AMBIENT AIR QUALITY ASSESSMENT AMONG INDUSTRIAL AREAS OF A COASTAL CITY KARACHI

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Abstract

The level of air pollution in cities of Pakistan is alarming high even among South Asia countries. The region itself cities having worst air quality in the world. Significantly damaging human health, eminence of life, economy and environment. The detriment from Pakistan's urban air pollution result in weather patterns beyond study and prediction. This study will however highlights the issue of air pollution in Karachi, country's most polluted and populated city. This study was conducted in industrial zones, including residential and commercial areas. The data was collected using HAZ-SCANNER (HIM-6000) apparatus, which measured the ambient air pollutants like Nitrogen Oxides (NOx), Carbon Monoxide (CO), Sulphur Dioxide (SO_2), and Particulate Matters (TSPM, PM_{10}, and $PM_{2.5}$). The study found that the concentration of particulate matters (TSPM, PM_{10}, and $PM_{2.5}$), CO, and NO_2 values in sampling sites were less moderate in the post-monsoon season as compared to the pre-monsoon season. This could be due to the seasonal monsoon effects. However, the levels of PM_{10} and $PM_{2.5}$ were still on the higher side than the national standards. It was also noted that the North Karachi industrial area, which had fewer and smaller industrial units, was comparatively less at risk. The high levels of air pollutants have severe health implications and can cause chronic diseases. Therefore, it is important to implement local environmental standards regarding ambient air pollutants to mitigate the negative impact on human health and economic activities. This study calls for more focused attention and implementation of such standards to ensure a healthier and sustainable environment.

Index Terms: Urban Pollution; Air Pollutants; Industrial Zones; Health Effects; Pre-Monsoon; Post-Monsoon

1. INTRODUCTION

Recently Asian countries had significant growth in terms of its development, urbanization, and energy use [1, 2]. The number of sources of air pollution has considerably increased [3]. Air pollution have a significant impact on ecosystems, [4] climatic changes, metrology, and human health [5]. In many Asian cities, such as Beijing, New Delhi, and Karachi, this has resulted in poor air quality and high levels of air pollution [6], with detrimental effects on people's health and wellbeing. Air pollution is responsible for millions of premature births and deaths each year [7] and a significant economic burden due to healthcare costs and lost productivity of the resources [8]. Air pollution also contributes to climate change

and the degradation of ecosystems [9], exacerbating existing environmental challenges. Therefore, reducing air pollution levels and improving air quality is a requisite for sustainable development and the safety of present and future generations [10, 11]. Extreme employment movement, enormous population, and exceptional increase in vehicle usage are posing environmental influence in the area [12, 13]. As a result, air pollution throughout Asia, particularly in South Asia, where emission controller tools and approaches are not consistently being adopted [14] has performed as a significant risk to the environment, the health of the populace, and quality of life [15, 16].

Coastal city Karachi's location and climate make it particularly vulnerable to the negative effects of air pollution. The high population density [17], industrial activities, and transportation emissions contribute to the city's poor air quality. The hot and dry weather conditions exacerbate the problem by trapping pollutants in the air, leading to increased health risks for the residents [18]. The economy of Karachi is larger and more diversified [19]. Numerous organizations in various parts of the city, including Korangi Industrial & Trade Estate, Sindh Industrial & Trading Estate (SITE), North Karachi Industrial & Trade Estate, FB Area, Port Qasim, etc., have their industrial hubs in the city [20].

The unplanned and uncontrolled expansion of industries and their increasing emissions is a major contributor to air pollution in both urban and rural areas [21-23]. Industries emanate various pollutants such as Particulate Matter (PM), Sulfur Dioxide (SO_2), Nitrogen Oxides (NOx), and Volatile Organic Compounds (VOC's), which can have detrimental effects on both the environment and public health [24]. Pollutants can travel long distances and affect areas far away from the industrial zones, leading to degradation of the environment and pollution of rural areas [25, 26]. It is important for industries to adopt green technologies and practices to reduce their emissions and minimize their impact on the environment. [1]. However, burning solid waste, municipal waste and construction poses a serious threat to both the environment and people [27]. In a study, reviewed the air pollution and its influence on plants, humans, and water in Pakistan in the different big cities in Pakistan [28]. Human health and ecosystem impacts, air pollution also has economic impacts, such as reduced agricultural productivity and increased healthcare costs [29]. Therefore, controlling air pollution is vital for sustainable development and to mitigate the negative impacts on the environment, human health, and economy. Implementing regulations and policies to reduce air pollution from industries, vehicles, and power plants, as well as promoting the use of renewable energy sources, can help to address this critical issue. Numerous researchers and scientists [6, 30, 31] have working several air quality models for air quality plotting and evaluating the health impacts.

Air quality have direct impact on climate change [32], and proactive measures are needed from authorities to minimize the deleterious effects on people and the environment. The goal of this study was to measure the level of atmospheric trace gases such as CO, NO_2, SO_2, and Particulate Matters (TSPM, PM_{10}, and $PM_{2.5}$) in the major four industrial zones

of Karachi city. The measured levels were then compared to the recommended levels adopted by Sind environmental protection agency [33].

