Adam Smith International

Peshawar Clean Air Alliance

SEED

UKaid

STATUS OF
AIR POLLUTION IN PESHAWAR

Study Report

The Peshawar Clean Air Alliance (PCAA) is a volunteer association of civil society individuals and groups sharing a common vision of improved air quality for Peshawar, supported by the Sustainable Energy & Economic Development (SEED) programme, which is funded by the UK's Foreign, Commonwealth & Development Office.

Acknowledgements

We would like to appreciate and acknowledge the guidance provided by Peshawar City Traffic Police and Hayatabad Industrial Zone management, in helping explain air pollution aspects related to their sectors. Further, we would like to thank members of the Peshawar Clean Air Alliance (PCAA) for sharing their comments and feedback, which added direction to the study.

We would also like to thank the SEED team for their support throughout the project, especially Ms. Nazish Afraz, Programme Economist SEED, for reviewing the report multiple times, Mr. Ahmed Rafay Alam, Adviser SEED, for assisting in the design of this study, and Dr. Omar Mukhtar Khan, Team Leader SEED, for his valuable input.

Foreword

It gives me immense pleasure at the launch of a groundbreaking document, Status of Air Pollution in Peshawar (SAPP), that bridges the gaps in real-time data on air quality, with evidence-based indicators and future policy direction for a Peshawar Air-Quality Management Plan. This document provides an analysis of Peshawar's air quality that will enable policymakers to better understand the causes of air pollution in the city.

With multiple sources of emissions, including formal and informal industrial, vehicular, brick kilns and municipal waste incineration being the top, the report serves as an eye-opener with regards to the transport and vehicular sector being the top contributor that deserves immediate action plan alongside other sectors. This report will undoubtedly help focus policy action towards the neglected transport sector.

In February 2021, a number of civil society representatives, including academics, policymakers, media representatives, public health, and environmental experts from Peshawar, convened and launched the Peshawar Clean Air Alliance (PCAA) with a vision "to see the mountains of Peshawar Valley once again." Since then, the PCAA has developed an Action Plan to achieve its vision of increasing the total number of clean air days to over 100 by 2025. This voluntary civil society organization has been divided into four groups focusing on air pollution research, research into the health impacts of air pollution, alternative technologies and communication and outreach.

Improving air quality is a long term effort. It requires a shared vision that's longer than the political cycle and a multi-sectoral approach envisioned by the air quality report. Though PCAA is a small step in a long and arduous struggle, it asserts the irrefutable human right to clean air and thus many preventable diseases and deaths.

Dr. Adil Zareef

Convener

Peshawar Clean Air Alliance

Foreword

Accessibility to real-time air quality data is one of the biggest challenges for effectively tackling air pollution in Peshawar. This report sheds light on the importance of such data and rightly identifies the gaps that need to be addressed to improve air quality. Under its core mandate, the Environment Protection Agency (EPA) believes in working with all stakeholders within the government, civil society, and business community in achieving the objective of healthy air quality in Peshawar. The initiative taken in this regard by the Peshawar Clean Air Alliance (PCAA) and the Sustainable Energy & Economic Development Programme (SEED) is commendable.

Status of Air Pollution in Peshawar report is perhaps the most comprehensive and insightful endeavor undertaken to reiterate the nature and seriousness of the complex issues. Stakeholders across the board need to focus on expanding the network of air quality monitors in the city, which is crucial for localized disaggregated data, to manage and control the various sources of emissions – such as vehicles and industries – through informed policies and regulations as identified in this analytically rich report. EPA intends to work closely with other government counterparts to develop an actionable road-map to institutionalize the recommendations put forth in this report and looks forward to building a strong network with development partners to expedite action against air pollution and realize the mutually-shared vision of a clean and green Khyber Pakhtunkhwa.

Muhammad Anwar Khan

Director General
Environmental Protection Agency (EPA)
Khyber Pakhtunkhwa

Foreword

In 2021, the World Air Quality Report declared Pakistan the second most polluted country, and Peshawar to be the ninth most polluted city in the world. The average PM2.5 concentration levels in Peshawar were ten times higher than World Health Organization (WHO) standards. Such high levels of pollution are severely harmful for the health and quality of lives of the nearly two million citizens of Peshawar, as well as the economic productivity of the city that currently provides livelihoods to people throughout the province. Moreover, if these patterns continue unabated, Peshawar might soon become an unliveable city altogether.

Despite such a dire situation, there is no official operational reference standard air quality monitoring device available with the Environmental Protection Agency of Khyber Pakhtunkhwa (KP). Without real-time air pollution data and no sound insights into the primary sources of the pollution, there can be no effective regulation or policy to tackle this issue, which we believe is central to PCAA and SEED's vision of improving air quality in Peshawar.

This report is a welcome start to a journey toward improving our understanding of air pollution in Peshawar. It provides insights into the composition, variation and sources of air pollution in Peshawar. It also offers specific recommendations for the government to take firm measures against the rising air pollution before it is too late. In parallel, it encourages the civil society to advocate for a cleaner Peshawar and streamline efforts for greater local capacity and increased collaboration with the government on this issue.

I congratulate the PCAA team on this excellent and timely report. I hope that the insights and data spur an informed discussion and debate amongst policymakers and civil society

Dr. Omar Mukhtar Khan

Team Leader
Sustainable Energy & Economic Development (SEED) programme

ABOUT
THE REPORT

About the Report

Pakistan, as a country, has most recently been ranked as the second most polluted country in the world in the context of ambient air pollution. It is known to be a perennial problem in major urban areas, including the Peshawar region in Khyber Pakhtunkhwa (KP). Pakistan is also the most urbanized country in South Asia, which translates into a significant proportion of the national population impacted by air pollution.

Peshawar, in particular, lacks real-time ambient air monitoring, and year-long data for recent years does not exist. Air pollution monitoring is mandated to the KP Environment Protection Agency (KP-EPA), however, it lacks the capacity and apparatus necessary to perform these duties. With numerous industries, a population of more than 4 million, and 1 registered vehicle for every 6 persons in the city (based on 2017 census), the anthropogenic impact is significant in terms of gaseous and solid air pollutants, which in turn leads to considerable environmental and public health burden on the province.

With the exception of a few academic studies, this overall impact has not been assessed, and requires in-depth investigation in order to build actionable evidence for policy interventions and desirable mitigation. Furthermore, due to the multi-sectoral nature of air quality management, a detailed list of objectives should be defined, with relevant stakeholders highlighted for effective coordination and collaboration.

This ***Status of Air Pollution in Peshawar*** (SAPP) report addresses the voids in data, pertinent indicators, and analyzes evidence to provide input for a ***Peshawar Air-Quality Management Plan*** (PAQMP). This report is also allied with the ***Peshawar Air Pollution Rapid Assessment*** (PAPRA) report, which provides a deep-dive into the data gathered.

The proposed policy options are based in the networked governance approach, which would be conducive to inter-governmental collaboration with the civil society.

The report has been produced by the Peshawar Clean Air Alliance (PCAA), a civil society-led network of stakeholders sharing a common vision of improving Peshawar's air quality. The PCAA is formed under the UK's Foreign, Commonwealth & Development Office (FCDO) funded Sustainable Energy and Economic Development (SEED) Programme, implemented by Adam Smith International (ASI) in partnership with the government of Khyber Pakhtunkhwa (GoKP).

Contents

List of Figures & Tables **1**

Executive Summary **3**

About the Data 5

Literature Review 7

Methodology 10

Limitations 12

Air Quality Profile 14

Sectoral Profiles 22

Emissions Inventory 27

Source Apportionment 31

Discussion 34

Consultation 37

Recommendations 39

Works Cited 42

List of Figures & Tables

Figure 1 Map of Peshawar showing data-acquisition sampling area and on-ground monitors 15

Figure 2 PM2.5 Annual mean observed through CAMS 16

Figure 3 AOD Annual mean observed through CAMS 17

Figure 4 Comparison of PM2.5 observed through CAMS and US Consulate AQMS 18

Figure 5 Variation %age in PM2.5 data from CAMS and US Consulate AQMS 19

Figure 6 Comparison of PM2.5 data from AirVisual Pro (LCM) and US Consulate AQMS 20

Figure 7 Monthly PM2.5 mean for 2005-2020 21

Figure 8 Total Volume of Petroleum Products used in Khyber Pakhtunkhwa during 2016-2021 23

Figure 9 Registrations of Motor vehicles in Peshawar district during 2012-2020 24

Figure 10 Change in Motor vehicle registrations from 2012 to 2020 25

Figure 11 Number of Industrial Units in Peshawar District and in its vicinities 25

Figure 12 Petroleum Products used in the Transport and Industry sectors during AY2021 28

Figure 13 Emissions Inventory of Peshawar during AY2021 29

Figure 14 Estimated Yearly LPG use in Peshawar, based on PEYB 30

Figure 15 Estimated Yearly Gas consumption in Peshawar, based on PEYB 30

Figure 16 Estimated Yearly Biomass burning in Peshawar, based on internal calculations 30

Figure 17 Breakdown of Aerosols observed at 550m through CAMS 32

Figure 18 Source Apportionment of Air Pollution in Peshawar 33


باب خیبر

EXECUTIVE **SUMMARY**

Executive Summary

Peshawar has been declared as the 3rd most polluted city in Pakistan, and the 9th most polluted in the world, in the 2021 World Air Quality report. Over the past decade, air quality has deteriorated, which is consistent with observations in other major urban centers in Pakistan. However, the various types of pollutants, trends, and their sources, require closer investigation. This study report looks at these aspects, using all available open-source air quality data, as well as publicly released sectoral statistics from the government and private-sector to produce an emissions inventory for the Peshawar region.

The study finds that annual **Fine Particulate Matter** (PM2.5) in Peshawar has ranged between 61.40 µg/m^3 and 80.09 µg/m^3 exceeding the current national and provincial standards by 4-5 times, and the WHO air quality guidelines by 12-16 times. High levels of PM2.5 have considerable health impacts on the population of Peshawar. The city does not have an effective air quality monitoring network, run by the regulator, which has created this blind-spot.

The major sources of pollution are transport, industry, domestic solid-fuel usage, municipal waste burning, and dust. Between 2012 and 2020, the number of registered vehicles in Peshawar rose by 85%, while a larger increase (168.8%) was noted in motorbikes and scooters. The vehicle figures are likely underestimated, as anecdotal evidence suggests a significant number of vehicles plying on the roads are registered in Islamabad and other cities. Peshawar also has the highest concentration of industry in the province, and generates the most solid-waste. Consumption of various fossil fuels across these sectors and burning activity are the drivers of air pollution in the city. Among these sources, transport emissions contribute more than half (58.46%), followed by dust, domestic sector, industry, waste-burning, and lastly commercial activity.

Based on these findings, the study recommends: (1) Expanding monitoring capacity [to increase public awareness and enable precautionary measures]; (2) Encouraging higher public transport usage, [through better accessibility, incentives, and public communications]; (3) Developing alternative and/or subsidized heating methods [to curtail wood-burning]; (4) Behavioral change campaigning [publicizing affordability and eco-friendliness of alternative transport and fuel options]; (5) Aligning urban forestation [for air quality management]; and (6) Increasing role of civil society, universities, startups and private sector [by streamlining efforts and creating forums for collaboration].

ABOUT
THE DATA

About the Data

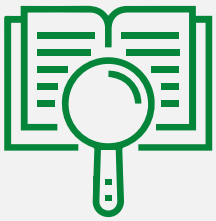
The primary purpose of this report is to serve as a guide to air pollution trends and its sources in the Peshawar region. The report is a first-step towards developing detailed data-sets and analyses, which inform policy interventions for air-quality management in the region. As consistent monitoring and validated air-quality data is unavailable from the public regulator, this report largely depends on open-access data from multiple sources, for Fine Particulate Matter (PM2.5) and Aerosol Optical Depth (AOD). Data harmonization and extrapolation were performed where required. The collated data-sets were also thoroughly reviewed and evaluated over various time periods and with other comparable measurements to ensure validity and robustness.

As mentioned, the report focuses on PM2.5 and aerosol data. This preference has been taken as most contemporary standards indicate that PM2.5 has the highest impact on public health, while AOD is used to guide source apportionment and component analysis of air pollution. The analysis has been initially done in the data-analysis report, parts of which have been reproduced in this report.

For the source apportionment of air pollution, the report relies on quantification of cumulative emissions, by developing an emissions inventory of the Peshawar region. This approach is relatively less technical than source-oriented models and receptor-oriented models. However, this method has been selected due to the requirements and limitations of this study. Further, it is commonly used in contexts where air pollution assessments have previously not been done.

