IMPACT OF THE GREEN LOCKDOWN AND CONSTRUCTION ACTIVITIES ON LAHORE'S AIR QUALITY INDEX (AQI) DURING NOVEMBER 2024.

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ABSTRACT: This study investigated the impact of a temporary construction ban and Green Lock Down on air quality in Lahore, Pakistan. During November 2024, Lahore experienced a period of severe air pollution with AQI values consistently exceeding 400. With smog reaching critical levels in Lahore, authorities implemented a "green lockdown" around the US Embassy, designating a 1-kilometer radius as a restricted zone. Green lock down was implemented in many other areas of Lahore as well. To further mitigate the severe air pollution, all construction activities (1345 sites) were temporarily banned across the city. Air quality data from IQAir sensors, meteorological data, and information on construction sites Green Lock Down Areas were collected and analyzed. The results did not show a significant localized improvement in air quality during the construction ban, and Green Lock Down. The Impact of construction activities is observed at street level. But at the ambient level, the impact of the ban was limited due to the continued influence of other pollution sources and the prevailing stagnant meteorological conditions. This period was characterized by stagnant atmospheric conditions and increased pollutant emissions. A subsequent shift in weather patterns, with increased wind speeds and rainfall, played a crucial role in dispersing pollutants and significantly reducing AQI levels. This study highlights the complex interplay of various factors, including meteorological conditions, construction activities, and other pollution sources, in determining air quality in urban environments.

Key Words: Green Lock Down, Smog, Meteorology, PM2.5, Temperature.

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INTRODUCTION

Lahore, Pakistan's second-largest city, faces significant environmental challenges, particularly severe smog episodes that typically occur from October to December. This smog is primarily attributed to a confluence of factors, including vehicular emissions, industrial pollution, crop burning in neighboring regions, and unfavorable meteorological conditions such as temperature inversions and low wind speeds.Air quality within the city frequently deteriorates, with the Air Quality Index (AQI) exceeding hazardous levels and surpassing the World Health Organization (WHO) safe limits for both PM2.5 and PM10 particulate matter (Qu& Xia, 2024). This phenomenon is characterized by a substantial increase in particulate matter, especially PM2.5, which poses significant health risks due to its ability to penetrate deep into the respiratory system (Mirza *et al*., 2022).

In the winter season (November to February), Lahore experiences temperature inversions, where a layer of cooler air traps pollutants near the ground, exacerbating the concentration of PM2.5 and PM10. During this period, high humidity can also contribute to the formation of secondary aerosols, further deteriorating air quality. Additionally, the lack of rainfall and limited wind speed during these months prevent the dispersion of these pollutants, making air quality particularly hazardous. This is why Lahore's Air Quality Index (AQI) often exceeds the hazardous levels during winter (Kausar, A., *et al*. , 2023) (Hussain, N., *et al*. , 2024).

As the weather transitions into spring (March to May), air quality begins to improve, with rising temperatures helping to disperse pollutants. However, pollution from industrial emissions, construction activities, and dust remains a challenge. Monsoon rains from June to September further contribute to improving air quality by cleansing the atmosphere and reducing particulate matter. The frequent rainfall washes pollutants from the air, temporarily improving air quality (Hussain, N., *et al*. , 2024). However, humidity during the monsoon season can also enhance secondary aerosol formation, which may slightly increase PM2.5 levels in certain urban areas. The long-term trend of poor air quality in Lahore is largely driven by meteorological conditions combined with human-induced pollution sources such as vehicle emissions and industrial activity (Hussain, N., *et al.* , 2024).

- **Temperature and Atmospheric Stability**: High temperatures promote the formation of secondary pollutants, such as ozone, through photochemical reactions. Atmospheric stability, influenced by temperature gradients, determines the vertical dispersion of pollutants. For example, temperature inversions trap pollutants near the surface, leading to higher concentrations of smog and particulate matter (PM2.5) (Jacobson, M. Z, 2012).

