Vol.02, Issue 02 (2022): 28-37
DOI: 10.58921/jse.02.02.040

Journal of Sustainable Environment
ISSN (p): 2710-2386, ISSN (e): 2957-9228

Published by
1885 SMI UNIVERSITY

Cumulative Impact Assessment of Thermal Power Plants using AERMOD Modeling.

Abdul Jabbar[1*], Omme Hany[1], Muhammad Mansha[2], Syed Jamil Hasan Kazmi[3], Farheen Khanum[3] and Noreen Horanz[4]

[1] Institute of Environmental Studies, University of Karachi, Karachi.

[2] Pakistan Space & Upper Atmosphere Research Commission (SUPARCO) Karachi – Pakistan.

[3] Department of Geography, University of Karachi, Karachi.

[4] Department of Geography, Federal Urdu University for Arts, Science & Technology, Karachi.

Corresponding Author: jabbarenv@gmail.com

ABSTRACT

Megacities in Pakistan have some of the poorest air quality emissions worldwide. An estimated 0.865 million unexpected deaths a year are attributed to urban air pollution, with Asia accounting for 60% of these deaths. The Karachi's ongoing urbanisation, industrialization, and motorization have significantly increased the amount of various air pollutants, which has serious consequences for both the environment and human health, to analyze theses impacts at single source Environmental Impact Assessment is mandatory in Pakistan whereas Cumulative Impact Assessment (CIA) process is not available. Mega city like Karachi needs strict criteria to overcome the air quality issues therefore, AERMOD Model along with ArcGIS have been used to provide a practical CIA tool to Sindh Environmental Protection Agency to analyze these impacts. In this study five proposed thermal power plants of total 3450 MW capacity were selected for short-term and long-term cumulative impacts. The short-term cumulative impacts of Nitrous Oxides (NOx) and Sulphur Dioxide (SO_2) were considered as 1-h and 24- h, whereas long term was considered as annual. The results of NOx emissions were 170 µg/m^3 for 1-h, 33 µg/m^3 for 24-h and annual was 14.5 µg/m^3. While the SO_2 emissions were 199 µg/m^3 for 1-h, 29.8 µg/m^3 for 24-h and long-term annual was 7.5 µg/m^3 respectively. All the limits are complying with national and international standards because, the wind speed (5-8 m/s) and wind direction has a substantial impact on flow field which results in lowering the ground level concentrations of the pollutants in the study area. This is further caused by the strong sea breeze from the Arabian Sea which is termed as blessing for the residents of the study area.

KEYWORDS: *Cumulative Impact Assessment; AERMOD; Thermal power plants.*

1. INTRODUCTION

Pakistan is currently facing a severe energy emergency, with annual power demand gaps of up to 5,500 MW, similarly the gap between supply and demand has been steadily increasing in recent years, this enormous disparity has necessitated 12–16 hours of load management across the country (National Power Policy, 2013). It is projected that Karachi's power needs will increase by 72% (5,200 MW) over the next ten years (K-Electric, 2016). The Pakistani government has given the private sector permission to produce electricity to fill this shortage. The capital of Sindh, which covers an area of 3,530 km^2, is Karachi (Karachi Metropolitan Corporation, 2017), whose population has skyrocketed to 16.1 million according to the 2017 Population Census; whereas in 1998 the city's population was 9.8 million (Pakistan Bureau of Statistics, 2017; and Pakistan Bureau of Statistics, 1998) and ongoing urbanization, industrialization, and motorization have significantly increased the amount of various air pollutants, which has serious consequences for both the environment and human health, (Tanveen *et al.*, 2018). Moreover, Karachi is the biggest city in Pakistan and positioned as the dirtied city on the planet (Alam *et al.*, 2011) furthermore, the city was also ranked 134th out of 140 in the Economist Intelligence Unit's Global Livability Report, making it one of the world's ten least livable cities (EIU, 2017). Correspondingly, air contamination is turning into a rising concern overall and has shown relationship between intense or ongoing openness to air contamination which results mortality (Rajak *et al.*, 2019; Newell *et al.*, 2018 and Fajersztajn *et al.*, 2017). As a matter of fact, during critical air pollution scene, the mix of SOx and PM has been required as a justification behind the overflow mortality and SO_2 exposure results in respiratory symptoms such as decreased lung function, chest tightness, coughing, and respiratory infections (Peters *et al.*, 1997; Braun-Fahrlander *et al.*, 1997; Soyseth *et al.*, 1995; Higgins *et al.* 1995; Schwartz *et al.* 1994; Braback *et al.* 1994; Hoek and Brunekreef 1993; Vedal *et al.*, 1987; Saric *et al.*, 1981; and Stebbings and Hayes, 1976). Subsequently, SO_2 is poisonous to the human body, particularly for an individual having respiratory illness like emphysema and it might cause pneumonia (Hashmi *et al.*, 2005). High NO_2 air can cause irritation to human respiratory tract airways. NO_2 and NOx also combine with other airborne substances to generate hazardous particulate matter and ozone when ingested (USEPA, 2021).

