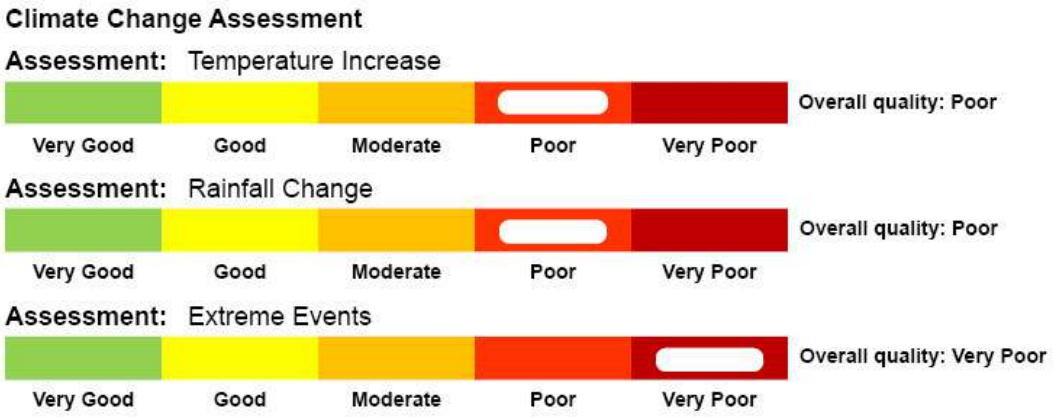


Figure 6-13: Damage to Houses due to torrential rains and thunderstorms during 2023

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

2.7 Overall Quality Assessment



3 MANAGEMENT

3.1 Initiatives taken by the Government

Government of the Punjab is well sensitized about the risks and consequences related to climate change and is taking crucial initiatives in terms of climate change mitigation, adaptation, resilience and climate finance. Some imperative endeavors by Government of the Punjab pertaining to climate action are as follows:

3.1.2 Energy, Transport and Industry Sector

i. Energy savings of 55 GWh are anticipated in public institutions through solarization projects initiated by Energy Department under Punjab Green Development Program.
ii. Government of the Punjab is piloting 27 electric buses in the province, which would be a groundbreaking step towards provincial contribution to the commitments made by the country in its Nationally Determined Contributions (NDCs)
iii. About 500 micro-enterprises, covering five industrial sectors i.e., stone crushing, rice husking, re-rolling units and steel furnaces are being financially supported by Industries Department for adopting Resource Efficient and Cleaner Production (RECP) Technology under Punjab Green Development Program (PGDP).

3.1.2 Agriculture Sector

Followings initiatives have been taken by the Punjab Government for climate change mitigation/adaptation in agriculture sector:

i. Field experiments are being carried out to increase fertilizer use efficiency, which will lower fertilizer losses and GHG emissions.
ii. Experiments are being conducted on use of green manures and farm yard manures to increase yields, improve soil health and increase carbon sequestration. All these steps increase soil health.
iii. Soil and water samples from fields are being taken and advisory service is provided to the farmers which results in proper use of inputs under climate change scenario.
iv. All the developed technologies are being disseminated to the farming community through production plan, farmer days and other media.

v. Installation of high efficiency irrigation system on 3,200 acres of land.

vi. Installation of solar system to operate coupled high efficiency irrigation system on 2,000 acres.

vii. Construction of 55 farm pounds and 55 dug wells in barani areas of the Punjab.

viii. Improvement in lining of 732 watercourses.

ix. Rehabilitation of 445 irrigation schemes outside canal commands.

x. Provision of 300 LASER land leveling units to the service providers/ farmers.

xi. Furthermore, the Agriculture Extension Wing is also providing information and guidance to the farmers on coping heatwave conditions and adapting their agricultural practices accordingly. This includes educating them on appropriate irrigation techniques, crop selection, and timing for planting and harvesting to minimize heat stress on crops etc. (Figure 6-14).

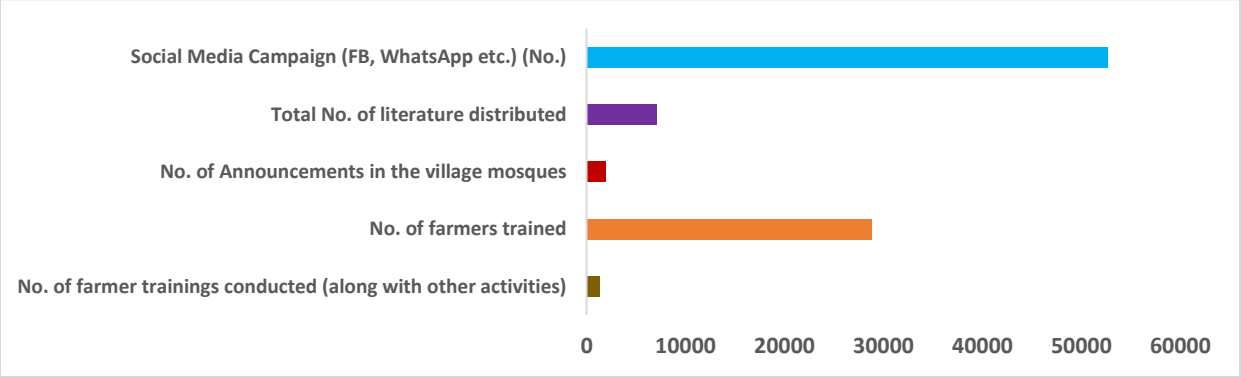


Figure 6-14: Awareness Activities on Climate Change by Agriculture Department, Punjab

xii. Advisory services along with other activities are provided regarding improving water use efficiency, conservation tillage practices, manure management, alternate measures to puddling like direct seeding for rice crop etc.

xiii. Aggressive tree planting initiatives are carried out annually at farmer fields and agriculture offices, which will be crucial in reducing atmospheric pollutants. As per the current year 2023 report from the field offices, 67,480 saplings have been planted in offices and farmer fields.

xiv. For the development and introduction of drought resistance crop varieties, many major crops related Institutes like wheat, rice, maize, cotton, sugarcane, pulses, oil seeds etc. are working under the umbrella of Ayub Agricultural Research Institute (AARI), Faisalabad are engaged in research activities to combat climate change.

xv. Climate Change Research Center (CCRC) was also established at AARI, Faisalabad under certain term of references (TORs) in 2015 and it is effectively working. Therefore, to meet the challenges of current environmental and climatic scenarios, following Climate Smart Agriculture Technologies/activities are being considered:

- Climate-smart management for rice production
- Drip irrigation as a Climate-smart practice
- Assessment of climate-smart breeding needs
- Planting cotton crop in raised Beds/ridges
- Regulated Deficit Irrigation (RDI) an optimization approach

- Awareness of weather data/early warning system
- Re-defining and updating the Agro Ecological Zones (AEZs)
- Crop residue and farm waste management
- Developing a Climate Smart Agriculture plan

3.1.3 Irrigation sector

Government of the Punjab is striving for climate adaptation and resilience in following domains through multiple projects initiated by Irrigation Department:

i. Demand management measures to increase water use efficiency and productivity
ii. Construction of large and small reservoirs, rain water harvesting and storage, groundwater recharge, groundwater management etc. to improve inter seasonal water availability
iii. Strengthen resilience and adaptive capacity to climate related disasters

Furthermore, the interventions by EPCCD with co-benefits in climate mitigation are detailed in Chapter eight.

3.1.4 Forestry Sector

Urban tree plantations were carried out in 2023, both by the Forest Department's plantation efforts and to meet the requirements of environmental approvals. A total of 328,428 trees were planted throughout Punjab.

3.1.5 Climate Finance

i. The government is spending an amount of US$ 273 million for reforming the environment and climate sector and green development under PGDP till May 2025.
ii. A Green Financing Strategy has been formulated for Punjab, which presents a comprehensive assessment of Punjab's environmental challenges and vulnerabilities to climate and natural disasters, coupled with its commitment to international agreements and local challenges.
iii. A Green Climate Fund project “Transforming Indus Basin with Climate Resilient Agriculture and Water Management” is underway between GoPb and Food and Agriculture Authority (FAO). The project aims to increase resilience to climate change among the most vulnerable farmers in the Indus basin and to strengthen the Government of Pakistan’s capacity to support communities in adapting to climate change.
iv. Climate budget tagging (CBT) has been adopted to provide decision support in provincial climate change framework. CBT is being institutionalized as a priority in Government of the Punjab Planning and Development (P&D) Board that will help informing policy choices regarding disasters and climate investments.
v. An Environment and Climate Change Cell has been established in P&D Board Punjab, working on climate related actions and financing. The cell is assisting P&D Board in the process of getting accredited for Green Climate Fund (GCF).
vi. The Punjab Budget Strategy Paper (2022–2025) states that, in addition to department-specific allocations, Punjab will prioritize setting aside funds for mitigating and adapting to

climate events in order to maintain a buffer for backup and resource diversion in emergency situations.

vii. Disaster Risk Finance is a fundamental component of Punjab's Public Financial Management Reforms Strategy 2025 which aims to develop finance management systems to manage fiscal risks from disasters.

viii. Several activities in the World Bank's Punjab Resource Improvement and Digital Effectiveness (PRIDE) are executed by the Government of the Punjab through its Finance Department, to support mitigation and adaptation to climate change as climate co-benefits. These include:

- The program proposes the inclusion of environmental cost in medium-term macro-fiscal framework of the GoPb under its DLI-2.
- Formulation of a Disaster Risk Financing Strategy (DRFS) to provide the framework for establishing a disaster risk management fund to finance investments for disaster risk reduction and risk mitigation and adaptation and a mechanism for disaster response and recovery.
- Improvements in the regulatory framework to support Local Government (LG)'s responsiveness to disaster risks.
- Performance grant mechanism to incentivize LGs for disaster risk mitigation by promoting adaptation activities.
- Preparation of SOPs for environmental management of e-waste.

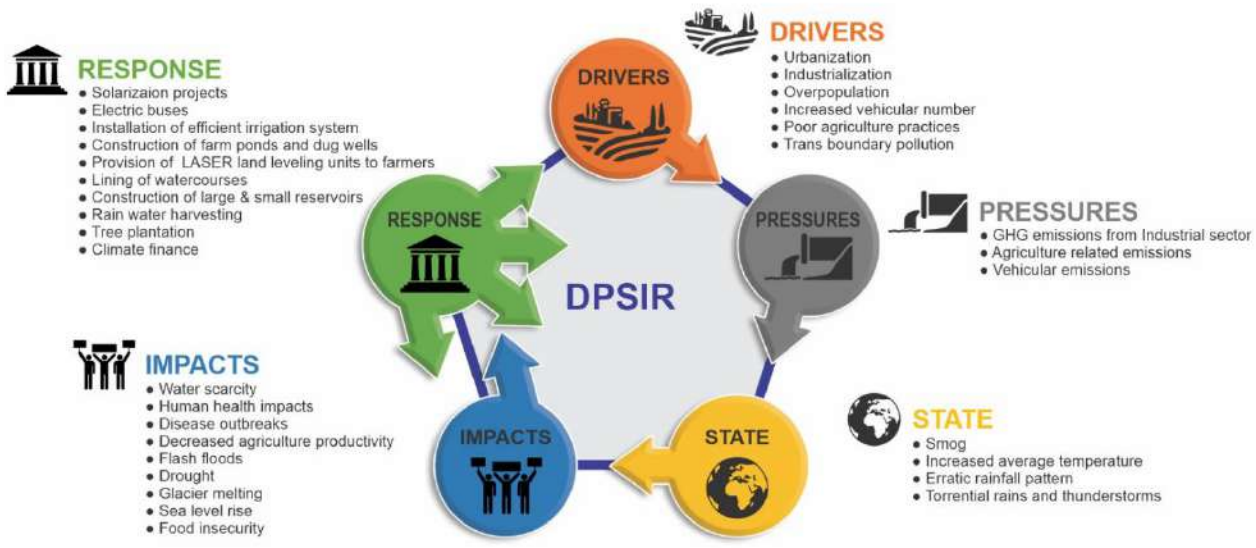


Figure 6-15: DPSIR framework for climate change in Punjab

4 THE WAY FORWARD

Punjab, though proactively engaged in the climate action may consider following interventions for expeditious and effective outcomes to combat climate change:

Building Climate Profile and Database of the province: There is no regularly updated data on climate change trends at the provincial level. There is need of capacity building, institutional strengthening, technology transfer, research and development to establish, maintain and update the data on GHG emissions, sectoral carbon footprints, climate-resilience of province and climatic variability over time for better policy decisions, leading to visible positive strands in Punjab's climate action.

Climate and gender mainstreaming: Integrating climate adaptation, with specific consideration of gender as an essential component of the planning (programs and projects), policy –, and decision – making as well as the regulatory functions of the department.

Planning for adaptation: Formulating strategic plans for Punjab to reinforce its adaptive capacity and resilience to climate-driven disasters, food and water insecurity, loss and damage to infrastructure and human lives.

Encouraging climate-resilient investments across province: Exploring the international climate funding and grants, development and management of climate funds and formulation of Punjab's financial framework for Climate Change Adaptation.

Role-playing for the International Commitments: developing linkages between the provincial climate actions and the international obligations related to climate adaptation and mitigation.

CHAPTER 7 ENVIRONMENTAL PERFORMANCE OF WASTEWATER TREATMENT AND SOLID WASTE MANAGEMENT FACILITIES

KEY FINDINGS

- During survey in 2023, total 434 industrial waste water treatment plants (WWTPs) were identified in Punjab.
- Amongst these plants, primary, secondary and tertiary WWTPs are 54.6%, 43.6% and 1.8%, respectively.
- Highest numbers of WWTPs have been found in Faisalabad (28%) followed by Lahore (20%), Sheikhupura (08%), Kasur (06%), Gujranwala (04%), Okara (03%), Sahiwal (03%), Khanewal (03%), Muzaffargarh (03%) and Rahim Yar Khan. (02%).
- Highest number of WWTPs were found in the textile sector followed by sugar mills, leather, food, rice mills, chemical projects, oil and fats vegetable ghee, beverages, thermal power generation and pharmaceuticals.
- In most of the WWTPs BOD_5 COD and Sulfide remained higher than the PEQS after treatment.
- Punjab's average municipal solid waste (MSW) collection is poor and is 50% below the optimal level of 75%.
- Poor MSW management in Punjab results in soil, water and air pollution, negatively impacting its surrounding environment.
- Addressing Punjab's waste management crisis requires an integrated approach incorporating legal, technological, financial and community efforts.

1 OVERVIEW

This chapter delves into the assessment of wastewater treatment plants operating within various industries across the province of Punjab, along with an examination of solid waste management facilities, encompassing municipal and hospital disposal facilities. Within the three primary industrial zones of Punjab (Faisalabad, Sheikhupura, and Lahore) numerous wastewater treatment facilities are in operation. Regrettably, the effluents discharged from these facilities do not consistently adhere to the prescribed PEQs.

2 ENVIRONMENT

2.1 Industrial Wastewater Treatment Plants

During 2023, field formulation of EPA Punjab, has carried out a detailed surveys for the identification of wastewater treatment plants installed in their respective territorial jurisdictions across the Punjab. The survey has two major components i.e.

(i) verification of earlier installed wastewater treatment plants earlier identified during 2022 for the preparation of State of Environment Report, 2022 and
(ii) identification of more wastewater treatment plants.

During this survey, 37 WWTP in addition to previously identified WWTP, have been identified. For collection of information as well as for its updation a module[157] was developed by SP&IU for the EPA staff. The module has two functionalities i.e., one was the verification of earlier added record and second was the addition of records of any new wastewater treatment plants. The information of each wastewater treatment plant was entered/updated in the module.

For the survey, the wastewater treatment plants were divided into three types based upon treatment technology i.e., primary, secondary, and tertiary WWTPs. Primary wastewater treatment plants are those which use physical operations to eliminate floatable and settle able solids from wastewater. The secondary WWTPs are those where the majority of organic matter is removed through biological and chemical processes. Whereas, in tertiary wastewater treatment plants additional processes are employed to eliminate constituents that were not removed during secondary treatment[158]. During the survey, a total of 434 waste water treatment plants were identified. Amongst these the percentage of primary, secondary and tertiary WWTPs was 54.6%, 43.6% and 1.8%, respectively.

[157] https://idm.pgdp.pk/admin/wwtp/wwtpdetail/
[158] https://www3.epa.gov/ttnchie1/ap42/ch04/final/c4s03.pdf

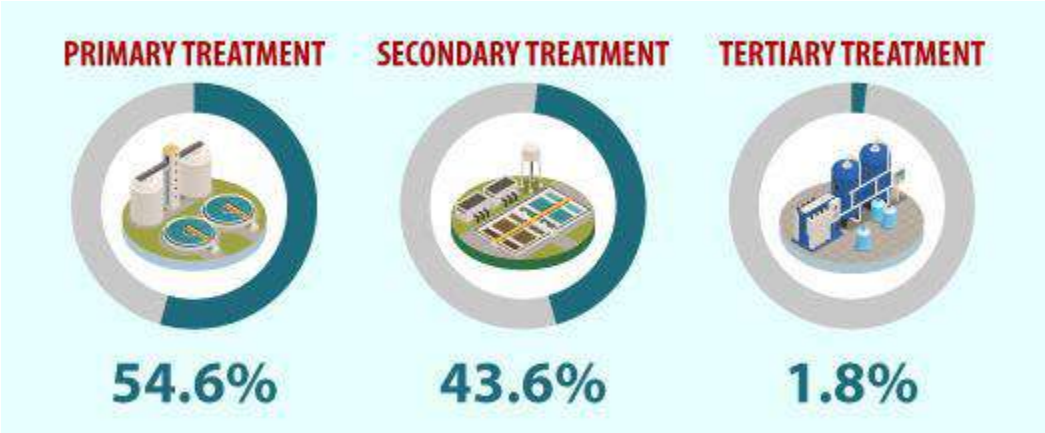


Figure 7-01: The percentage of wastewater treatment facilities in the Province

The geographical spread of these WWTPs is given in Figure 7-2.

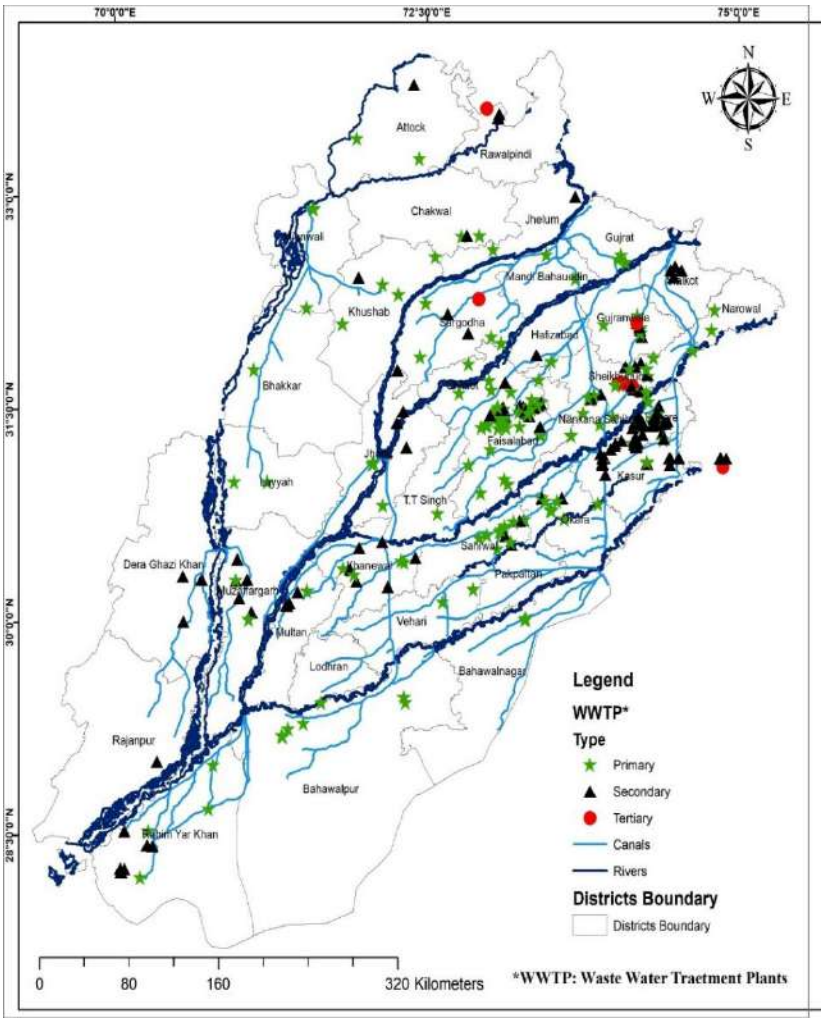


Figure 7-02: Geographical Spread of Wastewater Treatment Plants in Punjab

Highest numbers of wastewater treatment plants were found in Faisalabad (28%) followed by Lahore (20%), Sheikhupura (08%), Kasur (06%), Gujranwala (04%) Okara (03%),

Sahiwal (03%), Khanewal (03%), Muzaffargarh (03%) and Rahim Yar Khan (02%).The remaining districts have WTPs in single digit varying from 1 to 8 in numbers. The districts wise identified number of WTPs is given in Figure 7-3.

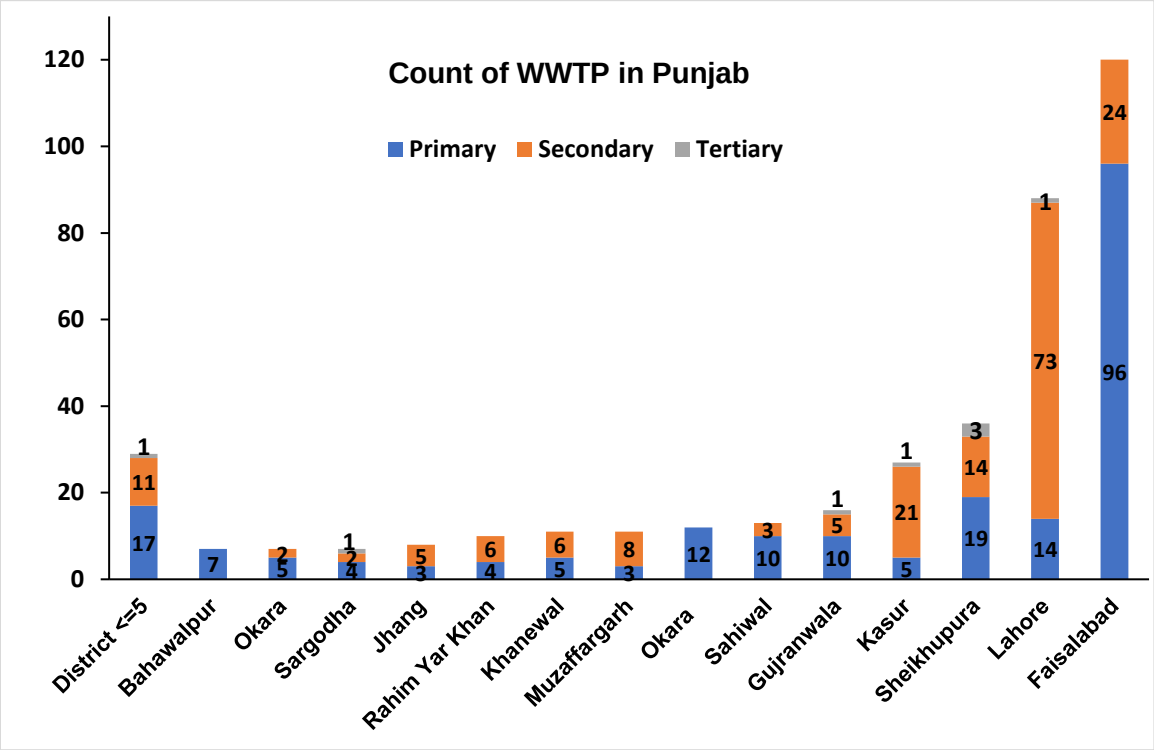


Figure 7-03: District wise installation of wastewater treatment plants.

These wastewater treatment plants are installed in various industrial sectors i.e. textiles, sugar mills, food, rice mills, paints and dyes and cement plants etc. The highest number of waste water treatment plants were found in the textile sector followed by sugar mills, leather, food, rice mills, chemical projects, oil and fats vegetable ghee, beverages, thermal power generation and pharmaceuticals. Industrial sector-wise distribution of WTPs is given in Figure 7-4.