- **Wind Patterns**: Wind plays a critical role in dispersing pollutants. Strong winds dilute pollutant concentrations, improving air quality, while stagnant conditions lead to localized pollution hotspots. Regional transport of pollutants through prevailing winds can also spread pollution across vast areas, such as the Indo-Gangetic Plain (Liu, J., *et al*. 2024) (Pu, W., *et al*., 2024).

- **Humidity and Precipitation**: High humidity enhances the formation of secondary aerosols, which contribute to PM2.5 levels. Precipitation, on the other hand, washes pollutants from the atmosphere, reducing air pollution but potentially transferring pollutants to water bodies (Jacobson, M. Z, 2012).

- **Pressure Systems and Weather Events**: Large-scale weather systems, such as high-pressure systems, inhibit vertical mixing of air, leading to pollutant accumulation. Conversely, low-pressure systems and associated storms can disperse pollutants effectively, albeit temporarily (Liu, J., *et al*. 2024).

- **Urban Heat Islands (UHI)**: Urban areas experience higher temperatures due to the heat retention properties of buildings and asphalt, exacerbating photochemical reactions and air pollution in cities (Pu, W., *et al*., 2024).

- **El Niño and Monsoons**: Global phenomena like El Niño can alter precipitation and wind patterns, indirectly influencing pollutant dispersion and concentration. For example, weaker monsoon rains may fail to cleanse the atmosphere effectively (Liu, J., *et al*. 2024).

- **Cyclonic Systems**: Cyclones and storms can temporarily improve air quality by dispersing pollutants over larger areas or depositing them onto surfaces (Jacobson, M. Z, 2012) (Pu, W., *et al*., 2024).

Meteorological conditions contributed up to **65% of PM2.5 variability** in certain urban regions of China, emphasizing the interplay between weather and anthropogenic emissions (Liu, J., *et al*. 2024).Persistent temperature inversions in winter are a key driver of smog episodes in regions like South Asia, where fine particulate matter levels often exceed safe thresholds (Pu, W., *et al*., 2024) (Zhang, Y., *et al*. , 2024).

MATERIAL AND METHODOLOGY

This study aimed to investigate the impact of a temporary construction ban on air quality and enforcement of Green Lock Down in Lahore, Pakistan. Data were collected from various sources to analyze the impact of this intervention.

Data Collection:

- **Construction Site Data:** A comprehensive list of 1345 construction sites across Lahore was compiled, including their locations (latitude and longitude). These sites were categorized by administrative area.

- **Air Quality Data:** Hourly AQI data were collected from relevant IQAir sensors located near construction sites and within the lockdown areas. Data was collected for a period of two weeks before and after the construction ban (October 27th to November 24th, 2024).

- **Meteorological Data:** Meteorological data, including temperature, wind speed and direction, humidity, rainfall, and atmospheric pressure, were obtained from the Pakistan Meteorological Department for the same period.

Data Analysis: Descriptive statistics, including daily and hourly average AQI values, were calculated for each sensor during the study period. Time series analysis was conducted to identify trends in AQI before, during, and after the construction ban. Correlation analyses were conducted to investigate the relationship between AQI and meteorological parameters like wind speed.

Impact Assessment: A comparison of AQI levels during the construction ban period with the pre-ban and post-ban periods was conducted to assess the impact of the intervention. The relative contribution of construction activities to overall air pollution levels was also examined.

Data Visualization: Graphs and maps were created to visualize AQI trends, spatial patterns, and the relationship between AQI and other factors.

RESULTS AND DISCUSSION

During November 2024, especially from the 09th to the 16th, the cities of Lahore, Rawalpindi, Peshawar, and Multan experienced a significant surge in air pollution levels, leading to a hazardous Air Quality Index (AQI). The trend of AQI during November is shown in Figure 1. This period was characterized by stagnant weather conditions, limited wind dispersion, and increased pollutant emissions from various sources, including vehicular exhaust, industrial activities, and residential heating.

However, a shift in weather patterns occurred around the 17th of November, with rainfall in Islamabad and increased wind speeds across the region. These meteorological changes disrupted the stagnant air mass, dispersing pollutants and leading to a noticeable decrease in AQI levels in the affected cities.