The various sources of emissions are available at Port Qasim Authority (PQA) study area for example transport, fertilizers, ship operations, textile units and power plants and the proposed power plants of total capacity 3450 MW will work on Coal and LNG/RLNG based fuel to fulfill the city's rising need. It is anticipated in the EIAs that "discharges from power plants would influence the encompassing environs and air nature of the city" (Faiza, 2018; GEMSL, 2017; EMCPL, 2016; HBPL, 2016; HBPL, 2015; and HBPL, 2014), past examinations in the review region recommended that 80% of oil utilized by K-Electric at Port Qasim is the fundamental wellspring of SO_2 outflows alongside Pakistan Steel Factory (Hashmi *et al.*, 2005), another review uncovers the current furthest reaches of SO_2 and NOx are ordinarily higher than WHO air quality standards (Colbeck *et al.*, 2011).

Environmental Impact Assessment is mandatory in Pakistan whereas Cumulative Impact Assessment (CIA) process is not available. The mega city like Karachi needs strict criteria to overcome the air quality issues therefore, AERMOD Model along with ArcGIS have been used to provide a practical CIA tool to Sindh Environmental Protection Agency to analyze the air quality issues and include CIA tool as a legal requirement for sustainable future of Karachi city.

2. MATERIAL AND METHODS

2.1 Study area

The Port Qasim Authority (PQA) study area of 49 by 49 km was selected for air quality analysis as shown in Fig.1 because; The site is away from the thickly populated area and highly contaminated due to industries. The town wise population data of the study area was taken from the Pakistan Bureau of Statistics to understand the air pollution impacts on human health; the details are presented in Figure 1.

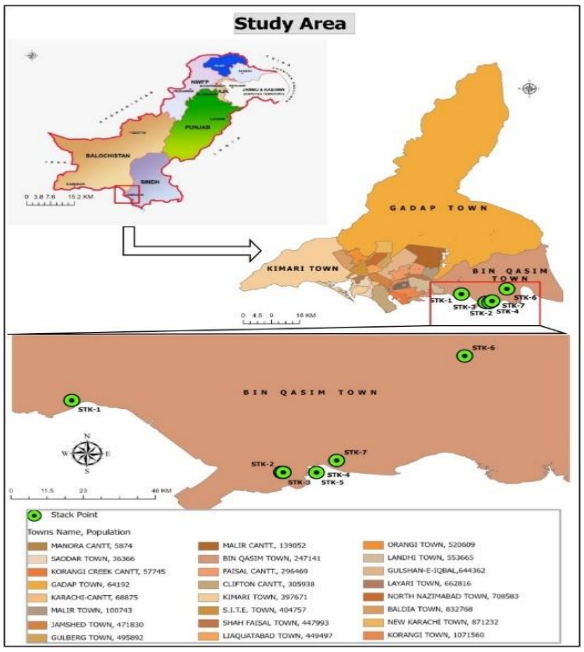
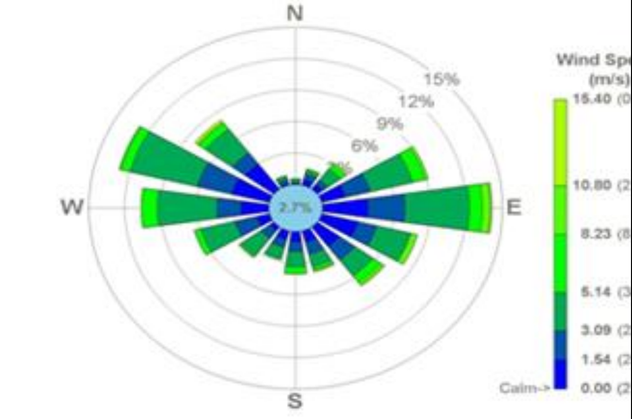