Emissions inventories are a comprehensive stock-take of assumed emissions based on various anthropogenic activities. This requires detailed assessments of key sectors, to account for their individual emissions, and is summed together. The calculation uses predetermined emission factors (EF) for the estimation of major pollutants. Major international non-governmental organizations such as the European Energy Agency (EEA), International Energy Agency (IEA), and Inter-governmental Panel on Climate Change (IPCC) have developed EF databases for aerosol and green-house gas emissions. This study uses the EEA database, which is preferred because of its more recent update.

Lastly, the report peruses several secondary data-sources and systematizes them into required input data-sets for the calculation of sectoral emissions. These sources include government departments and organizations. Certain important data-points, such as fuel usage in the region, are also corroborated using information from non-governmental/private sector organizations. Limited information was found during the literature review, however, all sources are cited wherever used.



LITERATURE **REVIEW**

Literature Review

A wide array of reports and studies were examined to assess the depth of existing evidence available on air pollution indicators for the Peshawar region. Within the review, limited to no information was available on the source apportionment of pollution. Several reports, particularly technical assistance documents from International Non Government Organiszations (INGOs), record levels of particulate matter and gaseous pollutants from various years. However, this data is inconsistent, with measurements not available for concurrent time-periods, using different methods or instruments for measurements, and/or using varying standards depending on the years they were recorded in. Among academia, most interest seems to be in the 'extremely polluted' regions of Punjab, the Federal Capital territory, and Karachi 'the financial hub'.

A review of such studies, from 2009, mentions 50 papers, but among them, not a single one covered or focused on Peshawar, particularly for particulate matter.[1] However, this list was not inclusive of collaborative studies between researchers and organizations. Our review suggests that earliest measurements of particulate matter (PM) available for Peshawar were recorded in the mid-1990s as part of assistance provided by the Japan International Cooperation Agency (JICA), which have been reproduced by Qadir (2001) for the Asian Development Bank (ADB).[2] Ghauri et al. (2007) present measurements of total suspended particulate (TSP) from monitoring conducted during 2003-2004 at five sites in Peshawar by the Pakistan Space & Upper Atmosphere Research Commission (SUPARCO).[3] This is followed by coarse particulate matter (PM10) measurements taken during 2004, which were published by the Worldbank (2006c) as part of the Pakistan Country Strategic Environment Assessment.[4] Further, Cleaning Pakistan's Air published by the Worldbank (2014) provides measurements for Fine Particulate matter (PM2.5) from 2007 to 2010.[5] Alam et al. (2011) provide PM10, PM2.5 and PM1 measurements for a short-period from 2010.[6] Again, Alam et al. (2015) analyze both coarse and fine particulate matter measurements taken in 2011, and provide source apportionment for PM10.[7] This study used Positive Matrix Factorization (PMF) with receptor-oriented modelling for source apportionment, and found re-suspended soil/dust, transportation, kilns, domestic fuel burning and small-industries as the sources of PM10 in Peshawar.

1 "The state of ambient air quality in Pakistan—a review." Colbeck et al. (2009). *Environmental Science and Pollution Research.*

2 Air Quality in Urban areas in Pakistan Vs Transport Planning: Issues and Management tools." Qadir (2001). *Asian Development Bank.*

3 "Development of baseline (air quality) data in Pakistan." Ghauri et al. (2007). *Environmental Monitoring and Assessment.*

4 Pakistan Country Strategic Environment Assessment (2006c). *Worldbank.*

5 Cleaning Pakistan's Air: Policy Options to Address the Cost of Outdoor Air Pollution." Sánchez-Triana et al. (2014). *Worldbank.*

6 "Aerosol size distribution and mass concentration measurements in various cities of Pakistan." Alam et al. (2011). *Journal of Environmental Monitoring.*

7 "Particulate Matter and Its Source Apportionment in Peshawar, Northern Pakistan." Alam et al. (2015). *Aerosol and Air Quality Research.*

More recently, with the installation of reference-standard monitoring equipment at the US Embassy and Consulates (including in Peshawar) and the availability of low-cost monitors has brought considerable attention to worsening air pollution in Pakistan. The World Air Quality reports (2019, 2020, 2021) released by IQAir publish PM2.5 data for major Pakistani cities, along with a ranking.[8] Similarly, Worldbank Country Environment Analysis (2019) includes Low-cost monitor data.[9]

The Air-Quality Life Index (AQLI) under the Energy Policy Institute at University of Chicago (EPIC) published PM2.5 data, derived from satellite-based analysis, for Pakistani cities (Greenstone and Fan, 2019).[10] Satellite-based analyses have become more reliable with significant advances and investments in remote-sensing instruments on international satellites, and hence, see increased usage due to easier data-accessibility, consistency, and reduced monitoring costs. This approach is also used in the UN Food and Agriculture Organization (FAO) assistance to the Agriculture Department of the Govt. of the Punjab in determining air pollution trends in winter-smog impacted areas of Punjab (2018).[11] Bilal et al. (2021) also use this approach to collate air-quality data across many Pakistani cities, and rank them on the basis of pollution trends.[12]

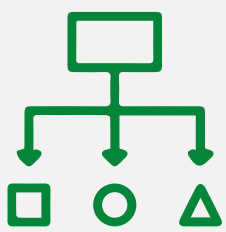
8 World Air Quality reports (2019, 2020, and 2021). IQAir. <https://www.iqair.com/world-air-quality-report>

9 "Opportunities for a Clean and Green Pakistan: A Country Environmental Analysis." (2019). *Worldbank.*

10 "Pakistan's Air Pollution Challenge & Potential for Longer Lives." Greenstone and Fan (2019). *Air Quality Life Index.*

11 Remote-sensing for Spatio-temporal Mapping of Smog in Punjab and Identification of Underlying causes using GIS techniques." 2018. *Food and Agriculture Organization of the United Nations (FAO).*

12 "Air pollution scenario over Pakistan: Characterization and ranking of extremely polluted cities using long-term concentrations of aerosols and trace gases." Bilal et al. (2021). *Remote Sensing of Environment.*



METHODOLOGY

Methodology

This study used a mixed methods approach, combining primary and secondary sources for data-gathering. This is supplemented with qualitative insights through a Focus Group Discussion (FGDs) and Key Informant Interviews (KIIs)-with participants selected through convenience sampling, covering various stakeholders, including departmental officials, civil society members and industry representatives. These conversations were primarily conducted to understand the existing institutional landscape for air-quality management, its capacity, limitations, and scope for possible synergies among them and with civil society. The Key Informants (KIs) belonged to Peshawar City Traffic Police and KP Economic Zones Development and Management Company (KPEZDMC).

For primary and secondary data acquisition, the methodology takes into account the paucity of air-quality data available for the region, and uses various open-source datasets to fill in gaps, and depends on various public statistical reports for other variables. This has been described in detail in the 'About the Data' section. The data sources used for air-quality were AirNow (US Embassies & Consulates database), IQAir, and Copernicus Atmospheric Monitoring Service (CAMS). During the study period, daily data for a two-week period was also recorded through a low-cost monitor.

Sectoral data-sets were developed using official reported statistics recorded in the Development Statistics of Khyber Pakhtunkhwa[13] for various years. Monthly petroleum consumption figures have also been sourced from reports of the Oil Companies Advisory Council (OCAC). Further, to isolate variables for Peshawar region, various estimations have been taken where required, which were linked to population, household, industry, and transportation figures. These estimations are also adjusted based on unpublished figures shared during KIIs. The calculation approach for each sector is described in the data analysis section.

The study also relied on guidance and review by the SEED team. Before finalization of the report and its recommendations, the data-analysis report and the draft of this study underwent thorough feedback. Lastly, a workshop was organized under the auspices of the PCAA and the draft was also presented to the members in attendance for their suggestions and advice. All such recommendations and revisions have been incorporated into various parts of the study, and a summary of the workshop is included as a separate section.

13 "Development Statistics of Khyber Pakhtunkhwa." Bureau of Statistics, Planning & Development Department. *Govt. of Khyber Pakhtunkhwa.*

LIMITATIONS

Limitations

The study has several limitations, due to both the nature of the research design as well as the limited technical capacity for air-quality monitoring in Pakistan. These limitations have also been recognized as part of the inception report, and do not impact the objectives of this study.

The study period was December 2021 and January 2022, which meant it was not practicable to implement a city-wide, on-ground survey of households, traffic or industry. Therefore, estimated figures are used, which are likely to either under-report or over-report pollutants in the emissions inventory. However, the margin of variation would be small, and does not impact the overall purpose of this study. All adjustments and assumptions are mentioned, alongside the reasoning for applying them.

Firstly, on-ground air-quality data is very limited, with consistent daily data only available from May 2019 onwards through the US Consulate in Peshawar. Further, past data is scanty, with significant coverage gaps. As discussed in the literature review, not much academic research has been conducted on air-quality in the Peshawar region.

Secondly, the study does not include a chemical composition analysis segment, which restricts deeper sectoral evaluation and pollutant examination. Such an analysis may also reduce inaccuracies in source apportionment. This limitation was unavoidable, among other reasons, because samples of air for only winter months was possible.

Thirdly, the process of developing emissions inventories has inherent uncertainties, which include over-simplification, incompleteness due to model limitations, and lack of representative data that shows real-world emissions.

Lastly, as a significant part of the study depends on statistics reported by the government departments and other relevant bodies as well as on pre-defined emission factors, it is possible that inaccuracies in them impacted the quality of the data-sets developed based on them. For certain anthropogenic activities, such as wood-burning, only estimations are possible. Similarly, complex combustion activities are considered in a simplified manner as required variables for emissions calculations were not available.

AIR QUALITY **PROFILE**

Air Quality Profile

The Peshawar district covers an area of 1,518 km² and is home to approximately 5 million people (2020 estimate); among them, nearly half reside in the urban areas of Peshawar city. Poor air quality in the region has a varying degree of health impact on the population. The Air-Quality Life Index (AQLI) estimates that citizens of Peshawar can add up to 2.3 years to their life-expectancy if PM2.5 levels meet World Health Organization (WHO) guidelines.[14] Turning this estimate around, this also means that currently they are losing these years because of high levels of air pollution.

For the purposes of creating an air quality profile, the Peshawar city region is considered geospatially, on the basis of a shared air mass (selected as a bounded box), covering an area of approximately 514 km².

Figure 1: Map of Peshawar Showing Data-Acquisition Sampling Area and On-Ground Monitors

As visible, the area covers what is considered the 'central zone' or the urban area of the Peshawar district. This area also has the largest industrial cluster in the district. However, it can be assumed that air pollution within this zone may also originate from the outside.

14 "Pakistan's Air Pollution Challenge & Potential for Longer Lives." Greenstone and Fan (2019). *Air Quality Life Index.*