The incident highlights the significant impact of meteorological conditions on air quality in the region. Stagnant weather patterns can trap pollutants, exacerbating air pollution levels. In contrast, increased wind speeds can help disperse pollutants and improve air quality.

Data of fifteen air quality monitoring points is shown in Figure 2. During the period of November 5th to 16th, 2024, the air quality in Lahore deteriorated significantly, with AQI levels consistently exceeding 400. This hazardous air quality was primarily attributed to stagnant atmospheric conditions, limited wind dispersion, and increased pollutant emissions from various sources, including vehicular exhaust, industrial activities, and residential heating.

However, a shift in weather patterns occurred around November 17th, with rainfall in Islamabad and increased wind speeds across the region. These meteorological changes disrupted the stagnant air mass, dispersing pollutants and leading to a noticeable decrease in AQI levels in the affected cities.

Figure 4 shows minimum and maximum temperature trend during November, 2024. Smog and dust particles in the atmosphere can significantly reduce the amount of solar radiation reaching the ground. This reduced solar radiation limits the daytime heating of the surface, resulting in lower "Actual Hi" temperatures compared to the average historical highs. While smog and dust particles reduce solar radiation during the day, they can also trap heat near the surface at night. This "greenhouse effect" caused by the smog layer can prevent heat from escaping into the atmosphere, leading to higher "Actual Lo" temperatures compared to the average historical lows.