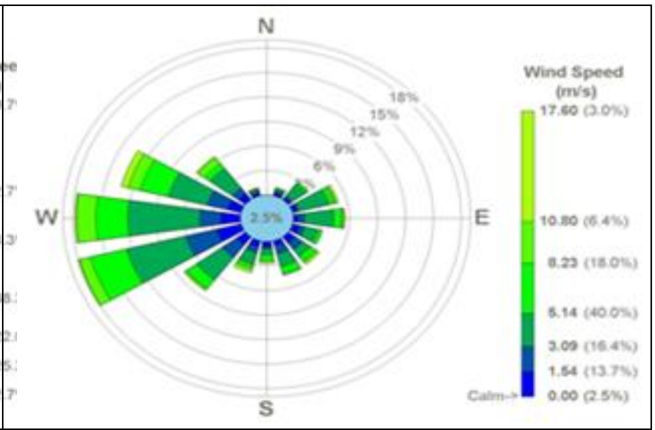
Figure 1. Study area (Port Qasim Authority Pakistan)

2.2 Dispersion modeling

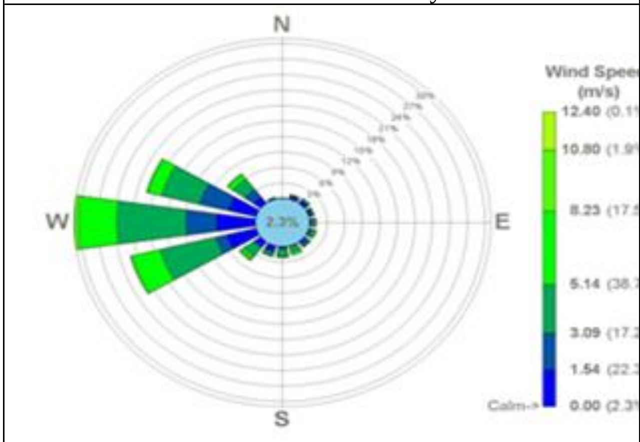
AERMOD (American Meteorological Society/Environmental Protection Agency Regulatory Model) is a steady-state regulatory air dispersion plume model developed by USEPA, it assumes the concentrations at all distances during a modeled hour governed by the temporally averaged meteorology of the hour. The AERMOD modeling system consists of two pre-processors and the dispersion model i) AERMET-meteorological preprocessor ii) AERMAP for characterizing the terrain and generating receptor grids. In this research, AERMOD View™ 8.9.0 and ArcGIS 10.4 model were used, the hourly surface meteorological data for the year 2016 was taken in Samson format from SUPARCO-Pakistan processed with AERMET and monthly Wind-rose plots were generated are showing dominant wind direction and wind speed as shown in Figure 2 from a to l. The data analysis indicated that wind is blowing from North West in January as shown in (a) from West in February to May as shown in (b) to (e), from East in June as shown in (f), from South West in July to October as shown in (g) to (j) and North East in November to December as shown in (k) to (l) then through AERMAP outputs maps were developed using ArcGIS.