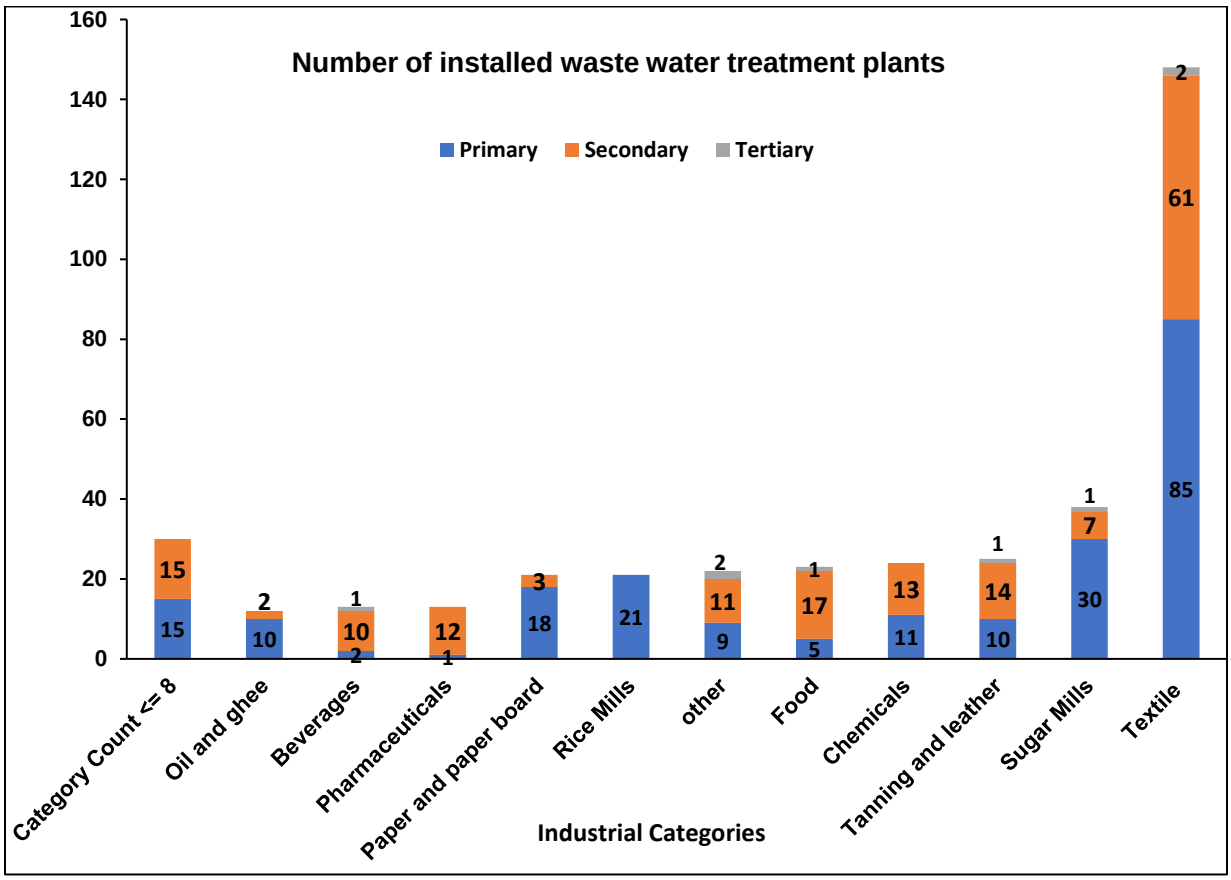


Figure 7-4: Category wise installation of wastewater treatment plants.

Figure 7-05: Types of industries assessed for their wastewater treatment facilities.

2.1.1 Environmental Performance of Industrial Wastewater Treatment Plants

In order to gauge the environmental performance of wastewater treatment plants, EPA Laboratories carried out analysis of liquid effluent samples before and after treatment either received from the district offices of EPA Punjab or collected at their own. It is pertinent to mention that two "Grab" samples were taken from each wastewater treatment plant. The analyses of these samples were carried out to evaluate the compliance of the Punjab Environmental Quality Standards for Municipal and Liquid Industrial Effluents, 2016[159]. This standard contains 32 parameters i.e.; Temperature, pH, Biochemical Oxygen Demand (BOD_5) at 20°C, Chemical Oxygen Demand (COD), Total Suspended Solid (TSS), Total Dissolved Solid (TDS), Grease and Oil, Phenolic compounds (as phenol), Chloride (as Cl^-), Fluoride (as F^-), Cyanide (as CN^-), An-ionic detergents (MBAs), Sulfate (SO_4^{2-}), Sulfide (S^{2-}), Ammonia (NH_3), Pesticides, Boron (B), Chlorine (Cl_2) and heavy metals including Cadmium (Cd) , Chromium (trivalent and hexavalent), Copper (Cu), Lead (Pb), Mercury (Hg), Selenium (Se), Nickel (Ni), Silver (Ag), Zinc (Zn), Arsenic (As), Barium (Ba), Iron (Fe) and Manganese (Mn). Among these 32 parameters EPA Punjab owing to limited capacity of analysis; could analyze only Temperature, pH, BOD_5, COD, Sulfate, Chloride, TSS and TDS in the effluents of industrial wastewater.

The analysis of effluent of wastewater treatment plants installed at various sectors is as follows.

- In **the Textile sector**, pH was already within the prescribed limits of PEQS. After the treatment, the average value of Sulfate was reduced within the PEQS limits. Whereas BOD_5 (520 mg/l), COD (719 mg/l), Sulfide (12.62 mg/l), Chloride (1094 mg/l), TDS (4849 mg/l) and TSS (220 mg/l) remained higher than the PEQS values even after treatment.
- In **Sugar Mills**, pH and Sulfate were already within the prescribed limits of PEQS. After the treatment, the average value of Chloride was reduced within the PEQS limits. Whereas BOD_5 (1094 mg/l), COD (1381 mg/l), Sulfide (5.0 mg/l), and TDS (3558 mg/l) and TSS (259 mg/l) remained higher than their PEQS values even after the treatment.
- In **the Food Sector**, pH, Sulfide, Sulfate and Chloride. were already within the prescribed limits of PEQS. After the treatment, the average value of BOD_5, TSS and TDS were reduced within the PEQS limits. However, COD (383 mg/l) remained higher than their PEQS values even after the treatment.
- In **Rice Mills**, pH, Sulfate, Chloride, TSS and TDS were already within the prescribed limits of PEQS. After treatment the average value of Sulfide was reduced within PEQS limits.
- In **Others Sectors**, pH, Sulfate, Chloride, TSS and TDS were already within the prescribed limits of PEQS. However, BOD_5 (109 mg/l) and COD (235 mg/l) remained higher than their PEQS values even after the treatment.
- In **Paints and Dyes**, pH, Sulfate, Chloride and TDS were already within the prescribed limits of PEQS. The average value of TSS was reduced within the PEQS limits. However,

159 https://epd.punjab.gov.pk/system/files/Punjab%20Environmental%20Quality%20Standards%20for%20Municipal%20And%20Liquid%20Industrial%20Effluents%20final_0.pdf

BOD_5 (100 mg/l) and COD (227 mg/l) remained higher than their PEQS values even after the treatment.

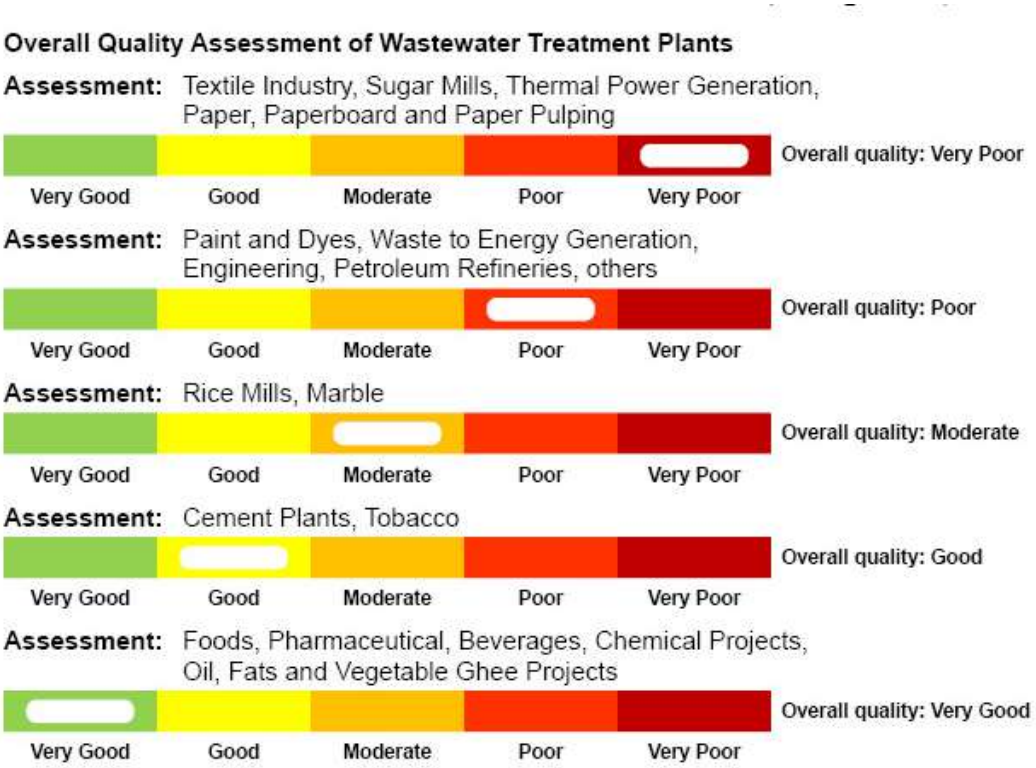
- In **Cement Plants**, pH, Sulfate, Chloride, and TDS were already within the prescribed limits of PEQS. However, Sulfide (2.4 mg/l) remained higher than the PEQS value even after the treatment.
- In **Pharmaceutical Plants**, pH, Sulfate, Chloride, TSS and TDS were already within the prescribed limits of PEQS. The average value of Sulfide (0.9 mg/l) was reduced within the PEQS limits after treatment.
- In **Waste-to-energy generation**, pH, Sulfate, Chloride and TDS were already within the prescribed limits of PEQS. However, COD (282 mg/l) and Sulfide (4.00 mg/l) remained higher than their PEQS values even after treatment.
- In **Thermal Power Generation**, pH, Sulfate, Chloride, TSS and TDS were already within the prescribed limits of PEQS. However, COD (158 mg/l) and Sulfide (4.00 mg/l) remained higher than their PEQS values even after the treatment.
- In **Beverages**, pH, Sulfate, Chloride and TSS were already within the prescribed limits of PEQS. After the treatment, the average values of Sulfide (0.8 mg/l) and TDS (1575 mg/l) were reduced within the PEQS limits.
- In **Tobacco Industries**, pH, BOD_5, Sulfate, Chloride and TDS were already within the prescribed limits of PEQS. The average value of TSS (180 mg/l) was reduced within the PEQS limits after treatment, while COD (164 mg/l) remained higher than the PEQS value even after treatment.
- In **Engineering**, pH, Sulfate and Chloride were already within the prescribed limits of PEQS. Average value of TDS (3450 mg/l) was reduced within the PEQS limits after treatment. Whereas COD (192 mg/l) and Sulfide (4 mg/l) remained higher than the PEQS values even after the treatment.
- In **Petroleum Refineries**, pH, Sulfate, Chloride, and TDS were already within the prescribed limits of PEQS. However, COD (162 mg/l) and Sulfide (4 mg/l) remained higher than the PEQS values even after the treatment.
- In **Paper and Paperboard, Paper Pulping Industries**, pH, Sulfate and Chloride were already within the prescribed limits of PEQS. However, TSS (922 mg/l) and TDS (8800 mg/l) remained higher than their PEQS values even after the treatment.
- The analysis of effluents, before and after treatment shows that the wastewater was complying with the PEQS for tested parameters in **Marble Sector**, **Manufacturing of Apparel** including **Dyeing and Printing** sector. While in **Chemical Projects** only BOD and COD values exceeded the PEQS values that to fell under compliance limits after treatment. The average values of various parameters before and after wastewater treatment are given at Table 7-1.

Table 7-1: Average values of parameters before and after treatment of wastewater treatment plants.

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	8.9	8.7	795	520	921	719	4.1	12.6	625	566	1289	1094	283	220	5363	4849
Sugar Mills	6.2	6.5	1958	1094	2732	1381	6.4	5.0	533	445	1172	927	344	259	4000	3558
Foods	8.3	7.9	198	50.5	610	383	0.8	0.8	430	333	603	474	209	124	3565	2960
Rice Mills	7.4	7.9	NA	N.A	381	355	1.1	1.1	495	484	600	579	166	146	2827	2708
Paint & Dyes	6.3	6.8	2566	100	5683	227	N.A	N.A	255	174	368	280	1957	140	2311	1387
Cement Plant	7.7	7.5	224	72	324	148	8.4	2.4	279	210	433	326	239	124	2331	1876
Marble	8.1	8.5	N.A	N.A	93	95	0.5	0.6	409	400	511	463	236	135	1470	1460
Manufacturing of apparel	7.4	7.3	35	38	90	102	N.A	N.A	208	203	420	290	103	53	1978	913
Pharmaceutical	7.3	7.1	229	61	517	132	1.1	0.9	168	135	198	158	160	30	1075	910
Waste to Energy generation	8.6	8.6	N.A	N.A	344	282	8.0	4.0	428	384	432	378	238	194	2842	2654
Thermal power generation	7.9	7.8	N.A	N.A	256	158	8.0	4.0	334	298	402	316	78	40	1908	14282
Beverages	7.5	7.2	172	64	172	130	4.2	0.8	312	198	175	45	110	50	3926	1575
Chemical projects	6.9	7.3	136	36	352	96	N.A	N.A	412	208	270	165	170	90	1840	1450
Tobacco	7.2	7.2	368	54	940	164	N.A	N.A	168	134	100	175	1140	180	1080	1010
Engineering	6.7	7.1	N.A	N.A	274	192	8.0	4.0	416	342	342	358	298	256	3842	34500
Petroleum refineries	7.2	7.4	N.A	N.A	194	162	8.0	4.0	428	372	526	498	202	186	2608	1826
Oil, fats and vegetable ghee projects	7.2	7.4	96	44	212	109	N.A	N.A	144	108	160	110	100	20	830	760
Paper, paperboard, and paper pulping	8.2	8.2	N.A	N.A	5980	5440	4.0	4.0	540	520	784	546	1040	922	8900	8800
Others	7.8	7.6	707	109	1381	2345	N.A	0.5	234	184	405	393	378	77	1721	1543
PEQs Values	**7-9**		**80**		**150**		**1.0**		**1.0**		**1000**		**200**		**3500**	

B* = Before treatment, A*= After treatment, N.A=Data not available, Green color=Within PEQs limits, Red color= Beyond PEQs limits

2.1.2 Overall Assessment of Industrial Wastewater Treatment Plants



2.2 Assessment of Environmental Performance of Solid Waste Management Facilities in Punjab

2.2.1. Municipal Solid Waste Management in Punjab

The physical composition of municipal solid waste (MSW) in Punjab reveals various individual components, which constitute the main portion of the waste. These components include plastics, rubber, textile waste, paper, food, glass, leaves, grass, animal waste, demolition waste, ashes, and residues. The quantities of these components vary in the waste depending upon the source. Waste generation rates depend on the population, consumption level and lifestyles. Around 51 million people live in urban areas and 76 million in rural areas of Punjab[160]. The average waste production in divisional headquarters of the Punjab ranges from 115 tons/day (DG Khan) to 5000 tons/day (Lahore), reflecting that the waste generation rates are higher in large metropolises, where waste production is high, lifestyles are mainly urban, and the population is rapidly growing. A variety of vehicles are utilized for transporting or transferring solid waste collected from different collection points. The province's waste collection and transport equipment include open trucks, tractors/trolleys, arm roll containers/trucks, handcarts, and donkeys for primary collection. Additionally, municipalities hire sweepers and sanitation workers to collect MSW from dustbins and small heaps using wheelbarrows. The waste is stored in formal and informal depots, and the streets and roads are swept.

[160] Population Census of Pakistan, 2023

The generation of solid waste depends on economic factors, with individuals living in high-income areas producing more solid waste as compared to the residents of low-income areas. In these areas, informal scavenging and local self-help are used to dispose of waste in informal and technically illegal dump sites. Individuals usually keep recyclable materials such as paper, plastic, metals, and glass and sell them for recycling to waste dealers or street vendors. Scavengers collect mixed garbage, including recyclables, from various dumpsites. The state of municipal solid waste generation, collection and disposal is summarized in Table-2[161].

Table 7-2: Municipal Solid Waste Generation, Collection and Disposal in Punjab

Solid Waste Generation (tons/day)	Solid Waste Collection Rate (Tons/day)	No. of Designated Dumping Sites	Area of Each Dumping Site (Acres)	Capacity of Each Dumping Site	Quantity of Waste Dumped (Tons)		
					Daily	Monthly	Annually
LAHORE							
0.43 per capita/day	84%	1	200	17 Million Tons	5,000	135,000	1,620,000
RAWALPINDI							
850	641	1	73	In use Since 2003	1229	37342	448101
FAISALABAD							
1600	1275	1	48	Around 8-10 Acres (20% Approx.)	1275	36,975	443,700
GUJRANWALA							
1251.50	880	1	62.5	53.5 Acres (Approx. 85%)	880	21,081	252,979
SARGODHA							
330	250	1	163	25 Years	250	7500	91000
MULTAN							
1018	750	1	7	2.45 (Approx. 35%)	800	21015	275,466
BAHAWALPUR							
0.55 / capita 418 tons	293	1	25	80% filled	293	8778	106,945
DG KHAN							
260	220	1	37.5	8 Years	220	6800	81600
SAHIWAL							
135	135	1	7	20,000 Tons	135	4050	49140

Open waste burning and dumping along roadsides, drains and canal banks is a common practice in the province, leading to air pollution and disease spread. The environmental

[161] Local Government and Community Development Department, Punjab (2023)

performance of Solid Waste Management Facilities (SWMFs) is insufficient in Punjab. Primary issues identified include improper waste disposal and inadequate waste collection. These issues have put public health, the environment, and the economy at stake. The release of pollutants and leachate from the landfill sites to the environment makes these facilities a significant health and environmental risk. The problem is exacerbated by inadequate transportation and collection systems, leading to public waste and serious health issues.

2.2.2 Environmental Performance of Solid Waste Management Facilities

The environmental performance of SWMFs located in Punjab was assessed like the one carried out for SOE Report 2022. However, the study area was scaled up from the four districts i.e., Rawalpindi, Lahore, Faisalabad, and Multan in SOE Report 2022 to 09 divisional headquarters for SOE Report 2023. The study area included districts Lahore, Gujranwala, Sahiwal, Sargodha, Rawalpindi, Faisalabad, Multan, Bahawalpur, and DG Khan. The types of waste selected for the study were municipal solid waste and hospital waste, whereas the types of SWMFs included the MSW landfill/dumping sites and public/private hospital waste incinerators. Air, soil, and leachate were monitored from MSW landfills/dumping sites, whereas public and private incinerators were assessed for stack emissions and ash. In the results section city names have been abbreviated for briefness: Lahore (LHR), Rawalpindi (RWP), Bahawalpur (BWP), Faisalabad (FSD), Multan (MN), Sargodha (SGD), Sahiwal (SHW), DG Khan (DGK), and Gujranwala (GJW). The following sections discuss the study's findings for both types of SWMFs.

i. **Landfills/Open Dumping Sites**

A. Leachate

The parameters tested from the leachate of MSW landfill/dumping sites included the chemical oxygen demand (COD), biological oxygen demand (BOD), total suspended solids (TSS), Ammonia (NH_3), Arsenic (As), Cadmium (Cd), Arsenic (As), Zinc (Zn), and Iron (Fe). The results are compared with the Punjab Environmental Quality Standards (PEQS) for Municipal and Liquid Industrial Effluents (2016) pertaining to the non-availability of specific PEQS for leachate. Two leachate samples were collected from each of the selected (nine) landfill sites. All results were in PEQS limits except the COD, BOD, and TSS.

COD results have shown higher values than the PEQs standard (400 mg/l) in all the leachate samples. Excessive COD indicates high levels of organic pollution, which can lead to reduced oxygen levels in water bodies, affecting aquatic life. BOD values are also very high in all the leachate samples, with the highest in the Lahore samples. High BOD levels suggest a high organic load, potentially from sewage or decaying matter. It also may reflect high levels of organic pollutants, which can be harmful if ingested. All the leachate samples showed higher TSS values than the standard value, with the highest value from Sargodha. High TSS levels can degrade water quality, potentially carrying pathogens and toxins that can affect human health if used for drinking or recreation. Results on leachate are shown in Figures 7-6 to 7-8.

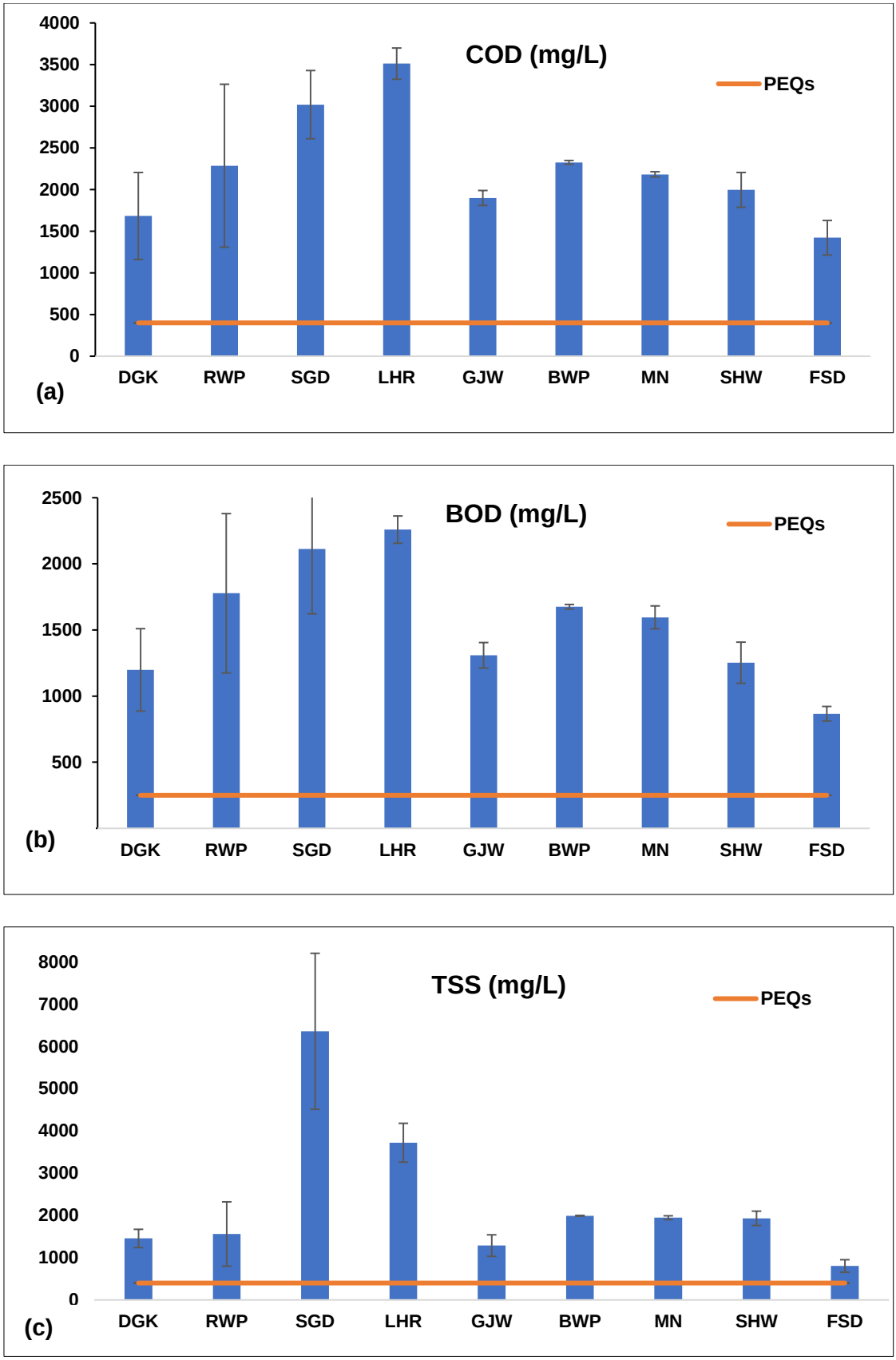


Figure 7-06: Leachate Analysis (a. COD, b. BOD, c. TSS) from Landfill Sites.

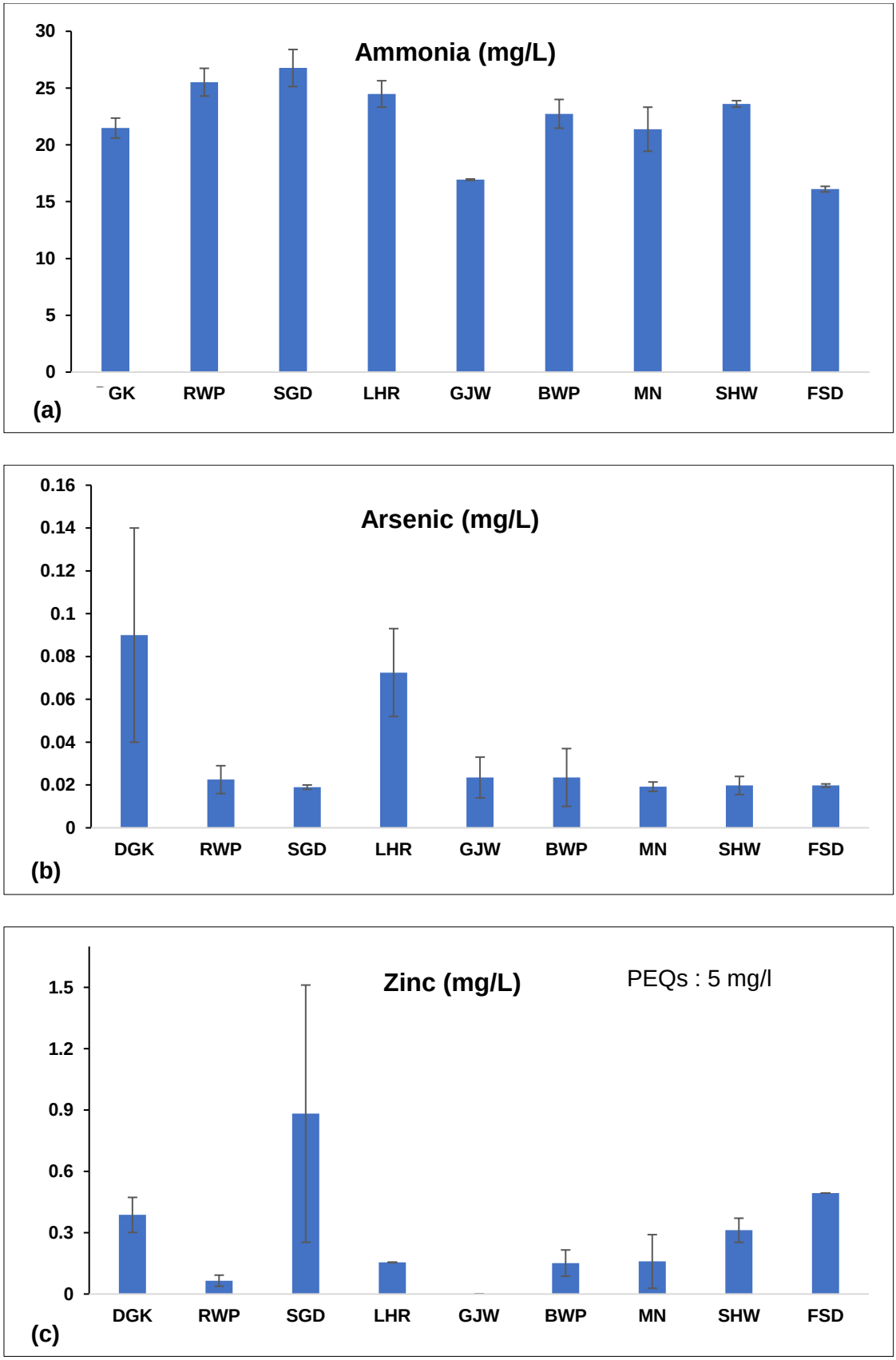


Figure 7-07: Leachate Analysis (a. Ammonia, b. Arsenic, c. Zinc) from Landfill Sites.