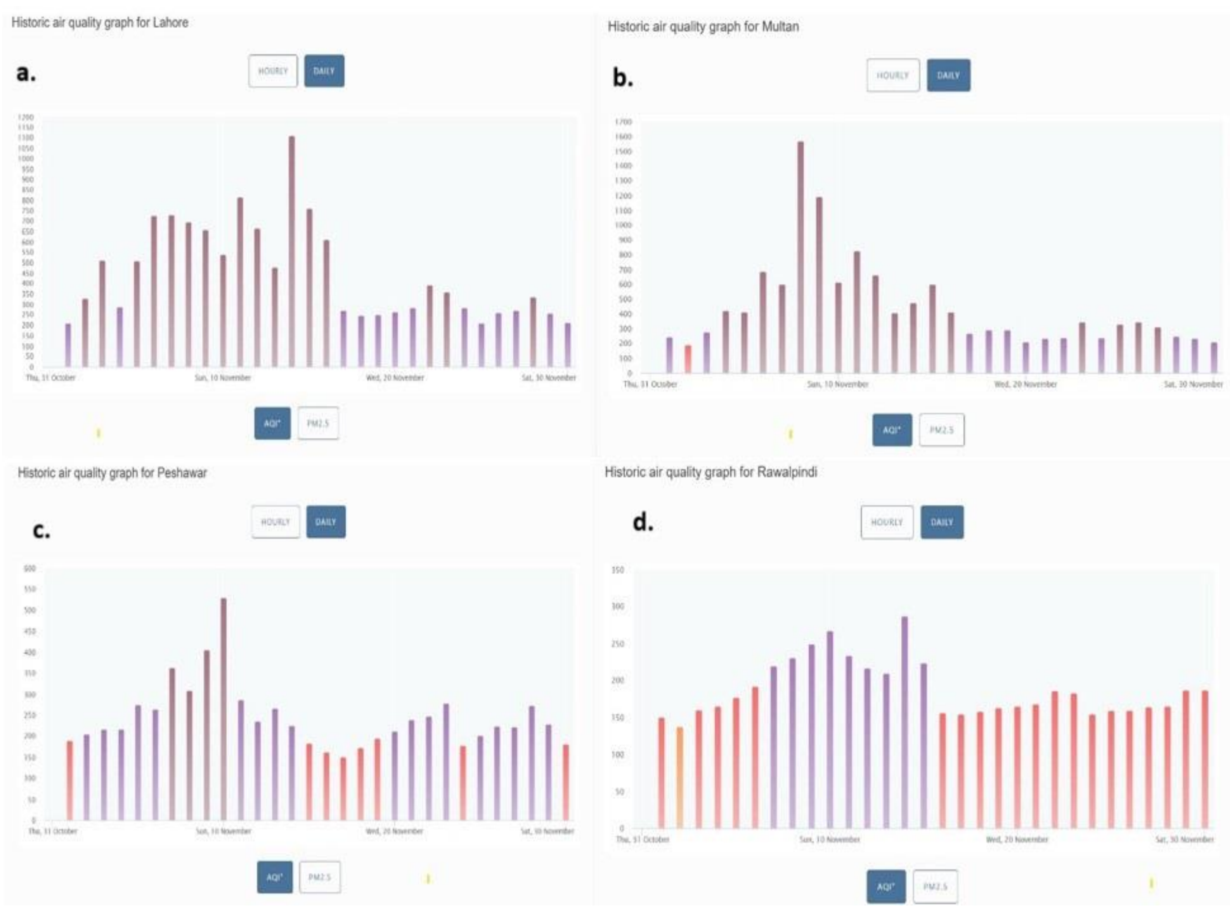

Figure 1: AQI trend at (a.) Lahore, (b.) Multan, (c.) Peshawar and (d.) Rawalpindi during November, 2024

Date	Multan	Rawalpindi	Peshawar	Lahore
10/Nov	615.0	268.0	530.0	539.0
11/Nov	829.0	234.0	288.0	816.0
12/Nov	666.0	217.0	237.0	667.0
13/Nov	409.0	210.0	267.0	478.0
14/Nov	478.0	288.0	226.0	1110.0
15/Nov	600.0	224.0	184.0	763.0
16/Nov	415.0	157.0	163.0	612.0
17/Nov	269.0	155.0	152.0	273.0
18/Nov	293.0	159.0	174.0	249.0
19/Nov	292.0	164.0	195.0	253.0
20/Nov	212.0	166.0	212.0	264.0
21/Nov	235.0	169.0	240.0	286.0
22/Nov	243.0	186.0	248.0	395.0
23/Nov	346.0	183.0	278.0	360.0
24/Nov	241.0	155.0	178.0	286.0
25/Nov	331.0	160.0	203.0	210.0
26/Nov	349.0	160.0	224.0	262.0
27/Nov	313.0	165.0	222.0	273.0
28/Nov	250.0	166.0	274.0	336.0
29/Nov	237.0	187.0	229.0	259.0
30/Nov	217.0	186.0	181.0	213.0
1/Dec	235.0	190.0	216.0	225.0
2/Dec	247.0	187.0	154.0	231.0
3/Dec	190.0	159.0	164.0	192.0
4/Dec	185.0	159.0	165.0	170.0
5/Dec	216.0	165.0	203.0	191.0
6/Dec	187.0	167.0	215.0	201.0
7/Dec	181.0	167.0	295.0	198.0
8/Dec	164.0	185.0	229.0	210.0
9/Dec	177.0	176.0	158.0	199.0
Average	320.7	183.8	223.5	357.4

Figure 2: AQI Trend in Lahore, Multan, Rawalpindi and Peshawar during peak Smog Season