2. MATERIAL AND METHODS

The Sindh Industrial and Trading Estate area (SITE), North Karachi Industrial Area, Korangi Industrial Area, and Landhi Industrial Area were the four primary industrial zones where this research study was conducted (Table 1 and Figure 1). Ambient air data of various pollutants was collected from 24 sampling locations. Textile, chemical, pharmaceutical, glass, plastic, and food items are the main industries in these regions. Nitrogen oxides (NOx), carbon monoxide (CO), sulphur dioxide (SO_2), and particulate matters (TSPM, PM_{10}, and $PM_{2.5}$) were among the pollutants analysed. In order to gather data, a random sampling technique was adopted, with visits made primarily during the busiest working hours (0800–1800). The samples were collected by visiting the localities at random in the months leading up to the pre-monsoon (May to June) and post-monsoon (October to November) seasons for three years (2017-2019). The instrument utilized for data gathering is the HAZ-SCANNER (HIM-6000) USA [34]. Portable battery operated instrument, the HAZ-SCANNER be able to provide up to 12 simultaneous important air gases, including real real-time $PM_{2.5}$, PM_{10}, and TSP readings with data logging. Particle readings were taken using the infrared light scattering technique, while toxic gas readings were taken using electrochemical sensors (Figure 2).
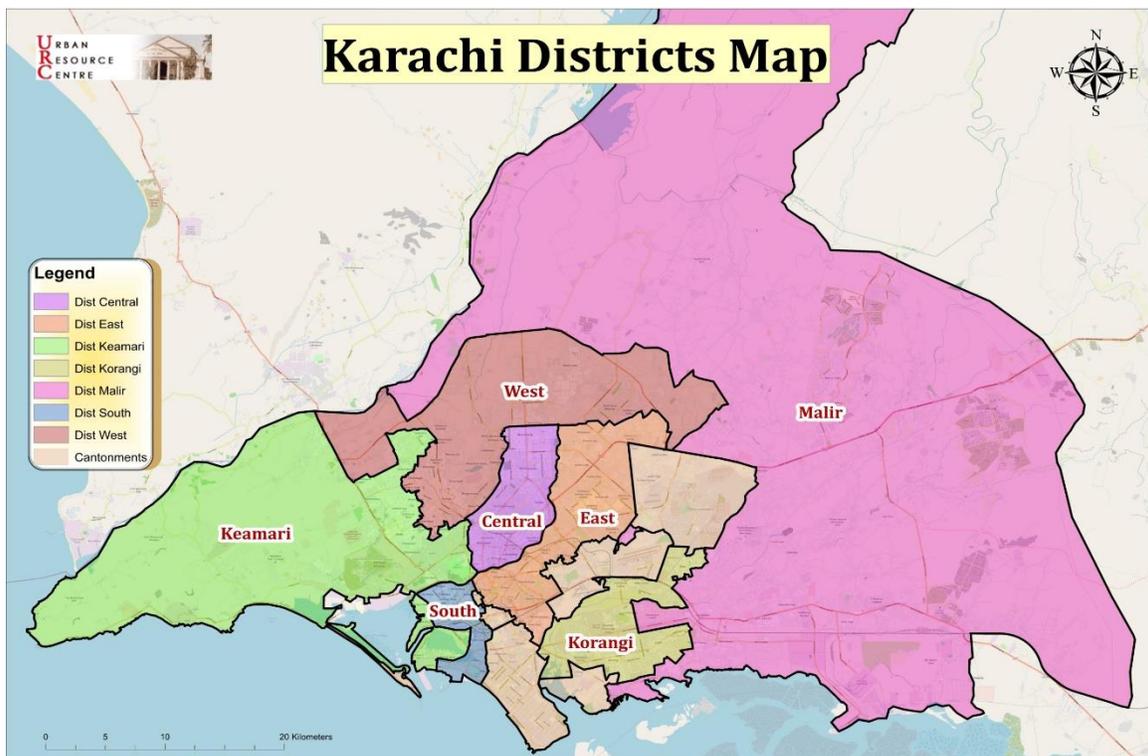

Figure 1: Location map of the study area

Table 1: Major industrial zone of costal city Karachi

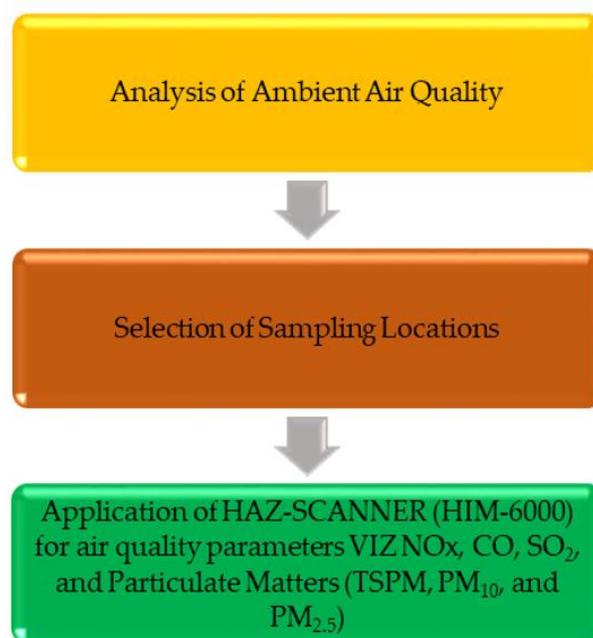| Major Industrial Zones	Description
Sindh Industrial Trading Estates (SITE)	On a total of 4500 acres (1800 ha) of land west of the Lyari River, there are more than 2000 industrial units. Textile, steel, pharmaceutical, automotive, chemical, and engineering, beverage, and grain mills are some of the major industries. As worker colonies grew up around the industrial estate, the town expanded.
Korangi Industrial Area	It is spread over an area of 8500 acres. 8500 acres make up its total surface area. Around 3000 facilities, including those for the textile, steel, pharmaceutical, automotive, chemical, engineering, food, and wheat milling industries, are located in the Korangi Industrial Area.
Landhi Industrial Area	Its land area is around 11,000 acres (4,500 ha), and it is made up of medium- and large-sized industries. Numerous industries are located in the industrial area, including wheat mills, textile, pharmaceutical, automotive, chemical, and steel.
North Karachi Industrial Area	It came into existence in 1974. It is scattered and spread over an area of 725 acres with more than 2000 commercial, industrial, and service units containing automobile, textile, engineering, and food, etc.