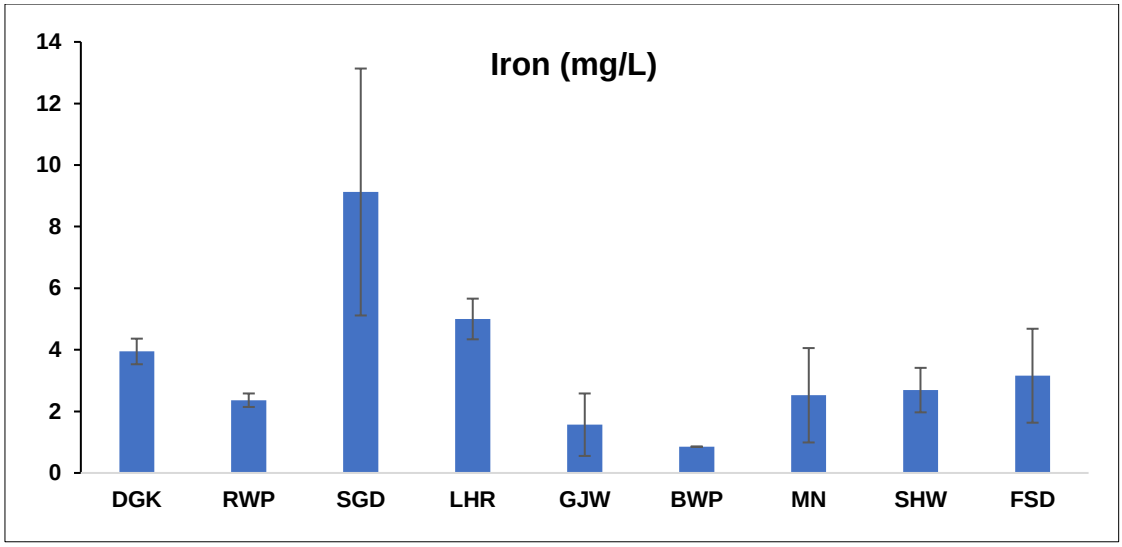


Figure 7-08: Leachate Analysis (Iron) from Landfill Sites.

B. Soil

For soil analyses, the parameters monitored include the pH, Electrical Conductivity (EC), Cadmium (Cd), Arsenic (As), Lead (Pb), Zinc (Zn), and Iron (Fe). Soil samples were collected from landfill sites of selected nine districts. The results were compared with US International Standards of Soil Quality[162]. Cadmium in all soil samples was below the detection level. Almost all other parameter values were in compliance with the standards except pH of all soil samples, which is above the standards. The highest pH value is from Gujranwala sample. Electrical Conductivity (EC) values of the soil range from low to highly saline. Multan's soil is highly saline, as is revealed by its highest EC value. The results of the tested parameters are shown in Figures 7-9 and 7-10.

[162] Alloway, B.J. (1990) Heavy Metal in Soils. John Wiley and Sons, New York, NY, USA

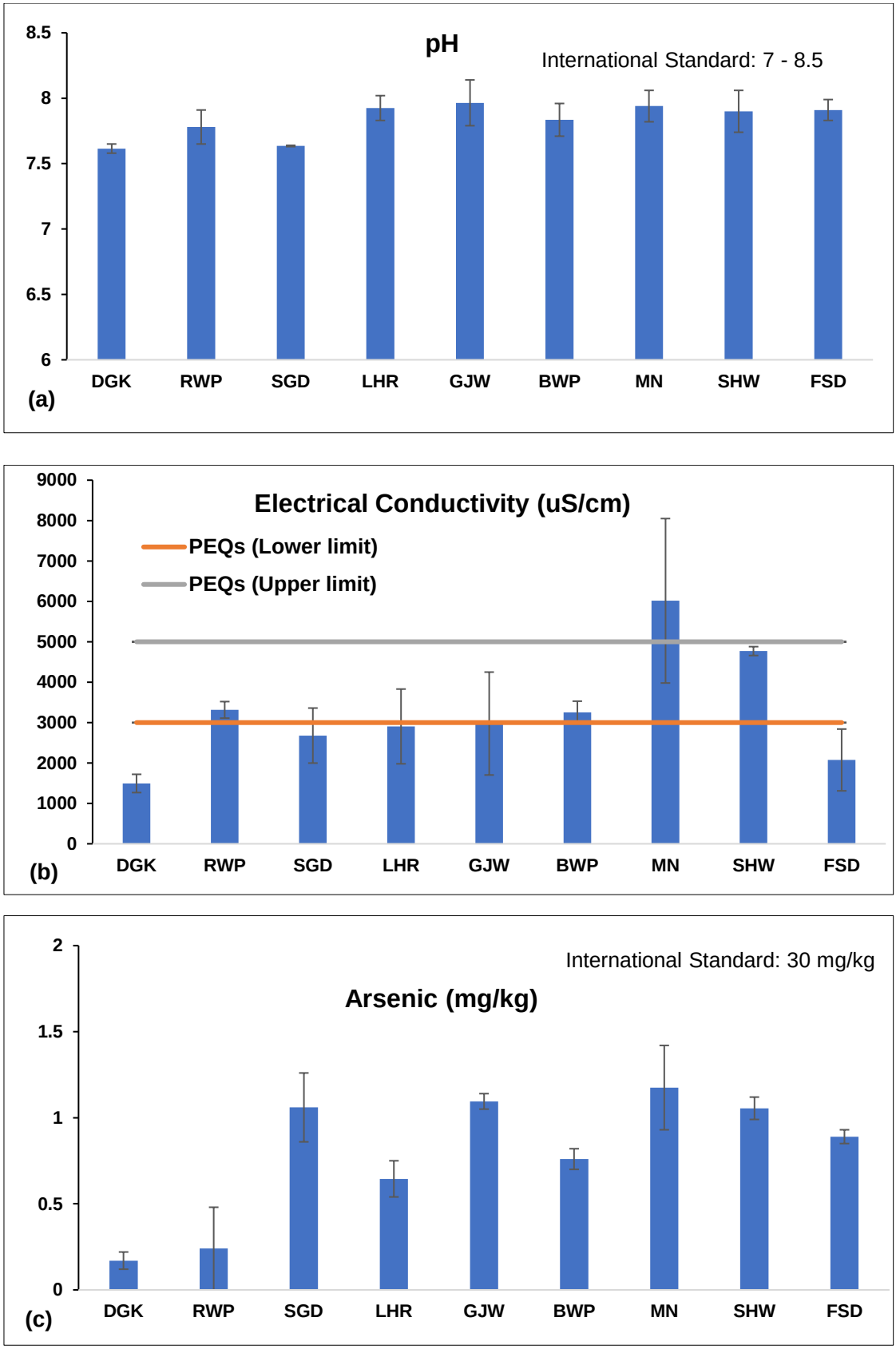


Figure 7-09: Soil Analysis (a. pH, b. EC, c. Arsenic) from Landfill Sites

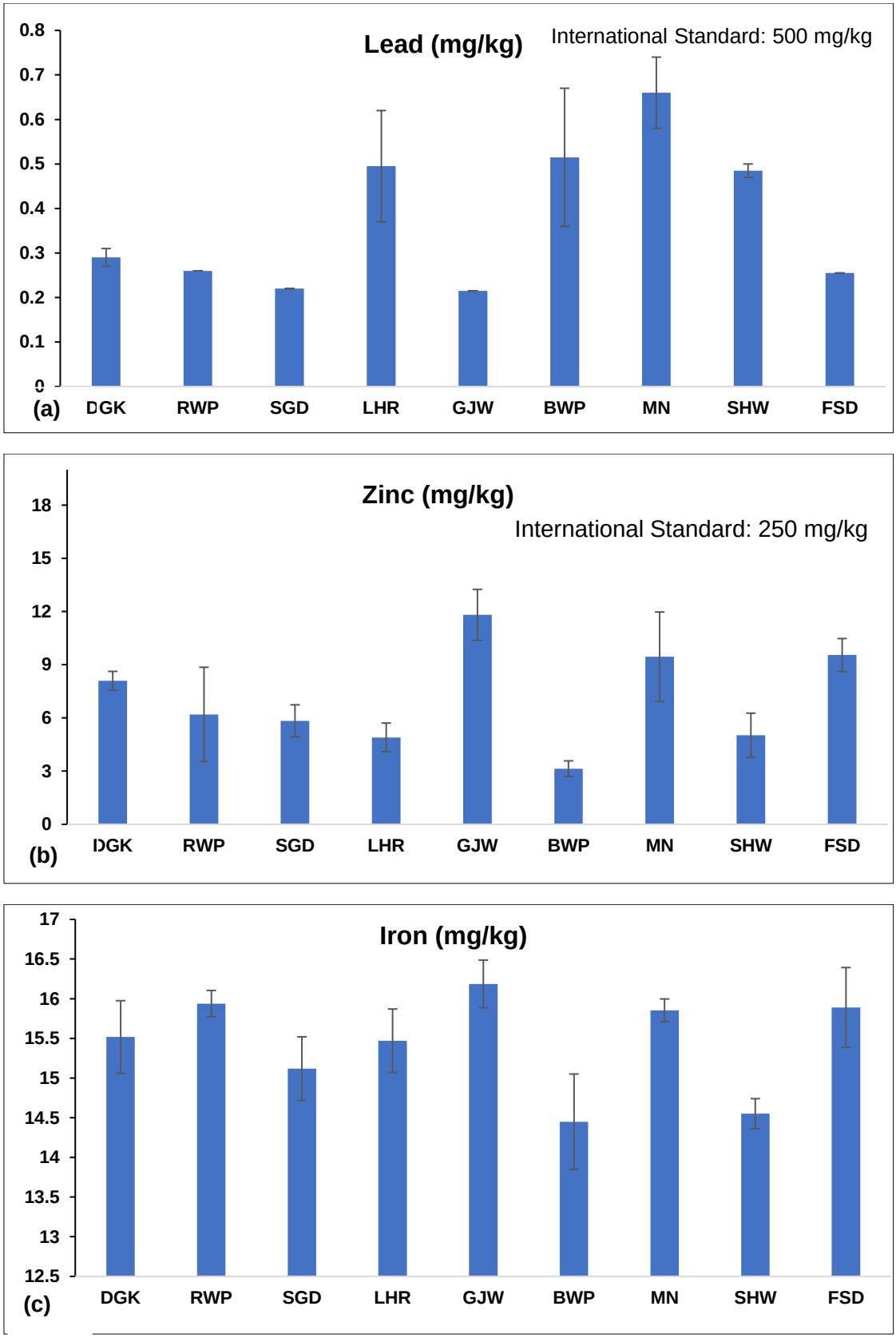


Figure 7-010: Soil Analysis (a. Lead, b. Zinc, c. Iron) from Landfill Sites

C. Ambient Air

The ambient air quality assessment parameters in landfill sites were SO_2, NO, NO_2, Ozone, SPM, PM_{10}, and $PM_{2.5}$. The results were compared with the PEQS for ambient air (2016). SO_2, NO, NO_2, and Ozone parameters were under the PEQs values, while the SPM, PM_{10}, and $PM_{2.5}$ exceeded standard values. Most sites have ozone levels within limits; however, Rawalpindi Site-I and Lahore Site-II were approaching the standard limit. Ground-level ozone can cause chest pain, coughing, throat irritation, and airway inflammation. Lahore, Rawalpindi, Multan, and Sahiwal have SPM levels exceeding standards, indicating poor air quality. High levels of SPM can lead to respiratory and cardiovascular diseases and reduced lung function. PM_{10} levels were within standards for most sites, with a few showing elevated levels near the standard limit. Exposure to high PM_{10} can cause health effects such as aggravated asthma, decreased lung function, and respiratory symptoms. $PM_{2.5}$ levels were mostly within the standard range, though several sites were close to exceeding it. $PM_{2.5}$ can penetrate the lung barrier and enter the blood system, causing cardiovascular, cerebrovascular, and respiratory impacts. The results of ambient air are given in Figures 7-11 to 7-13.

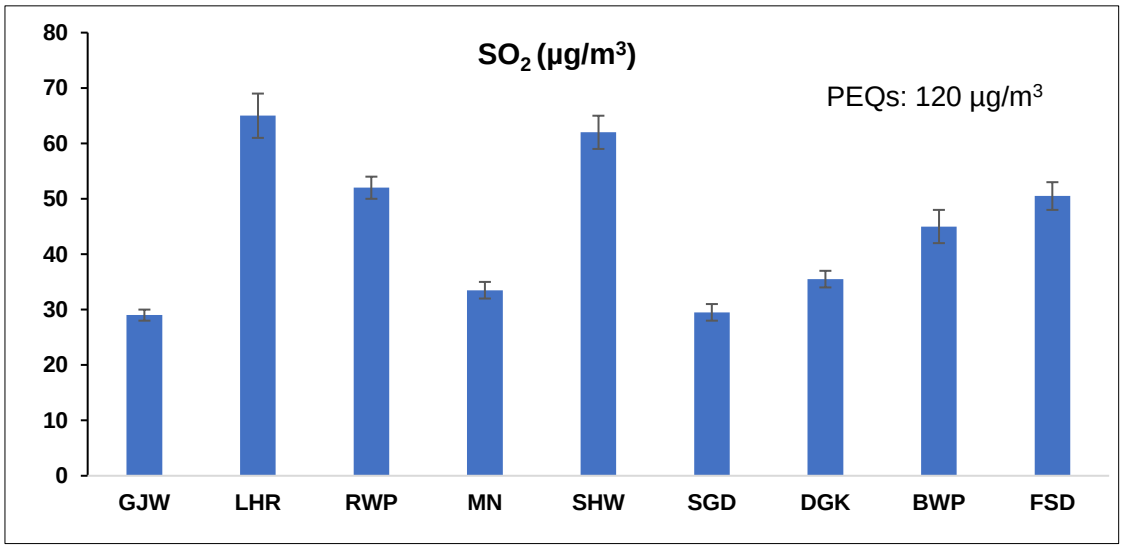


Figure 7-011: Ambient Air Analysis (SO_2) from Landfill Sites

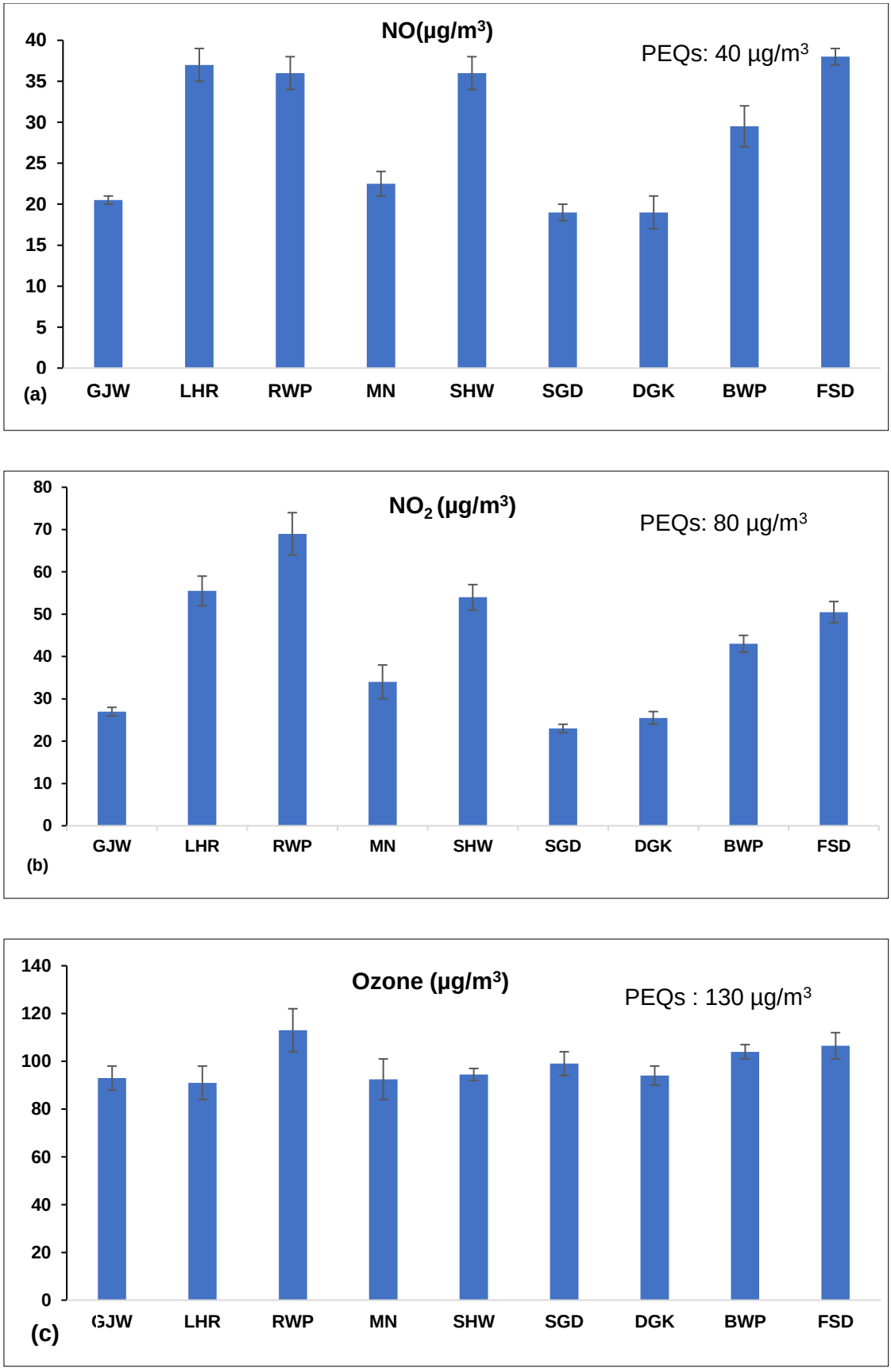


Figure 7-012: Ambient Air Analysis (a. NO, b. NO_2, c. Ozone) from Landfill Sites

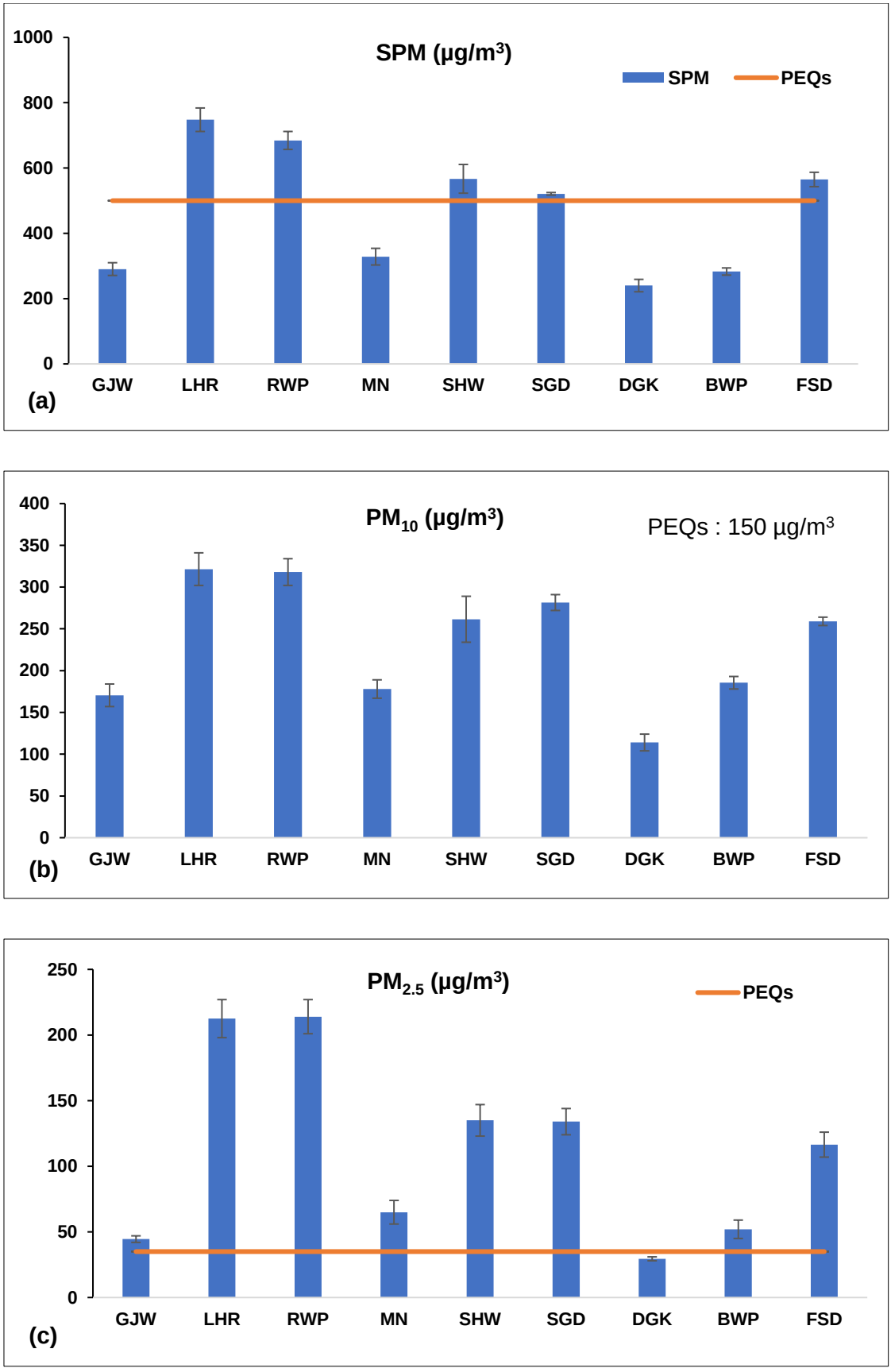


Figure 7-013: Ambient Air Analysis (a. SPM, b. *$PM_{10,}$ $PM_{2.5}$) from Landfill Sites*

ii. Incineration Facilities

A. Stack Emissions

Stack emissions were measured from various public and private incineration facilities across nine districts. The parameters assessed included CO, NO_x, NO_2, NO, SO_2, HCl, and particulate matter (PM). The results indicate that emissions for all measured pollutants were within the permissible limits set by the PEQS, demonstrating compliance across all tested facilities in the selected districts. This compliance indicates effective pollution control measures in place at these incineration sites. The results of stack emissions are shown in Figures 7-14 to 7-16.