Date	Valancia Town Lahore	University of Management and Technology	Block A Johar Town	Pakistan Engineering Services	WWF-PAKISTAN	Ghazi Road Interchange	VTS	CERP Office	Syed Maratib Ali Road	Climate Finance Pakistan (PakAirQuality)	Phase8-DHA	Askari 10	LAS Lahore	Shahrah-e-Quaid-e-Azam	US Consulate in Lahore
9-Nov-24	-	442	282	857	576	710	-	1019	863	-	774	781	473	561	793
10-Nov-24	-	388	545	757	483	599	-	825	744	-	829	584	408	462	621
11-Nov-24	-	767	714	1189	780	918	-	1368	1241	-	774	750	679	766	909
12-Nov-24	-	703	593	1066	703	786	686	1228	867	-	512	602	455	405	558
13-Nov-24	-	469	297	789	471	575	538	805	744	-	344	396	396	251	428
14-Nov-24	-	1091	832	1731	1112	1240	1398	2015	178	-	728	910	885	670	823
15-Nov-24	797	662	430	1302	728	935	951	1425	1214	1026	601	668	605	344	767
16-Nov-24	677	542	385	981	609	680	737	1065	905	794	556	490	480	327	604
17-Nov-24	333	264	252	323	267	274	282	351	281	292	226	215	243	208	271
18-Nov-24	238	243	242	273	244	263	260	356	249	283	217	195	223	266	274
19-Nov-24	234	247	254	289	253	247	263	368	263	346	209	215	253	242	314
20-Nov-24	277	254	232	347	245	266	262	325	260	286	276	251	239	239	358
21-Nov-24	269	263	257	395	275	283	285	366	281	309	337	275	256	248	354
22-Nov-24	444	357	378	518	439	403	446	479	482	341	311	338	312	266	408
23-Nov-24	406	343	305	481	373	346	400	459	473	311	245	287	298	252	362
24-Nov-24	293	276	268	393	339	286	322	0	347	274	231	232	265	222	293
25-Nov-24	207	206	186	253	226	213	227	256	225	213	186	181	197	175	224
26-Nov-24	226	229	229	293	249	261	270	339	307	277	228	233	257	232	321
27-Nov-24	265	286	251	344	281	279	277	372	293	281	238	220	251	206	287
28-Nov-24	286	341	302	402	323	272	401	406	378	411	265	242	274	277	422
29-Nov-24	247	273	231	308	256	254	267	278	275	262	231	230	234	198	304
30-Nov-24	191	218	186	250	208	217	217	282	219	221	222	195	184	165	221
1-Dec-24	196	241	199	268	224	235	233	244	213	245	245	209	199	180	255
2-Dec-24	228	256	221	253	225	212	230	233	0	233	235	196	198	177	245
3-Dec-24	197	202	177	203	202	188	202	174	204	189	181	164	179	160	204
4-Dec-24	170	181	161	179	173	174	176	157	163	173	156	132	165	136	177
5-Dec-24	206	194	175	206	183	198	193	221	170	218	179	162	179	158	217
6-Dec-24	209	206	185	215	192	199	208	221	185	220	186	178	180	174	250
7-Dec-24	197	199	190	227	198	209	204	209	179	216	203	194	192	178	232
8-Dec-24	204	204	187	246	209	217	212	206	199	224	203	197	191	174	244
Average	**292**	**352**	**305**	**511**	**368**	**398**	**376**	**535**	**413**	**319**	**338**	**331**	**312**	**277**	**391**

Figure 3: AQI trend during peak smog season

Figure 4: Trend of minimum and Maximum temperature during Novemeber, 2024 in Lahore
Source: https://www.accuweather.com/en/pk/lahore/260622/november-weather/260622

The combination of reduced solar radiation during the day and the trapping of heat at night by the smog layer likely contributed to the observed temperature anomaly around November 14 and16. This resulted in lower maximum temperatures and higher minimum temperatures than what would typically be expected for that time of year.

Figure 5 shows wind speed pattern during October, November and December. The wind speed data for November shows a distinct pattern compared to October and December. Notably, there are significantly more "calm" periods throughout November, indicating lower wind speeds compared to the other two months. Strong wind events are also less frequent in November. However, a series of strong wind events observed around November 17th, 18th, and 19th likely played a crucial role in dispersing smog and improving air quality during that period.

In contrast, both October and December exhibit higher wind speeds with more frequent occurrences of "moderate breeze" and even "fresh breeze." This suggests that stronger winds were more prevalent during these months, contributing to better air quality by dispersing pollutants.