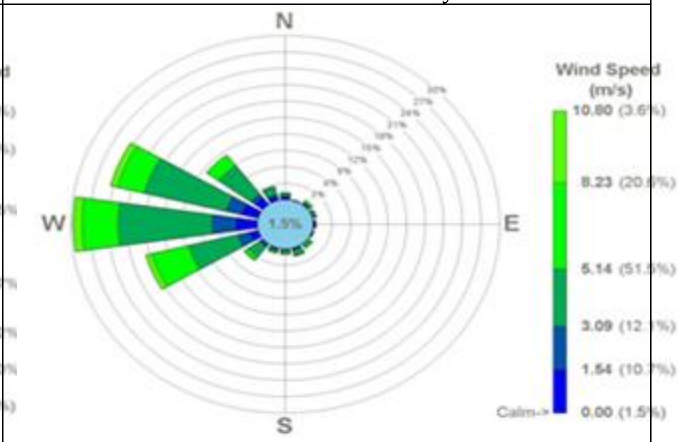
a: Windrose Plot for January 2016



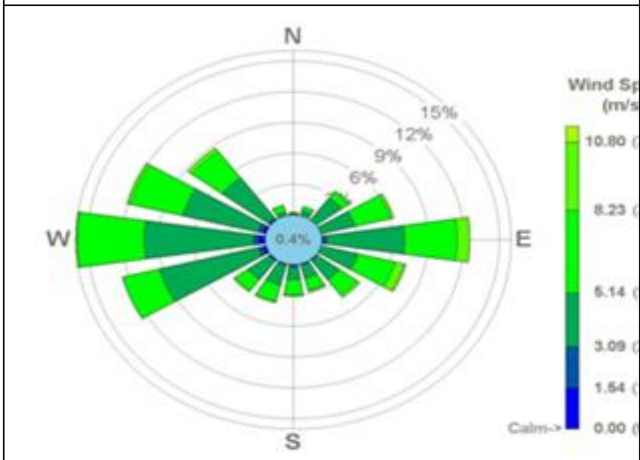
b: Windrose Plot for February 2016



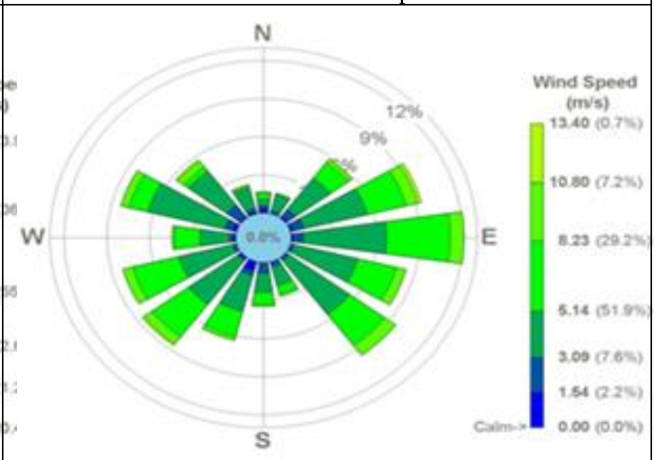
c: Windrose Plot for March 2016



d: Windrose Plot for April 2016

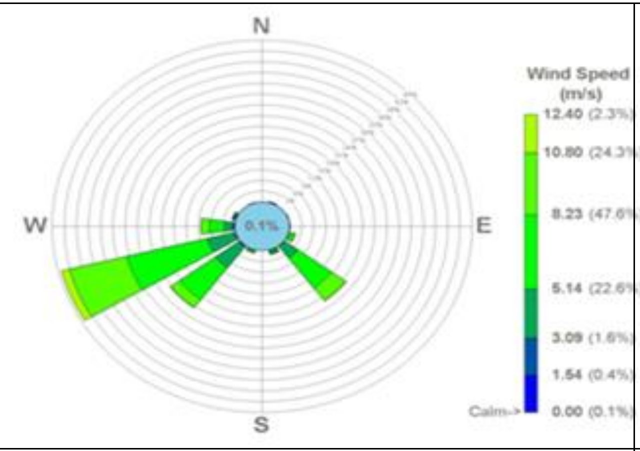


e: Windrose Plot for May 2016

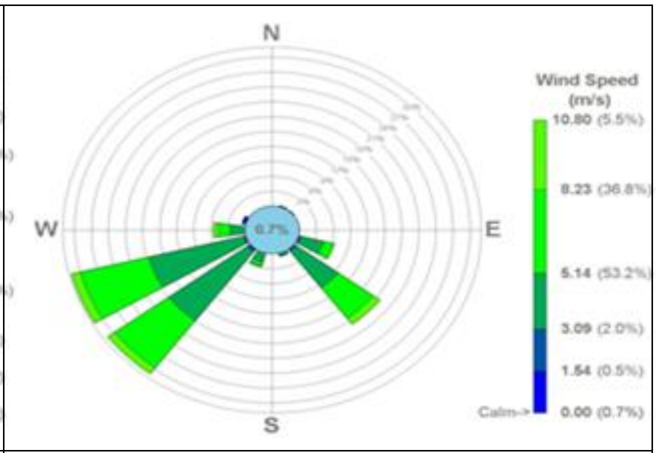


f: Windrose Plot for June 2016

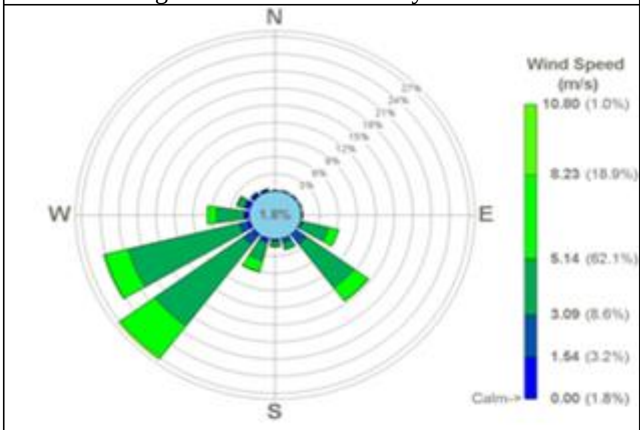
Figure 2: Windrose Plots for the year 2016 (a to f)



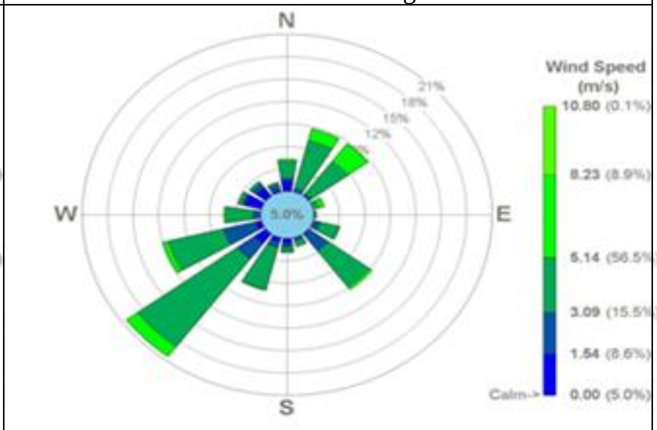
g: Windrose Plot for July 2016



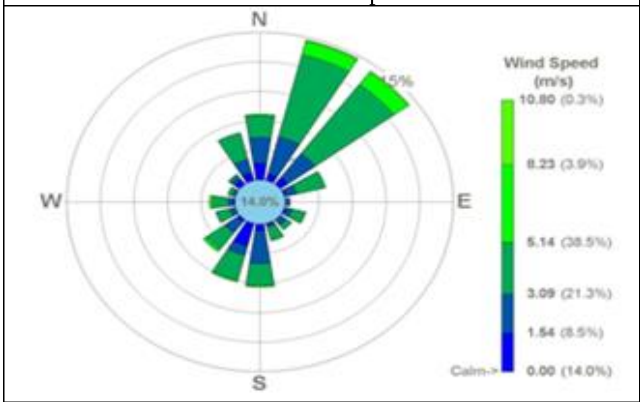
h: Windrose Plot for August 2016



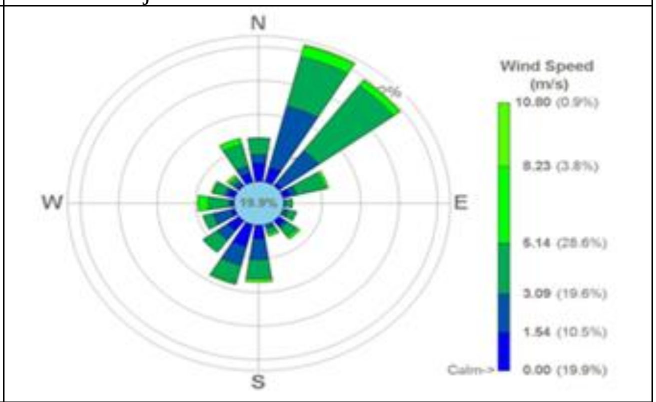
i: Windrose Plot for September 2016



j: Windrose Plot for October 2016



k: Windrose Plot for November 2016



l: Windrose Plot for December 2016

Figure 2: Windrose Plots for the year 2016 (g to l)

2.3 Model inputs

Selection of UTM zone 42 in the datum of WGS 84 and NOAA/ESRL RADIOSONDE UPPER AIR PROFILING data along with hourly surface meteorological data of 2016 were utilized. Then datasets were pre-handled with AERMET (pre-handling device) to create AERMOD documents *i.e.*, profile and surface file, results were demonstrated for 1-h, 24-h, and yearly periods of SO_2 and NOx additionally the power plants will work for 24-h at full burden, anticipated as highest level of air pollution.