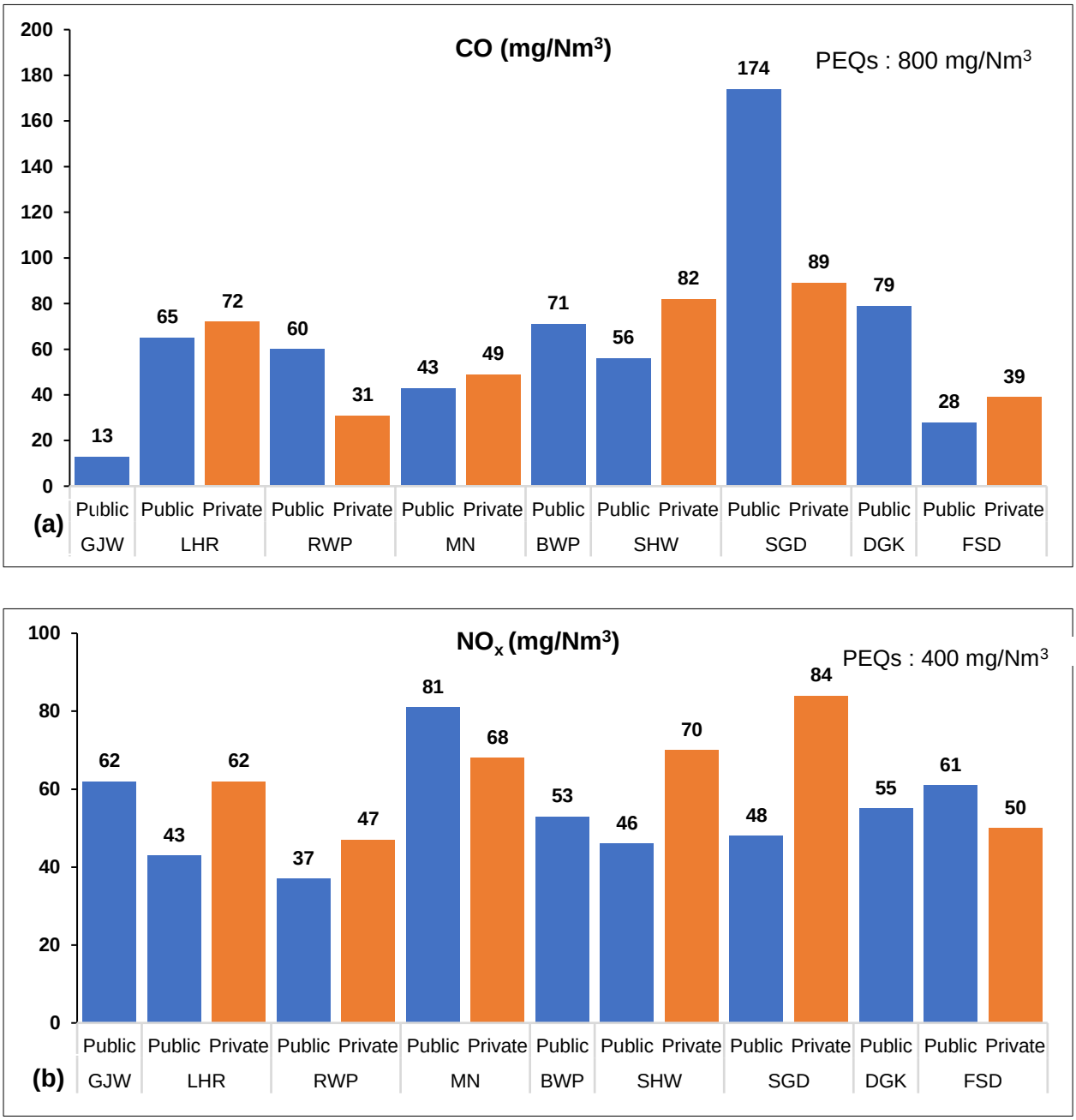


Figure 7-014: Stack Emissions Analysis (a.CO, b. NO_x) from Incinerators

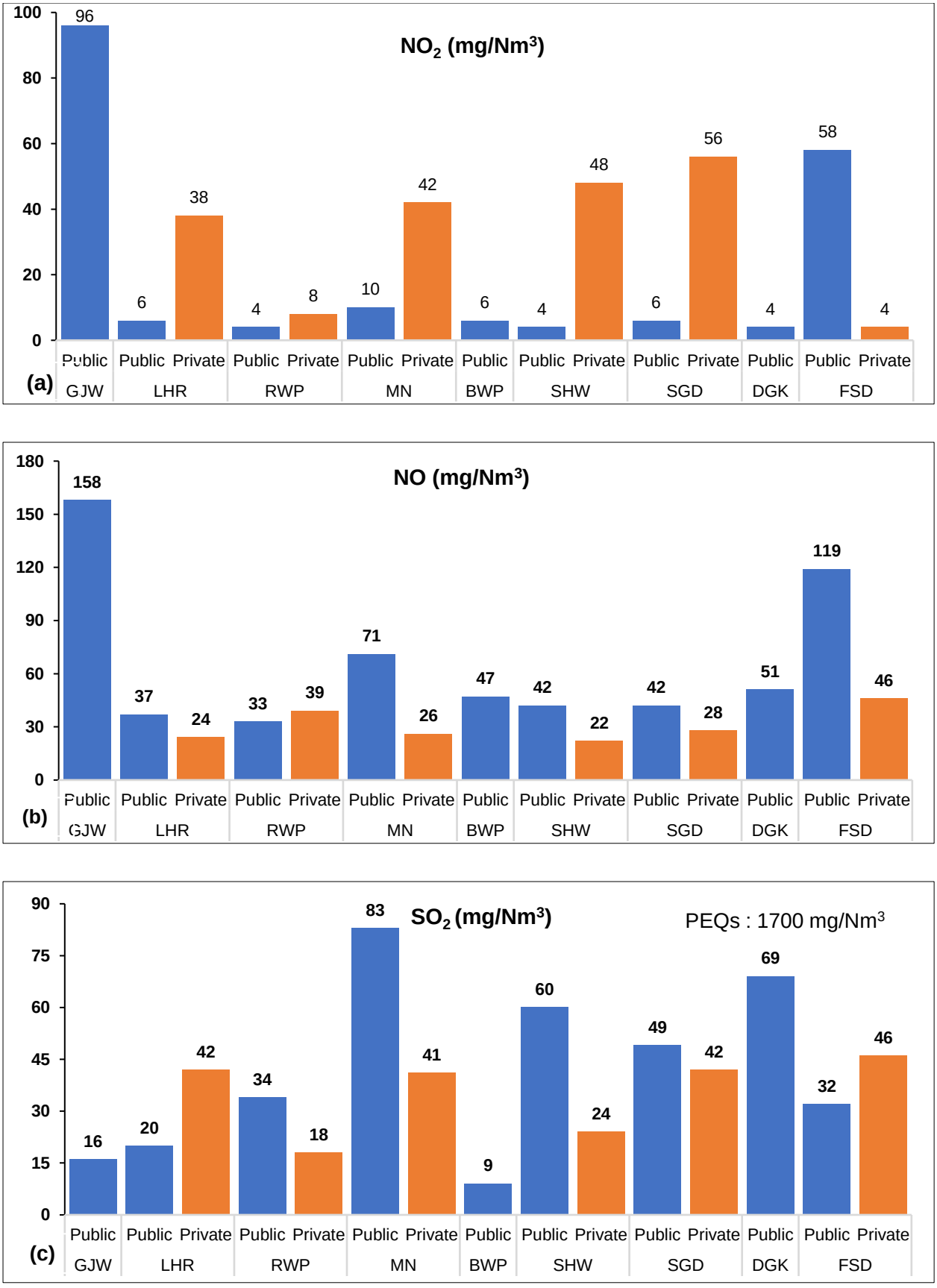


Figure 7-015: Stack Emissions Analysis (a. NO_2, b. NO, c. SO_2) from Incinerators

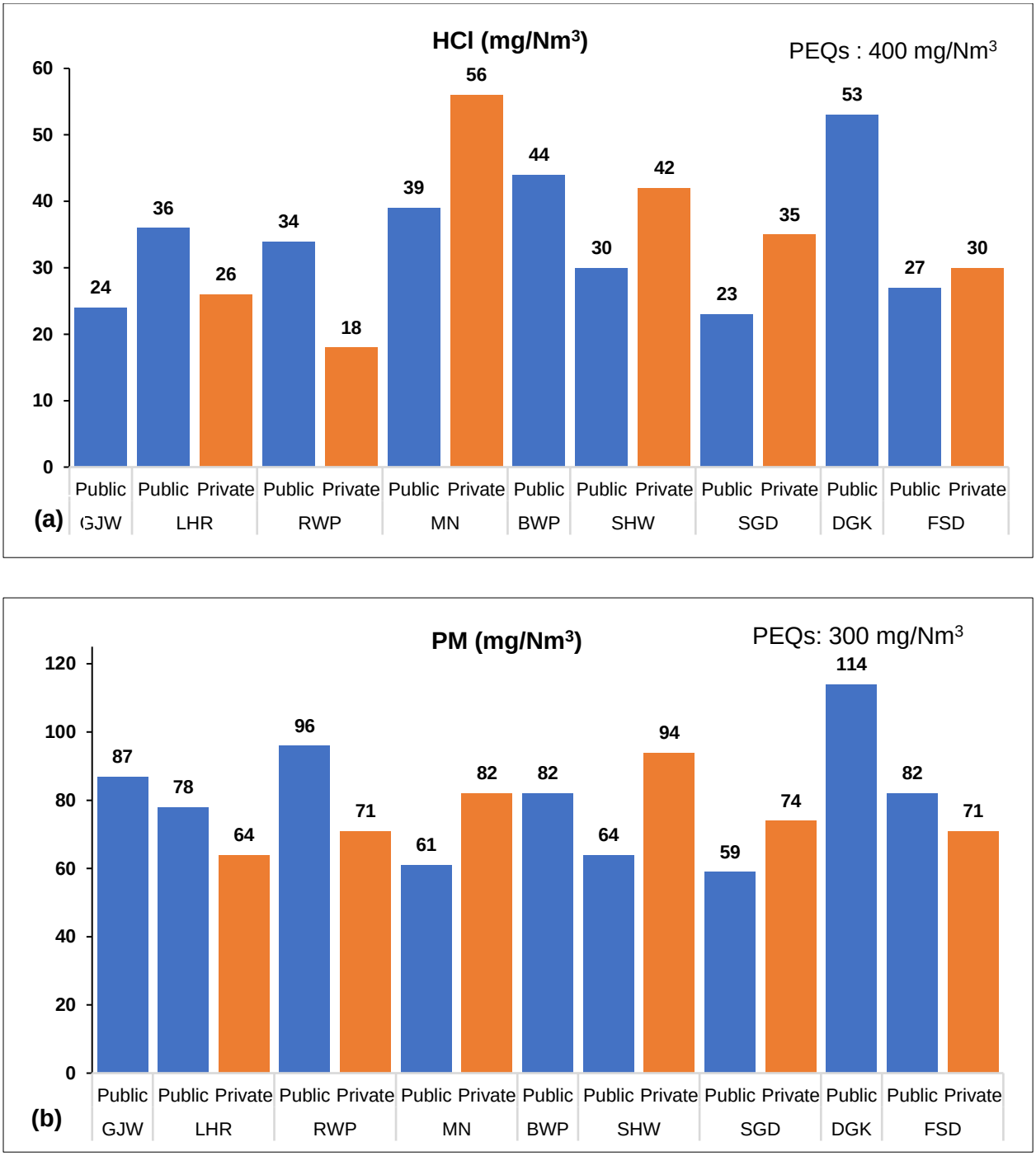


Figure 7-016: Stack Emissions Analysis (a. HCl, b. PM) from Incinerators

B. Ash Analysis

For the ash analysis, different parameters like percentages of unburnt carbon, chromium, lead, copper and microbial contamination were examined from the ash produced in incineration facilities. Private and public incinerators were selected in the vicinity of selected nine districts. There are no such PEQs standards for Ash analysis. A high percentage of unburnt carbon showed incomplete combustion. Only three samples showed lead concentration, while others were below the detection level. Private incinerators from Gujranwala and Sahiwal showed some chromium content. Private

incinerators from Rawalpindi and Faisalabad have shown copper concentration values. The results of the ash analysis are given in Figures 7-17 and 7-18.

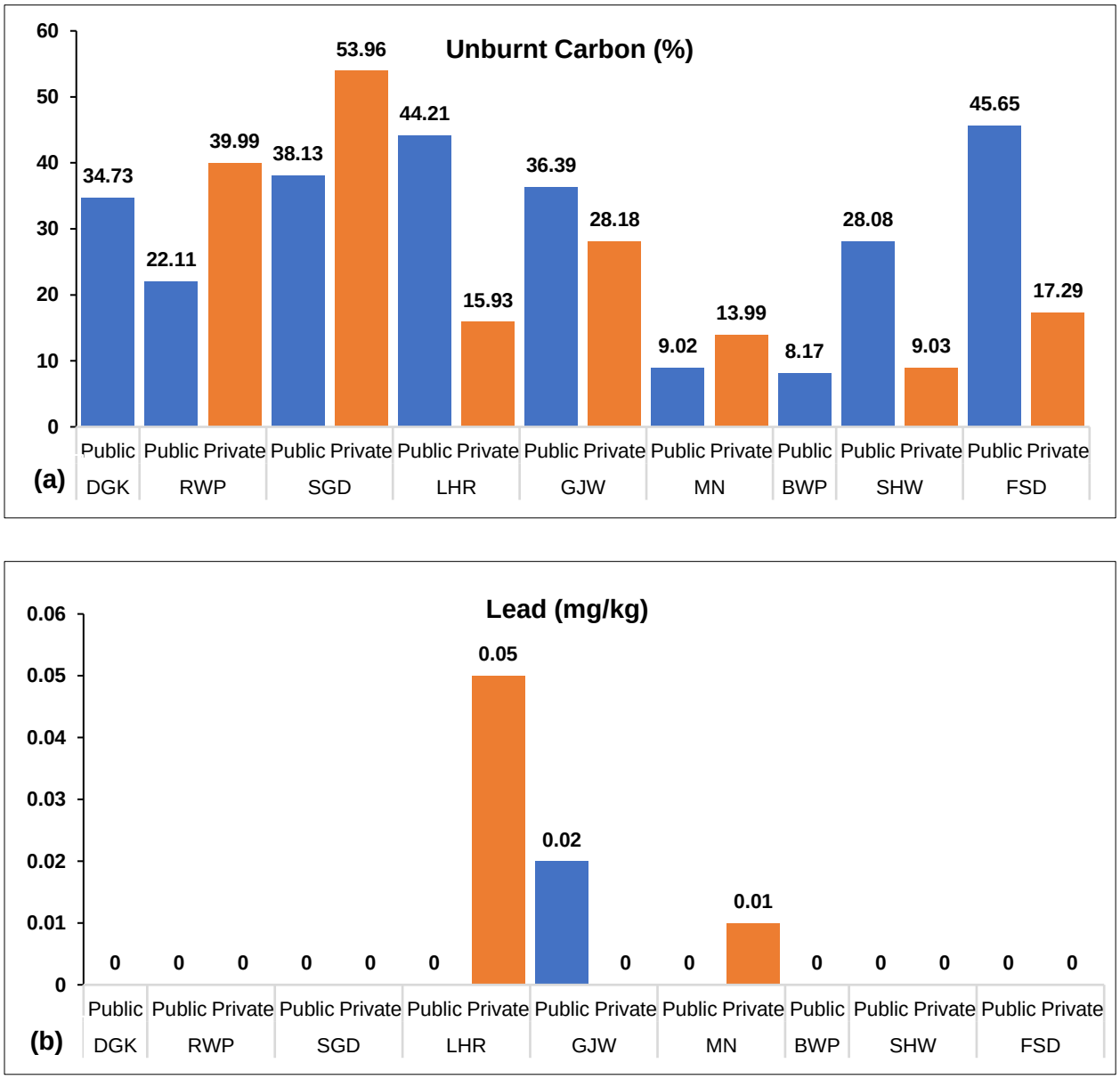


Figure 7-017: Ash Analysis (a. Unburnt Carbon, b. Lead) from Incinerators

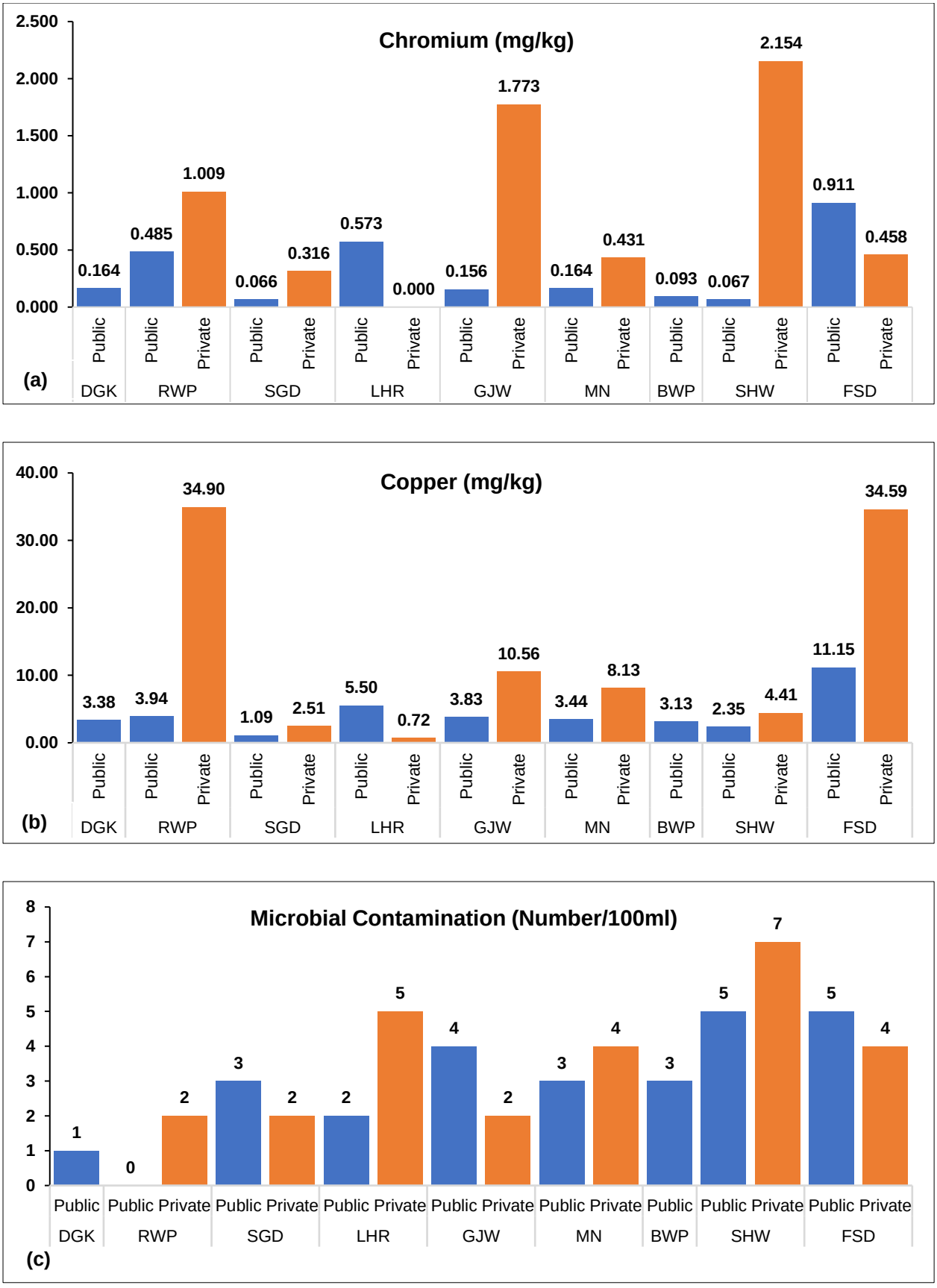


Figure 7-018: Ash analysis (a. Chromium, b. Chromium, c. Microbial Contamination) from Incinerators

2.2.3 Overall Assessment

3 MANAGEMENT

Most cities in Punjab have a solid waste collection rate of around 50% of the total waste generated, which is well below the required 75% necessary to keep a city clean. Unfortunately, none of the cities in Punjab have a proper SWM system in place, from the collection of solid waste to its final disposal. There is no proper door-to-door collection system, placement of containers, or designated transfer stations/secondary collection points. Public waste collection is often inefficient due to lack of funds, and as a result many cities are turning towards subcontracting waste collection and street sweeping services to private companies. However, this trend has not yet been fully implemented in Pakistan. Several NGOs, such as Waste Busters are actively involved in waste collection and have achieved remarkable success. However, street/road sweeping services are irregular and mainly limited to administrative, commercial, and industrial areas. There are too few formal collection bins, such as masonry enclosures, containers, and trolleys, to accommodate the waste generated in these cities, and these bins are not located according to population and area requirements. This shortage of bins has led to many people opening heaps of waste in some cities.

The problems associated with solid waste management in Punjab cannot be attributed solely to limitations in urban resources. Rather, they lack a comprehensive waste management system and strategy encompassing governance, institutions, finance, and technology. The challenges include inadequate legal and regulatory frameworks, lack of awareness among municipal residents regarding solid waste handling and treatment, insufficient SWM administration and institutional arrangements, financial and technological difficulties in constructing and operating waste treatment facilities and equipment, a shortage of SWM experts and municipal collectors/scavengers, lack of private sector and community involvement, and a dearth of research in the solid waste sector.

Addressing the issues of SWM in Punjab requires a comprehensive and interdisciplinary approach. Therefore, legal, and institutional implementation, with environmental, technological, and economic methodologies, is required to establish an appropriate SWM system for Punjab. Additionally, a social and policy approach is recommended to increase public awareness regarding SWM in Punjab. Residents' active participation and understanding of the importance of proper waste treatment are fundamental for the success of SWM. In concepts and programs for SWM staff and workforce, it is essential to ensure the success of policies, develop waste treatment/management concepts, and learn the theory and practice of SWM.

The current waste disposal system does not involve treatment except for separation of recyclable items by the scavengers. Open dumping is prevalent, which causes significant environmental damage, particularly on flood plains and ponds. Municipalities often hire or lease land long-term for this purpose without taking adequate mitigating measures. The uncollected waste presents a grave risk to public health, as it clogs drains, creates stagnant ponds, and provides breeding grounds for mosquitoes and flies leading to the spread of diseases like malaria and cholera. Even the collected waste often ends up in improper disposal sites such as, open pits, ponds, rivers, and agricultural land, due to inadequate disposal sites. The country's population growth, urbanization, and industrialization exacerbate the problem of environmental degradation, which is already quite advanced and worsening as the economy develops.

The problem of illegal dumping sites in open spaces is widespread. Even the "official" disposal sites do not meet environmental standards, as delivered garbage is dumped without any protection against leachate infiltration, and no leachate collection and treatment gas evacuation/flaring systems are in place. These minimum requirements are essential for acceptable waste management practices. The presence of waste pickers on the sites risks public health and hinders efficient operation. In Pakistan, sanitary landfilling, composting, and incineration are relatively new concepts. Open dumping is the most common practice, and dumpsites are often set on fire to reduce waste volume which adds to air pollution caused by uncovered dumped waste. The implementation of sanitary landfilling is still in its early stages, with no landfill regulations or standards for compliance and monitoring. However, national guidelines for these standards are being developed by consultants under the National Environmental Action Plan Support Program (NEAPSP).

Extracting the expenditure exclusively used for waste management services from financial records can be challenging, as it is often merged with other public accounts like water supply, sewage treatment, or health. In most cases, the budget for SWM is not allotted properly, and it is usually covered by the general budget fund of local governments, making it difficult to control and monitor. The expenditure on SWM varies from 20% in Multan to 4% in Sialkot of the total budget allocated for city district government (CDG) and town municipal administration (TMA). The major portion of the budget, around 80%, is used to pay the salaries and pensions of the sanitation staff, while the costs for maintenance and equipment are very low, approximately 5%. The labor cost in DG Khan constitutes 90% of the total SWM expenditures, but the cost for maintenance is just 2%. Most municipalities, except for Lahore and Rawalpindi, do not appropriately levy the waste collection fee. In Lahore, the local authority imposes a 30% solid waste fee on water bills, yet the cost of recovery is less than 10% of the total cost. In Rawalpindi, households must pay 180 Rs per month for solid waste services, while commercial areas are exempt from this fee. As a result, the direct

cost recovery through user fees/charges is quite low. While many Pakistanis may agree that the public should not bear the full cost of government services when private parties benefit from them, it is critical to establish fair charging standards to achieve cost recovery.

The private sector has played a role in waste management in Punjab for 15 years. However, due to the inability of municipal governments to provide adequate sanitary services to small communities outside of their jurisdiction, they formed contracts with private companies. Despite this, CDGs and TMAs still face a shortage of proper equipment and manpower and are exploring privatization as an alternative solution. As a result, private companies, like Lahore and Rawalpindi, were hired as pilot projects to manage waste-related issues in a few municipalities. Some of these projects were successful and continue to operate under the contract, while others failed.

The environmental assessment conducted across nine districts in Punjab revealed varying impacts from solid waste management facilities on soil, leachate, and air quality. Landfill soil samples showed generally uniform concentrations of pH, cadmium, arsenic, lead zinc and iron across sites, while electrical conductivity readings suggested variations in salinity levels that were particularly prevalent at the Multan landfill site. Even with these findings, overall soil conditions do not pose health hazards. Leachate analysis revealed significantly higher chemical oxygen demand (COD), biological oxygen demand (BOD), and total suspended solids (TSS), exceeding permissible environmental quality limits, suggesting significant organic pollution with potential harm done to aquatic life and water quality. High levels of BOD and TSS, especially noted in Lahore and Sargodha, could contain pathogens or toxins harmful to people's health and environmental integrity.

At first glance, ambient air quality assessments and incineration facility emissions showed mixed results. Air quality near landfills revealed elevated levels of suspended particulate matter (SPM), PM_{10}, and $PM_{2.5}$ particles that may pose risks to respiratory and cardiovascular health in certain districts, even while other pollutants like SO_2, NO, and NO_2 remain within safe limits. Incineration facilities reported stack emissions that fell within permitted levels, suggesting effective pollution control measures are in place. Ash analysis at these facilities also suggested adherence to environmental standards. However, findings of unburnt carbon and heavy metals suggest room for improving combustion efficiency and pollution controls in private incinerators. While there may be areas of concern surrounding leachate and air quality near landfills, incineration practices appear to comply with environmental regulations, underscoring the necessity for ongoing oversight and improvement within waste management practices.

3.1 DPSIR Framework

DPSIR framework of wastewater and solid waste facilities present in Punjab is as follows:

Drivers

a) Punjab is witnessing rapid population growth, urban expansion and industrialization that greatly strains its waste management systems (both solid and waste water), placing further demands upon waste removal and advanced solid waste management techniques.
b) Institutional deficiencies increase these difficulties through inadequate waste

generation supervision and limited resources dedicated to effective waste disposal methods.

c) Lack of public awareness is also considered a driver in the waste management problems.

Pressures

a) Greater volumes of industrial effluents produced.
b) With an increasing population, utilities and waste production usage have also increased. Healthcare facilities are significant contributors of solid waste.
c) Managing the increasing waste volume is becoming more challenging due to the limited waste collection and segregation infrastructure.
d) Formal recycling programs and incineration options also present challenges in managing its disposal systems effectively.

State

a) Increase load of pollutants in the aquatic water bodies causing human health impacts and damaging ecosystems.
b) The current state of Solid Waste Management in Punjab is not up to the mark regarding environmental performance.
c) This is evident from the insufficient collection and incineration of hospital waste and the widespread practice of open dumping of municipal waste.
d) Illegal activities such as unauthorized recycling and theft of hospital waste further exacerbate environmental and public health concerns.
e) Additionally, leachates from landfill sites pose significant environmental risks, including groundwater contamination and ecosystems.

Impacts

a) Improper liquid solid waste management has severe consequences that affect human health, the environment, and socio-economic factors.
b) Poor waste management can lead to increased diseases caused by waste, such as disease outbreaks or potential epidemics, which pose significant health risks.
c) Environmental implications include air, soil, and water quality degradation, which require remedial actions to maintain.
d) Sociological concerns involve increased breeding sites for mosquitoes and aesthetic and odor issues.