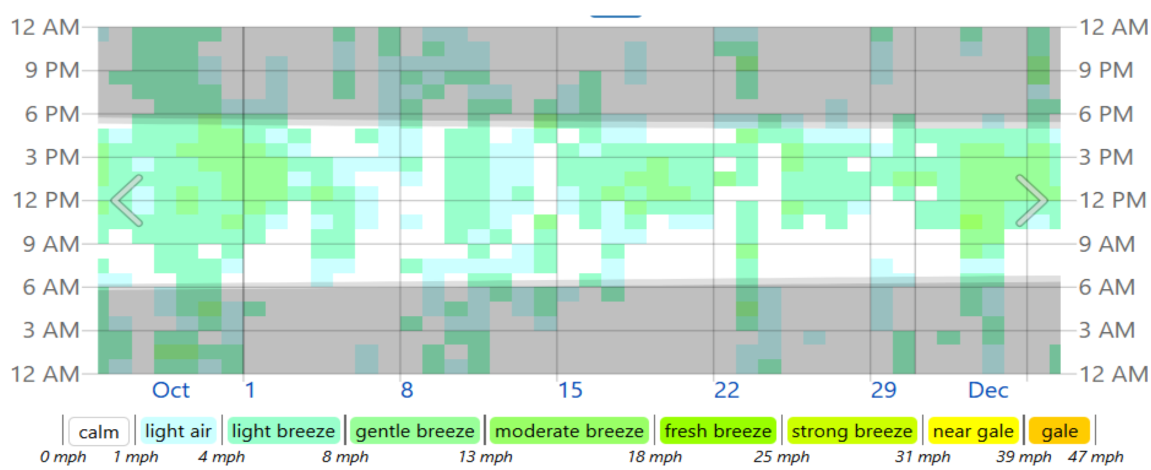

Figure 5: Comparison of wind pattern of November with October and December
Source:https://weatherspark.com/h/m/108021/2024/11/Historical-Weather-in-November-2024-in-Lahore-Pakistan#Figures-WindSpeed

Figure 6 shows weather pattern of Lahore from 2015 to 2024. The October to December period in Lahore typically exhibits meteorological conditions that are conducive to the formation of smog. These months are characterized by lower temperatures, lower wind speeds, and limited rainfall.

Low wind speeds contribute significantly to the accumulation of pollutants in the atmosphere as they hinder the dispersion of pollutants. The absence of strong winds prevents the effective dispersal of pollutants, allowing them to accumulate in the atmosphere.

Furthermore, the lower temperatures during this period create a stable atmospheric condition, often characterized by temperature inversions. In a temperature inversion, a layer of warm air traps cooler air near the surface, preventing the vertical mixing of air and trapping pollutants close to the ground.