Analysis of Ambient Air Quality

Selection of Sampling Locations

Application of HAZ-SCANNER (HIM-6000) for air quality parameters VIZ NOx, CO, SO$_2$, and Particulate Matters (TSPM, PM$_{10}$, and PM$_{2.5}$)

Figure 2: Research Methodology Workflow for Air Quality Analysis

3. RESULTS AND DISCUSSION

One of the primary causes of the decline in ambient air quality is pollution from industrial activity and violation SEQS[35]. The magnitude of industrial air pollution has increased many fold. The volume of industrial emission has increased significantly from the previous years [36]. In this research, assessment has been done whether ambient air data meet the Sindh Environmental Quality Standards (SEQS), or not. For this purpose, evaluation

has been done on a temporal seasonal basis (Table 2). In the pre-monsoon, all four industrial zones, including Sohrab Goth, Godhra Road, Yunus Chorangi, Denim Road, Labour Square, Bilal Chorangi, and Murtaza Chorangi, have significantly high mean particulate matter (TSPM, PM_{10} & $PM_{2.5}$) values. All locations, including Labour Square, Denim Road, Yunus & Dawood Chorangi, Mutraza Chorangi, and Sohrab Goth, have moderate amounts of carbon monoxide (CO), nitrogen oxide (NO_2), and sulfur dioxide (SO_2).

Table 2: Industrial Air Pollution Levels in Karachi (2017-2019)

| Parameters ($\mu g/m^3$)											
	CO		NO_2		SO_2		TSPM		PM_{10}		$PM_{2.5}$	
SEQs /	10 (mg/m³)		80		120		500		150		75	
Sampling sites	PMS	PtMS	PMS	PtMS	PMS	PtMS	PMS	PtMS	PMS	PtMS	PMS	PMS
H B Chorangi	1.1	1.2	32	27	22	25	485	275	130	135	55	62
Siemen square	1.5	1.5	35	33	25	21	490	375	150	150	87	74
Ghani square	1.56	1.01	40	28	41	31	550	515	175	177	92	80
Valika Road	2.1	1	45	25	35	19	320	240	140	130	73	64
Labour Square	2.2	0.9	49	36	29	23	550	240	150	110	87	48
Denim Road	2.2	1	51	25	33	25	411	210	140	98	77	39
Bilal Chorangi	0.3	0.2	49	38	27	22	295	250	129	120	76	55
Vita Chorangi	0.8	2.4	28	33	21	19	370	270	167	120	88	65
Singer square	1.5	2.7	25	42	35	25	301	190	128	99	75	51
Murtaza square	2.11	3	35	48	24	34	540	490	185	185	105	85
Darulaloom	0.5	1.8	20	38	26	27	725	201	390	95	227	37
Shan Chorangi	0.7	2.1	39	35	35	19	350	180	115	90	50	27
Nagan square	0.5	0.3	62	37	47	25	260	425	120	135	53	65
Sohrab Goth	2.5	1.2	71	45	39	21	620	515	275	150	150	87
Shafiq Morr	1.1	0.8	21	33	27	17	590	190	260	85	150	52
Godhra Road	3.98	2.11	31	49	27	22	450	200	130	98	65	45
Sakhi Hassan	2.7	2.5	20	22	20	25	290	190	130	96	65	35
Water pump	0.2	0.15	20	26	21	16	260	210	115	97	66	25
Yunus square	3.4	2.5	67	55	35	31	290	550	125	197	46	120
Dawood square	2.1	1.5	45	33	34	26	640	575	360	195	185	130
LIAR	0.2	0.5	30	24	22	19	740	240	301	115	185	50
YB Chorangi	0.9	0.4	55	28	38	25	365	290	175	192	83	37
Zafar Town	0.6	0.7	73	44	31	23	275	220	133	90	55	36
Future Morr	1.8	1.6	39	51	35	28	245	340	114	130	55	54

* PMS - Pre Monsoon, PtMS - Post Moonsoon; SEQs – Sindh Environmental Quality Standards

The Figure 3 illustrates the changes in pre and post monsoon readings of various air pollutants, namely CO, NO_2, SO_2, TSPM, PM_{10}, and $PM_{2.5}$. Each figure displays the pollutant's levels along with a horizontal line representing the boundary set by the State Environmental Quality Standards (SEQs). The difference between the two lines indicates

the variation in pollutant concentration. Figure 3(a) shows the variation in CO readings, Figure 3(b) indicates the narrowing gap in NO_2 levels in certain localities, and Figure 3(c) demonstrates that the difference between pre and post-monsoon SO_2 readings falls within acceptable limits. Figure 3(d) depicts areas of concern through the intersection of the SEQS boundary and noted readings for TSPM. The severity and presence of PM_{10} are shown in Figure 3(e) by the intersection of both lines, and Figure 3(f) highlights industry violations in $PM_{2.5}$ levels at the intersection of the SEQS boundary and the observed readings.
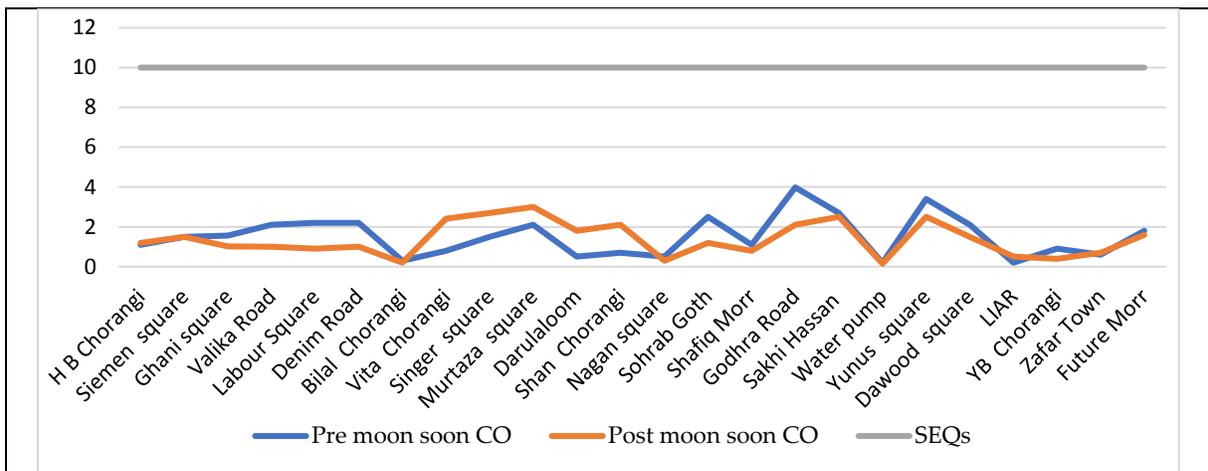
3(a): CO Levels Variation