Response

a) After the 18th Constitution Amendment of 2010, environmental management in Pakistan is now the responsibility of the provincial authorities.
b) Punjab Vision 2020 prioritizes waste management, especially in water supply, wastewater, and sanitation. In 2007, the Urban Unit, Punjab developed solid waste management guides that have been used for waste management.
c) A well-rounded plan for managing solid waste is crucial for tackling the challenges associated with waste disposal.
d) To improve waste management practices, it is important to strengthen institutional frameworks. Alongside this, raising public awareness through various initiatives can help encourage proper waste disposal habits, promote compliance with regulations, and enable faster identification of issues.

   Innovative methods such as waste-to-energy conversion and organic composting can

significantly reduce landfill pressure, creating a more sustainable approach to waste management in Punjab.

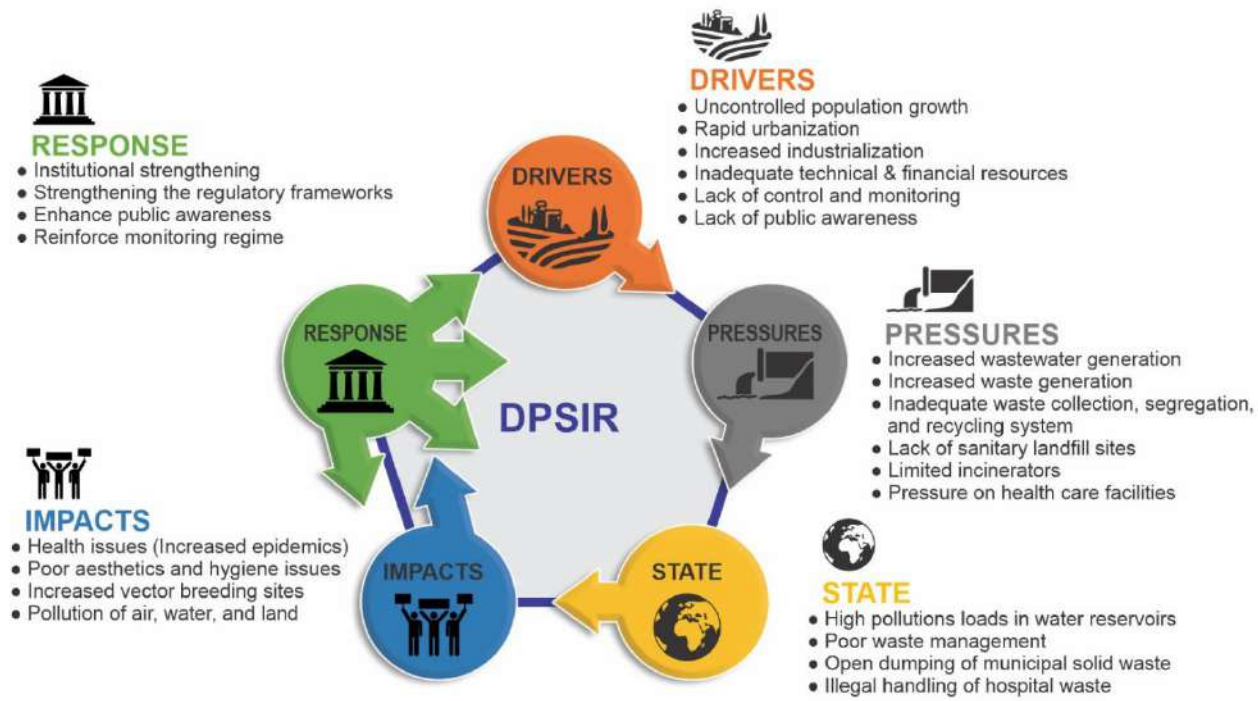


Figure 7-19: DPSIR Framework for solid waste management and wastewater treatment in Punjab

4 THE WAY FORWARD

Updating treatment efficiency: The environmental performance of waste water treatment plants shows a partial compliance of PEQS. There is need to upgrade the treatment efficiency of each plant in terms of non-compliance parameters of PEQS.

Reduction in pollution load: Every waste water treatment plant shall establish a base line for its effluents. After establishment of baseline, efforts shall be made to reduce the pollution load on environment in a step wise manner.

Installation of the state-of-the-art waste water treatment plants: Every industry should take lead in installation of state-of-the-art WWTPs that are latest in technology and latest in development cycle.

Monitoring dashboard: In order to monitor the efficiency and environmental performance of each WWTP, there is a dire need to establish a monitoring dashboard having direct access to the quality being discharged from WWTP into the environment.

Implement Recycling and Waste Reduction Practices to Decrease Landfill Waste: Adopt recycling practices that significantly decrease the volume of landfill-bound waste. Consolidate responsibilities through public entities or engage the private sector for sustainable waste management planning and establish conditions encouraging private sector participation.

Enhancing Public Awareness and Sector Capacity: Launch public awareness campaigns and capacity-building programs to educate on the importance of waste

management. Integrate social programs for waste pickers into formal waste management efforts for optimal effectiveness of plans.

Promoting Composting as a Waste Management Strategy: Promoting composting should become part of waste disposal strategies in urban areas of Punjab, as over 50% of their organic waste can be composted. Composting can not only aid waste reduction efforts but also contribute towards improved soil health, making this practice especially suitable in regions with dry and degraded soil conditions.

Targeting Plastic Waste reduction: Plastic waste collection and processing should be prioritized, including campaigns promoting textile bag use instead. Outsourcing waste management services could lead to more efficient, comprehensive, and environmentally protective services.

Sustainable Waste-to-Energy Solutions: Turning waste into renewable energy sources reduces reliance on landfills while contributing to lower greenhouse gas emissions. It is key that technologies efficiently convert waste to energy while remaining environmentally sound and economically feasible.

Sanitary Landfills for Environmental Safety: Establish sanitary landfills to meet international standards and minimize pollution risks and public health threats. Engineered landfills are essential in safely disposing of non-recycled or compostable waste, featuring systems to monitor leachate and methane emissions that could compromise environmental contamination.

Guidelines and Legal Frameworks to Promote Compliance: Create comprehensive guidelines and an efficient legal framework that standardize waste management practices. This should enforce segregation, collection, disposal, and clear regulations between public and private entities involved in waste management.

CHAPTER 8 MEASURES TAKEN TO CONTROL POLLUTION AND IMPROVE ENVIRONMENTAL QUALITY

KEY FINDINGS

- Environment Protection Department has been renamed as Environment Protection and Climate Change Department (EPCCD).
- Remarkable advancement for the establishment of divisional environmental complexes (DECs) was made during 2023
- EPCCD Punjab is developing a '*green building*' for its offices. The building will be certified in compliance with the LEED Gold Standard.
- Nine additional AQMS are being installed in Lahore Division and work for further 21 stations in other divisions is in progress.
- Policy reforms (being notified/approved/revised) include Punjab Clean Air Policy-2023; Smog Prevention and Control (SPC) Rules, 2023; Plastic Management Strategy; Punjab Environmental Protection (Production and Consumption of Single Use Plastic Product) Regulations, 2023; Revision of Existing Punjab Environmental Quality Standards (PEQS) and Development of Industry-specific Environmental Quality Standards (EQS).
- Anti-smog actions taken in 2023 included, constitution of special smog prevention squads, powers delegation under Smog Prevention and Control (SPC) Rules-2023, launch of Android Application and Complaint Line and Anti-smog actions taken by stakeholder departments (LWMC, LG&DG and Transport etc.)
- During dengue surveillance 255,497 inspections were carried out resulting in removal of 266 dengue larvae, issuance of 3528 notices, lodge of 232 FIRs and 19,321 source removals.
- 60 kilograms of hospital waste was confiscated by EPA Punjab and sealing of 35 units engaged in illegal handling and storage of hospital waste.
- 328,428 trees were planted throughout Punjab to meet conditions imposed in environmental approvals for EIA and IEE and by the forest department.

1 OVERVIEW OF THE DEPARTMENT'S 'RESPONSE' TO THE 'STATE' OF THE ENVIRONMENT

EPD Punjab has made significant progress in improving its environmental protection and pollution control services in the year 2023. The department has advanced 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. An overview of the Department's 'Response' to the 'State' of the environment in Punjab is shown in Figure 8-1 and details are provided in the proceeding sections

Figure 8-1: Measures taken to control environmental pollution by EPCCD during 2023

1.1 Institutional Reforms

1.1.1 Enhancing the sectoral regime

EPD Punjab is improving its sectoral regime, by incorporating climate change into its business regulations. The department is now known as the Environment Protection and Climate Change Department (EPCCD).

1.1.2 Divisional environmental complexes

Currently, all of the regional labs and EPA field offices are located on the campuses of other government agencies or in rented facilities. Under the approved EPCCD restructuring plan, remarkable advancement for the establishment of divisional environmental complexes (DECs) was made during 2023. Three important offices will be housed in the DECs:

i. Office of Divisional Director (Environment)
ii. Office of Deputy Director (Environment)/District Head
iii. Office of Deputy Director (Labs)/EPA regional Lab

These complexes are being established in 9 divisional headquarters of Punjab i.e., Bahawalpur, DG Khan, Faisalabad, Gujranwala, Lahore, Multan, Rawalpindi, Sahiwal and Sargodha. During 2023, the work for the establishment was commenced in 07 districts. Construction of these complexes would improve the province's environmental governance by streamlining the environmental approvals process thus promptly and effectively enforcing the Punjab Environmental Protection Act, 1997.

1.1.3 Green building

EPCCD Punjab is developing a multistory office building to house its secretariat and headquarters of its allied agencies. The building is being developed as a '*green building*'[163] to be certified in compliance with the USGBC[164] LEED[165] Gold Standard. As such, this initiative is intended to ensure a minimum negative impact on the environment during construction and subsequent operations. A seminal endeavor in Punjab, the EPCCD Green Building is the first-of-its-kind office building in the public sector in the country. Its development will entail ensuring sustainable site development, water savings, energy efficiency, green complying material selection, and enhanced indoor environmental quality. It will also set a precedent for future public sector construction and aid in development of relevant standards.

Figure 8-2: Planned View of the EPCCD Green Building (artistic impression)

The Green Building is being developed on a plot area of 5 kanals in Gulberg II, Lahore. It is designed to be a 7-storey building structure with 2 basements (for parking), encapsulating a total covered area of 99,415 sq. ft. The development of the building was approved by the Provincial Development Working Party (PDWP) in its 24th meeting for FY 2023-24 at the stipulated cost of Rs. 3,312.765 million. The Infrastructure Development Authority of the Punjab (IDAP) has been commissioned for the design and construction of the building infrastructure. It is expected to be completed and handed over to EPCCD by the end of March 2026.

The green building will house three additional allied agencies of EPCCD Punjab in addition to the Environmental Protection Agency (EPA) Punjab i.e., Environmental Monitoring Center (EMC), Environmental Technology Center (ETC) and Environmental Policy Center (EPC). Government of the Punjab has approved 50 positions for EMC under a Director General (the operational head of EMC) through

[163] Green or Sustainable Building is a structure that uses processes that are environmentally responsible and resource-efficient throughout the building's life cycle (siting, design, construction, operations, maintenance and demolishing).
[2] United States Green Building Council
[3] Leadership in Energy and Environmental Design

Statement of New Expenditure (SNE) during FY 2022-23. The paper work for ETC and EPC is also in process.

1.1.4 Establishment of Punjab Environment and Climate Change Endowment Fund

Punjab has created an Environment Endowment Fund as a long-term source of support for environmental initiatives, studies and activities as stated in SOE Report 2022. Operationalizing EEF is a priority for the Punjab government. With the intention of achieving this goal, the Punjab Skills Development Funds (PSDF) Board has decided to incorporate Section 42 of The Companies Act into the fund's legal framework through the Securities and Exchange Commission of Pakistan (SECP). It will turn into a steady source of funding for green and environmental initiatives that are put forth by the public and commercial sectors, as well as civil society to pilot and showcase environmentally beneficial projects.

The government has also named this fund as Punjab Environmental and Climate Change Endowment Fund (PECCEF). Besides environmental projects, this fund will also consider projects related to climate mitigation and resilience.

1.1.5 Automation regime of EPCCD

The execution of the project ‘Automation Regime of EPCCD Punjab” is being geared up. PITB has been mobilized for development of following components: The progress on the project of automation regime of the department is progressing at a rapid pace. The project has six major components, including E-Environmental Approvals, E-Enforcement, E-Laboratories, E-Industrial mapping, E-Monitoring System and E-Information Sharing. The procurements of IT equipment including printers, scanners, desktops and laptops have also been initiated.

1.2 Policy reforms

1.2.1 Punjab Clean Air Policy-2023

Government of the Punjab approved and notified the Punjab Clean Air Policy along with phased Action Plan in April 2023, in line with fundamental rights under Constitution of Pakistan (1973), UN Sustainable Development Goals (SDGs), Clean and green Pakistan movement and Nationally Determined Contributions (NDCs), 2021. The goal of the policy is to maintain clean air in the province by reducing emissions and promoting sustainable development that will increase access to a more livable environment. The policy is equipped with a phased action plan with defined roles and responsibilities of all relevant sectors.

The policy has strengthened and enhanced the existing regulatory and inspection regime of air pollution control in the province. The relevant departments have initiated the implementation of the policy and action plan in their respective jurisdictions. The notification of Smog Prevention and Control (SPC) Rules-2023, commencement of formulation of the investment plan are noticeable instances of the implementation efforts commenced by EPCCD during 2023.

1.2.2 Smog Prevention and Control (SPC) Rules-2023

Government of the Punjab notified the Punjab Environmental Protection (Prevention and Control of Smog) on June 7, 2023, which provide standard operating requirements for brick kilns, industrial units, resource recovery units and pyrolysis plants to ensure

prevention of air pollution contribution by these units. The rules further restrict the stuble burning and open waste burning in the province. In addition, vehicular emissions from are restricted to stay within permissible limits defined under Punjab Environmental Quality Standards.

1.2.3 Plastic Management Strategy

The Punjab Environmental Protection Council constituted under the Act ibid has approved the Plastic Management Strategy, framed under DLI-4 of PGDP, in 2023. The strategy is based on 5 pillars and 22 targets, systematically a three-phase Action Plan up to 2030 is proposed for implementation of the strategy i.e. Short-term (up till FY-2025); Medium-term (up till FY 2027); and Long-term (up till FY 2030). Pillars of draft strategy include the; (i) Induction of Plastics Regulatory Regime (ii) Technological Innovation and Recycling Infrastructure (iii) Economic Incentives and Levies (iv) Institutional Capacity Building, and (v) Citizens Engagement and Awareness. The strategy proposes establishment of "Provincial Steering Committee" under the Chairmanship of Chief Secretary, establishment of a plastic management cell, compulsory registration, setting-up of a plastic management information system, mandatory Extended Producers Responsibility and awareness and sensitization.

1.2.4 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 regularized the production and consumption of single use plastics by notifying regulations thereon in June-2023. The regulations are applicable to the plastic manufacturers, transformers, recyclers/up-cyclers, importers, collectors and consumers (commercial/bulk only). The regulations ban the production and consumption of certain single-use plastic products such as plastic cotton bud sticks, plastic balloon sticks, plastic sticks of flags, disposable plastic cutlery, etc.

For implementation of plastic management strategy, a plastic management cell will be established in EPA Punjab that will have an adequate human resource and equipment to carry out the implementation of the strategy and its subsequent interventions. The persons or entities dealing with the plastics shall have to be registered with the EPCCD through plastic management information system which will be developed in due course. An electronic database and management information system shall be established for keeping track of plastic production, recycling, monitoring, effectiveness of implementation, better policy making and an overall enhanced oversight and control of plastics.

1.2.5 Revision of existing Punjab Environmental Quality Standards (PEQS) and development of Industry-specific Environmental Quality Standards (EQS)

The Results "Area 1" of the PGDP: Strengthening Environmental Governance via regulatory reforms contains provision for revision of existing environmental quality standards and development of missing EQS, including industry-specific standards. EPCCD Punjab executed an ADP scheme titled "Development of Missing Environmental Quality Standards (EQSs) & Revision of Existing Environmental Quality Standards for Punjab".

The study was divided into two components i.e. Component-A for Development of Missing Environmental Quality Standards and Revision of Existing Standards for

Punjab and Component-B for Development of Industry Specific Punjab Environmental Quality Standards for sixteen industrial sectors

A Panel of Experts including experts/specialist from relevant departments and organizations (academia, PCSIR and PCRWR) was designated to review the draft PEQS and give recommendations thereof. In addition to the series of meetings of panel of Experts, eight consultative sessions including stakeholders from relevant industries, chambers of commerce, government departments, NGOs and academia were conducted to seek their opinion/feedback on the draft PEQS. In the light of feedback received during stakeholder consultative sessions and recommendations by the Panel of Experts, the final reports were prepared along with draft PEQS for both components.

1.2.6 Punjab Climate Change Policy

Draft Punjab Climate Change Policy has been matured up to the stage that a panel of experts, comprising members from United Nations entities, GIZ Pakistan and senior academics have endorsed the document. The policy has been drafted with a thorough consultation and contributions from concerned stakeholders from government sector. Four working groups, comprising 25 government departments were constituted to finalize the policy document.

A consultative session to finalize the draft policy after its review from gender perspective was also organized in last quarter of CY 2023, in the follow – up of which, the policy draft was revised to make it gender – inclusive and gender – responsive, In the last quarter of CY 2023, a consultative session was held to finalize the draft policy following a review from a gender perspective. During this follow-up, the policy draft was updated to make it more gender-inclusive and gender-responsive, along with due diligence for climate justice.

1.3 Environmental monitoring

The department is underway of expanding and strengthening its one of the most important areas of jurisdiction, i.e. environmental monitoring. DLI-2 of the PGDP is particularly focused on the enhanced environmental monitoring regime of EPCCD Punjab. Updated progress on certain initiatives related to environmental monitoring are:

1.3.1 Air and water quality monitoring stations

Under DLI-2, EPCCD has also installed 09 additional AQMS in Lahore Division and is work for further 21 stations in other divisions is in progress. Furthermore, work has been awarded to international consulting firms for installation of 15 Water Quality Monitoring Stations (WQMSs) at the major water bodies in Punjab. Priority has been given to surface waters (rivers, canals, drains and lakes) for installation of WQMS for collection of real-time data on water quality.

1.3.2 Industrial inspections

The Environment Protection Department in Punjab, under the Punjab Green Development Program (DLIs 1-3), has actively conducted more than 2,000 inspections for industrial effluents and 250 inspections for stack emissions. Throughout 2023, the Environment Protection Agency (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. Notably, the

achievement of these goals is directly linked to unlocking the allocated US$ 3 million from the World Bank as part of the PGDP initiative

1.4 Technology transfer

1.4.1 Combined effluent treatment plant (CETP)

Sialkot located in north-east Punjab along the Indus basin is one of Pakistan's most important industrial cities with export-oriented economy. It is also famous for exporting leather products all over the world. There are over 250 tanneries located in 10 different clusters scattered in and all-around Sialkot city. These tanneries produce large volumes of waste water and lack proper wastewater treatment facilities which is considered to be a major threat to ground and surface water especially during floods.

Recognizing the importance of the issue it is planned, under the PGDP to shift the tanneries at a dedicated standard tannery zone away from the main city having a Combined Effluent Treatment Plant (CETP) with a capacity of 12000 m^3/day. Initially 1st Module (Phase-I) of CETP for the treatment of 4000 m^3/day of tannery effluent will be constructed.

1.4.2 Devising solution for solid waste management of leather sector in Sialkot tannery zone

WWF Pakistan is implementing an EU funded project namely “International Labour & Environmental Standards (ILES) Application in Pakistan's SMEs”. The project aims at enhancing capacities of the textile and leather sector SMEs to adopt (SEMPs) Smart Environmental Management Practices to reduce overall energy and water footprint of textile and leather manufacturing, in addition to addressing other relevant environmental issues such as air and noise pollution and solid waste management. Whereas, in an effort to control the environmental hazards caused by the tanning industry in Sialkot and to improve the climate change adaptation capacity, United Nations Industrial Development Organization (UNIDO) is implementing a Global Environment Facility (GEF) funded project, titled “Mainstreaming Climate Change Adaptation through Water Resource Management in Leather Industrial Zone Development”. The initiative had been started to shift scattered tanneries to a centralized location and provide various facilities like common effluent treatment plant, solid waste disposal site, common effluent collection system and flood management. Moreover, the project Sialkot Tannery Zone (STZ) is in establishment phase with the aim is to develop focused industrial growth in Sialkot by developing international standard tannery zone in the region. (STAGL), UNIDO & WWF Pakistan have collaborated to support Sialkot Tannery Zone for “Devising Solution for Solid Waste Management of Leather Sector in Sialkot Tannery Zone”. Plan will be submitted by end of Dec., 2023 by STZ.

1.4.3 Safe disposal of mercury from compact fluorescent lamps (CFLs)

For disposal of lights and bulbs being replaced by the energy efficient appliances under DLI-5 of PGDP, a CFL machine has been procured by the Energy Department and housed at CERAD Lab, UET KSK campus during 2023. Purpose of the machine is to safely extract the mercury from CFLs using mercury absorption filters. Subject filters are to be disposed of in an environment friendly manner under expert supervision.

1.4.4 Pilot project for low-cost wastewater treatment plants

EPCCD is also underway to pilot low-cost wastewater treatment technologies particularly for municipal wastewater generated from housing societies and rural communities. For this purpose, the department has engaged NESPAK to provide detailed design and engineering estimation for the construction of low-cost WWTPs that will use natural wastewater treatment technology and have low CO_2 footprint.

1.5 Capacity building

Under PGDP, SP&IU intends to strengthen and enhance institutional capacities of implementing government departments and other entities in the Punjab regarding socio-environmental safeguard instruments through introduction of a concrete capacity building program. This capacity building program will generally focus on Initial Environmental Examination (IEE), Environmental Impact Assessment (EIA) and Environmental and Social Impact Assessment (ESIA) vis-á-vis Environment and Social Systems Assessment (ESSA) of PGDP. It will also cover environmental and social considerations in project management, planning, monitoring and decision-making in line with best international practices. Following the training needs assessment, ten sessions will be conducted to share department's experiences and lessons learnt through this training program.

1.6 Public communication campaign on single-use plastics

A comprehensive Public Communication Campaign was executed throughout November and December 2023 across the province of Punjab to fulfill the objectives outlined in DLR-4 of the Punjab Green Development Program. The primary goal of the campaign was to heighten public awareness regarding the negative environmental and health impacts of single-use plastics.

The campaign utilized a diverse array of media tools, messaging strategies, and a well-organized set of communication activities. Various channels, such as seminars, awareness sessions in schools, outdoor campaigns, print/electronic/social media advertisements, and bulk SMS, were employed to effectively convey the message. Moreover, non-governmental organizations played a crucial role through active engagement with plastic producers, chambers of commerce, large retailers, civil society organizations, primary and secondary schools, and the media.

1.7 Regular operations

1.7.1 Environmental approvals

EPA Punjab is regulating the industrial and development projects under Section 12 of the Act ibid. During 2023, IEEs and EIAs were approved by EPA Punjab for the projects located in major districts of the Province.

1.7.2 Anti-Smog Campaign, 2023

Anti-smog campaign, 2023 was launched well-before the onset of critical air pollution episodes, as a pre-emptive measure for pollution control. Following activities were carried out during the campaign:

i. Constitution of special smog prevention squads

Special anti-smog squads were notified in May, 2023 in major districts of Punjab, including Lahore, Gujranwala, Faisalabad, Multan, Rawalpindi, Sheikhupura and Sialkot. In Lahore, the squads stayed active 24/7 with day and night shifts. The squads were assigned with the duty of enforcement activities i.e., inspections, inquiries, investigations and personal hearings under Section 6 of the PEPA 1997, against any activity that may contribute in smog formation and subsequent adverse environmental effects. The squads were facilitated by the online dashboard and android app namely 'EcoWatch' developed in assistance with Punjab Information Technology Board (PITB), where they could upload the geo-tagged monitoring data of industrial units inspected, and the control room monitored and tracked the movement of squads.

ii. Powers delegation under Smog Prevention and Control (SPC) 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 squads were to perform their duties in close coordination with Punjab Police and EPA Field offices.

iii. Android Application and Complaint Line

The WhatsApp complaint number ad 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. Details are provided in Chapter 9.

iv. Anti-smog actions taken by stakeholder departments

EPCCD, through its control room, coordinated with other stakeholder departments for actions taken by them to control anti-smog activities. The details of such activities are given in Figure 8-8-3 below:

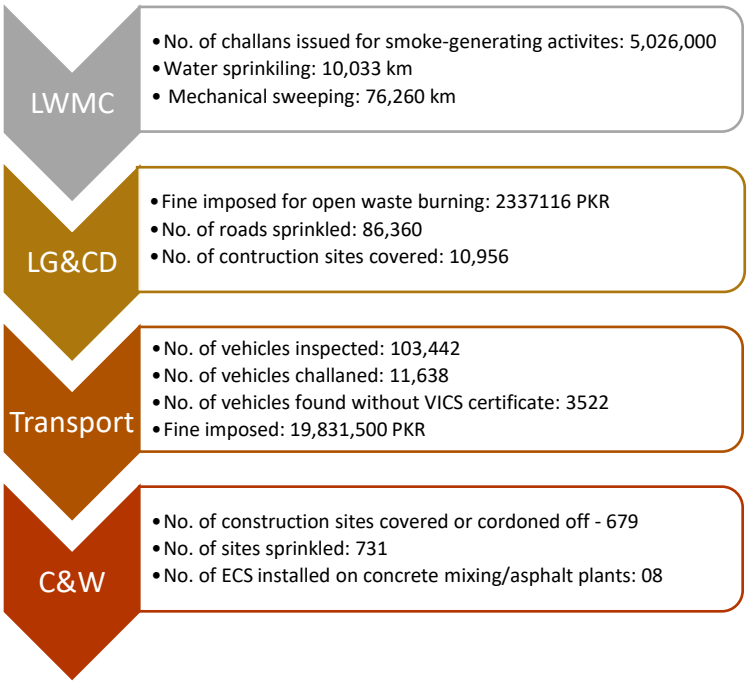


Figure 8-3: Anti-smog activities by other departments reported to EPCCD Control Room

1.7.3 Enforcement activities

While exercising the powers vested under Section 16 of the PEPA 1997, 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 (Figure 8-4)

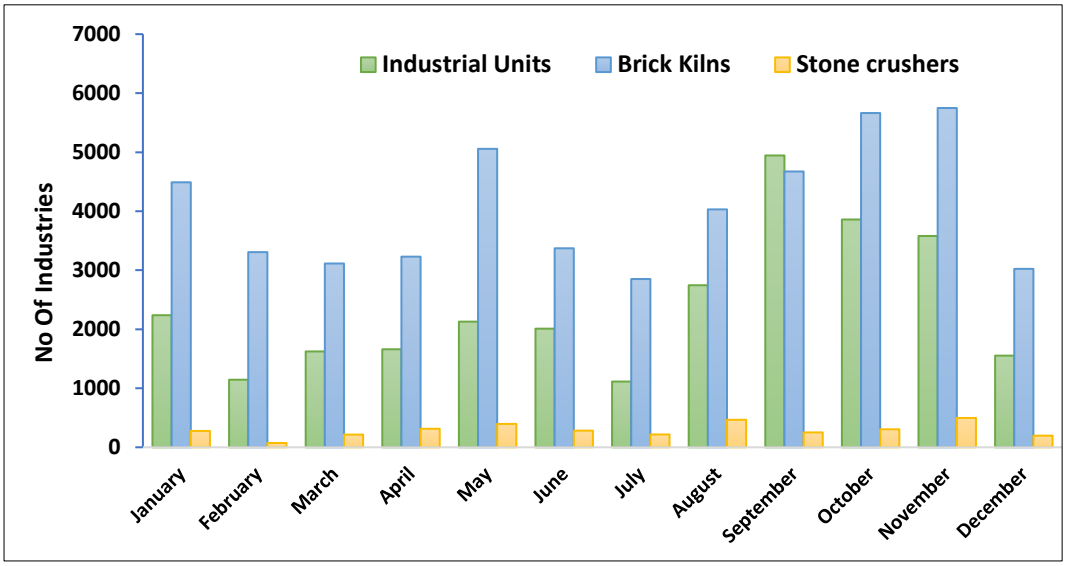


Figure 8-4: Inspections of polluting industries during 2023

During these inspections, 467 million PKR fine was imposed to the units violating the PEQS, whereas, 5970 air polluting industrial sources were sealed by the anti-smog squads of EPA Punjab. Enforcement actions were also taken against the smoke emitting vehicles (Figure 8-5).