Table 1: Baseline data

Pollutant	Unit	Averaging time	Measurements method	Concentrations
SO_2	$\mu g/m^3$	24-h	UV Fluorescence	19.2
NOx	$\mu g/m^3$	24-h	Gas phase Chemiluminescence	23.3

Table 1 displays the final NOx and SO_2 background concentrations in the study area. Whereas, emissions data was collected from Sindh Environmental Protection Agency (SEPA) GoS, which are shown in Table 2.

Table 2: Emissions data

Parameters	Lucky electric	Engro coal	Coal sinohydro	K electric		FFBL coal
Source ID	* Stack p. 1	* Stack p. 7	* Stack p. 4 and * Stack p. 5	* Stack p. 2	* Stack p. 3	* Stack p. 6
Source type	Point	Point	Point	Point	Point	Point
X-Coordinate	327122.44	335951.84	335270.37, 335270.17	334101.51	334159.29	340291.29
Y-Coordinate	2745560.45	2742659.81	2742109.23, 2742109.26	2742135.16	2742127.34	2747468.14
Stack no.	1	1	2	1	1	1
Stack height, m	200	40	200	45	45	70.00
Stack exit dia, m	8	6.75	7.00	7.3	7.3	3.00
Stack exit Temp: (C)	66	106.05	46	97	98	149
Gas exit velocity, m/s	20	20	20.00	20	21	18.00
Fuel type	Coal	GAS	COAL	RLNG	RLNG	(Coal Sub-Bituminous)
Plant Capacity, MW	660	450	2 X 660	450	450	110-120
NOx (g/s)	236	114.81	280.6	27.3	27.3	60.36
SO_2 (g/s)	118	361.12	108.9	NIL	NIL	126.06

Source: Sindh Environmental Protection Agency (SEPA)
* Stack Parameter

3. RESULTS & DISCUSSION

The modeling results of NOx predicted by the Model in the form of isolines ranged from 30 to 170 μg/m^3 1-h as shown Figure 3, 1 to 33 μg/m^3 24-h as shown in Figure 4 considered as short term cumulative impacts for this study, while long term cumulative impacts of NOx annual levels of emissions ranged from 0.3 to 14.5 μg/m^3 on the study as study area as shown in Figure 5. Whereas SO_2 predicted by the Model ranged from 10 to 199 μg/m^3 1-h as shown in Figure 6, 0.9 to 29.8 μg/m^3 24-h as shown in Figure 7 and NOx annual levels of emissions ranged from 0.3 to 7.5 μg/m^3 on the air quality of Karachi as shown in Figure 8. Due to unavailability of threshold limits for SO_2, NOx 1-h and Annual averaged emissions in Pakistan, BC Ministry of Environment guidelines were utilized as focus limits (BCME, 2009) as given in Table 3.

Table 3. Threshold limits

Receptors	Levels (μg/m^3)					
	SO_2			NOx		
Human health/environment	1 h	24 h	Annual	1 h	24 h	Annual
	450^a	160^a	25^a	400^b	200^b	60^c

BC MoE (2009) – a,b and c.

All the results are complying with national and international standards as shown in Table 4 is mainly because prevailing meteorological conditions within the modeling domain *i.e.*, wind speed (5-8 m/s) and wind direction as shown in Figure 2 (a to l) have a substantial impact on the air flow field, which results in lowering the ground level concentrations of the pollutants in the study area but the results are higher from the baseline concentration as shown in Table 1. Furthermore, strong sea breeze from the Arabian Sea is responsible for lowering the emissions limits in the study area which is termed as a blessing to the nearby residents.