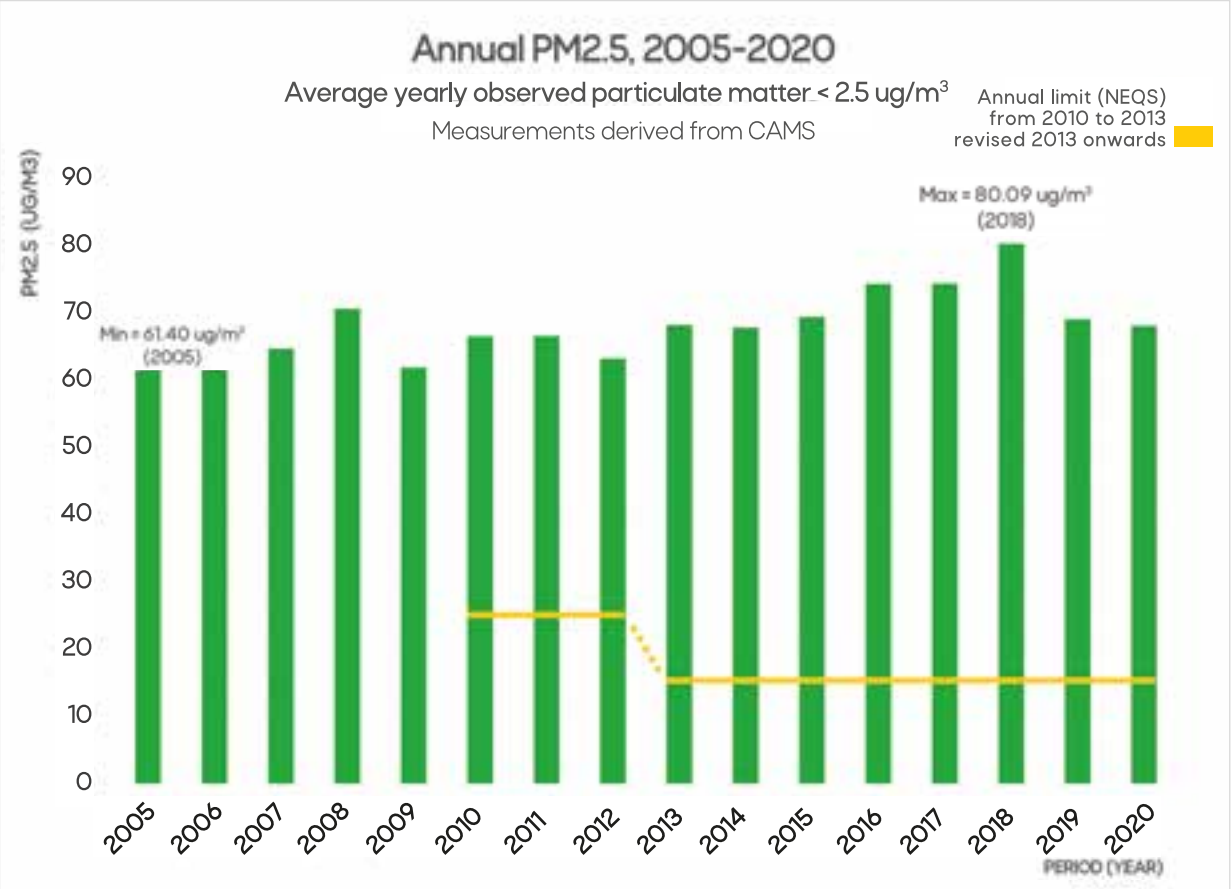


Figure 2: PM2.5 Annual Mean Observed Through CAMS

For this area, the satellite-based dataset of the Copernicus Atmosphere Monitoring Service (CAMS) has been acquired to assess long-range annual and monthly PM2.5 levels and establish trends of air pollution in the region. This dataset is available from 2005 to the current period, hence, it provides PM2.5 data for more than 16 years. The average yearly values have been illustrated on the following page.

The data indicates that PM2.5 levels have been higher in every year since 2005, when the dataset begins. The annual mean in 2005 was 61.4 µg/m^3. It can be further observed that the highest PM2.5 annual mean was recorded in 2018, at 80.09 µg/m^3. For all available years, the PM2.5 amount is more than 4 times above the current annual limit of 15 µg/m^3, as defined under the Provincial Environment Quality Standards (PEQS) for Ambient Air.

The noticeable anomaly of 2018 is further investigated using Aerosols data from CAMS.

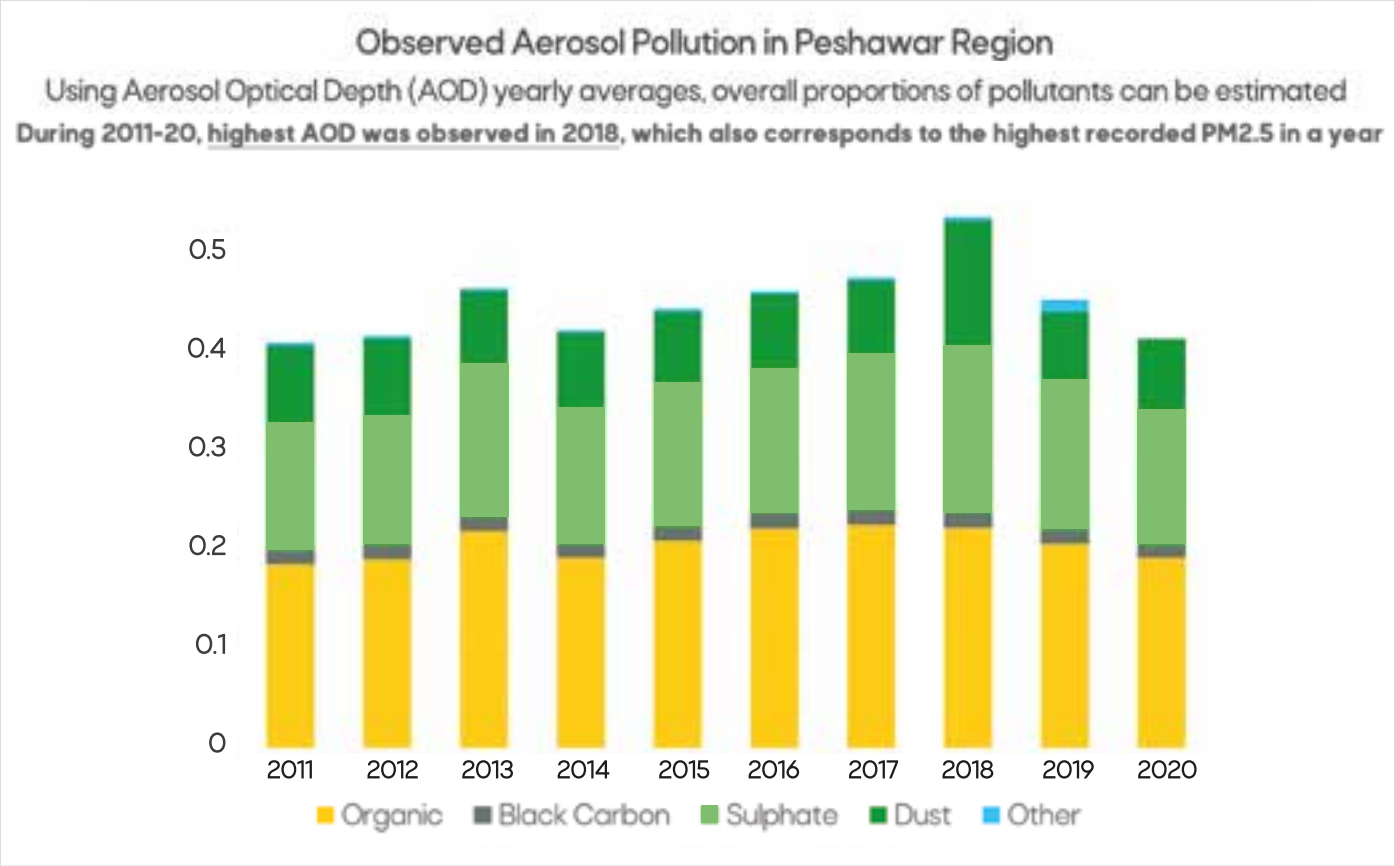


Figure 3: AOD Annual Mean Observed Through CAMS

The data indicates that unusually high amounts of dust aerosol was observed during the year, which may have been caused either by lower rainfall or due to the large-scale infrastructure construction activity for the development of the Peshawar Bus Rapid Transit (BRT).

Separately, the PM2.5 measurements from a BAM-1020 Air Quality monitoring station (AQMS), located at the US Consulate in Peshawar has also been acquired, which is available from May 2019 till date. Lastly, during the data-analysis period (January 2022), a low-cost monitor (LCM) was also placed in the Hayatabad area of Peshawar. The locations of these on-ground monitors have also been indicated in the map provided above.

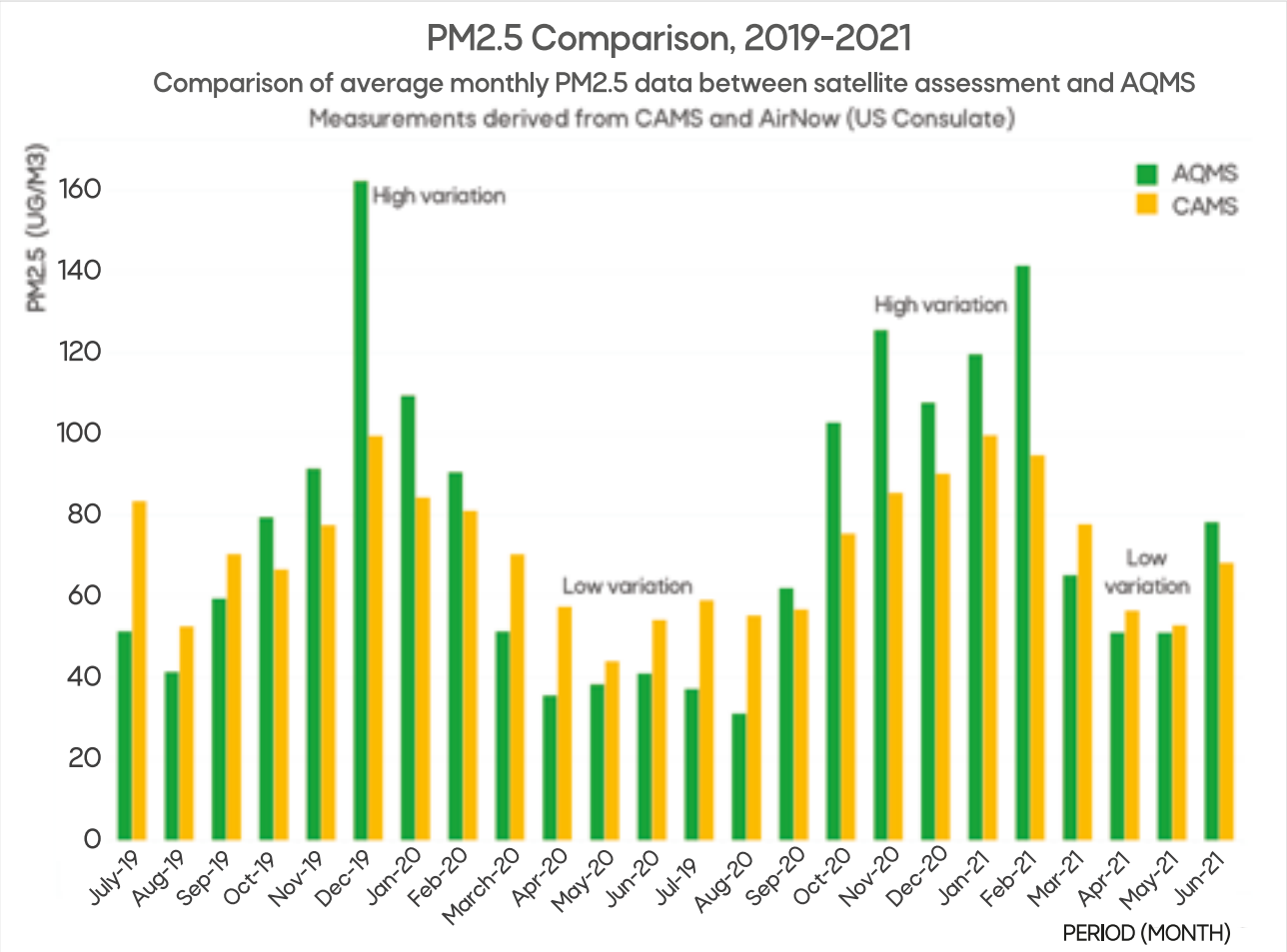


Figure 4: Comparison of PM2.5 Observed Through CAMS and US Consulate AQMS

While Satellite-based assessments provide regional information, the on-ground monitors are more useful for micro-level data, which is essential for local air-quality management. A comparison of data from CAMS and the AQMS shows that the air pollution trend between the two is largely correlated. However, the AQMS is more sensitive to high and low measurements, while data from CAMS varies lightly.

This is similar to taking the average of multiple on-ground monitors placed across the region, which has areas of high and low pollution, with the mean value nullifying extremes.

Therefore, it is also important to expand the network of on-ground monitoring in Peshawar, with both Reference-standard AQMSs and LCMs deployed around the city to get an accurate representation of city-wide air pollution.