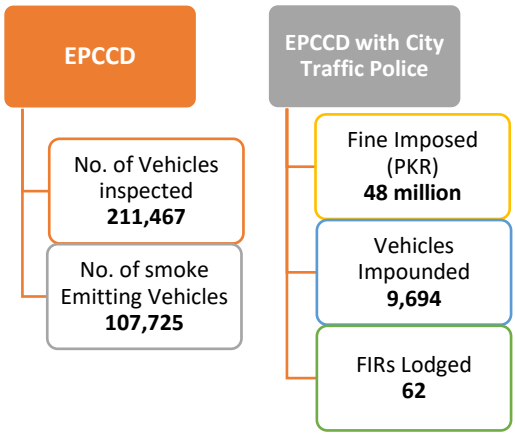


Figure 8-5: Actions taken against smoke - emitting vehicles during 2023

In addition to the actions taken to control air pollution, other environmental issues including the water pollution were also addressed by EPA Punjab. During CY 2023, more than 3500 notices were issued to the water polluting industrial units. Additionally, in response to directives from EPA Punjab, over 300 air pollution control devices were installed in various industrial units. In order to ensure the compliance of Section 13 of the act ibid, EPA Punjab is also regularly reviewing the cases of import of waste/scrap submitted for import licenses to the Ministry of Climate Change by the recycling units located in Punjab.

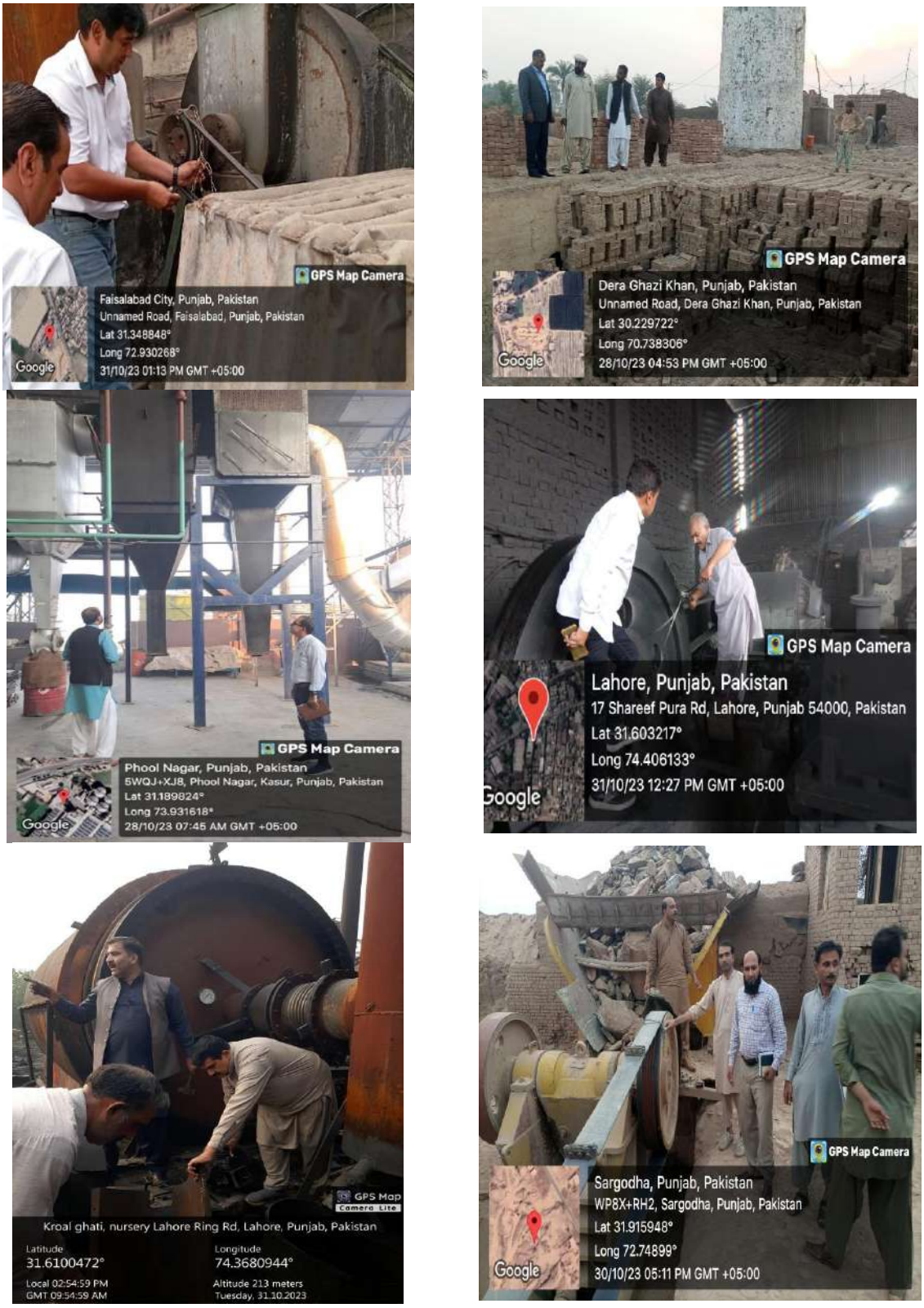


Figure 8-6: Environmental inspections in different industrial sectors of Punjab during (2023)

1.7.4 Dengue vector surveillance

The department is engaged in dengue vector surveillance at its five designated areas (including the under-construction sites, petrol pumps, CNG Stations, Service Stations) for inspection and housekeeping activities. In 2023, following activities were carried out during annual anti-dengue campaign:

a. Nomination of Dengue Squads
b. Setting the dengue visit targets and inventories of assigned areas
c. Preparation of Visit Micro-Plans
d. Android sets registration
e. Distribution of Anti-Dengue Surveillance Kits
f. Refresher Training course

In CY 2023, 255,497 inspections were carried out (Figure 8-8-7) for dengue surveillance throughout Punjab, during which 266 dengue larvae were detected. The sources of mosquito breeding were removed to avoid dengue virus incubation. The detailed progress on dengue vector surveillance during 2023 is given in Figures 8-7 and 8-8.

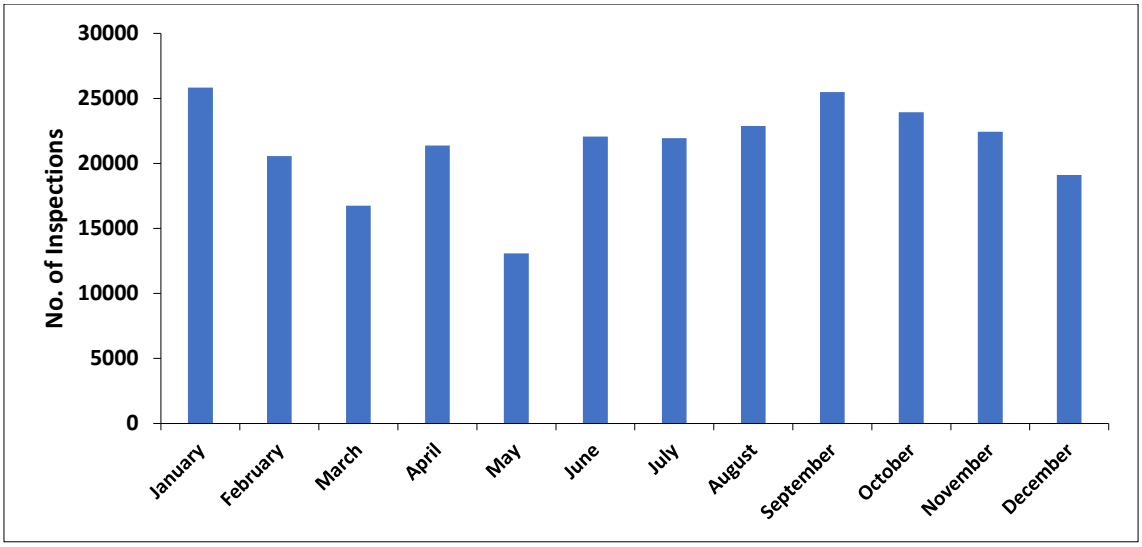


Figure 8-7: Number of Inspections for Dengue Surveillance during 2023

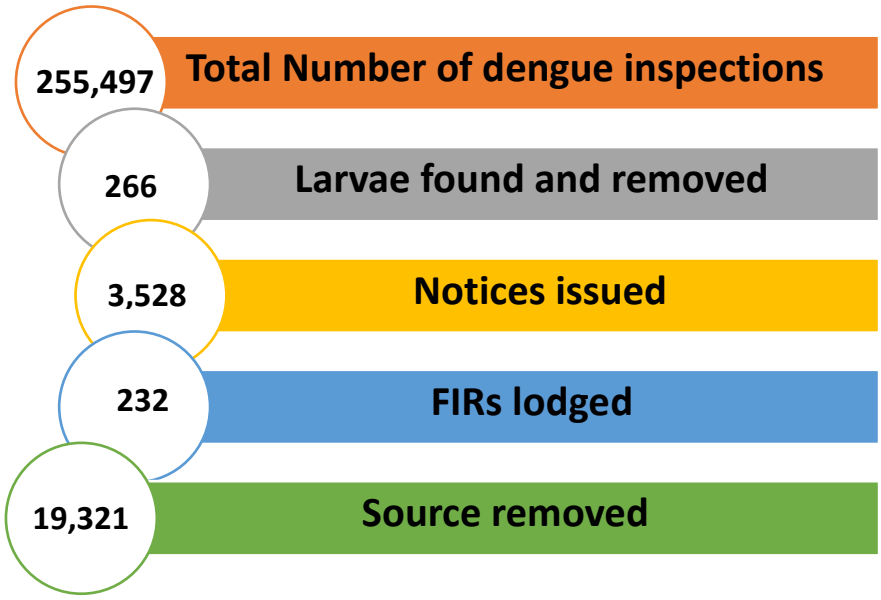


Figure 8-8: Progress of Anti-Dengue Campaign, 2023

In addition to surveillance activities, awareness raising on dengue virus and disease was also conducted during 2023 in all districts of Punjab, where 2,3162 awareness materials were distributed among general public throughout the province.

Figure 8-9: Dengue surveillance during 2023

1.7.5 Hospital waste management

EPA Punjab stepped into an advanced level of hospital waste management during 2023. Special round-the-year campaign was initiated in January 2023 to control the illegal handling and pilferage of hospital waste along with dealing municipal waste in

Punjab. 1334 junkyards were inspected (Figure 8-10). During these inspections, 60 kilograms of hospital waste was confiscated by EPA Punjab, sealing 35 units engaged in illegal handling and storage of hospital waste.

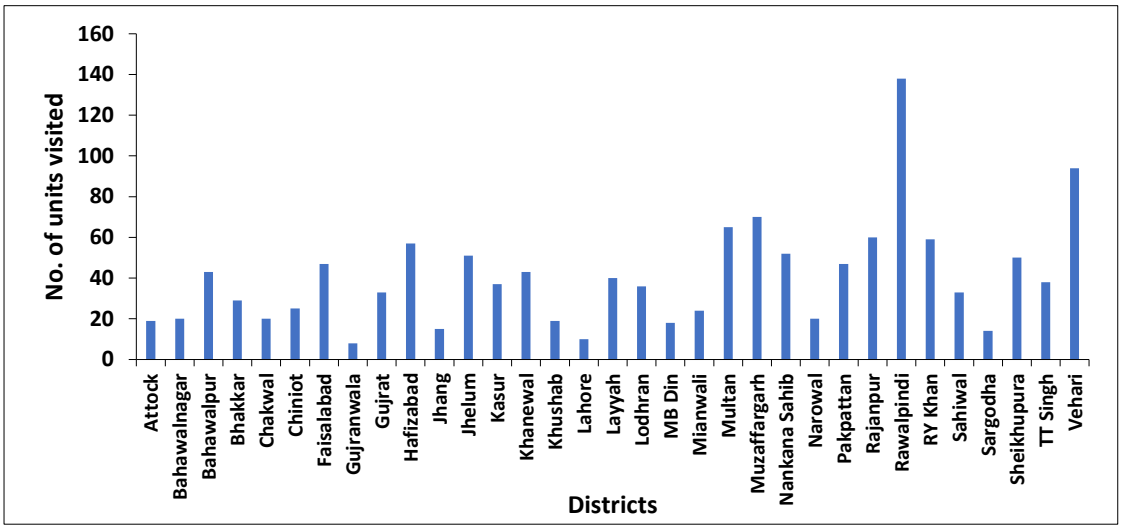


Figure 8-10: Inspections of junkyards to control the illegal handling and pilferage of Hospital Waste

A special dashboard, connected to an android application was developed to facilitate the field formation of EPA Punjab to upload their activities against the violators of Punjab Hospital Waste Management Rules (PHWMR), 2014. A total of 3250 hospitals (as defined under PHWMR-2014) were inspected to check compliance of the rules throughout Punjab during CY 2023.

1.7.6 Tree plantation

Urban tree plantation was carried out round the year 2023, through the conditions imposed in environmental approvals as well as during the plantation drives initiated by the Forest Department. A total of 328,428 trees were planted throughout Punjab. District-wise detail of plantations is shown in Figure 8-11.

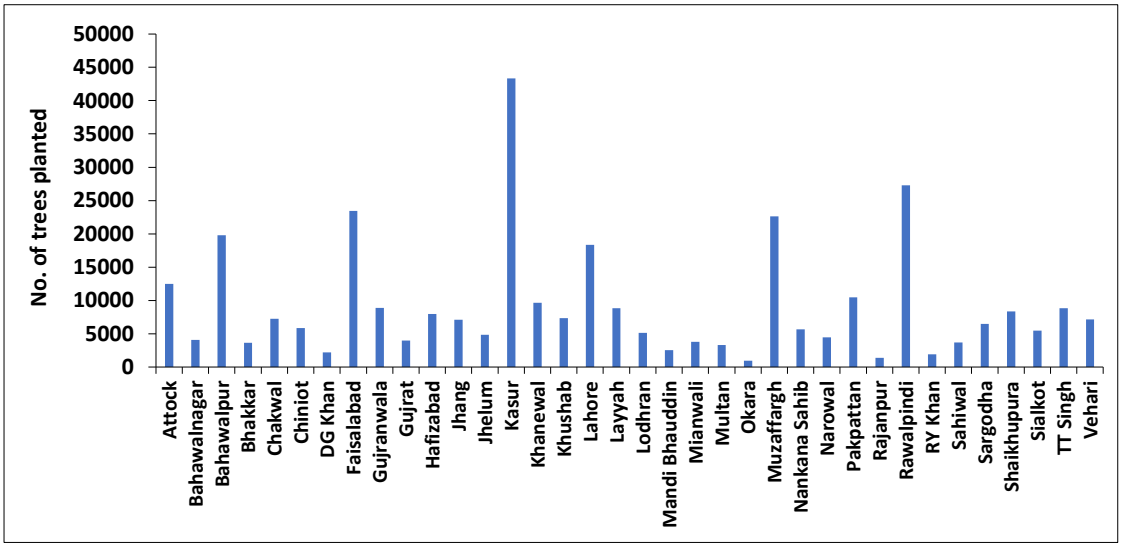


Figure 8-11: District-wise numbers of trees planted in Punjab during 2023

2 CONCLUSION

During CY 2023, EPCCD has achieved multi-dimensional endeavors in environment sector. The department foresees further strengthening of environmental governance in the province through the planned activities related to institutional, policy, monitoring and regulatory reforms along with enhanced coordination with stakeholders.

CHAPTER 9 ENVIRONMENTAL COMPLAINTS

KEY FINDINGS

- ECCPD 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 907 complaints were registered during 2023 related to various environmental issues, with the majority pertaining to air pollution (50%).
- Faisalabad district received the highest number of complaints (131) and remained at the top among all 36 districts.
- 552 registered complaints were successfully resolved, while 11 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.

1 OVERVIEW

Punjab Environment Protection Act, 1997 is explicitly providing 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 Act ibid, the Agency may undertake, inquires or carry investigation into environmental issues, either at its own accord or upon complaint from any person or organization. Grievance Redressal mechanism is an effective avenue for expressing the concerns for community and bringing positive social change by adopting remedial measures. It is a mean 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.

Grievance Redressal Mechanism operates through an efficient, responsive, and accessible complaint handling system as described below

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.

2 GRIEVANCE REDRESSAL MECHANISM

A well-designed Grievance Redressal Mechanism can help in a variety of ways to address the grievances raised by the public. Grievance Redressal Mechanism is increasingly recognized as a critical tool for promoting transparency and accountability linked with the department and offering a variety of approaches instead of a single grievance procedure. It is up to the complainant who should have influence over which approach to select.

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

- Manually in the Office of the Chief Minister, Chief Secretary, Secretary Environment, Director General EPA, Commissioner, Deputy Commissioner and Environment officer of the relevant districts

- Electronically through Prime Minister Delivery Unit, 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

2.1 Components of Grievance Redressal Mechanism

Primarily, GRM has following established components through which complaints are addressed

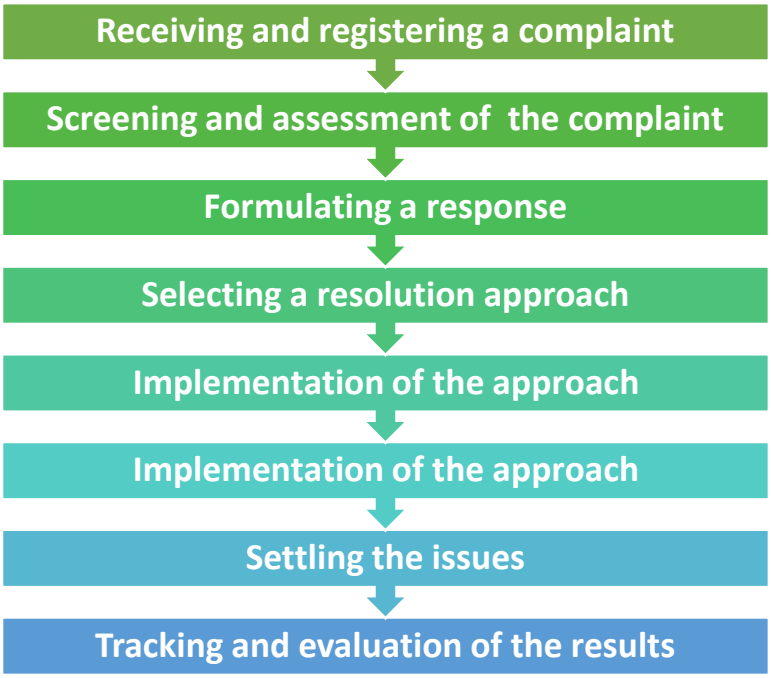


Figure 9-1: Components of Grievance Redressal Mechanism

Contrary to the year 2022 where 1091 complaints were received by the Environment Protection and Climate Change Department, 907 complaints were received in 2023. Faisalabad district received the highest number of complaints with a total of 131 in number and remained on top among all the 36 districts of Punjab, like previous year when 116 complaints were received by this district. Gujranwala remained second with total 77 complaints followed by Lahore and Sheikhupura with 75 and 66 complaints, respectively (Figure 9-2). Majority of the complaints lodged in Faisalabad and Gujranwala 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.

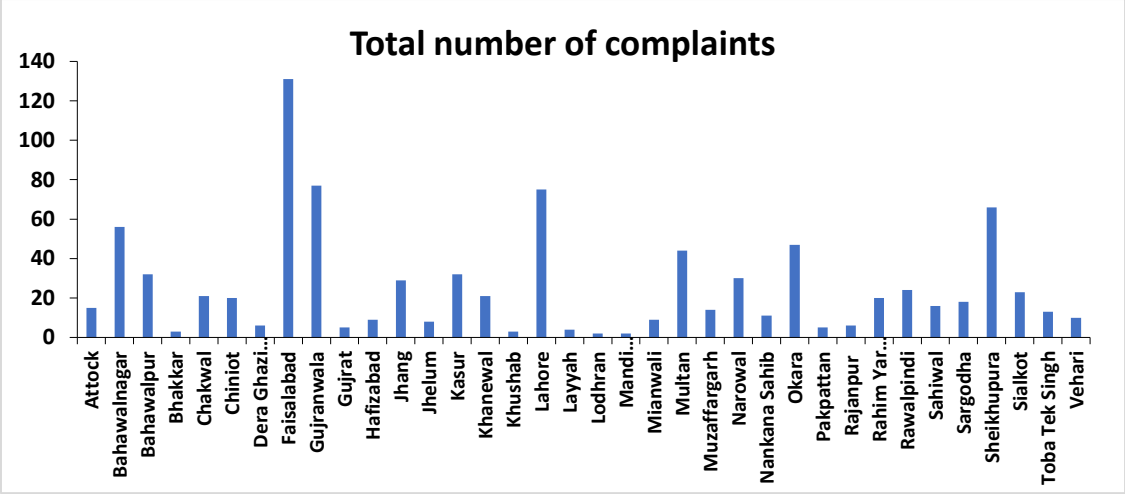


Figure 9-2: Total number of complaints received in different districts of Punjab in 2023

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.). Highest number of complaints were related to air pollution which were 50% of the total complaints and 11% were related to noise pollution lodged against crushing, metal and flour grinding type of industries (Figure 9-3). However, a few districts also receive multiple complaints related to air, noise, hazardous, cancellation of environmental approvals and that were categorized in 'Air, Hazardous, Noise NOC, & other Category' with total number of 129.

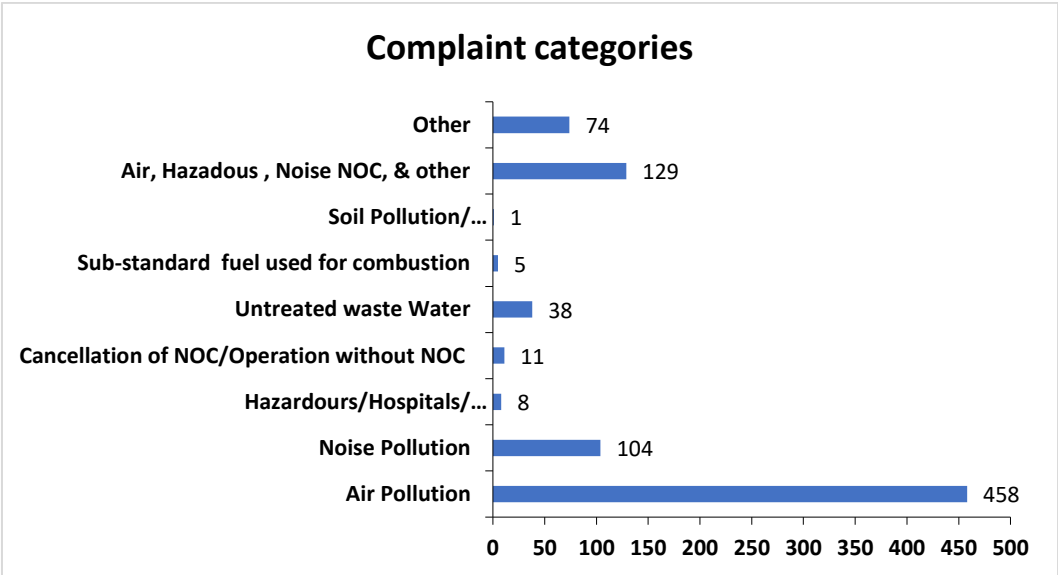


Figure 9-3: Complaints received in different categories

3 ACTIONS TAKEN AGAINST COMPLAINTS

Total 552 complaints were resolved in response to the 907 total registered complaints out of which 31 complaints are processed under trial in PET and only one complaint was given final decision in Okara district through PET/environmental Magistrate. Actions taken include sealing of 83 units and filing of 42 FIRs due to non-compliance with Punjab Environment Protection Act, 1997 read with PEQS across Punjab. Gujranwala and Faisalabad districts remained at top with maximum number of sealed units (25) and registered FIRs (09). Some of the complaints (108) are in process and 59 have been forwarded to the relevant departments for further action. Figure 9-4 shows the details of actions taken by the EPA for redressal of environmental complaints.