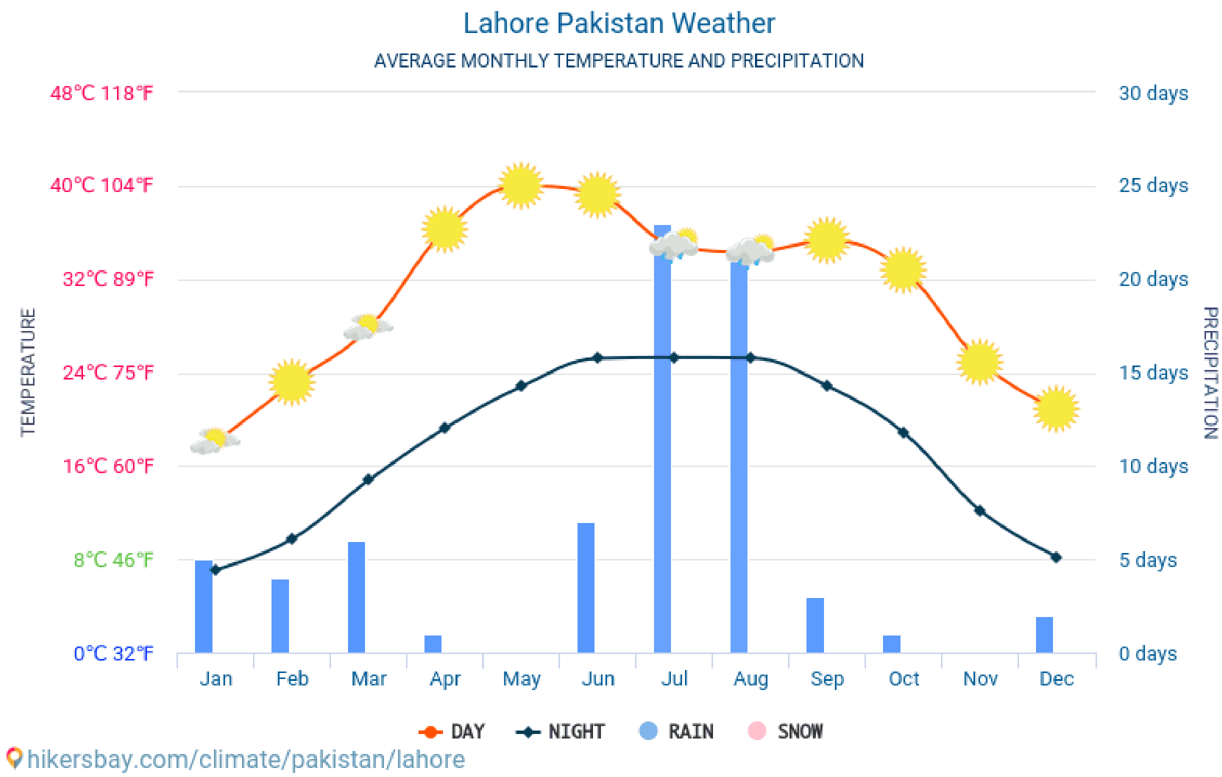

Figure 6: Weather pattern of Lahore from 2015-2024

Construction Moratorium and Its Impact on Air Quality: A significant number of construction sites in Lahore were temporarily halted, as part of efforts to improve air quality. This measure resulted in the closure of 1,345 sites across various areas of the city, including:

Table 1. Affected Areas and Number of Sites:

Area	Number of Sites
Allama Iqbal Town	138
Aziz Bhatti Town	57
Data GanjBakhash Town	70
Defence Housing Authority	445
Gulberg Town	229
Lahore Cantt	36
Nishter Town	98
Ravi Town	8
Saman Abad Town	105
Shalamar Town	20
Wahga Town	126
Walton Cantt	13
Total	1345

Impact on Air Quality: The temporary closure of these construction sites, particularly in densely populated areas like Gulberg and DHA, contributed to a noticeable improvement in air quality. The reduction in construction-related dust and particulate matter emissions helped to lower the AQI levels in these areas.

However, it's important to note that while the temporary ban on construction activities had a positive impact, other factors, such as meteorological conditions and vehicular emissions, also play a significant role in determining overall air quality.

Specific Examples:

- **Alhamra Gulberg:** The closure of **58 construction** sites around Syed Maratab Ali Road, where an IQAir monitor is located, likely contributed to the observed decrease in AQI.

While the temporary ban on construction activities in many areas of Lahore contributed to a significant improvement in air quality, it's important to note that some large-scale projects of national interest, such as the **Qaddafi Stadium project** in Gulberg, were exempted from the ban.However, even with ongoing construction at such sites, the overall air quality in the area has remained relatively low after16th November.

- **DHA Phase 8:** The closure of **260 construction** sites in this area may have also had a positive impact on local air quality, as indicated by the IQAir monitor.

Despite the lifting of the construction ban, the relatively low AQI levels in these areas suggest that other factors, such as improved weather conditions continue to contribute to better air quality.

Figure 3. AQI trend in Gulberg and DHA Phase VIII Lahore during November, 2024

The Table illustrates the impact of construction activities on street PM10 pollution by comparing PM10 levels on streets with ongoing construction to those on nearby "clean" streets (presumably without direct construction influence). The data shows a clear increase in PM10 concentrations in the presence of construction. At four different locations, PM10 levels on streets with construction activities ranged from 530 to 678 µg/m³, while corresponding "clean" streets had lower concentrations between 472 and 510 µg/m³. The calculated contribution of construction activities to PM10 pollution ranged from 10% to 21% across these locations, with an average contribution of 17%. This indicates that construction sites are a significant source of PM10 in urban environments, directly increasing the concentration of these harmful particles in the surrounding air. The variability in the contribution (from 10% to 21%) likely reflects differences in the intensity and type of construction activities at each location, as well as factors like weather conditions and the effectiveness of any mitigation measures in place. This data underscores the need for effective dust control measures at construction sites to minimize their impact on local air quality.