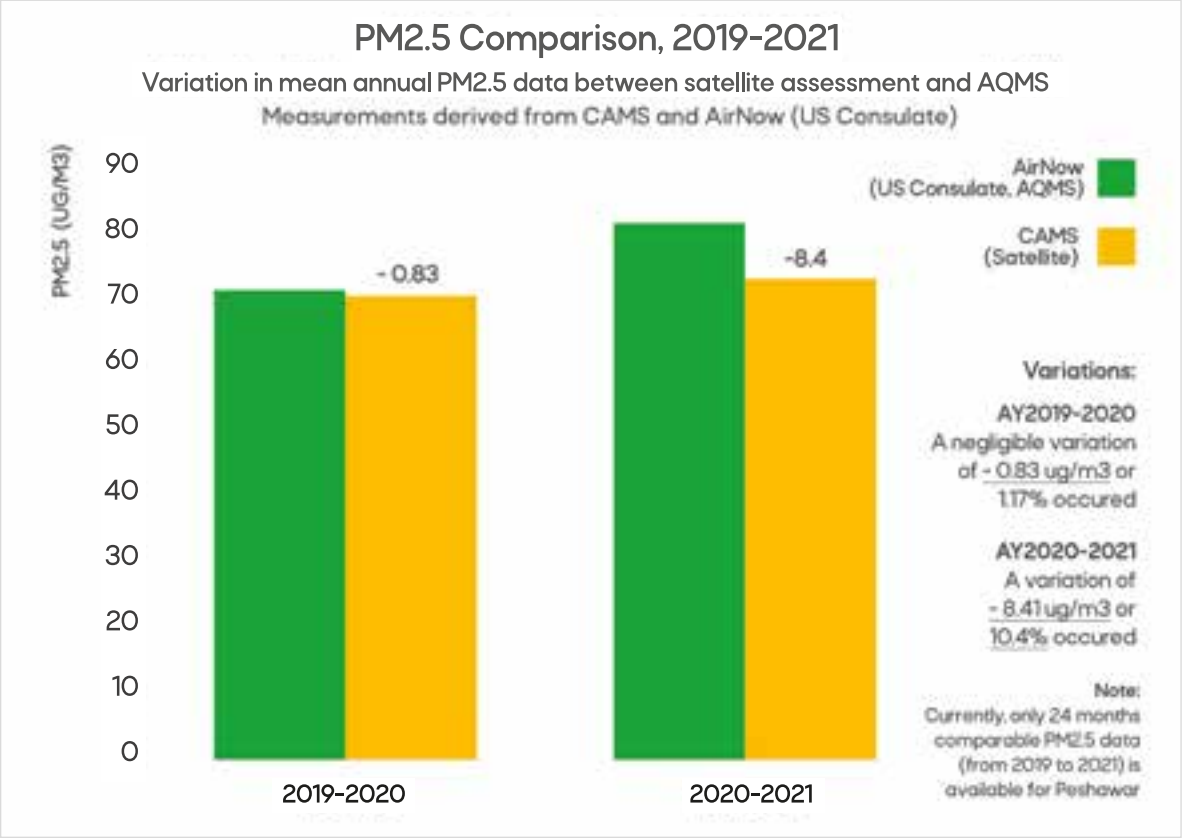


Figure 5: Variation Percentage in PM2.5 Data From CAMS and US Consulate AQMS

During 2020-21, the single AQMS recorded a 10.4% per cent higher mean PM2.5 as compared to measurements from CAMS, with variations mostly occurring during the colder months of the year. Bilal et al. (2021) also report that data from CAMS, although correlated with on-ground monitors, underestimates or overestimates measurements depending on the grid size used for data retrieval. Therefore, it is also important to expand the network of on-ground monitoring in Peshawar, with both Reference-standard AQMSs and LCMs deployed around the city to get an accurate representation of city-wide air pollution.

To further assess this, during the analysis period, the data from the AQMS and LCM was also recorded over two weeks and compared. As seen in the map, the LCM was placed in a suburban locality, at the edge of the analysis area, where surrounding PM emissions are observed to be lower than the central location of the AQMS, but follow a similar trend. The mean value for both monitors was taken, and is assumed as the average of the larger area between them. The AQMS recorded 10.13% higher PM2.5 compared to the mean, which is very similar to the variation with CAMS (i.e. 10.4%).

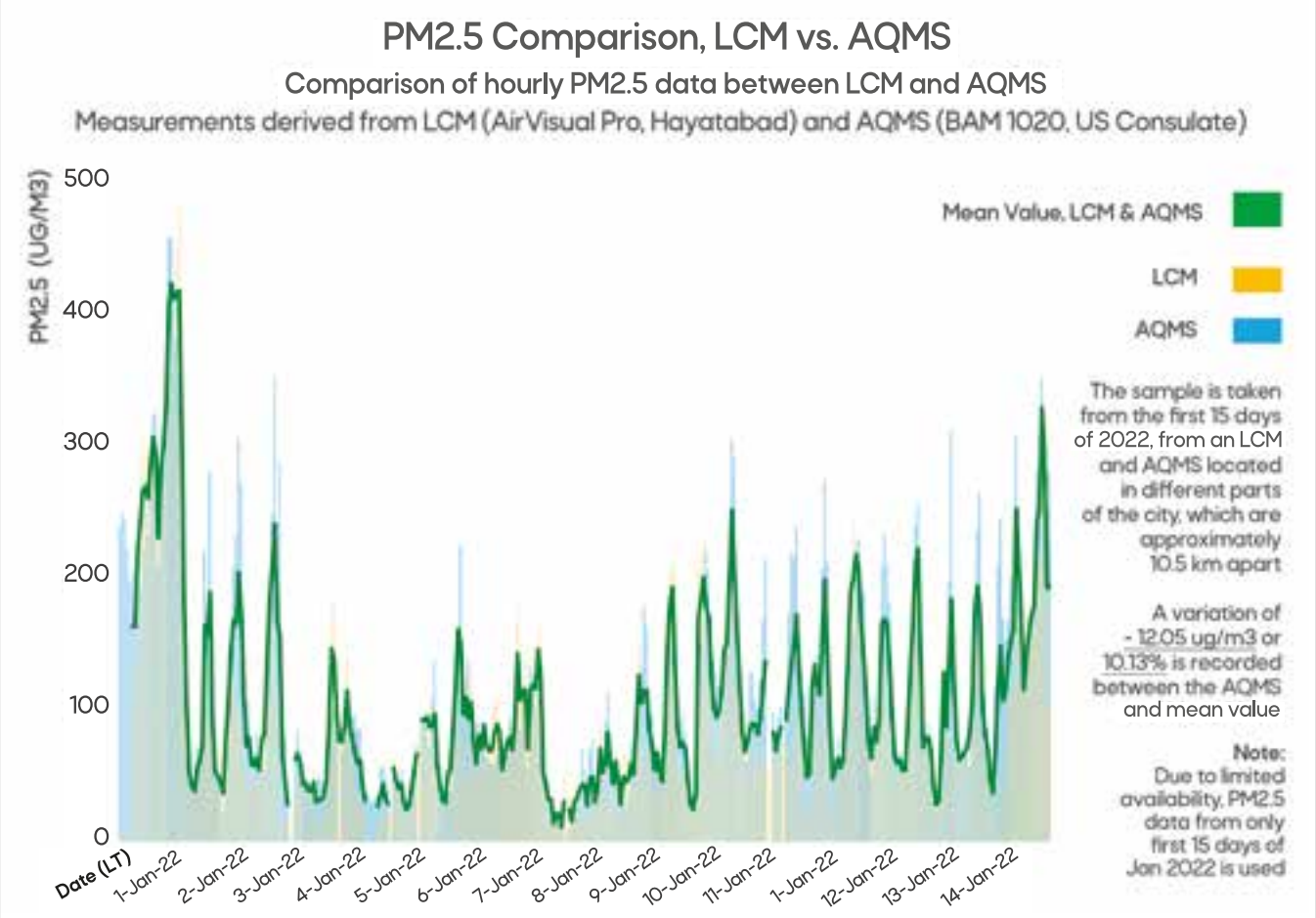


Figure 6: Comparison of PM2.5 Data From AirVisual Pro (LCM) and US Consulate AQMS

Lastly, from the CAMS dataset, it is also seen that a suppression of the pollution increase trend is observed from 2009 to 2014. As most economic activity is heavily dependent on fossil fuel usage in the country, this was likely due to economic slowdown during this period owing to the security situation in Khyber Pakhtunkhwa and high-costs of fuel imports, which further suppressed energy use in various sectors.

From mid-2014 onwards, the trend of increasing pollution appears to have resumed, which peaked in January 2018. Afterwards, another period of economic slowdown, followed by the Covid-19 pandemic, triggered a suppression and decline in pollution levels, which are likely to have risen back again in 2021.

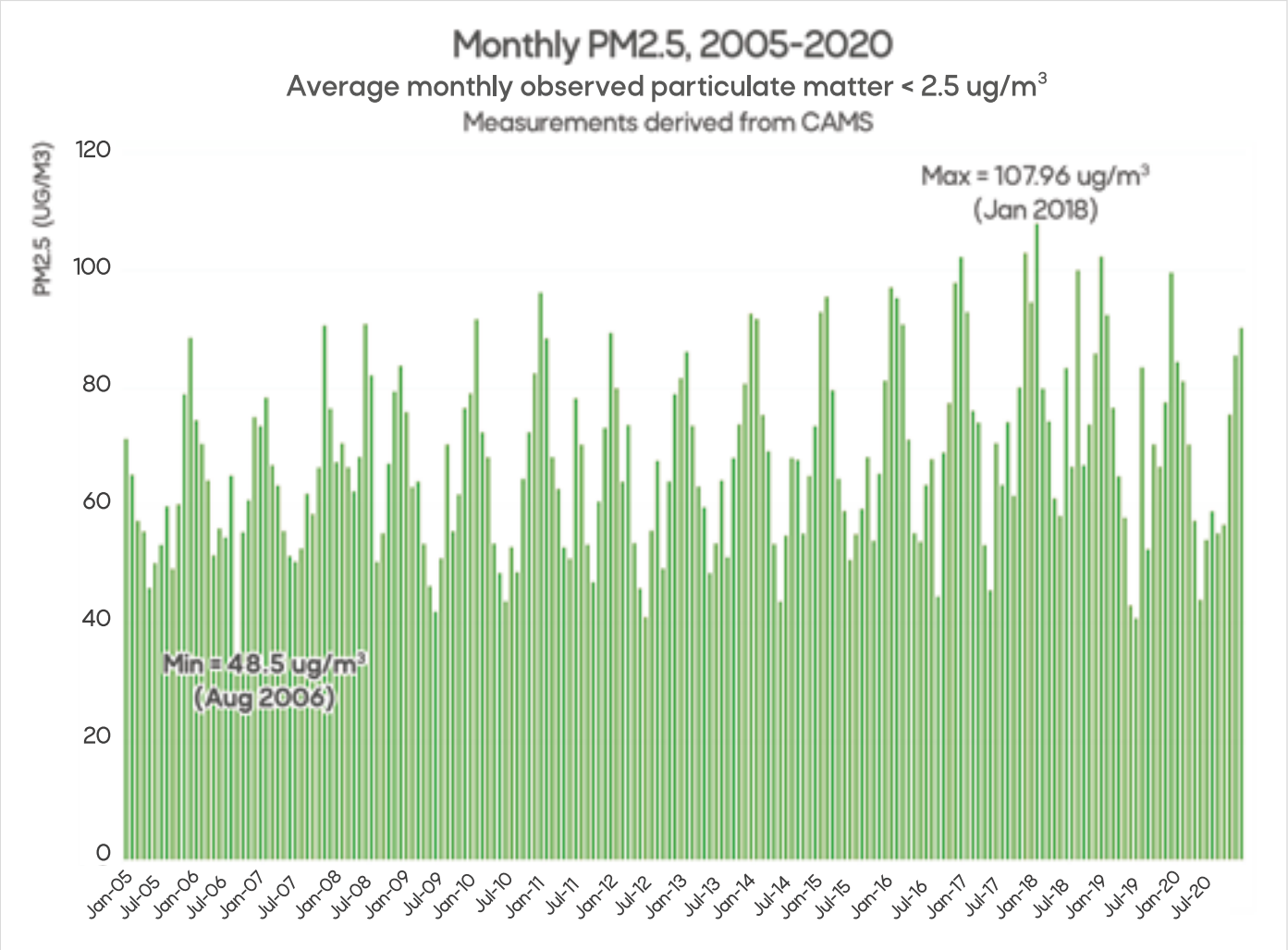
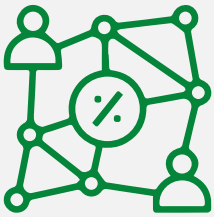


Figure 7: Monthly PM2.5 Mean For 2005-2020

As stated earlier, the available data indicates that the Peshawar region has not complied with the National or Provincial standards for annual PM2.5 average, at least for the past 17 years. This further suggests that the public health impact on the current working-age population during their growing years would have been considerable, translating into increased disease burden and incidence of various respiratory illnesses. The current trends indicate that immediate steps are necessary to prevent extensive public health impact.



SECTORAL **PROFILES**

Sectoral Profiles

In order to develop the Peshawar region's emissions inventory, it is necessary to assess all pertinent sectors, such as transport and industry. For the purposes of this assessment, the mentioned sectors, along with domestic, commercial and waste-burning, have been considered.