3(b): NO_2 Levels Variation

3(c): SO$_2$ Levels Variation

3(d): TSPM Levels Variation

3(e): PM$_{10}$ Levels Variation
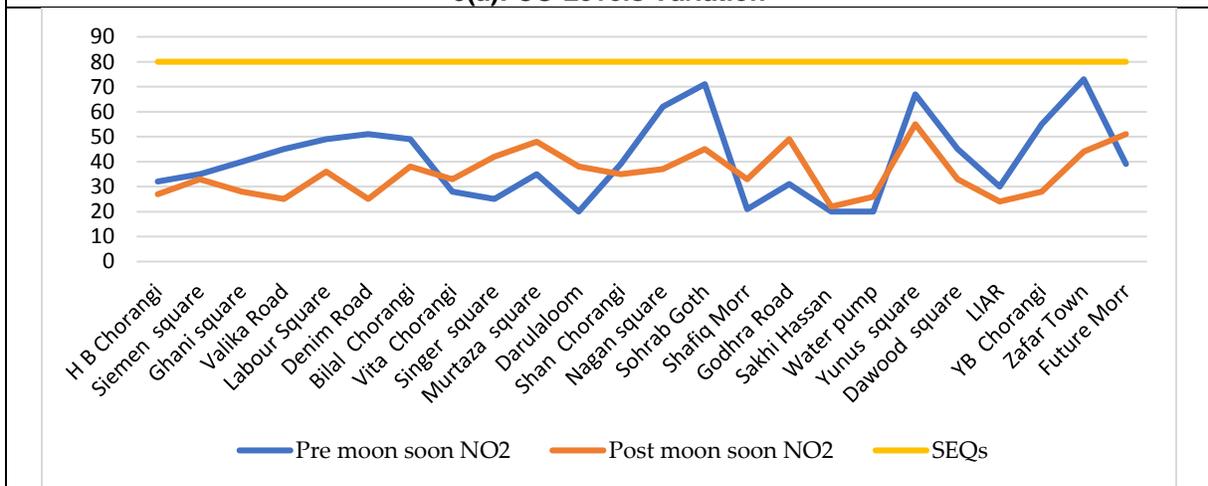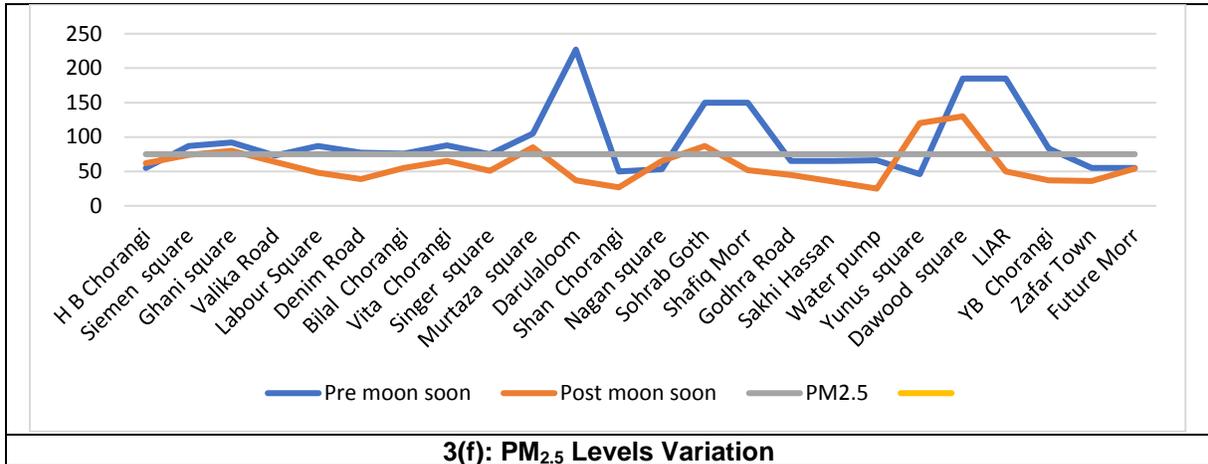
3(f): PM$_{2.5}$ Levels Variation
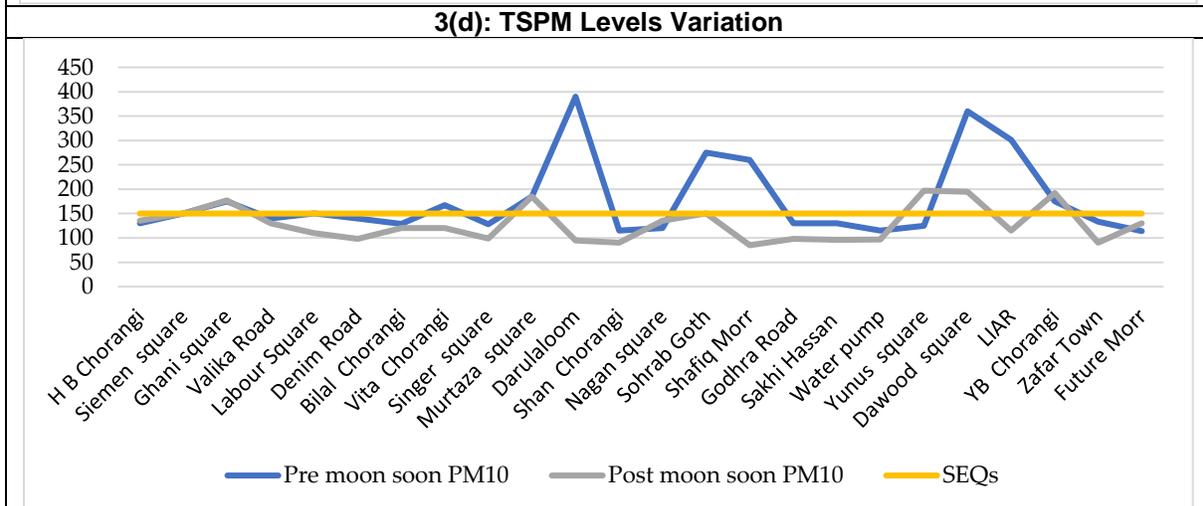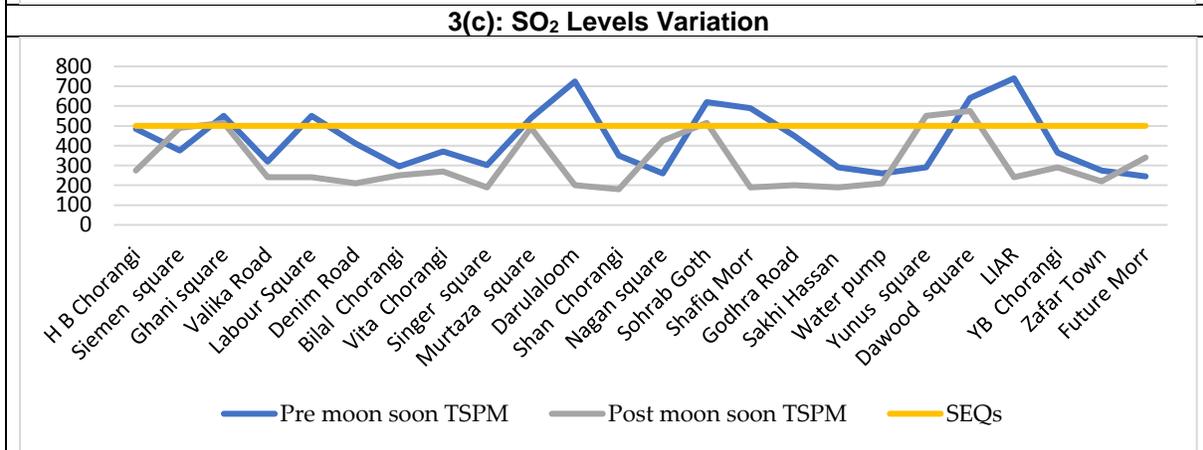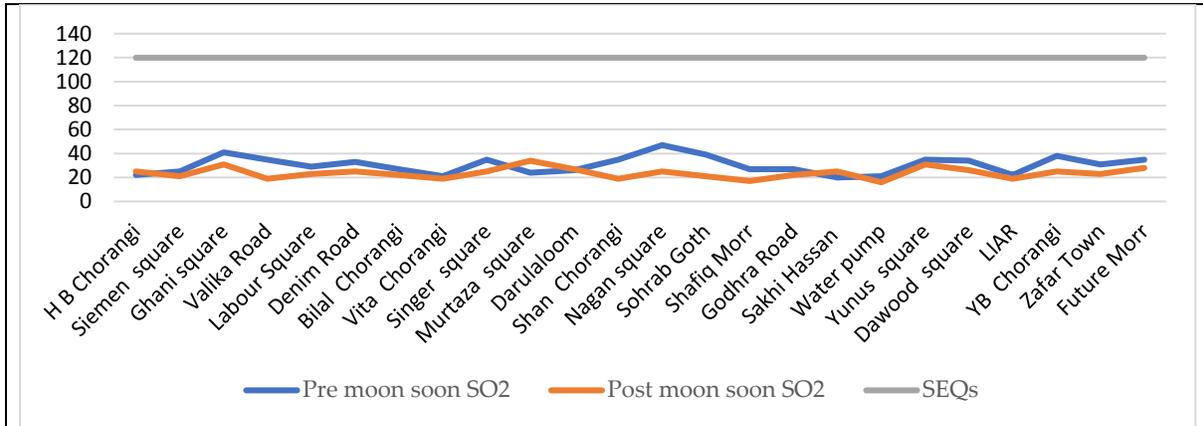
Figure 3: Variation of Air Pollutant Readings Before and After Monsoon Season

The figure 4 depicts the correlation between pre and post monsoon values of various air pollutants in Karachi. Each sub-figure presents a specific pollutant's correlation analysis along with the determination coefficient (R^2), which indicates the extent to which the dependent variable (pre-monsoon values) can be explained by the independent variable (post-monsoon values). The R^2 value for CO is 0.2753, indicating a weak correlation and suggesting that the values do not change significantly after the annual rains. Similarly, the correlation analysis for NO_2 (R^2 = 0.1551), SO_2 (R^2 = 0.0811), TSPM (R^2 = 0.0402), PM_{10} (R^2 = 0.0206), and $PM_{2.5}$ (R^2 = 0.0407) also exhibits weak correlations, suggesting limited changes in their values after the monsoon season. The provided structural equation models describe the relationships observed between the variables in each analysis, allowing for a better understanding of the patterns and trends in the data.