Table 4. Model Results

Parameters	Av: time	Min (µg/m^3)	Max (µg/ m^3)	NEQS (µg/ m^3)	SEQS (µg/ m^3)	MoE Canada (2009b) (µg/ m^3)
SO_2	1 h	30	170	-	-	450
	24-h 1st Percentile	1	33	-	-	160
	Annual	0.3	14.5	-	-	25
NOx	1 h	10	199	-	-	450
	24-h1st Percentile	0.9	29.8	-	-	200
	Annual	0.3	7.5	80	80	60

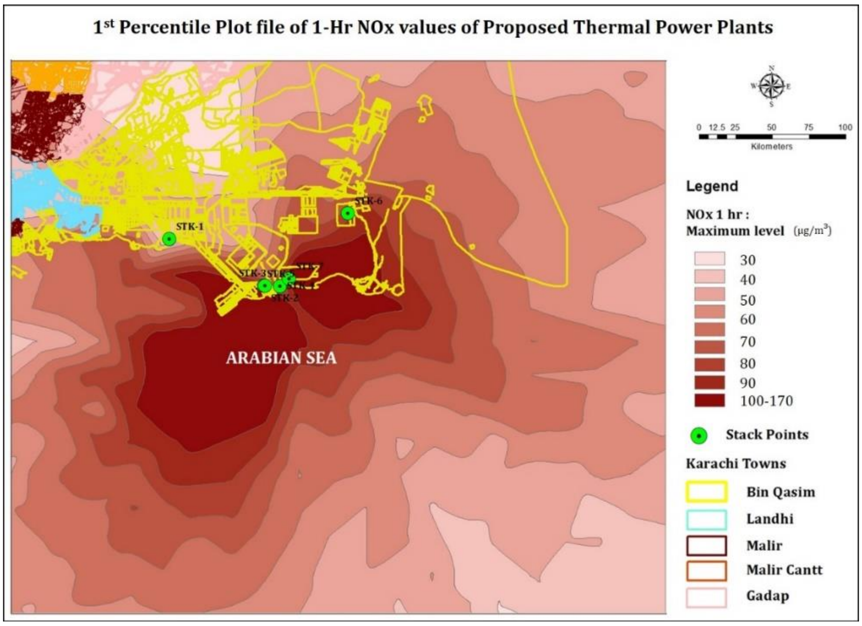