Significant gaps in data and records exist relevant to all the above sectors, while anecdotal information also indicates that available data may not be completely accurate. Information on the domestic and commercial sectors is particularly scanty, other than some indications of province-wise fuel supply information. Therefore, several such data-points have been extrapolated where limited information or at least a single variable is available. In other cases, assumptions have been made on the basis of previous years, sector-size and proportional ratios. The highest accuracy among all would be for the transport sector, followed by industry.

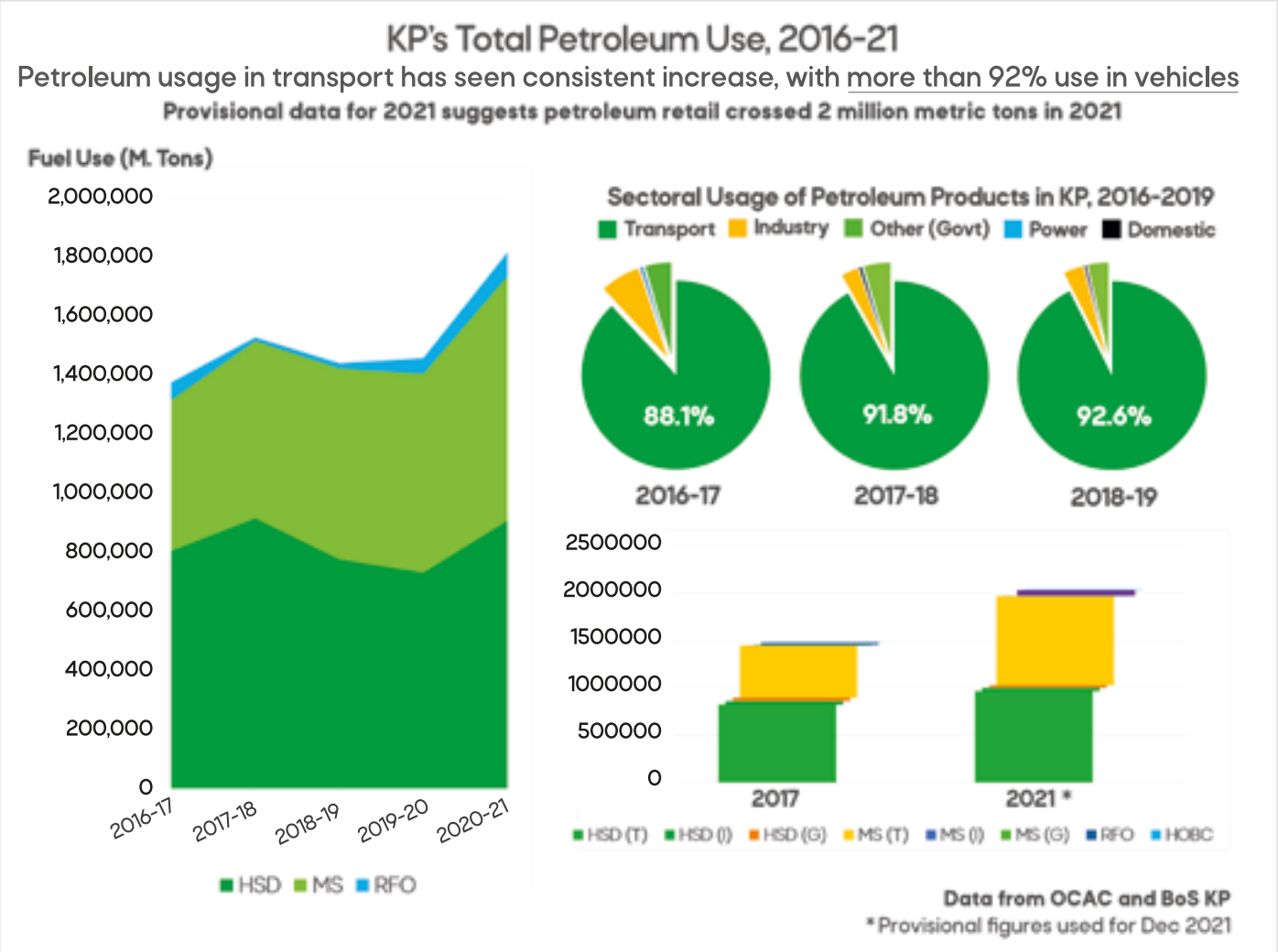


Figure 8: Total Volume of Petroleum Products Used in Khyber Pakhtunkhwa During 2016-2021

Transport sector is broken down into various motor-vehicle (MV) type categories per district. For Peshawar, we assume that the MVs registered in the district are most likely to be operating in the region (i.e. Peshawar city and its vicinities). This assumption means that we do not consider MVs registered elsewhere (i.e. Islamabad or Punjab), which might as well be operating in Peshawar, as well as the fact that all registered in Peshawar do not operate elsewhere. As numbers for such vehicles are not available, the number of total MVs registered is assumed as actual.

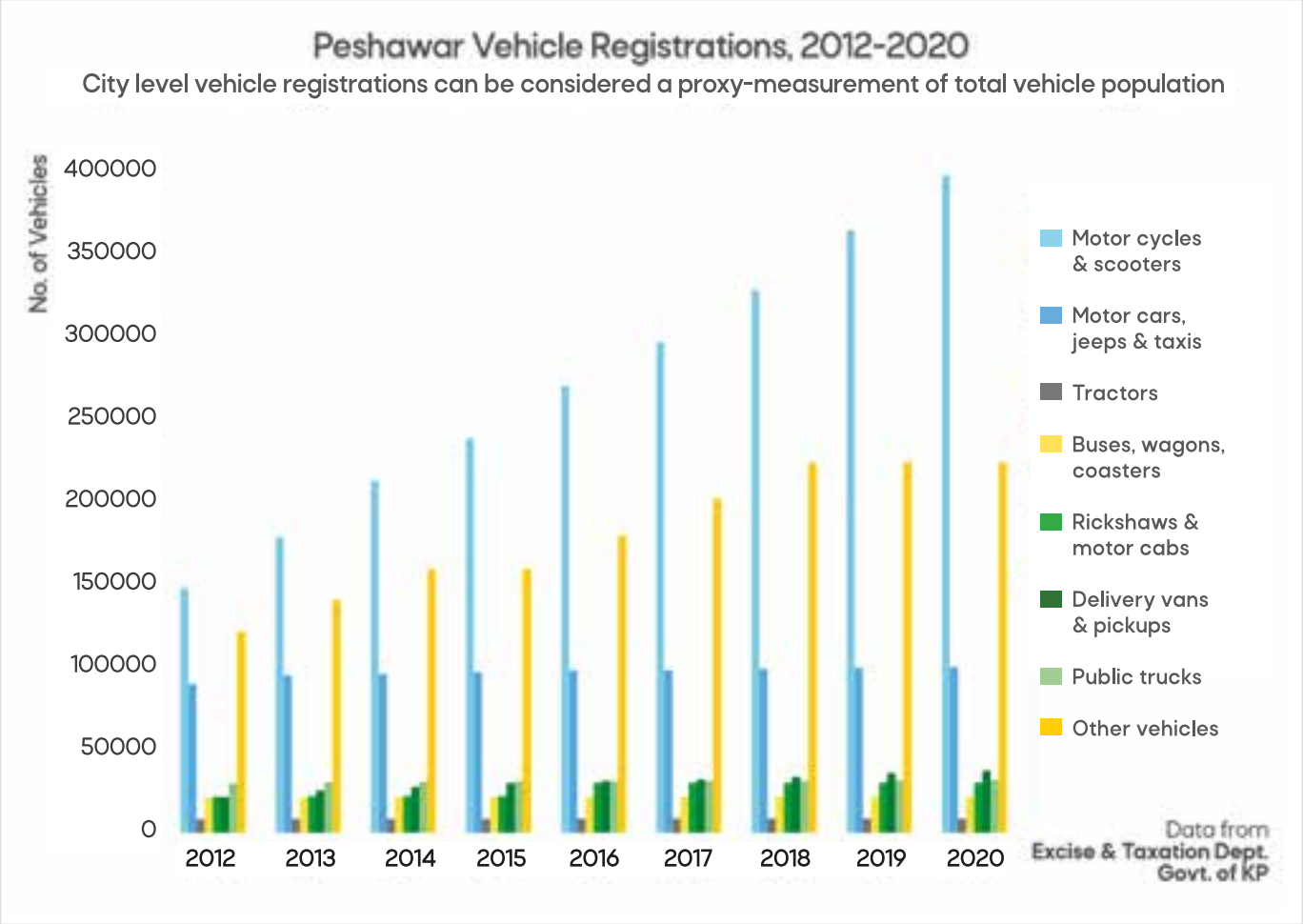


Figure 9: Registrations of Motor Vehicles in Peshawar District During 2012-2020

The official data indicates that nearly 850,000 MVs were registered by the end of 2020, with nearly half of them 'Motor-cycles & scooters'. From 2012 to 2020, the latter has increased by 168.8%, which indicates higher mobility needs but unavailability of adequate transit options.

Motor-vehicles in Peshawar are the highest among all districts in Khyber Pakhtunkhwa, owing to the city being the provincial capital, but also likely due to higher buying power. About 42.7% of all registered MVs in the province are from the Peshawar district. The proportion for 'Motor-cars, Jeeps & Taxis' is the highest at 54.9% of all MVs of this category in the province. This also means that the Peshawar region consumes the highest amount of various petroleum fuel products in the province.

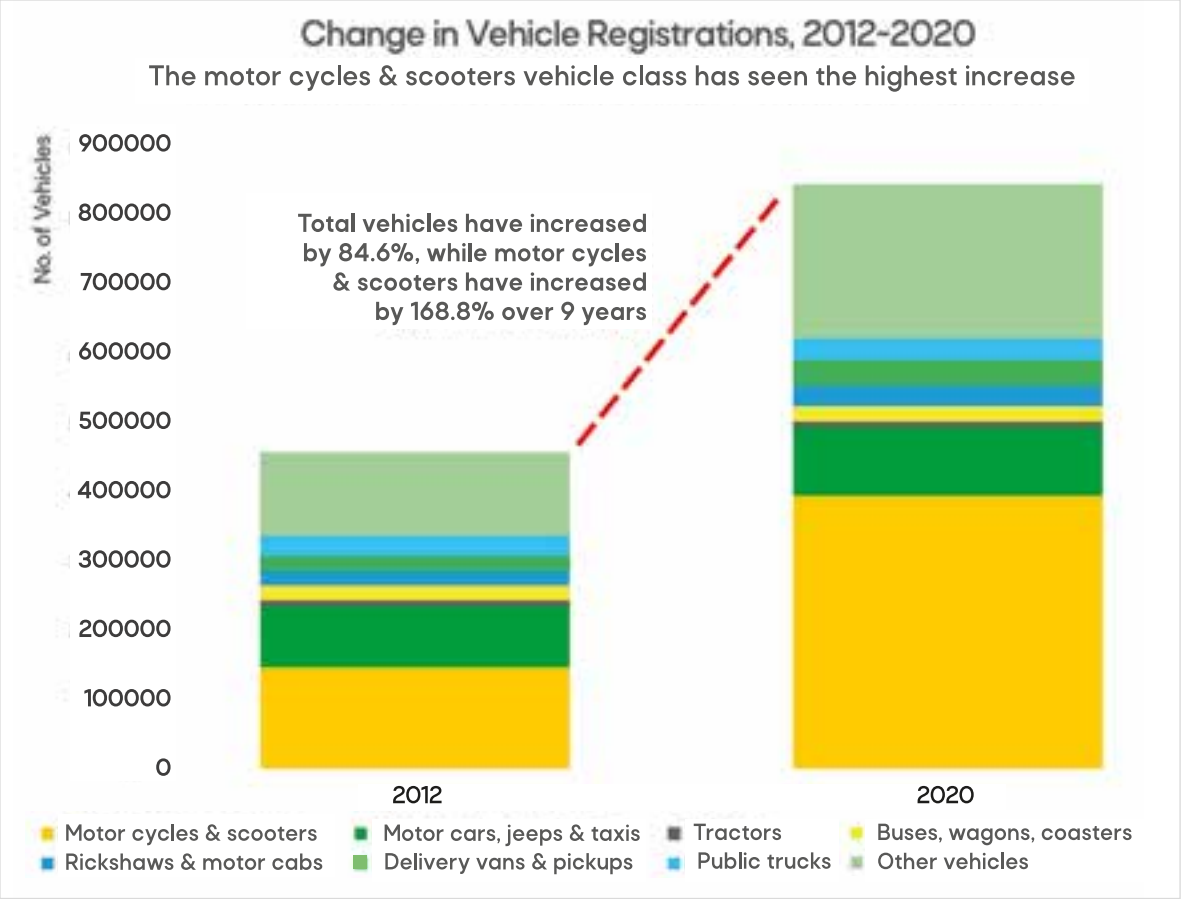


Figure 10: Change in Motor Vehicle Registrations From 2012 to 2020

Industry sector is similarly simpler to assess as the number of various industrial units in the district and the sector's proportional fuel usage is known. However, the quantum of use by type of industry, the type of boiler or burner and the efficiency of the combustion process is not known. It is hence assumed that fuels used by industries (including brick kilns) are linked to the size of the industry sector. According to figures from the KP Directorate of Industries & Commerce, more than 3,000 industrial units were operational in the province, while approximately 900 of these were located in the Peshawar district. It has also been estimated that 450 brick kilns are located in the district, of which most are towards the East, along the National Highway, and in the South, in the rural zone.