The Table 3 encompasses parameters such as CO, NO_2, SO_2, TSPM, PM_{10}, and $PM_{2.5}$, each accompanied by a specific equation. These equations establish the relationship between the levels of pollutants, denoted as PtMS, and their corresponding independent variable, PMS. By providing coefficients and constants, these structural equation models quantify the associations between the variables.

Table 3: Structural Equation Models for Air Pollutant Parameters

Parameters	Structural equation model
CO	PtMS = 0.4375 (PMS) + 0.7116
NO_2	PtMS = 0.0058 (PMS)^2 + 0.3102x+37.2
SO_2	PtMS = 0.0058 (PMS)^2 + 0.3102x+37.2
TSPM	PtMS = 0.1697 (PMS) + 233.93
PM_{10}	PtMS = 0.0663 (PMS) + 117
$PM_{2.5}$	PtMS = 0.1092 (PMS) + 49.05

1(a). CO: Assessing the CO Relationship Pre and Post Monsoon

1(b). NO$_2$: Exploring the NO$_2$ Correlation Pre and Post Monsoon

1(c). SO$_2$: Investigating the SO$_2$ Relationship Pre and Post Monsoon

1(d). TSPM: Analyzing the TSPM Correlation Pre and Post Monsoon

1(e). PM$_{10}$: Examining the PM$_{10}$ Relationship Pre and Post Monsoon

1(f). PM$_{2.5}$: Evaluating the PM$_{2.5}$ Correlation Pre and Post Monsoon
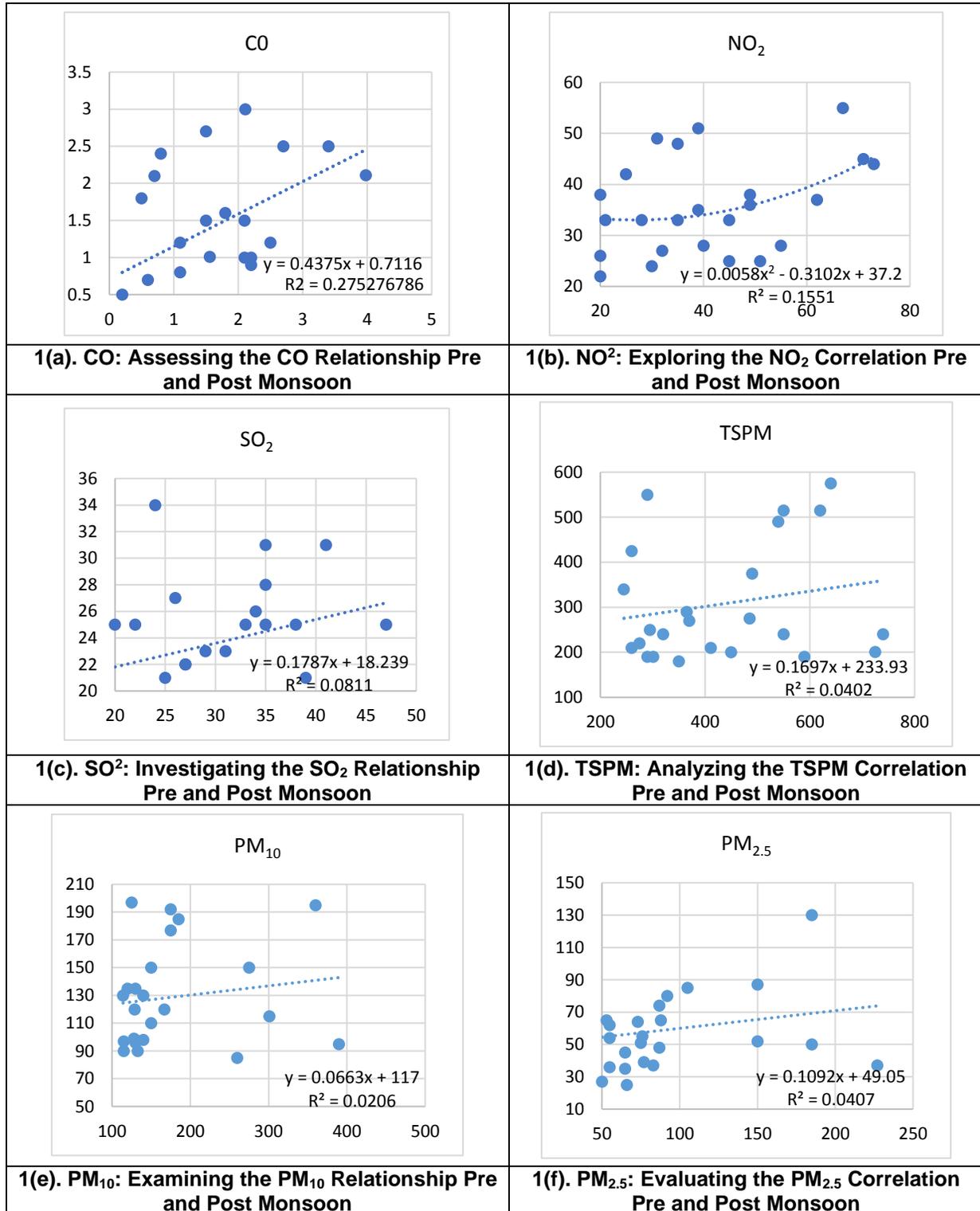
Figure 4: Impact of Monsoon Season on Air Pollutant Levels: Correlation Analysis