Location	PM10 (µg/m^3) Clean Street nearby	PM10 (µg/m^3) Street With Construction activities	Contribution to PM10
1	480	530	10%
2	510	634	21%
3	472	652	20%
4	492	678	16%
	Average		17%

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

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

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

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

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

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

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

Conclusions: The smog issue in Lahore reached a critical peak, prompting the Punjab EPA to implement a "green lockdown" around the US Embassy as an emergency measure. To mitigate the severe air pollution, construction activities were temporarily banned across the city of Lahore.From November 9th to 16th, Lahore, Rawalpindi, Peshawar, and Multan experienced a significant surge in air pollution levels, with AQI values consistently exceeding 400 in Lahore and Multan.

The Air Quality remained hazardous on almost all parts of Lahore. This period was characterized by stagnant atmospheric conditions, limited wind dispersion, and increased emissions from various sources, including vehicular exhaust, industrial activities, and residential heating.

The EPA Punjab banned construction activities at approximately 1345 sites in Lahore as part of its efforts to combat smog. Although the construction activities contribute 10% to 21% to street pollution, but at ambient level, it is difficult to find out the role of construction activities in increasing/decreasing pollution as the meteorological conditions remained favorable to sustain pollution in the region.

A shift in weather patterns around November 17th, with the onset of rainfall in Islamabad and an increase in wind speeds across the region, disrupted the stagnant air mass. This resulted in the dispersion of pollutants and a noticeable decrease in AQI levels across the affected cities..

These events highlight the significant influence of meteorological conditions on air quality. Stagnant weather patterns can trap pollutants, leading to severe air pollution episodes. Conversely, increased wind speeds can effectively disperse pollutants and improve air quality

Limitations of ban on construction activities: To mitigate air pollution, a temporary ban was imposed on construction activities at 1,345 sites across Lahore from November 10th to 17th.The closure of construction sites, particularly in densely populated areas like Gulberg and DHA, likely contributed to a localized improvement in air quality. The reduction in construction-related dust and particulate matter emissions likely played a minute role in lowering AQI levels in these areas.

It is important to note that while the construction ban could not commence a good impact, other factors, such as improved meteorological conditions (increased wind speeds and rainfall), also contributed significantly to the observed improvement in air quality.

Limitations of the Lockdown: The "green lockdown" implemented around the US Consulate had a limited geographical scope. The continued operation of construction sites in other parts of the city and other significant pollution sources likely negated a more substantial impact on overall air quality.

The observed decrease in AQI after the lockdown period was primarily driven by changes in meteorological conditions, highlighting the significant role of weather patterns in influencing air quality.

Recommendations: This study demonstrates the complex interplay of various factors, including meteorological conditions, construction activities, and other pollution sources, in determining air quality. While the temporary construction ban had a localized impact, its effectiveness was limited by the scope of the lockdown and the influence of other factors.

To effectively address air pollution in Lahore, a multi-pronged approach is necessary, including:

- Strengthening air quality monitoring systems.
- Implementing and enforcing stricter emission standards for industries and vehicles.
- Promoting the use of public transportation and non-motorized modes of transport.
- Implementing urban planning strategies to minimize the impact of construction activities on air quality.
- Raising public awareness about the importance of air quality and the steps individuals can take to reduce their impact.
- Replicated "green lockdowns" may be adopted with stricter measures to reduce emissions, such as mandatory work-from-home policies, restrictions on vehicle use, and partial closures of non-essential businesses.
- Continued research and monitoring are crucial to understand the dynamics of air pollution in Lahore and develop effective and sustainable solutions to improve air quality for the benefit of public health and the environment.

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