Industrial activity, particularly boilers, furnaces and kilns, use brown coal (lignite) or coke, both of which are highly polluting. However, key variables such as quantum used per sector are not available. Separately, these figures may not be inclusive of informal, small-scale industrial activities. Due to these reasons, the industry sector profile may be considered limited only to official reported numbers.

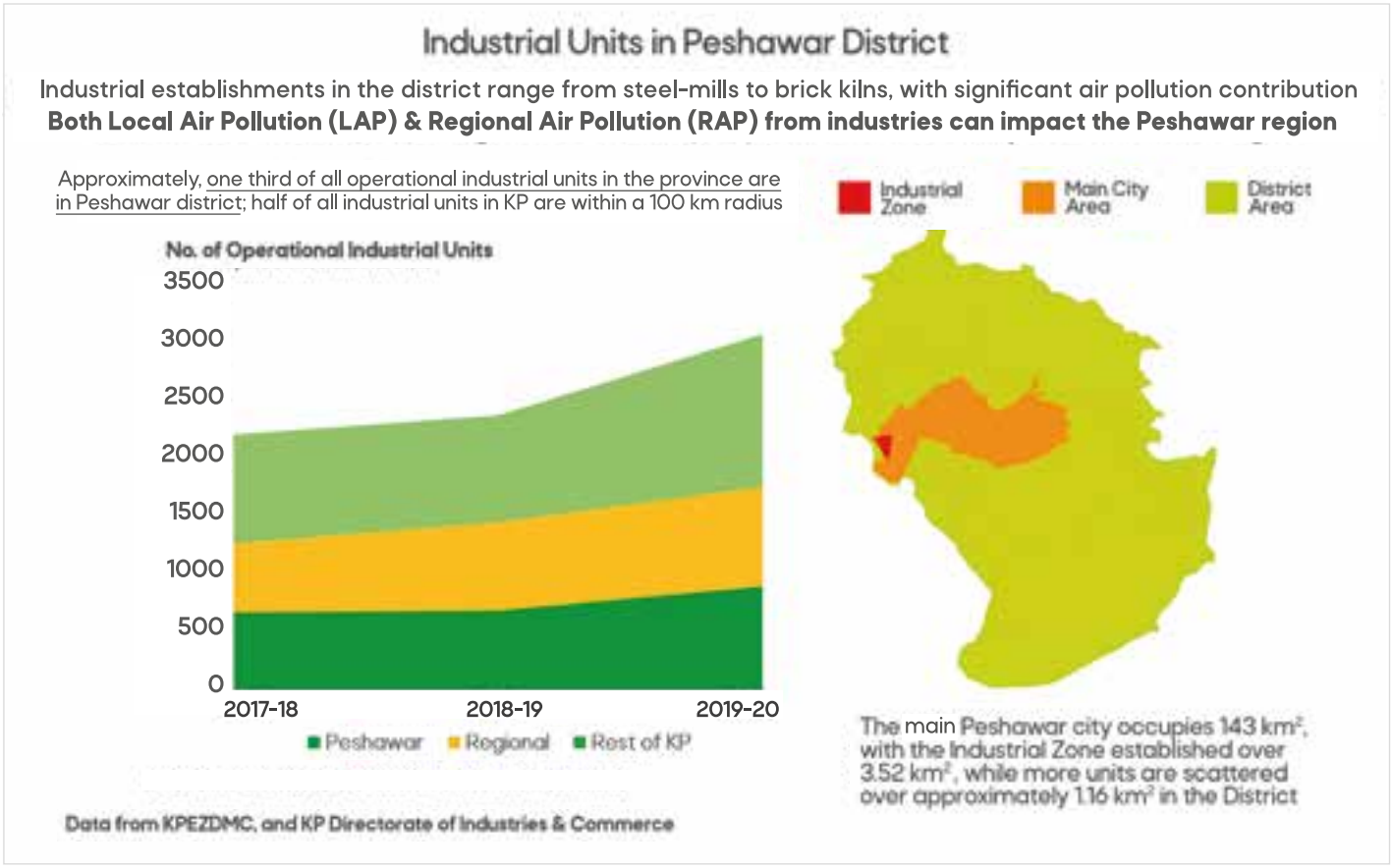


Figure 11: Number of Industrial Units in Peshawar District and in its Vicinities

Specified and detailed information on domestic and commercial sector activity is very limited. For the purposes of this assessment, the numbers have been extrapolated and scaled on the basis of population and households. Similarly, for waste-burning, it is assumed that one-fifth of the waste generated in Peshawar is burned. These figures are mentioned in the next section.

EMISSIONS **INVENTORY**

Emissions Inventory

An emissions inventory of a region is a comprehensive breakdown of the total pollutants in the air, on the basis of various combustion activities. The inventory aims to report 5 key air pollutants, namely Oxides of Nitrogen (NOX), Sulphur Dioxide (SO2), Carbon Monoxide (CO), Particulate Matter (PM) and Non-methane Volatile Organic Compounds (NMVOCs).

Various guidelines have been established by the European Energy Agency (EEA), International Energy Agency (IEA) and Intergovernmental Panel on Climate Change (IPCC) for calculating emissions inventory, through pre-determined emissions factors. This assessment uses EEA Tier 1 methodology, which accounts for the low-quality of datasets by adjusting through confidence intervals.

Based on provincial petroleum supply data, it is estimated that the Peshawar region consumed approximately 794,642 tons of petroleum fuel products during 2020-21. This is further broken down on the basis of petroleum type and sector usage.

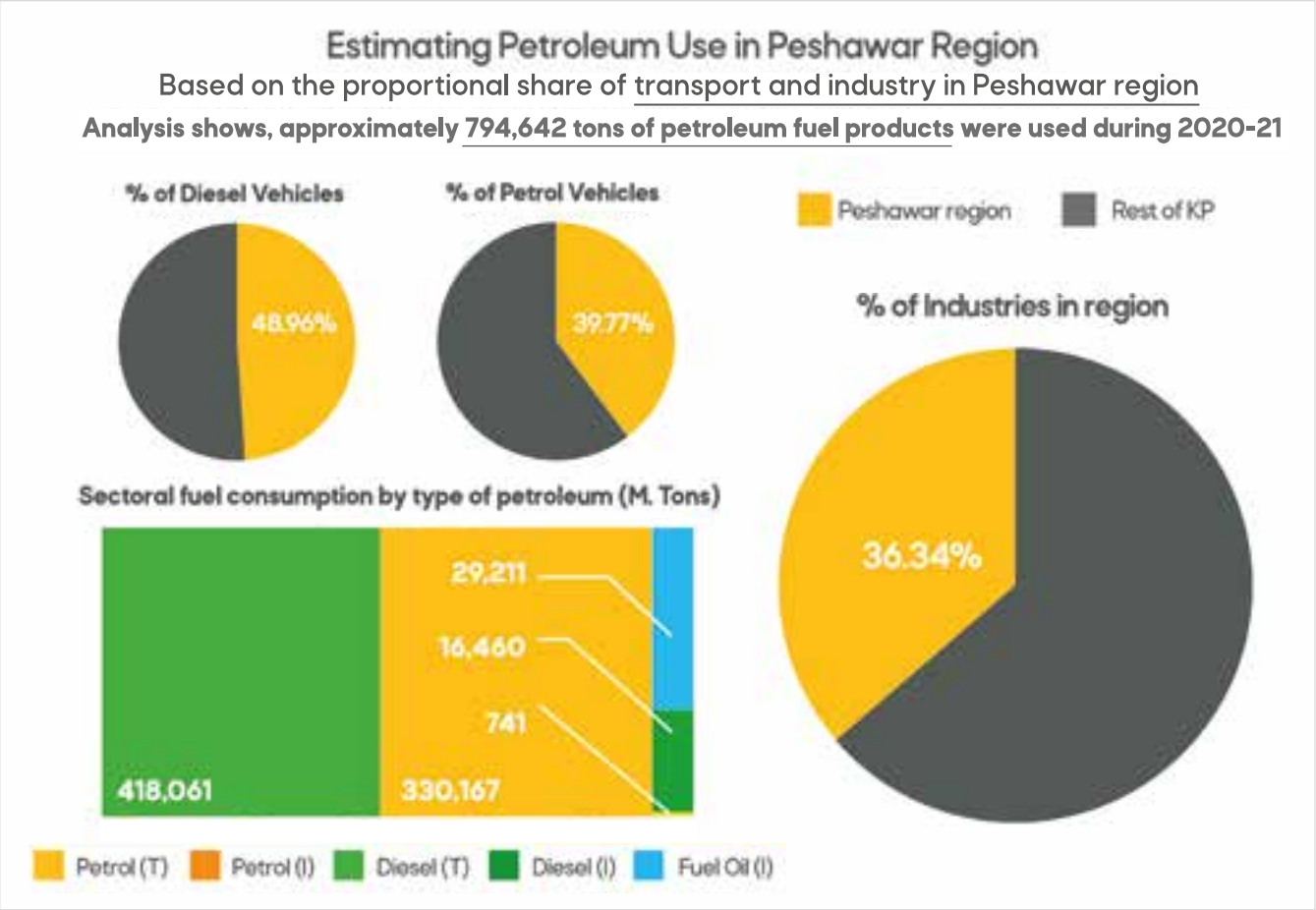


Figure 12: Petroleum Products Used in the Transport and Industry Sectors During AY2021

As no thermal power station operates in the Peshawar region, emissions from the power sector are negligible, and all fuel oil is assumed to be utilized by Industries. Diesel generator-sets are not separately accounted for, although diesel usage in the region includes any proportion used by domestic, commercial and industrial use of gen-sets.

Furthermore, based on analysis of reported data from the Pakistan Energy Yearbook (PEYB),[15] on average, nearly 14,000 tons of Liquefied Petroleum Gas (LPG) and 12,500 million cubic feet of Natural Gas (Gas) is consumed in the domestic, commercial, industry and transport sectors in Peshawar. In addition to this, an estimated 137,500 tons of brown coal (lignite) is also used in the region. Lastly, up to 200,000 tons of waste is generated in the city annually, of which a fraction is burnt for disposal or supplementary heating.