Karachi industrial sites on GIS plotting depict the location and no clear cut demarcation of industrial and residential areas. The map shows (figure 5 and Figure 6) that southern and central regions are less effected comparatively. No clear cut boundary demarcation shows that effects are wide spread and will affect the general populace, in and attached to industrial areas.
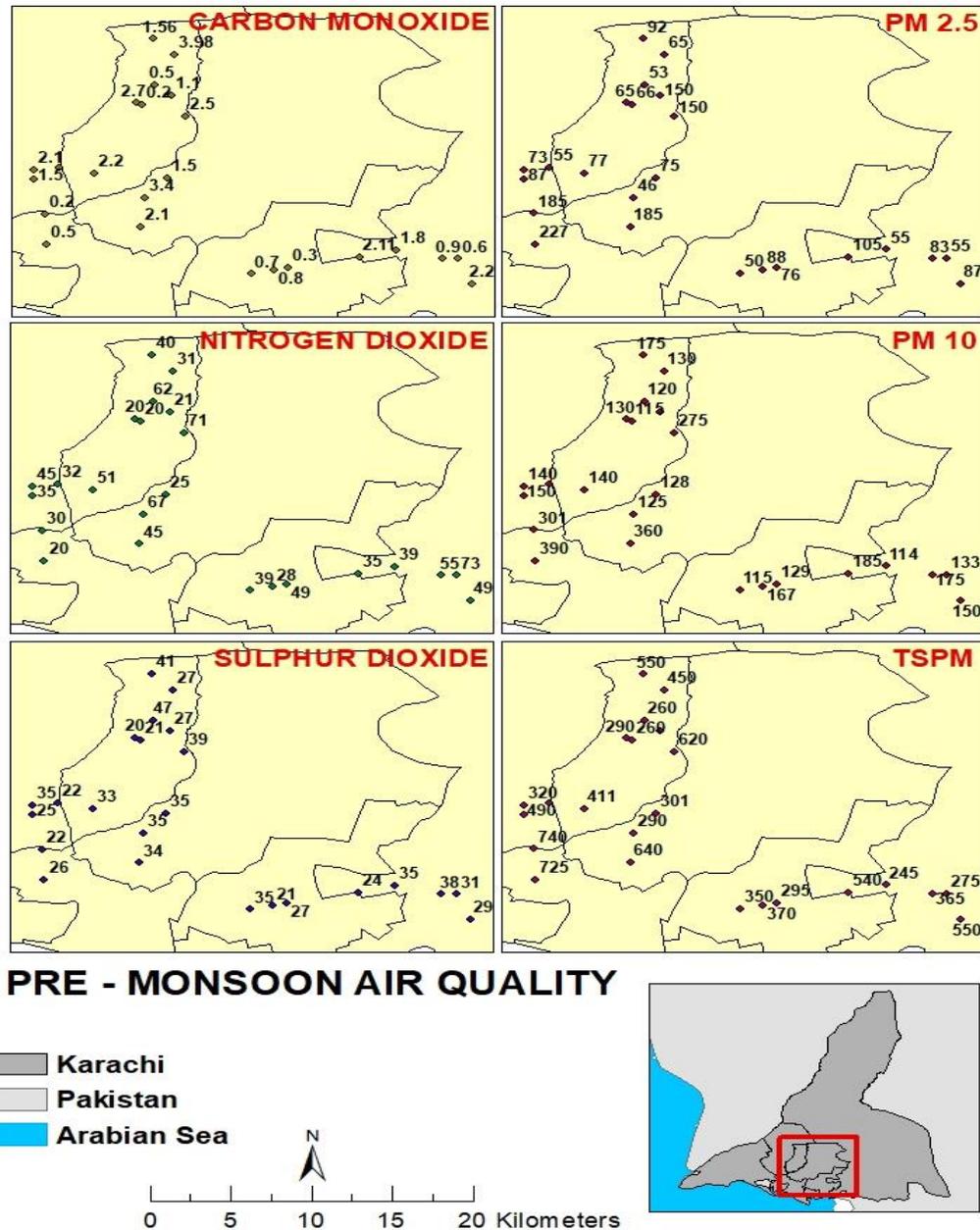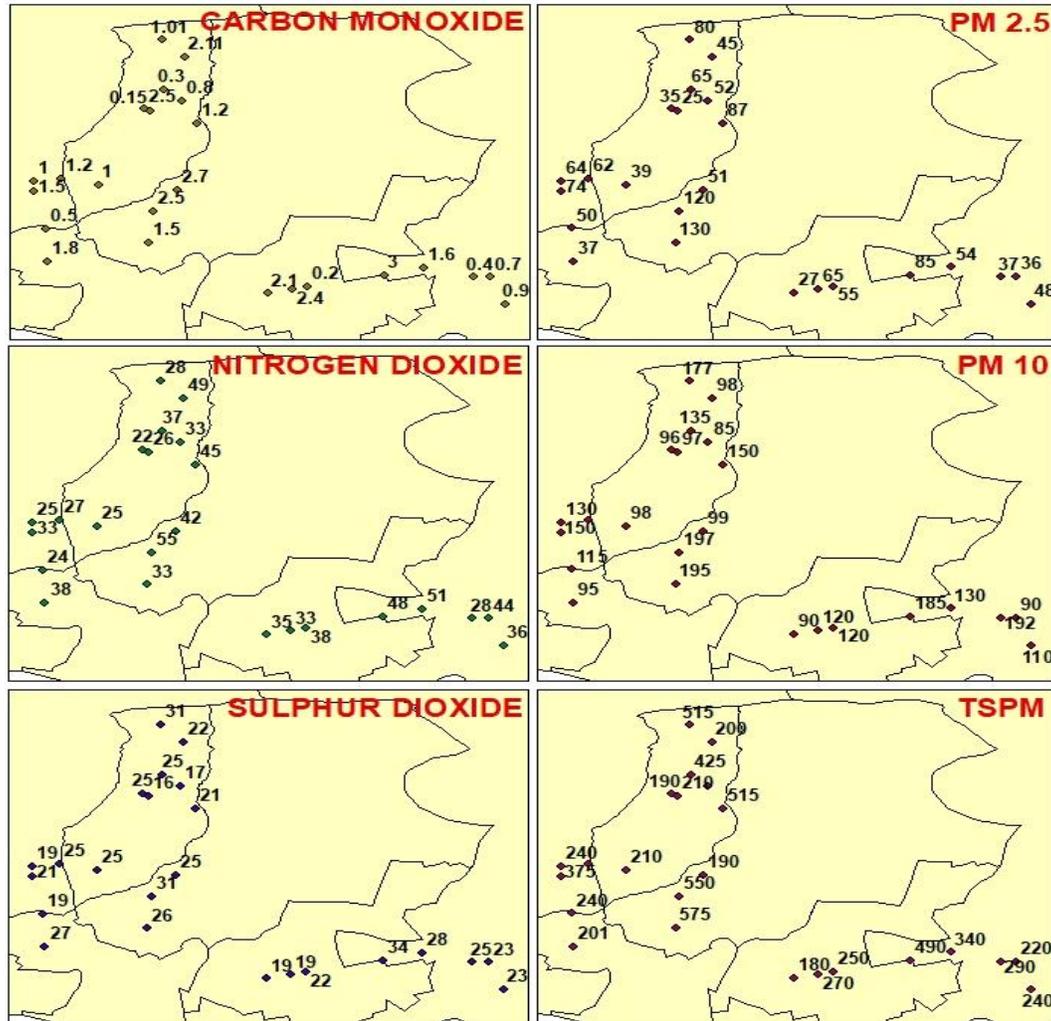