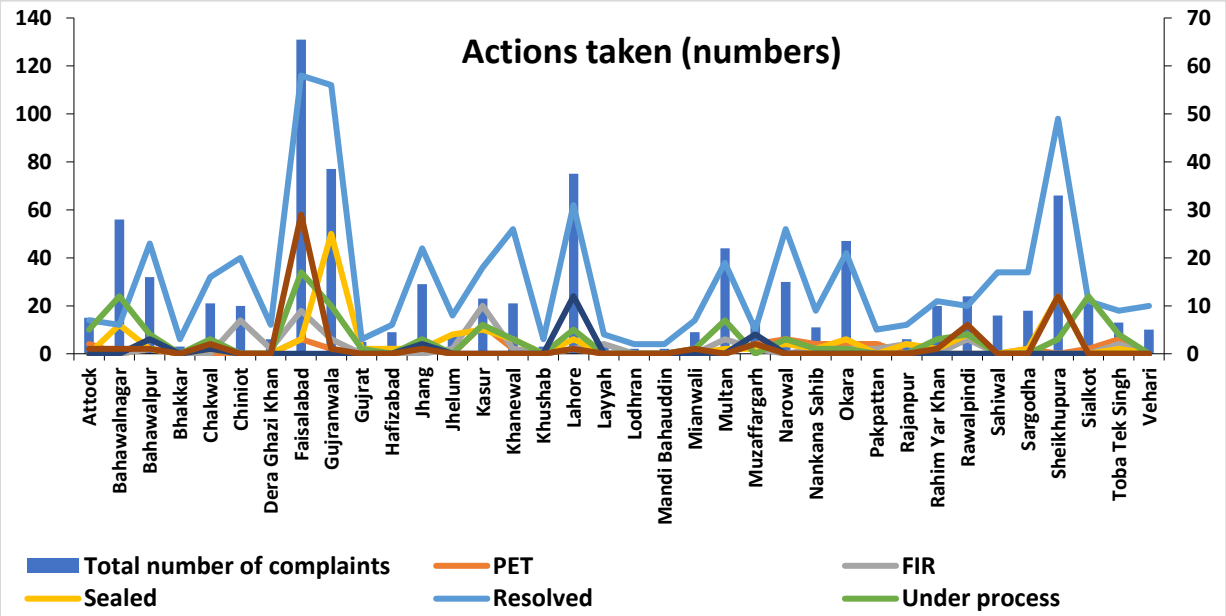


Figure 9-4: Actions taken in the year 2023 against filed complaints

Figure 9-5 is shows the number of fines imposed by the department to the non-compliant industries. Total 61 units were fined with minimum amount of Rs. 20,000 and maximum of Rs. 3.2 million in Jhang district.

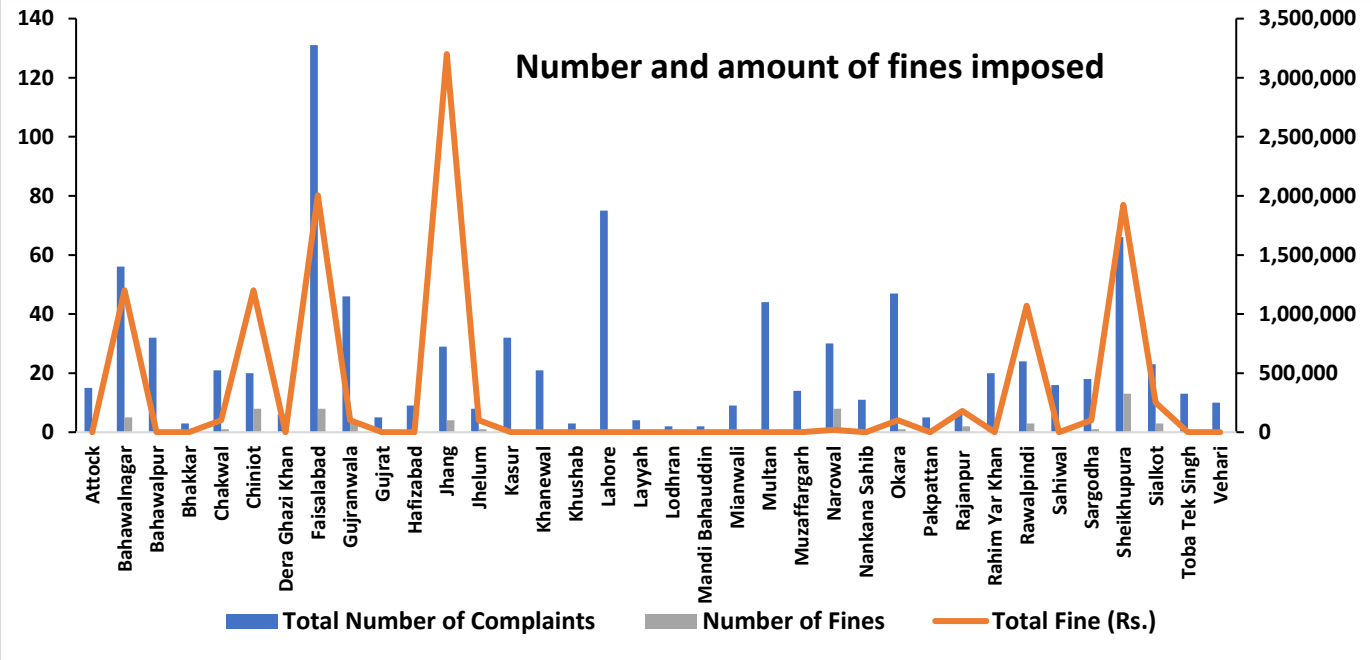


Figure 9-5: Number and amount of fines imposed on the non-compliant industries during 2023

3.1 Punjab Green Development Program to Address Community Grievances under the Program

Redressing grievances of affected people should be an integral part of a project's design, plan, and management. Setting up appropriate mechanisms to address community concerns, prevent adverse consequences and risks and bring about positive changes in people's lives and relationships is increasingly important in development projects. Resolving grievances of project-affected people at the lowest level, without allowing them to escalate into unmanageable levels equally benefits both the aggrieved parties and the project implementers.

Formal GRM has been established at program level to address the infrastructure related complaints arising from program execution activities. This system is operationalized since August 2023. Complaints can be directly filed while using an online compliant form readily available at PGDP website or maybe communicated through offices of Deputy Director (field formations).

3.1.1 Complaint Status since GRM operationalization

GRM mechanism is operationalized since August 2023 under the program provided with complaint form available at PGDP website (http://idm.pgdp.pk:8081). However, no complaint has been received so far related to the program activities.

4 THE WAY FORWARD

- Promoting an awareness and arranging capacity building sessions regarding grievance resolution will enhance accountability and encourage continuous learning.

- Introduction of automated digital system by eliminating the need for physical visits will contribute to the improvement of public services for redressal of complaints and promote e-governance.
- District-wise generation of GRM reports explaining the total number of complaints, their resolution and showing public concerns for betterment of the environment as well as addressing the social conflicts can prove be an important measure to make the system more transparent.

CHAPTER 10 ENVIRONMENTAL ACTION PLAN

Environmental action plan is a strategic document that outlines specific goals, measures and initiatives designed to address the environmental challenges and to achieve sustainable development. The aim of this action plan was to mitigate the negative environmental impacts arising from anthropogenic activities, conserving the natural resources and fostering environmentally sustainable practices. It was a commitment amongst the stakeholders for taking corrective actions within stipulated timeline. Action plan contained 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 means a duty entrusted to the Government organizations in the action plan for carrying out the interventions and sub-interventions.
- **Timelines:** Timelines means the time duration envisaged for carrying out sub-interventions.

Prior to proceeding further, it is noteworthy to mention that the State of Environment 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 i.e.; Short Term to be initiated/completed during CY-23 is first described in this chapter. In the second part, the Environmental Action Plan for State of Environment Report, 2023 (starting from CY-24) is given. Hence, all the sub-Interventions pertaining to Medium Term CY-24 (in SOE, 2022) are now Short Term CY-24 (in SOE, 2023), and Long Term CY-25 (in SOE, 2022) are now Medium Term CY-25 (SOE, 2023).

1 STATUS OF ENVIRONMENTAL ACTION PLAN IN SOE, 2022

The State of Environment 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 were also mentioned. The review of this Environmental action plan is as follows;

- **Interventions & sub-interventions:** There were 11 interventions in this Environmental action plan (*Table 10-1**)***

Table 10-1: Interventions in Environmental Action Plan, 22

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[166] from where focal persons were nominated for the successful implementation of the environmental action plan. These focal persons were working as pioneers in their respective departments for betterment of the environment (Table 10-2).

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

No	Agencies	Focal Person	No	Agencies	Focal Person
i.	Federal Board of Revenue	Ms. Angel David, Second Secretary (Rule & SROs)	**ii.**	Mines and Minerals	Mr. Aurangzeb, Deputy Director (Minor Minerals), Directorate General of Mines & Minerals
iii.	Energy Department	Nureen Arif, Manager (Environment), PMU, Energy Department, Punjab	**iv.**	Traffic Police	Mrs. Kishwar Sultana, DSP/SO
v.	Transport Department	Mr. Suleiman Majeed, Director (Planning), PTA	**vi.**	Forest Department	Syed Asim Azhar Naqvi, The Conservator of Forests, Extensions & Publicity Circle, Lahore
vii.	LG&CD	Mr. Barak-u-llah, Secretary, Punjab Local Government Board,	**viii.**	Industry Department	Mr. M. Ahad Gill, Industrial Expert, PDU, PSIC
ix.	C&W Department	Mr. Asif Ali, Deputy Director, O/o Chief Engineer (South), Punjab Highway Department, Lahore.	**x.**	WASA Faisalabad	Hafiz Moin-u-Din, deputy Director (Non-Tech) / Senior Research Officer
xi.	Irrigation Department	Chief Strategic Planning/ Reform Unit, Irrigation Department	**xii.**	WASA Multan	Mr. Omar Zafar, Deputy Director, Water Supply
xiii.	WASA Rawalpindi	Mr. Suleman Manzoor, Assistant Director (Water Quality) / JRO	**xiv.**	HUD & PHE Department	Mirza Mansoor Baig, Section Officer, UD-II HUD&PHED
xv.	WASA Lahore	Ms. Zoya Farooq, Deputy Director, P&D Directorate	**xvi.**	WASA Gujranwala	Mr. Muhammad Khurram Nabeel, Deputy Director (P&D), WASA

- **Timelines:** Total 71 sub-interventions under the given 11 interventions were outlined on a specific time scale i.e., 21 Short Term (CY-23), 33 Medium Term (CY-24) and 17 Long Term (CY-25). These interventions were either initiated or to be completed during the stipulated timeframe.

[166] Agencies mean Government Departments its attached departments and autonomous bodies etc.

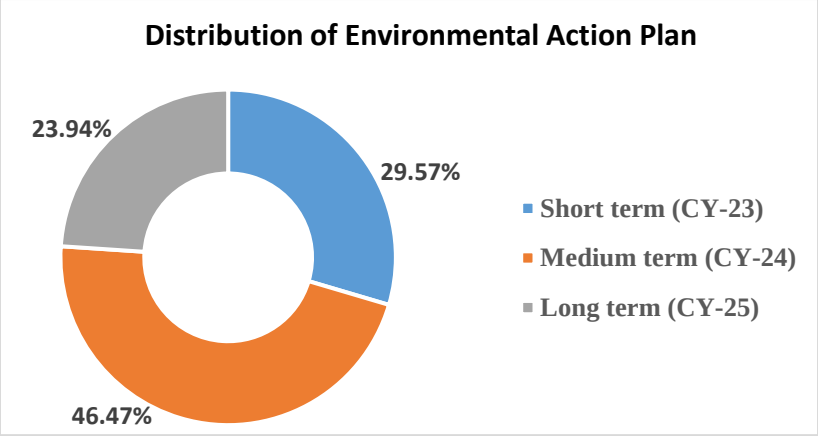


Figure 10-1: Distribution of Environmental Action Plan in Short-Term, Medium-Term and Long-Term goals of SOE, 22

The progress on the interventions/sub-interventions for the actions required to be initiated/completed during CY-23 is given in *Figures 10-2 to 10-5.*

Figure 10-02: Key achievements for Legislative interventions in 2023

Figure 10-03: Key achievements of Citizen Engagement and Industries in 2023

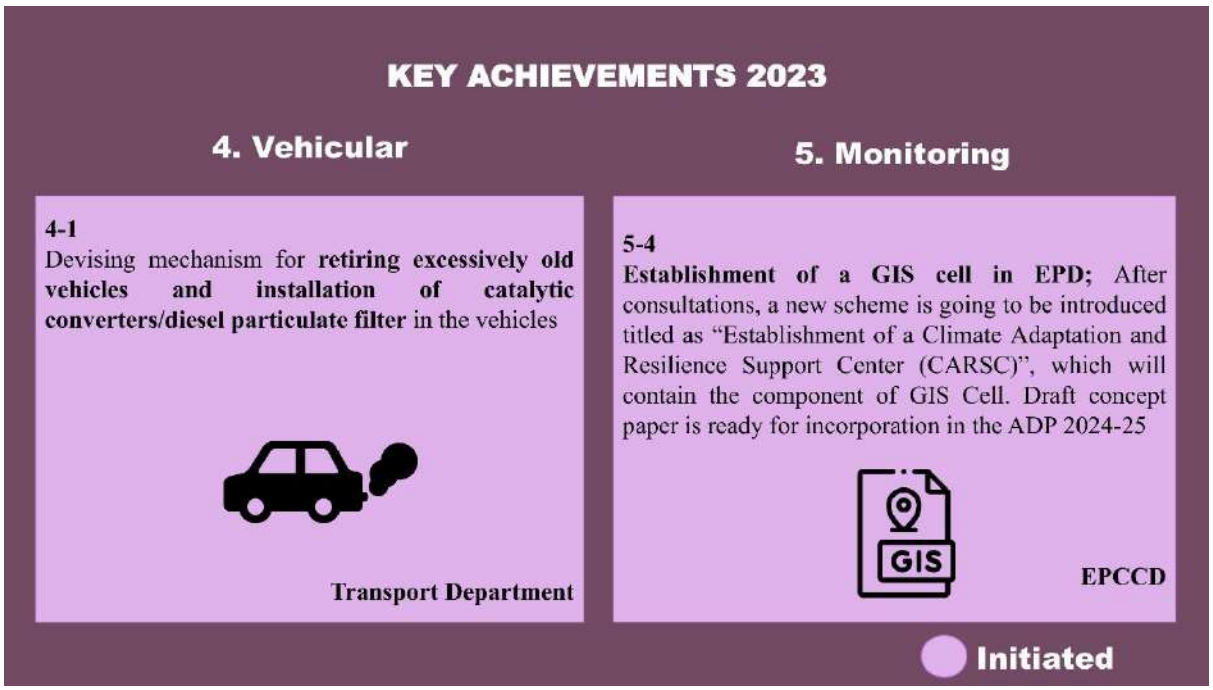


Figure 10-4: Key achievements for Vehicular and Monitoring interventions in year 2023

Figure 10-05: Key achievements of Sustainable Green Financing, Fugitive Dust Control and Remodelling Environmental Governance in year 2023

2 ENVIRONMENTAL ACTION PLAN FOR SOE, 2023

Environmental Action Plan, 2023 is also a three years plan starting from CY-24 and ending at CY-26. 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 *Table 10-3.*

Table 10-3: Timeline to complete/initiate sub-interventions of Environmental Action Plan.

Short Term (CY-24)	The targets under Short-Term category include immediate interventions. These sub-interventions are to be completed/initiated in calendar year 2024
Medium Term (CY-25)	The targets under Medium-Term category require implementation of modern strategies and policy support. These sub-interventions are to be completed/initiated in calendar year 2025
Long Term (CY-26)	Long Term category targets are to be completed/initiated till 2026. These sub-interventions require sustained policy measures.

Sub-interventions and respective responsibilities on the time scale were redefined as given in *Table 10-4.*

Table 10-5: Environmental Action Plan

1-Legislative		
Term	**Sub-interventions**	**Responsibility**
Short Term (CY-24)	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.)	EPCCD
Short Term (CY-24)	1-2 Certification and labelling system for green, energy-saving products	Energy Department
	1-3 Energy conservation standards for newly built urban buildings and industrial establishments	Energy Department
	1-4 Energy saving renovations/retrofitting in existing buildings and improved energy efficiency guidelines/ regulations/rules	Energy Department
	1-5 E-Waste Management Rules	EPCCD
Long Term (CY-26)	1-6 Additional legislative arrangements other than the Environment Act	EPCCD

2-Citizen Engagement		
Short Term (CY-24)	2-1 Establishment of air and water web-based data portal. Further, engage public, private and civil sectors in the development of joint policy framework to address environmental challenges like air, water quality	EPCCD
	2-2 Public communication campaigns on negative environmental and health impacts of single use plastic	EPCCD
Medium Term (CY-25)	2-3 Public communication campaigns on water conservation, rain water harvesting, and environment conservation etc.	EPCCD
Short Term (CY-24)	2-4 Implementation of health advisory in the wake of critical air pollution events	EPCCD
Long Term (CY-26)	2-5 Effective participation of stakeholders and public-private sector cooperation in decisions making-processes	EPCCD
Long Term (CY-26)	2-6 Enhancement of environmental health awareness and environmental concerns	EPCCD

3-Industries		
Short Term (CY-24)	3-1 Implementation of resource efficiency and cleaner production technologies	Industry Department
Medium Term (CY-25)	3-2 Implementation of zero water discharge/water conservations schemes in the water intensive industries like textiles, sugar etc.	Industry Department/ EPCCD
Medium Term (CY-25)	3-3 Introduction of carbon neutrality regime	EPCCD
Short Term (CY-24)	3-4 Evaluation of impacts of pollution sources on the soil quality	EPCCD
Medium Term (CY-25)	3-5 Installation of continuous emission monitoring systems	Industry
Long Term (CY-26)	3-6 Designing, Development and implementation of technologies for prevention of pollution at source	EPCCD
Long Term (CY-26)	3-7 Introduction of measures for the prevention of the production of hazardous wastes at the source	Industry/ EPCCD
Long Term (CY-26)	3-8 Increasing collaboration with the academia for research and development for sustainable development	EPCCD/ Universities

4-Vehicular		
Short Term (CY-24)	4-1 Enhancing the area of jurisdiction of vehicles inspection and certification regime to the private vehicles[167]	Transport Department
	4-2 Mandatory vehicle inspection certificate prior to sale and purchase of any vehicle regarding emission compliance	Excise Department
	4-3 Promote mass transport facilities in the major urban centers of the province	Transport Department
	4-4 Piloting of electric buses in Lahore, Punjab	Transport Department
	4-5 Devising mechanism to increase road denials of excessively old/pollution causing vehicles	Transport Department/ EPCCD
Medium Term (CY-25)	4-6 Green transportation, standards, action plans & solutions	Transport Department
Short Term (CY-24)	4-7 Road Engineering for removing traffic congestions in the major roads of the urban centers[168]	Traffic Police/ Development Authorities/ MC
Medium Term (CY-25)	4-8 Increase the counters for issuance/renewal of fitness certificates/route permits	Transport Department
Medium Term (CY-25)	4-9 Deploy the teams to check vehicles plying on road without fitness certificates & route permits	Transport Department/Traffic Police

[167] Traffic Police Punjab during CY-23 apprised that a special campaign has recently been launched against vehicles plying on road without or with expired fitness certificates & route permits.
[168] Traffic Police Punjab during CY-23 apprised that all districts have prepared the reports regarding road engineering required for removal of traffic congestion in urban areas and concerned authorities will be approached to do the needful within timeline.

5-Monitoring		
Short Term (CY-24)	5-1 Installation of at least 30 ambient air quality monitoring stations	EPCCD
	5-2 Installation of at least 15 water quality monitoring stations	EPCCD
	5-3 Establishment of a reference laboratory	EPCCD
	5-4 Establishment of noise and vibration monitoring networks	EPCCD
	5-5 Environmental monitoring of industrial effluents deteriorating the quality of river Ravi in Sheikhupura and Faisalabad	EPCCD

6-Air		
Short Term (CY-24)	6-1 Enactment of "The Punjab Clean Air Act"	EPCCD
Short Term (CY-24)	6-2 Area pollution and dust control/urban dust management	EPCCD/Housing Authorities/C&W
Short Term (CY-24)	6-3 Implementation of zero sand spillage regime regarding sand moving trolleys[169]	Mines & Minerals/District Govt./Traffic Police
Short Term (CY-24)	6-4 Investigation of sources of particulate matter for informed decision making	EPCCD
Medium Term (CY-25)	6-5 Implementation of Punjab Clean Air Policy (with phased Action Plan)	EPCCD
Short Term (CY-24)	6-6 Implementation of health advisory in the wake of critical air pollution events	EPCCD
Medium Term (CY-25)	6-7 Establishment of pollution inventory and pollution release and transfer register	EPCCD

[169] Traffic Police Punjab during CY-23 apprised that more than 7,000 uncovered vehicles/trolleys have been issued challans and about 15,000 have been impounded.

7-Water & Waste Water		
Medium Term (CY-25)	7-1 Construction of storm/rain water underground water recharge galleries in establishments (including public as well as private)	LG&CD/C&W Department
Short Term (CY-24)	7-2 Water metering for every connection of domestic and industrial establishments alongwith provision of clean surface water	WASAs and municipal authorities
Medium Term (CY-25)	7-3 Rehabilitation of dams, rivers, drains, and canals. Also ensure the implementation of watershed management practices and increase in water storage capacity of the province[170]	Irrigation Department
	7-4 Conservation of natural habitats especially the Ramsar sites	EPCCD
	7-5 Installation of municipal waste water treatment plants against each existing disposal station	LG&CD/ Housing Authorities/WASA's
	7-6 Construction of industrial waste water treatment plants	Private/EPCCD
	7-7 Mandatory provision of construction of municipal waste water treatment plants in new establishment of disposal stations	LG&CD

8-Solid Waste & Hospital/ Industrial waste		
Medium Term (CY-25)	8-1 Establishment of Integrated solid waste management facilities in each urban as well as rural areas	LG&CD
Short Term (CY-24)	8-2 Waste minimization at source (reduce, recycle, and reuse)	LG&CD
	8-3 Improve waste collection efficiency	LG&CD
Medium Term (CY-25)	8-4 Installation of waste to energy projects	LG&CD/Energy Department
Short Term (CY-24)	8-5 Provision of hospital waste management facilities by large private hospitals (having more than 30 beds)	Private/ Health Department
Medium Term (CY-25)	8-6 Provision of industrial waste management facilities in industrial or cluster levels	Industry Department
Long Term (CY-26)	8-7 Piloting and handing over of a catalytic hydrodechlorination unit for treatment of PCBs and similar hazardous chemicals	EPCCD & LG&CD

[170] Irrigation Department has informed that following projects will be completed by June 2025 Remodeling of Nikki Deg Drain (1,133million PKR), Flood protection of Kamoki & adjoining areas Sheikhupura (2,175 million PKR), Channelization of Deg Nullah (Land Acquisition Punjab Component)/Sheikhupura (3,175 million PKR), Management of Hill Torrents in DG Khan, Rajanpur (2,035 million PKR), Construction of Jalapur Irrigation Project and its System/Jhelum, Khushab (32,721 million PKR), Rehabilitation and Modernization of Islam Barrage (2,993 million PKR), Rehabilitation and up gradation of Trimmu Barrage, Punjnab Head Works/Jhang (16,800 million PKR) and construction of small Dams (11 on-going and 37 identified potential sites).

9-Climate Change		
Short Term (CY-24)	9-1 Establishment of a Climate Adaptation and Resilience Support Center (CARSC)	EPCCD
Medium Term (CY-25)	9-2 Establishment of Early Warning System for extreme weather events in Southern Punjab	EPCCD
Medium Term (CY-25)	9-3 Mapping the climate change vulnerability to develop a Climate Adaptation and Resilience Plan (CARP) for South Punjab	EPCCD
Medium Term (CY-25)	9-4 Piloting of a community conserved area in South Punjab for protection of desert ecosystems	EPCCD

10-Remodeling Environmental Governance		
Short Term (CY-24)	10-1 Establishment of Environmental Technology Transfer Center	EPCCD
	10-2 Incentivization of the environmentally compliant industries[171]	EPCCD/MOCC/ FBR
Medium Term (CY-25)	10-3 Collaboration/regional dialogues on transboundary water and air pollution	EPCCD/MOCC
Short Term (CY-24)	10-4 Establishment of Environmental Policy Center	EPCCD
Long Term (CY-26)	10-5 Provision of financial resources to NGOs and collaboration with them for sustainable development	EPCCD
Short Term (CY-24)	10-6 Implementation of Plastic Management Strategy	EPCCD

11-Others		
Short Term (CY-24)	11-1 Construction of Green Buildings in Lahore	EPCCD
Medium Term (CY-25)	11-2 Research and development for developing/adoption of indigenous technologies for pollution abatement preferably through industry academia licenses	EPCCD
	11-3 Establishment of woodlands especially in urban centers of indigenous and environment-friendly species	Forest Department
Short Term (CY-24)	11-4 Establishment of noise-free zones	EPCCD/ Development Authorities
Medium Term (CY-25)	11-5 Preparation of local environment action plans at the district levels with special reference to environmental protection and pollution prevention	LG&CD/EPCCD
Medium Term (CY-25)	11-6 Land-use classification of each district to gauge the urban sprawl, development pattern etc.	LG&CD/ Development Authorities

[171] During CY-23 the FBR responded that Pakistan being under Stand by Arrangement signed with IMF whereby, Pakistan is bound to avoid granting any new tax exemption/concession or preferential tax treatment, hence cannot incentivize the environmentally compliant industries. The Punjab EPD is requested to implement the Action Plan through non-tax incentive measures for example by penalizing the non-compliant industries. Therefore, the mandate to the respective provincial laws.