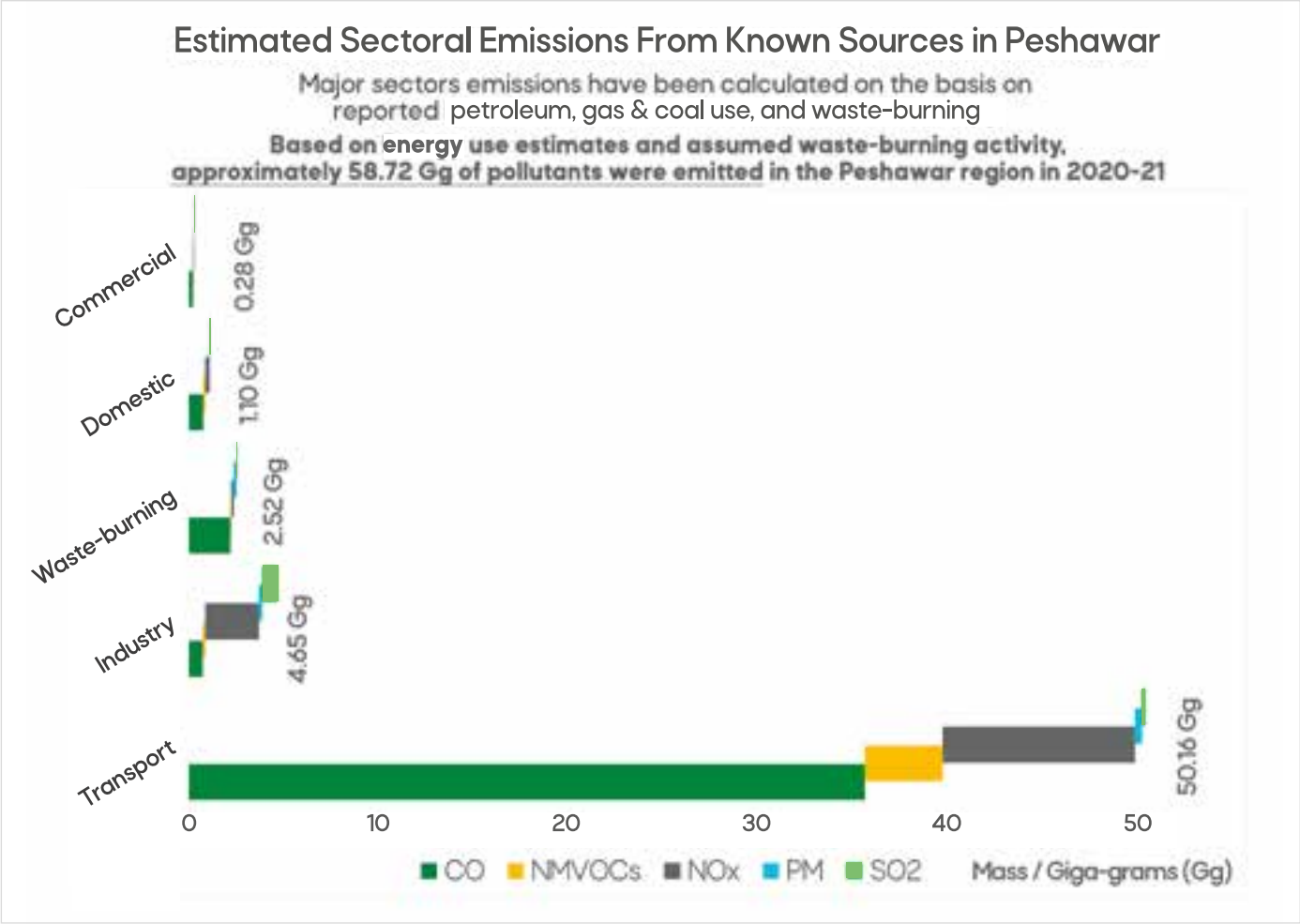


Figure 13: Emissions Inventory of Peshawar During AY2021

Based on these known-sources, it is estimated that 58.72 Giga-grams (Gg) of various air pollutants were emitted in the Peshawar region during 2020-21.

The estimated emissions inventory, as already described, may underestimate the full extent of the emissions as several variables required to account for other emissions are not available, or have been extrapolated based on known quantities and through literature review.

Khyber Pakhtunkhwa has one of the highest proportions of wood-fuel usage in the world, particularly in rural households.[16] About half of Peshawar's population lives in its rural areas,

15 "Pakistan Energy Yearbook." Hydrocarbon Development Institute of Pakistan (HDIP), Ministry of Energy (Petroleum Division). *Govt. of Pakistan*

16 "The Carbon Footprint of Traditional Woodfuels." Bailis et al. (2015). *Nature Climate Change.*.

and according to Census 2017 about 138,000 households in Peshawar used wood as fuel for heating. Similarly, wood-burning in commercial establishments is also common, as well as in certain industries as supplementary fuel. Bailis et al. (2015) reported that Pakistan has one of the highest proportions of wood use as a fraction of Non-renewable Biomass (fNRB) at 79%, while two regions (including KP) stood at 90%, which was the highest in the world. The source apportionment adjusts for such unquantifiable emission sources in the absence of itemized figures of wood-fuel and/or biomass, using analyzed aerosol ratios to allocate sectoral shares.

Sector	Usage *(in metric tonnes)*
Domestic	8,150
Commercial	2,400
Industrial	3,380

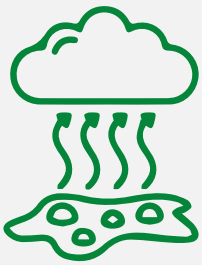
Figure 14: Estimated Yearly LPG Use in Peshawar, Based on PEYB

Sector	Consumption *(in million Cft)*
Domestic	3,660
Commercial	260
Industrial	5,400
Transport	2,910

Figure 15: Estimated Yearly Gas Consumption in Peshawar, Based on PEYB

Sector	Mass Burnt *(in metric tonnes)*
Waste	39,100
Wood	138,030

Figure 16: Estimated Yearly Biomass Burning in Peshawar, Based on Internal Calculations and Literature Review



SOURCE **APPORTIONMENT**

Source Apportionment

As previously described, Aerosols data can also be obtained through CAMS, to assess the breakdown of pollutants responsible for pollution.

Due to meteorological conditions, urban management and lack of green-spaces, many cities in Pakistan suffer from dust aerosol. Dust particulate is of varying size, ranging from coarse to fine particulate matter. Re-suspended soil/dust from barren spaces and roads, as well as anthropogenic dust from construction activities, also adds to this burden. As discussed in section 1, the higher levels of dust aerosol in 2018 may be due to the construction of the large Peshawar BRT infrastructure. Alam et al. (2015) also found that the most significant PM10 contribution in the city was from re-suspended soil/dust. Dust is also transported over long-distances in the region, particularly in a single air-shed.[17] Bilal et al. (2021) describe that Peshawar is impacted, in part, by transport of pollutants such as dust from its north-west and south-east, depending on seasonal meteorological changes.

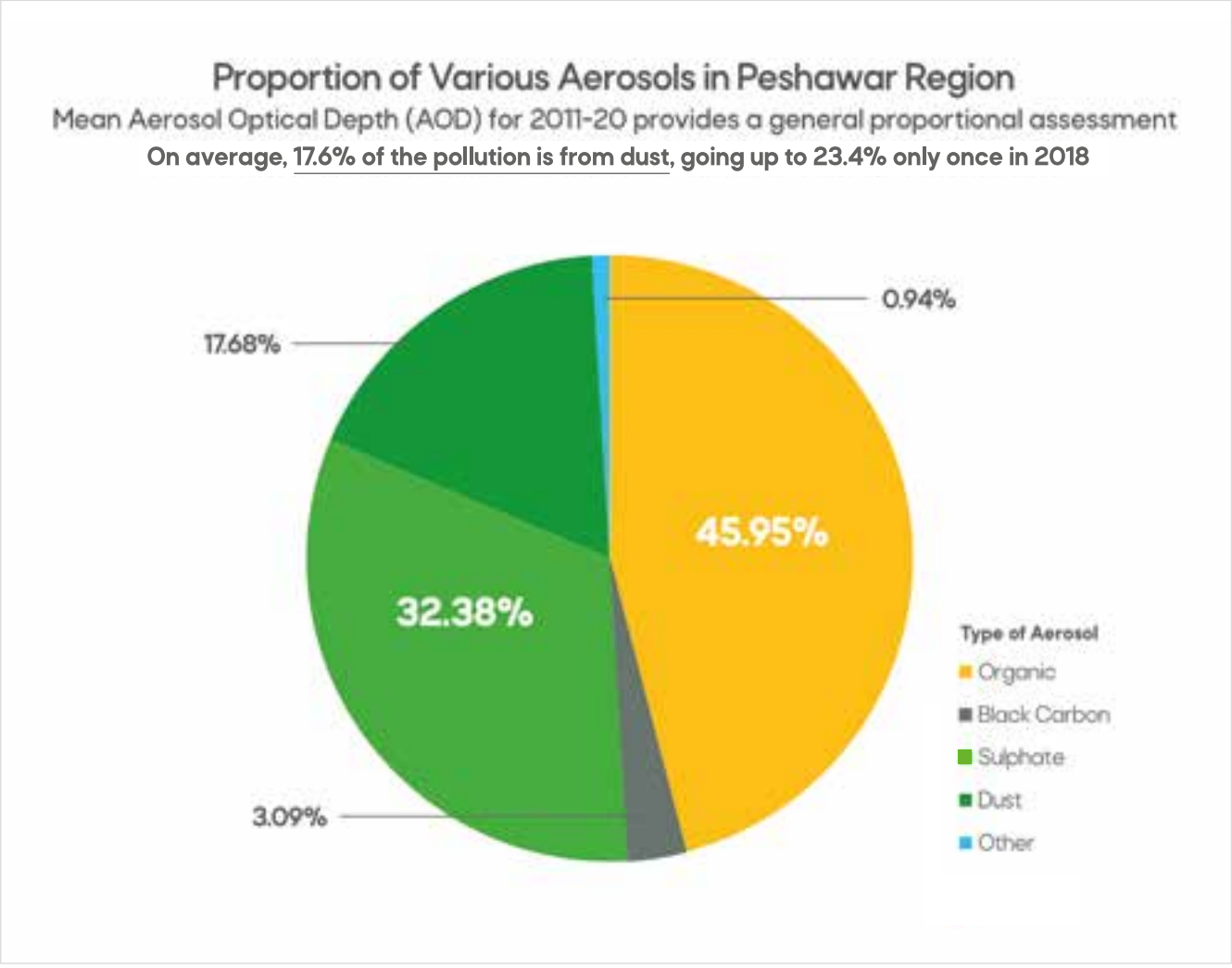


Figure 17: Breakdown of Aerosols Observed at 550m Through CAMS

17 *An Airshed is defined as a geographical area within which the air frequently is confined or channeled, with all parts of the area thus being subject to similar conditions of air pollution.*

Separately, non-dust aerosols are largely emitted as a result of combustion processes. Sulphate aerosol is also known to originate from volcanic activity, but no such contribution is possible in the analysis area. Hence, the presence of sulphate is due to the combustion of fossil fuels.

Black Carbon (BC), also known as soot, is fine particulate matter, which forms a small fraction of the total PM2.5. Biomass burning, coal, and diesel use are significant sources of BC. On average, BC is reported to be 10% of total PM2.5, but it may increase depending on conditions and burning activity. However, BC is also a major short-lived climate pollutant (SLCP), which contributes to global warming, along with Carbon Dioxide gas (CO2) and Methane (CH4). The *Integrated Assessment of Black Carbon and Tropospheric Ozone* (2011) suggests that 1g of BC has a warming potential of 100-2000 times compared to carbon dioxide of similar mass. Although, as BC is short-lived, it does not last in the atmosphere longer than 2 weeks. Its presence in the Peshawar region suggests that its sources are consistent, with regular emissions from various sectors.

Based on the aerosol analysis, and adjusted emissions of various sectors, an overall source apportionment has been established. It is estimated that the transport sector is the highest contributor to air pollution in Peshawar (58.46%), followed by dust and re-suspended dust, the domestic sector, industry, waste-burning, and lastly, commercial sector.