Figure 5: Pre monsoon geospatial analysis and visualization of air quality values
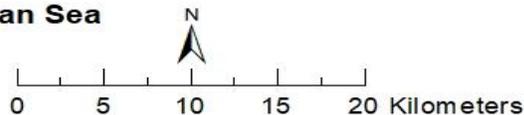
Figure 6: Post monsoon geospatial analysis and visualization of air quality values

In addition to natural processes, burning at very high temperatures produces NOx [37]. Nitrogen oxide is present in all industrial zones as a result of surrounding industries[38]. It is released into the atmosphere through power plants and automobile emissions at

roughly similar levels. These nitrogen oxides have a crucial role in increasing photochemical pollution,[39] including surface ozone (O_3), in addition to their impact on human respiratory health. However, the NOx in the atmosphere is to blame for common bronchitis and eye conditions in Karachi [28].There are seven compounds of NOx, generated by anthropogenic (human) activities [40].

In the industrial areas of Landhi, S.I.T.E. Area, and Korangi, which are more likely to be exposed to these pollutants, the maximum concentration of particulate matter PM_{10} & $PM_{2.5}$ was found in the air samples from all locations, exceeding the Sindh Environmental Protection Agency's (SEPA) standards of 150 & 75 $\mu g/m^3$ for PM_{10} & $PM_{2.5}$, respectively. High variations of PM_{10} & $PM_{2.5}$ are caused by industrial and traffic-related factors in all Zones. Open spaces in a nearby industrial activity that sees a lot of traffic for the transit of manufactured goods and raw materials spatially confine higher levels of particulate matter (PM_{10} & $PM_{2.5}$).

4. CONCLUSION

The results of this study show the significance manufacturing industrial activities, and pollution emissions to the notable concentration in ambient air. Due to Karachi's extensive industrial activity, poisonous gases and other pollutants can easily accumulate in the city's ambient air, which has an adverse impact on both the local environment and its inhabitants. The graphical and statistical modelling shows that, the presence of NOx, Cox and PM are present and they are persistent despite monsoon rain showers. Therefore more concrete measures are needed to control their presence and avoid the degradation of air quality and rheostat the spread of diseases. According to study results, the industrial zones of S.I.T.E., Korangi, and Landhi are particularly exposed to polluting gases. North Karachi, in contrast, is the area with the lowest risk due to the sparse presence of large-scale industry. The responsible authorities fail to implement the law in a proper manner. This study will look at the relationship between particle air pollution and particulate heights in Karachi's megacities. The PM_{10} and $PM_{2.5}$ readings are often two to three times higher than the SEQS requirements[41]. Studies conducted in other advanced nations have shown a strong correlation between higher PM_{10} & $PM_{2.5}$ levels and higher rates of hospitalizations for hypertension and cardio-vascular syndromes (myocardial infarction, ischemic heart disease)[41]. Metropolitan cities across the globe like New York on one side Chinese cities are facing the same dilemma[42] Additional research on the health implications in the megacity of Karachi is imperative given the obvious levels of air pollution that are acknowledged. The Air Quality Index (AQI), which reports on daily air quality and is linked to health impacts from exposure, is also suggested as a potential tool for future research[43].

Author Contributions: Industrial growth is essential for developing countries, however Pakistan is also among the top countries affected by climate change and the stimulus to climate change are uncontrolled industrial growth. Authors like many has highlighted the scenario and emphasis and novelty contribution are as follows.

- This research paper monitored the air quality parameter in the industrial sites of Karachi

- Paper highlighted the violation in air quality in different industrial sites

- Paper also monitored the air quality of different industrial sites in pre moon soon and post moon season to monitor effect of seasonal rain

- The persistent presence of air pollution despite rain shows continuous effect on populace health

- Paper also highlighted non-following local environmental laws.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

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