Long Term (CY-26)	11-7 Tapping of domestic and external sources of finance to investments for environmental protection and climate change	EPCCD/EPC
Long Term (CY-26)	11-8 Intensification of R & D activities	EPCCD
Long Term (CY-26)	11-9 Establishment of a Noise prevention cell under EPA Punjab	EPCCD
Medium Term (CY-25)	11-10 Development of policy instruments to deal with the problem of noise pollution	EPCCD

3 MONITORING & EVALUATION

A dashboard will be established for current Environmental Action Plan by EPCCD for continuous monitoring and updating of this action plan. The focal persons will play a pivotal role in the implementation of this plan at their respective organizations.

ANNEXURES

Annexure – A

Table A-1: Comments of draft TOC during public hearing for State of Environment Report, 2023

Commenter	Comments	Response
Mian Ahmad Saeed, Chairman, Sahiwal Chamber of Commerce	Much efforts have to be made for conservation of natural resources as well as water conservation. Agricultural Land is being converted into housing schemes and there are heavy rains and cloud burst episodes especially in urban centers. More legislation regarding regulations and stern fines has to be imposed against smog emitting vehicles and against violators of environmental laws. There is always a threat of flooding due to release of water by the India. In the present environmental regime, there are no efforts related to the conservation. However, much efforts regarding recycling are observed in the State of Environment Report, 2022.	Comment is about an environmental issue, not on the Table of contents of report
Dr. Atta-ul-Haq, Chief Executive Officer, Techno Clean Field	The proposed Table of Contents at serial No. 7.1 requires the effectiveness of industrial waste water treatment plants and what about the effectiveness of municipal waste water treatment plants? At serial No. 7.2 there is a description of solid waste management facilities. It is pertinent to mention that there is only one scientific landfill site in Lahore across the Punjab. There are other waste management companies in Gujranwala, Sheikhupura, Faisalabad and Bahawalpur but identification and availability of landfill site is the key bottle neck in establishment of an effective solid waste management system. Further, the report may also contain the description HSE and work place and intervention may be carried out for handing over of 160 vehicles from LWMC to the small cities to improve the State of Environment**.**	Effectiveness of industrial WWTPs will be discussed in the chapter in context of their environmental performance. There are no municipal wastewater treatment plants in Punjab. The number and capacities of landfill sites of Punjab will be discussed in report. HSE is not a component of environment as defined in PEPA 1997 and is not usually discussed in state of environment reports
Prof. Dr. Ghulam Murtaza, Professor/Director, University of Agriculture Faisalabad	There are no waste water treatment plants and solid waste management facilities for the industrial as well as Municipal waste water and Solid waste. Everywhere, industrial effluent is being mixed with the municipal effluent. Similarly, hospital waste is being mixed with the municipal solid waste. We all are cleaning our homes and dumping the solid waste in the neighborhood. At present, there are big cities, at least some new cities may be developed. In SOE, 2022 Arsenic is highly reporting with regards to contamination but it is not a big problem. Care shall be taken to report secondary data from the research Journals as research quality is being compromised over quantity. It is further suggested that in the proposed content following arrangement may be made i.e., “soil” may be change as “soil health”, “physical” may first come then “chemical” and	Secondary data will be quoted carefully from authentic sources

Commenter	Comments	Response
	then “heavy metal contamination” and then “fertilizers” and then “pesticides”.	
Samina Arshad, Director Punjab, Rahnuma - Family Planning Association of Pakistan (FPAP)	There is severe need to review climate changes verses over population. The impacts of population have to be examined in the context of environment. Further, there is an urgent need for creating awareness about the Government initiatives. There are small villages, rural areas which require special attention from the Government especially in terms of safe drinking water and solid waste management facilities.	Climate change, its population – related drivers and WASH sector will be discussed in the report
Shakeel Ansari, Member Faisalabad Chamber of Commerce	Earlier we have much resource of natural gas which is now depleted. Throughout the world, the energy is being produced by burning the municipal solid waste what action has been taken by us in this regard? There are various contributing factors regarding the air quality which needs to be addressed. Gas availability to the industry has to be ensured, as the use of local coal may cause number of diseases.	General comment. Energy sector of Punjab will be discussed briefly in the report
Shah Nawaz Khan, Relationship Manager, Strengthening Participatory Organization (SPO) Formed the Punjab Climate Action Network (PCAN)	There is a severe challenge of open defecation in the rural areas which require corrective measures. The Punjab Environmental Protection Policy needs to be promulgated at the earliest.	General Comment
Azhar Hussain, Deputy Chief Plan, Agriculture Department	Much discussion has always been made on the land conversion from agriculture to the residential category but lesser discussion is referred regarding efforts of the Agriculture Department wherein 200 bulldozers are being used for the land development. This may also be added in the upcoming report.	Response on environmental issued from government departments will be added in each relevant chapter
Fareeha Fatima, Section Officer (Tech-II), HUD & PHED Department	The ground water aquifer is being used for drawing of drinking water across the Punjab which results in depletion of ground water resources. We have to shift towards the surface water and also promote the rain water harvesting.	General comment
Noureen Arif, Manager Environment, Energy Department	The Government has to take lead in the renewable technology. There are grid emission factors available through which GHG emissions may be calculated further the contribution of energy resources in terms of thermal verses renewable may be consider for this report.	General comment
Ushna Tariq, Gender Management System, Women Development Department	The percentage of women in the population of Punjab has been increased to more than 51% and they are considered as vulnerable. Therefore, their representation/description may be added into the report, appropriately.	Gender will be discussed in report

Commenter	Comments	Response
Amber Aleem, Program Manager, The Urban Unit	Clarity may be provided regarding 10 divisional headquarters against which the report is going to be compiled. Noise quality is a neglected area which may be included into the upcoming report.	Names of divisional headquarters will be clearly mentioned in report. Noise data is not so far available. However, actions regarding noise quality monitoring and regulations will be added in the action plan so that the future reports may discuss this issue
Dr. Rana M. Atif, Deputy Director, Pakistan Meteorological Department	The report shall contain, air quality modelling as well as climate change modelling to the extent of the Tehsil level. There is data available and efforts have to be made with regards to the inclusion of academia for betterment of air quality.	Any data available with PMD pertaining to environmental and climate change context will be added in the report
Dr. Gul Zareen Ghafoor, Assistant Professor, Sustainable Development Study Centre (SDSC), Government College University Lahore	The report contains the data of the WASA across the Punjab which is not true representation as focus has to be made on distribution as well as household service. Further, there are standards not available for surface water quality and as well as soil quality.	Tap water quality will be added in the report to cover the consumption side of water. Available international standards will be used where local standards are not available.
Umer Hayat, Assistant Professor, Sustainable Development Study Centre (SDSC), Government College University Lahore	We have to focus on the contributing factors of the climate change. Until and unless we are unaware about the contributing factors, we will not be able to address the concerns. Further, heavy metals in soil may be reported. Globally attention is drawn towards micro plastic pollution, this year's World Environment Day theme was also related to plastic and we have to focus on it. Multilateral environmental agreements and their compliance has to be reported in the report along with transboundary pollution contributing factor.	Drivers of climate change will be discussed in the report. Heavy metals will also be discussed in soil chapter. MEAs and their implementation will be strengthened in future along with the institutional strengthening of EPCCD Punjab under PGDP and the future reports would discuss the MEAs in detail. Transboundary element of air pollution will be discussed in the report.
Naeem Bajwa, President, Lahore Conservation Society	Solid waste contains 60 to 70% organic – a pure resource – which is being wasted. At source waste segregation has to be carried out to minimize the waste into the environment. Tetra Pack have been found at everywhere even in the lake of Saif-Ul-Malook. There has to be a concept of extended producers' responsibility. Presently cities are not walkable there has to be multiple centers. The influence of EPD has to be on master planning of the cities. Carbon off setting needs to be done. Rain water harvesting is a neglected area. We have to engage academia and social sector for completion of feedback loop.	General comments
Nadia Tahir, Director Environment,	Urban development is facing severe issues of encroachment, re-settlement and rehabilitation. Such issues need to be addressed. We have highest number of laws in the world but they are	The urban settlement issues will be discussed in climate change chapter briefly.

Commenter	Comments	Response
Ravi Urban Development Authority	not being implemented. Laws needs to be implemented.	
Syed Mujahid Mumtaz, Director General, Sheikhupura Chamber of Commerce	While considering the potential of renewable energy their negative effects may also be considered.	General comment
Shahid Habib, Deputy Director, Irrigation Department	While discussing the action taken by the Government Departments to measure and control pollution it will be also beneficial if their laws, rules and regulations may also be discussed in the report.	As the report will contain the actions taken by Government Departments during 2023, previous laws, rules and regulations may not be discussed

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Annexure – B

Table B-1: Component-wise data streams for State of Environment Report, 2023

Sub-Component	Data requirements	Coverage/Scope	Data sources
1. Assessment of ambient air, surface water and groundwater, and soil quality, as extracted from the available monitoring data			
Air Quality	Ambient Air Quality (AQI)	Districts with AQMS availability	• EPA Lab, Lahore • SUPARCO
	No. of patients reported for respiratory and cardio-vascular diseases	All over Punjab	Health Department
Water Quality	Surface water quality	---	• PCRWR • EPA Lab, Lahore
	Ground/drinking water quality	Divisional headquarters/as per availability of data	• WASA Gujranwala • WASA Multan • WASA Rawalpindi • WASA Lahore • WASA Faisalabad • EPA labs
	Status of aquifers and groundwater quality		Irrigation Department
	River and canal discharges		
Soil & Land	Soil monitoring from residential, agricultural and industrial areas	The sites sampled for SOE Report 2022	Experts/consultant
	Heavy metal contamination in the soil exposed to industrial wastewater	Divisional headquarters	Experts/consultant
	Soil texture, organic matter and fertility	All over Punjab	Agriculture Department (extension wing)
	Land degradation	All over Punjab	Secondary data
2. Assessment of pollution sources that contributed to air, water, and soil pollution, including a summary inventory of pollutants, detailing time and intensity thereof			
Sources of Air Pollution	Industrial Stack Emissions	All over Punjab	EPA labs
Sources of water pollution	Industrial sources	All over Punjab	Directorate of (ML&I), EPA Punjab, EPA Labs
Sources of soil pollution	Industrial sources	Divisional Headquarters	Consultant
3. Assessment of environmental performance of wastewater treatment facilities and solid waste management facilities			
Effluent	Testing before and after treatment	All over Punjab	EPA Labs
Sludge & Emissions	Sludge and CH_4 testing	Divisional Headquarters	Consultant
Solid Waste (Municipal and Hospital waste)	Mapping of solid waste disposal facilities with capacity, waste generation, collection rates	All over Punjab	• LG&CD • WMCs

Sub-Component	Data requirements	Coverage/Scope	Data sources
	Assessment of environmental performance based on air, leachate, soil analyses (for MSW) and ash and stack emissions (for incinerators)	Divisional Headquarters	Consultant (through EPA certified lab and PCSIR)
4. Suitable course of actions taken to control pollution and improve environmental quality			
Regular operations of EPD Punjab and other departments for environmental protection and pollution control	• Actions taken under Sections 11, 12, 13 and 16 of PEPA 1997 • Other initiatives, policy instruments, regulatory reforms, institutional arrangement, etc. • ADP	All over Punjab	• EPA Punjab • Other Departments SP&IU
5. Summary of environmental complaints received classified by type of environmental issue, as well as actions taken in respect thereof			
Complaints data	All types of complaints	-do-	EPA Punjab
6. Public feedback on the report and EPD's responses thereto			
			Public consultations in 3 different cities
7. Government of Punjab's environmental action plan for the calendar years			
• Review of progress of EAP given in SOE 2022 • Preparation of EAP 2023	As per stipulated actions	-do-	Role – players of Environmental action plan (SOE 2022)

Table C-2: Drinking water standards – national and international

Sr. No.	Parameter	PEQS	WHO
1	**Color**	≤ 15 TCU	≤ 15 TCU
2	**Odor**	Non objectionable/ Acceptable	Non objectionable/ Acceptable
3	**Taste**	Non objectionable/ Acceptable	Non objectionable/ Acceptable
4	**EC**	NGVS	< 1500 µS/cm
5	**Alkalinity**	NGVS	< 200 mg/L
6	**Arsenic (As)**	≤ 0.05 µg/L	0.01 µg/L
7	**Hardness**	< 500 mg/L	-
8	**Bicarbonate**	NGVS	506 mg/L
9	**Carbonate**	NGVS	249 mg/L
10	**Chloride (Cl)**	< 250 mg/L	250 mg/L
11	**Fluoride (F)**	≤ 1.5 mg/L	1.5 mg/L
12	**Nitrate (NO_3)**	≤ 50	-
13	**pH**	6.5-8.5	6.5-8.5
14	**Potassium (K)**	NGVS	12 mg/L
15	**Sodium (Na)**	NGVS	200 mg/L
16	**Sulphate (SO_4)**	NGVS	250 mg/L
17	**TDS**	< 1000 mg/L	< 1000 mg/L
18	**Turbidity**	< 5 NTU	< 5 NTU
19	***T. coliform***	0/100mL	0/100mL
20	***E. coli***	0/100mL	0/100mL
21	***F. coliform***	0/100mL	0/100mL

* NGVS: No Guideline Value Set

Table C-3: Industry sectors and corresponding number of industrial units for discharged effluents (Source: EPA)

Industry Sectors	Industry Count
Animal feed	1
Auto parts	2
Beverages	5
Cement plants	2
Electrical appliances	2
Engineering	3
Fertilizer plants	1
Flour mills	70
Foods	19
Footware	2
Grid stations	2
Marble	5
Others	40
Rice mills	6
Soap & detergents	4
Sugar mills	2
Textiles	85
Thermal power generation	1
Tobacco	2
Mining (coal, precious metals/stone, S)	2
Paper, Paperboard, Paper pulping	33
Apparel manufacturing	38
Oils, fats, veg. ghee	10
Oil & gas extraction	2
Poultry farms	4
Pesticides	3
Chemicals	6
Pharmaceuticals	3
Bakeries, Sweets, etc.	1
Lubricant recycling	2
Leather & Tanning	123
Paints & Dyes	17
Protein factories	1
Furnaces	3
Mining (non-Fe metals, iron, steel rolling)	1
Glass	1
Grand Total	**504**

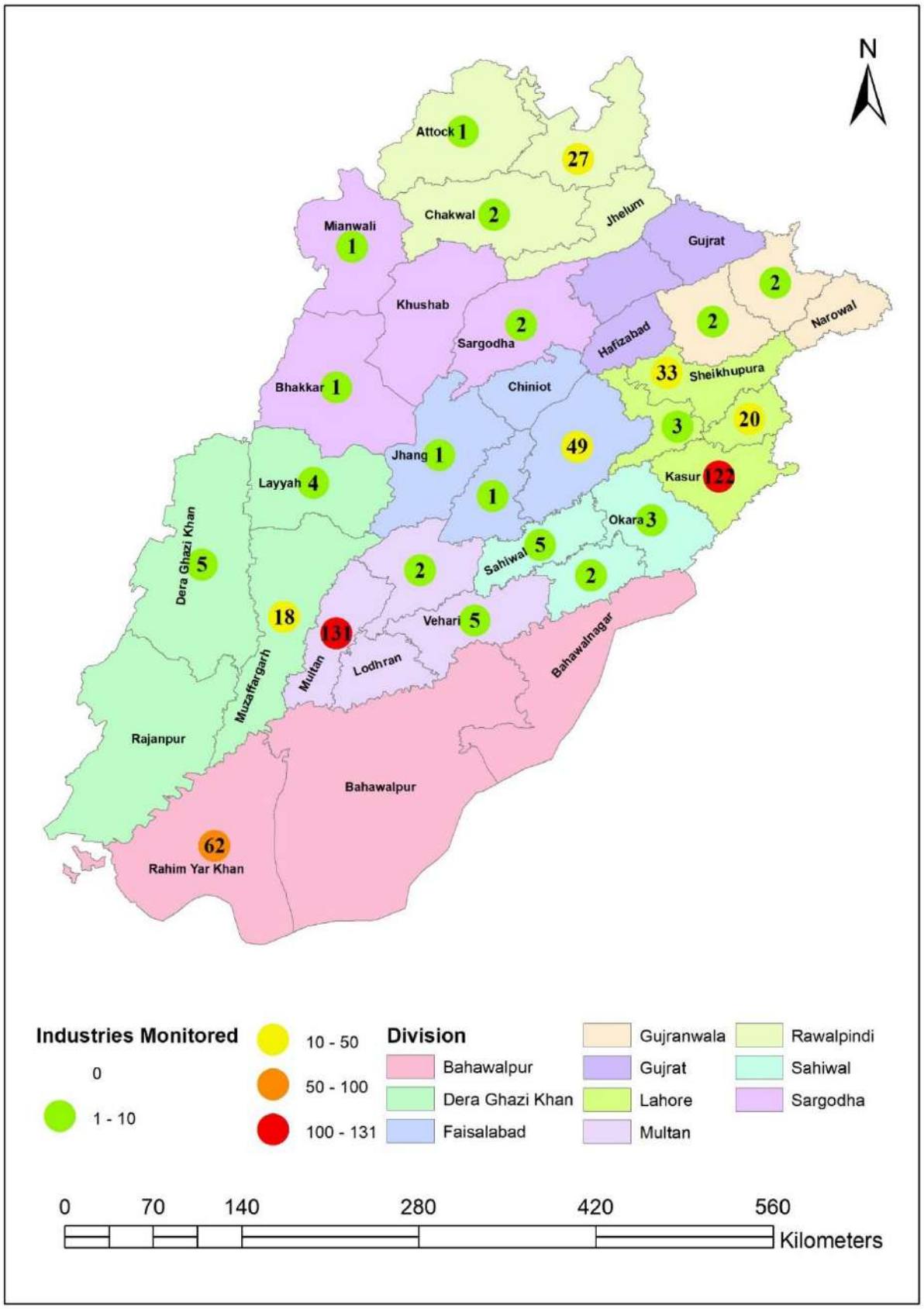


Figure C-0-1: District-wise number of industrial units monitored for discharged effluents (Source: EPA)

Annexure – D

SAMPLING PROCEDURES FOLLOWED FOR SOIL SAMPLING

A. Pre Sampling Protocol

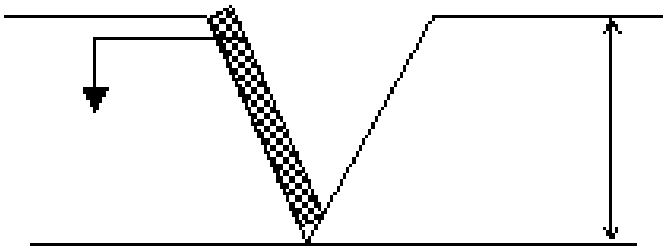
Following points were considered during the sampling of soil in the study area.

- Randomized (spatially well-distributed) samples, representative of urban area (including green belts, parks and household vicinities etc.) were collected
- Random homogenous grab soil samples were collected from the Industrial areas of the study area.
- For agricultural soil, sample were collected from the standing crop (between rows). Dead furrows, wet spots, areas near main bund, trees, manure heaps and irrigation channels were avoided while sampling.
- Soil samples were collected from land irrigated with treated and untreated industrial effluent from closed proximities of the study area.

B. Sampling Procedures

Following sampling procedures were opted during the soil sampling in the study area.

- Field was divided into different homogenous units based on the visual observation and farmer's experience.
- The surface litter was removed at the sampling spot.
- Auger was driven to a plough depth of 15 cm – 20 cm and the soil sample was drawn.
- 10 to 15 samples were collected from each sampling unit and were placed in a bucket or tray.
- Where the auger was not available, a 'V' shaped cut was made to a depth of 15 cm – 20 cm in the sampling spot using spade.
- Thick slices of soil were removed from top to bottom of exposed face of the 'V' shaped cut and placed in a clean container.



1 inch / 2.5 cm 6 inches (15 cm)

- The samples were thoroughly mixed and foreign materials like roots, stones, pebbles and gravels were removed.
- The bulk was removed to about half to one kilogram by quartering or compartmentalization.
- Quartering was done by dividing the thoroughly mixed sample into four equal parts. The two opposite quarters were discarded and the remaining two quarters were remixed and the process repeated until the desired sample size was obtained.

- Compartmentalization was done by uniformly spreading the soil over a clean hard surface and dividing into smaller compartments by drawing lines along and across the length and breadth. From each compartment a pinch of soil was collected. This process was repeated till the desired quantity of sample was obtained.
- Sample was collected in a clean cloth or polythene bag.
- The bag was labeled with information about name of the farmer, location of the farm, survey number, previous crop grown, present crop, crop to be grown in the next season, date of collection, name of the sampler etc.

C. Processing and Storage

All the standard protocols were observed during the lodging, processing and storage of collected samples in the study area.

D. Parameters monitored

The parameters of soil quality including pH, EC, As, Cd, Se, Hg, Zn, Mg, Fe, Pb, K, P, N and SAR, were analyzed according to the American Public Health Association protocols (***Table 6***).

The pH and EC were analyzed using the pH and EC meters, receptively by following the methods as described above. The heavy metals were determined using atomic absorption spectrophotometer. Potassium was determined using flame photometer while nitrogen was determined using Kjeldahl method in soil samples. Sodium absorption ratio was determined from the concentration of Ca, Mg and Na values by using the formula as given below (Eq. 2)

$$\mathrm{SAR} = \frac{\mathrm{Na}}{\sqrt{\frac{\mathrm{Ca} + \mathrm{Mg}}{2}}} \qquad (2)$$

Table D-1: Analytical methods to measure soil samples of various divisions of Punjab

Sr. No.	Parameters	Unit	Method
1	pH	---	APHA 4500-H+ B
2	EC	µS/cm	APHA 2510B
3	Arsenic	mg/kg	APHA 3114 C
4	Cadmium	mg/kg	APHA 3500 D
5	Zinc	mg/kg	APHA 3500 B
6	Iron	mg/kg	APHA 3111 B
7	Lead	mg/kg	APHA 3111 B
8	Selenium	mg/kg	APHA3500
9	Mercury	mg/kg	APHA 3112 B
10	Potassium	mg/kg	APHA 3500 B
11	Magnesium	mg/kg	APHA 3111 B
12	Phosphorus	mg/kg	APHA4500-P
13	Nitrogen	mg/kg	APHA4500-N
14	SAR	mg/kg	IS 11624:1986 (RA 2009)

APHA = American Public Health Association

Table D-2: Heavy metals and fertility status of various soil types in Punjab

City	Heavy metals (all soil types)		Urban	Industrial	Agriculture	Land Irrigated	Urban	Industrial	Agriculture	Land Irrigated	Urban	Industrial	Agriculture	Land Irrigated
	Hg	Se	Na (mg/kg) ± *SE*				Ca (mg/kg) ± *SE*				Mg (mg/kg) ± *SE*			
Faisalabad	ND	ND	785 ± 148	885 ± 258	1557 ± 283	951 ± 148	12.28 ± 0.7	11.3 ± 0.76	14.84 ± 0.65	21.22 ± 0.71	66 ± 7.17	29.33 ± 12.81	43.33 ± 6.64	32.33 ± 6.36
Lahore	ND	ND	661 ± 236	1325 ± 262	2451 ± 390	2428 ± 61	19.65 ± 0.76	11.4 ± 0.83	19.75 ± 0.83	12.38 ± 0.82	41 ± 4.58	40 ± 9.07	33.33 ± 5.78	54.33 ± 6.64
Sahiwal	ND	ND	555 ± 86	1021 ± 153	1858 ± 69	2215 ± 60	20.1 ± 0.82	21.23 ± 0.65	21.72 ± 1.22	16.8 ± 0.89	36 ± 9.17	26 ± 3	36.33 ± 6.69	53.67 ± 5.78
Bahawalpur	ND	ND	698 ± 116	954 ± 203	1654 ± 218	2128 ± 103	20.14 ± 0.89	15.77 ± 1.22	16.37 ± 0.64	11.49 ± 0.7	53.47 ± 2.11	52.55 ± 5.08	71.73 ± 2.93	58.67 ± 3.71
Multan	ND	ND	561 ± 85	822 ± 57	1625 ± 267	1917 ± 55	20.68 ± 0.71	164± 1.8	20.2 ± 0.82	15.77 ± 1.22	43.66 ± 3.45	53 ± 6.11	68.33 ± 10.4	70 ± 11.93
DG Khan	ND	ND	851 ± 85	922 ± 173	1592 ± 243	2395 ± 217	15.77 ± 1.08	12.28 ± 0.7	17.3 ± 0.88	20.68 ± 0.69	41.33 ± 0.68	52.33 ± 1.67	63.67 ± 2.4	63.33 ± 6.44
Rawalpindi	ND	ND	1621 ± 351	588 ± 181	2265 ± 28	1785 ± 437	9.82 ± 1.14	11.94 ± 0.83	10.47 ± 0.7	17.34 ± 0.76	69.33 ± 5.88	69.33 ± 7.69	67.67 ± 9.35	77.67 ± 12.14
Gujranwala	ND	ND	1433 ± 406	1250 ± 218	970 ± 162	1622 ± 336	11.89 ± 1.28	14.64 ± 1.47	15.87 ± 1.14	20.78 ± 0.89	39 ± 3.12	27 ± 4.04	60 ± 7.02	52 ± 3.51
Sargodha	ND	ND	8791 ± 131	8441 ± 19	6729 ± 186	8435 ± 22	16.8 ± 1.29	20.68 ± 1.39	16.81 ± 1.22	17.39 ± 1.14	51.1 ± 5.2	36 ± 2.51	42 ± 6.36	39.12 ± 1.2

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