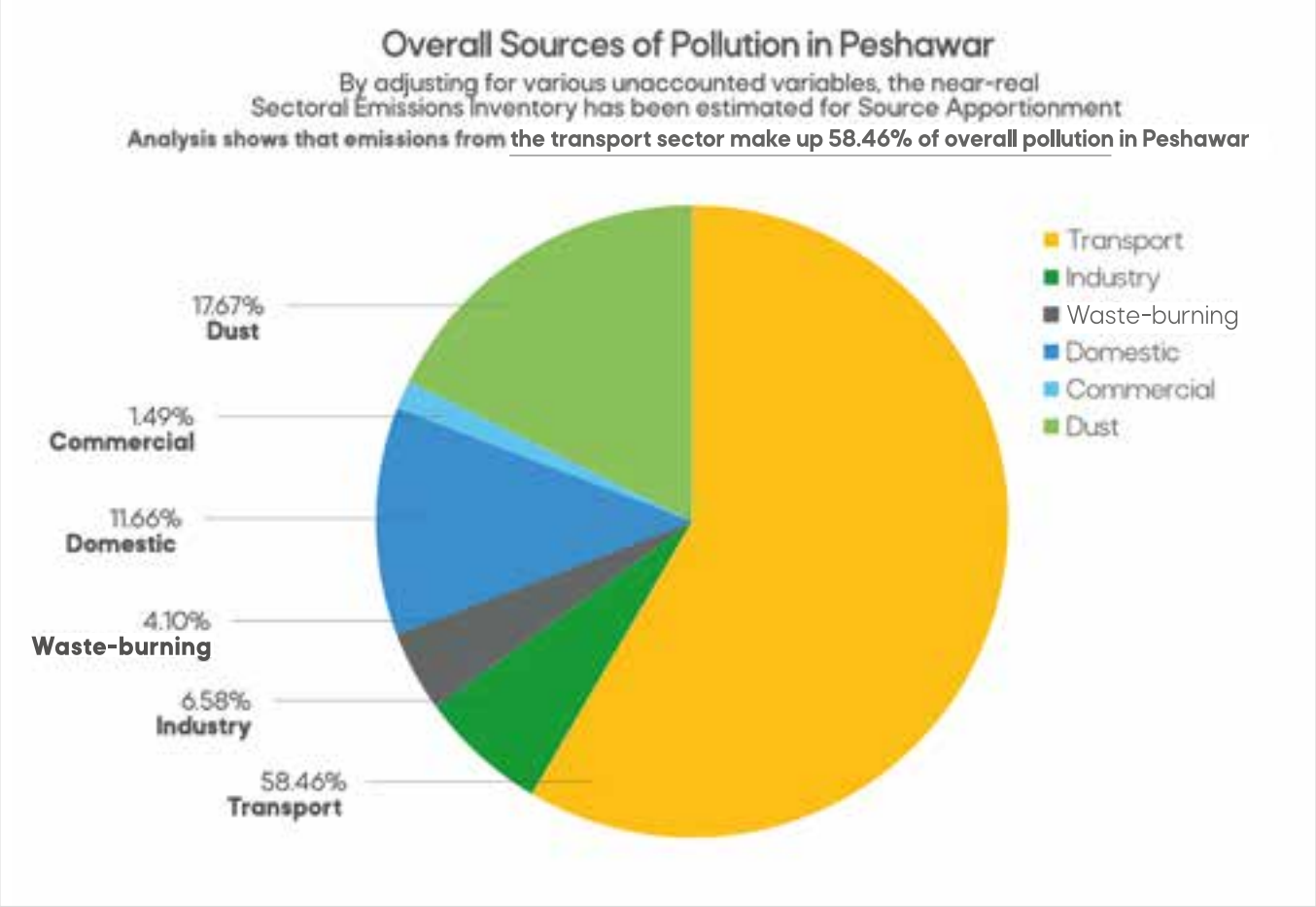


Figure 18: Source Apportionment of Air Pollution in Peshawar

DISCUSSION

Discussion

The study found that Peshawar city faces high levels of air pollution, and it has been a long-term problem. However, it has received low attention from policy-makers, which has been evident from the dearth of information available in pertinent government offices. The air pollution levels, particularly, in the winter months, place the city among the world's most polluted cities. In terms of health impact, it affects at least 5 million people, increasing public health costs and reducing human development achievement. Conservative estimates of these costs incurred over the past two decades would likely be in billions of rupees. The lack of capacity for monitoring air pollution is the primary cause behind low interest.

The report found that 58.46% of air pollution is linked to the transport sector. High levels of pollutant gases undergo reactions resulting in the production of fine particulate matter. Further, coarse and fine particulate matter is directly emitted through various anthropogenic activities and also added to by elevated levels of dust.

The results show that the largest leap in mitigating air pollution will come from developing targeted policy interventions aimed at the transport sector. The transport sector emits pollution both due to the use of poor quality fuel available in retail and the absolute number of vehicles on the roads. Motor vehicles undergo significant wear-and-tear over their operational life and release particulate, particularly through brake pads and reduced engine efficiency. Separately, lead in gasoline and Sulphur in high-speed diesel results in particulate matter emissions. Due to the very high percentage of Sulphur (0.5-1%) in diesel, and the non-availability of Euro-5 emissions compliant diesel engines, it is not possible to implement diesel particulate filters (DPFs). Some proportion of commercial and industry sector emissions are also likely to be linked to fuel quality, as energy generation through furnace oil boilers and diesel generators produce particulates which cannot be mitigated effectively with filtering.

In the course of the study, it is also determined that a significant concern is biomass burning, both in the form of open waste-burning as well as fuel in households. Wood-burning is prevalent in the rural areas, but is also used in many urban households. This is likely to be the biggest cause of household air pollution (HAP), which is known to be specifically detrimental to the health of women who are exposed to fumes and particulate during activities such as cooking and heating. From a policy perspective, the availability of affordable heating solutions for households can drastically reduce HAP levels. Targeting the domestic sector may also be simpler and provide relief at the household level.

This study proposes the development of a Peshawar Air Quality Management Plan (PAQMP). This will be a first-of-its-kind policy document in Pakistan, focusing on the multi-sectoral challenge of poor air quality in an urban setting. As described in this study, the primary challenges in the city are related to the emissions from the transport and domestic sector, while certain industries require mitigation as well, particularly kilns and

furnaces. Under the Federal Rules of Business, quality standards of petroleum products (such as high-speed diesel) are governed by the Petroleum Division of the Federal Government.[18] This means that the provinces cannot govern the quality of fuel which is available in cities. However, various other options for interventions exist which may be executed at the Provincial or District level. Further, under the KP Rules of Business, the emissions linked with various sectors fall within the jurisdictions of a wide-array of departments,[19] hence, an air quality management plan will require a networked governance approach, with environmental management being the common goal. Within the network, the civil society and private-sector will be important stakeholders for driving the direction of public acceptability and nudging for behavioral change, for which the Peshawar Clean Air Alliance (PCAA) is rightly placed to be the representative body.

18 "Schedule II, Rules of Business 1973 (Amended 27th May 2021)". Cabinet Secretariat. *Govt. of Pakistan.*

19 "Schedule I, Rules of Business 1985". Establishment & Administration Department. *Govt. of Khyber Pakhtunkhwa.*

CONSULTATION

Consultation

The findings of the data-analysis report and draft study report were presented to stakeholders, under the auspices of the Peshawar Clean Air Alliance (PCAA), for a consultation, in order to inform them as well as receive feedback and critique. The SEED team also participated in the consultation.

The participants showed concern at the increasing levels of pollution, while sharing their views on various sectoral contributions. Among the salient discussion themes, two stood out the most. Firstly, participants emphasized the need for a proactive and well-funded Environment Protection Agency (KP-EPA), which can monitor air quality levels and effectively implement standards. Participants also suggested the involvement of elected Local Governments, such as through implementing low-cost monitoring at the lower levels. Secondly, they desired an increase in the role of civil society in environmental governance, and the provision of platforms that increase the responsiveness of departments and institutions relevant to air quality management.

Regarding findings of the source apportionment, nearly all participants agreed that emissions from transportation need to be curtailed. PCAA members suggested penalties and interventions, such as wider vehicle emission checks and 'pollution tax'. They further highlighted the need for investigating the public health impact of poor air quality. The SEED team informed the audience that a public health study will also be produced, based on the findings of this study report. Lastly, the participants desired a multi-sectoral approach in dealing with air pollution, and further that such information should be widely disseminated to inform the public.

RECOMMENDATIONS

Recommendations

1. Expanding monitoring capacity should be a top priority, which will increase public awareness and enable precautionary measures. Monitoring needs to particularly focus on Industrial clusters, and major roads and intersections. As a starting point, a minimum of 10 low-cost monitors need to be deployed around the city to record PM2.5 levels, along with at least 1 reference-standard air-quality monitoring station situated in the Peshawar (Hayatabad) Economic Zone to measure PM, NOx, SO2, and COx levels. The real-time data generated should also be made available to the public through online platforms and screens placed at public spaces, industrial areas, and intersections.

2. Encouraging higher Public Transport usage, through better accessibility, incentives, and public communications. Peshawar currently has a relatively good Bus-rapid Transit (BRT) system. However, considerable accessibility issues exist, which are a hindrance to mass acceptability. To increase accessibility, Feeder routes are required, as well as improving walkability and Non-motorized transport (e.g. bicycles) access towards BRT Stations through the creation of crossings, buffer-zones and bicycle lanes, and speed-breakers near pedestrian zones. Further, incentives such as reduced-fares should be implemented during peak-hours and weekends. The revenue costs of these measures should be recovered from private transport users in the form of pollution or green taxes, which are applicable on vehicles during peak-hours. Lastly, 'car-pooling' may be introduced as a government policy, which enshrines that private cars with less than two-thirds occupancy may not be allowed during peak-hours, as it may discourage individual use of cars for daily journeys to offices and schools.

3. Developing alternative and/or subsidized heating methods, to curtail wood-burning. Wood from 'non-renewable' forest sources is widely being used in KP, along with other forms of biomass (e.g. crop residue), as a fuel source. Wood-burning in Peshawar district is of considerable concern as it can be more polluting than other fuels and should be curtailed. The prevalence of wood-burning, as well as a possible increase in the future, is due to the non-availability or higher expenses of other fuels. To curtail the use of wood-burning, a program to introduce smokeless stoves is recommended for the district. Further, alternate fuel sources must be introduced, such as bio-gas (e.g. from organic municipal waste) or pelletized solid biomass (e.g. from crop residue).

4. Campaigning for behavioral change by publicizing affordability and eco-friendliness of alternative transport and fuel options, particularly during current inflationary pressures. During the past few years, the public has been facing high inflation, particularly due to pressures on the international energy market. This translates into higher costs of living. According to the Pakistan Bureau of Statistics, since August 2018, the highest inflation has been seen in Motor-fuel (56.14%) and Gas utility (114.64%) sub-categories. However, consumption has not drastically declined as alternatives are either not available or have lower public adoption. Therefore, marketing cheaper alternatives through public communications, along with incentives, may enable long-term adoption which will help reduce both air pollution as well as inflationary pressures on households.

5. Aligning urban forestation efforts strategically with air quality management. Planting trees is known to be a useful climate change mitigation strategy. Urban forests remove carbon and reduce urban heat. However, its role in air quality management is indirect and requires strategic placement to work. Trees do not effectively 'filter' or remove air pollutants such as PM, CO, SO2, etc., and are primarily CO2 absorbers during the photosynthesis process. While pollutant gases cannot be removed, leafy trees act as barriers to the spread of PM particles. This technique allows the creation of barriers between urban/industrial zones and residential zones. Additionally, as the study shows high-levels of Dust (17.67%) to be a contributing factor to air pollution, planting trees alongside major roads and intersections will help reduce the transport of road-side dust during dry weather. Hence, developing and implementing a comprehensive, urban-oriented Peshawar City Greening Strategy is recommended. This approach would mitigate both climate-change and air pollution.

6. Increasing the role of civil society, universities, startups and the private sector, by streamlining efforts and creating forums for collaboration. As already shown, air quality management will require widespread collaboration across various public and private entities, and civil society. Hence, it is recommended to further opportunities of collaboration and interaction. This can be done in the form of Innovation Funds/Challenges dedicated to Air quality solutions, Quarterly forums and newsletters to review progress, and organizing trainings for capacity building on various aspects of air quality management. This approach will also catalyze the development of local expertise and technology, which will be increasingly required for sustainable management.

WORKS CITED

"Aerosol size distribution and mass concentration measurements in various cities of Pakistan."
Alam et al. (2011). Journal of Environmental Monitoring.

"Air pollution scenario over Pakistan: Characterization and ranking of extremely polluted cities using long-term concentrations of aerosols and trace gases."
Bilal et al. (2021). Remote Sensing of Environment.

"Air Quality in Urban areas in Pakistan Vs Transport Planning: Issues and Management tools."
Qadir (2001). Asian Development Bank.

"Cleaning Pakistan's Air: Policy Options to Address the Cost of Outdoor Air Pollution."
Sánchez-Triana et al. (2014). Worldbank.

"Development of baseline (air quality) data in Pakistan."
Ghauri et al. (2007). Environmental Monitoring and Assessment.

"Development Statistics of Khyber Pakhtunkhwa."
Bureau of Statistics, Planning & Development Department. Govt. of Khyber Pakhtunkhwa.

"Opportunities for a Clean and Green Pakistan: A Country Environmental Analysis." (2019). *Worldbank.*

"Pakistan's Air Pollution Challenge & Potential for Longer Lives."
Greenstone and Fan (2019). Air Quality Life Index.

Pakistan Country Strategic Environment Assessment (2006c). *Worldbank.*

"Pakistan Energy Yearbook." *Hydrocarbon Development Institute of Pakistan (HDIP), Ministry of Energy (Petroleum Division). Govt. of Pakistan.*

"Particulate Matter and Its Source Apportionment in Peshawar, Northern Pakistan."
Alam et al. (2015). Aerosol and Air Quality Research.

Remote-sensing for Spatio-temporal Mapping of Smog in Punjab and Identification of Underlying causes using GIS techniques." 2018. *Food and Agriculture Organization of the United Nations (FAO).*

"The Carbon Footprint of Traditional Woodfuels."
Bailis et al. (2015). Nature Climate Change.

"The state of ambient air quality in Pakistan—a review."
Colbeck et al. (2009). Environmental Science and Pollution Research.

World Air Quality reports (2019, 2020, and 2021).
IQAir. <https://www.iqair.com/world-air-quality-report>

Adam Smith International

Peshawar Clean Air Alliance

SEED

UKaid

Status of Air Pollution in Peshawar

Study Report