Figure 3: 1-h averaged NOx emissions

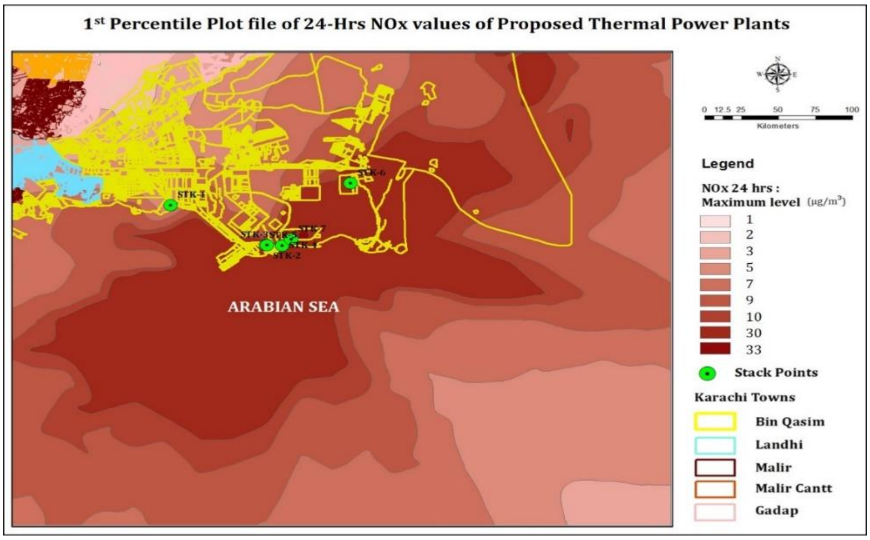


Figure 4: 24-h NOx emissions

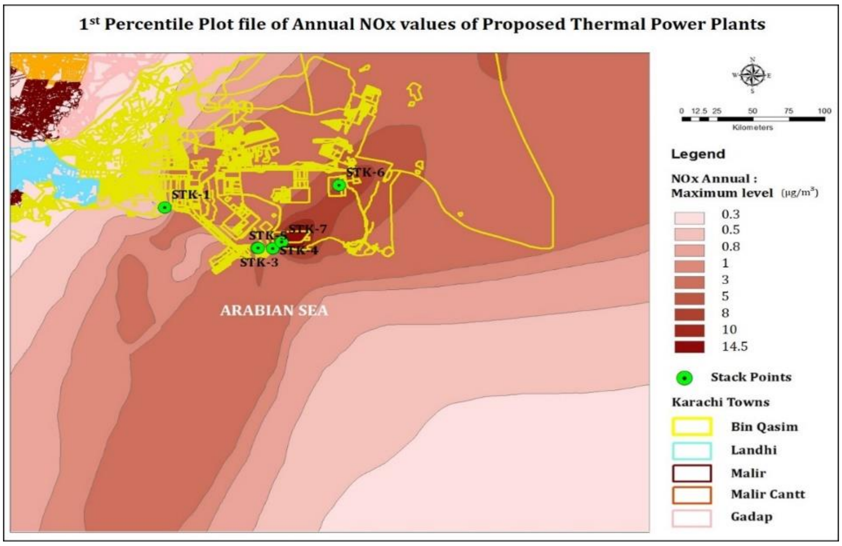


Figure 5: Annual averaged NOx emissions

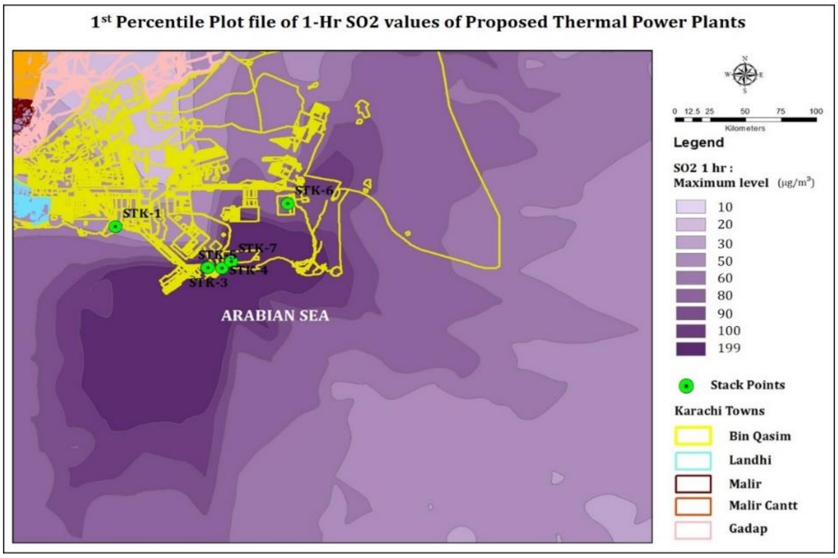


Figure 6: 1-h averaged SO_2 emissions

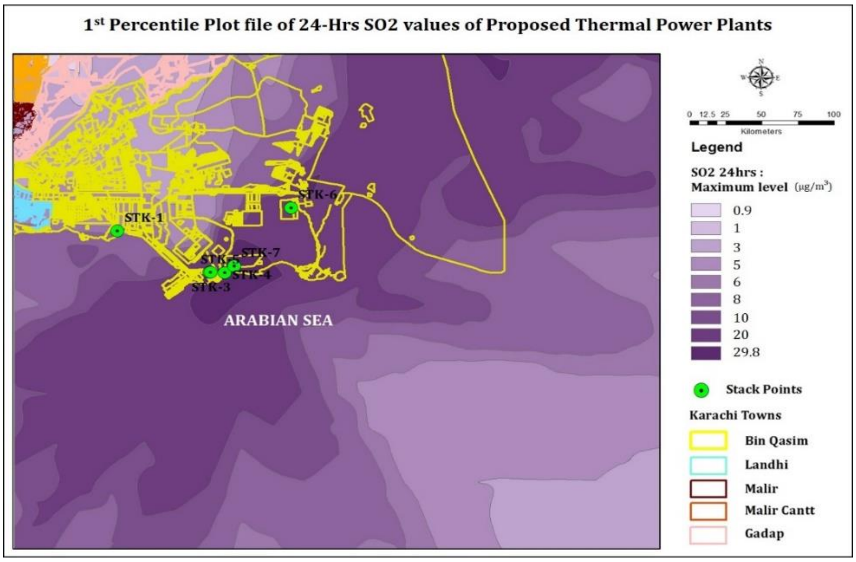


Figure 7: 24-h averaged SO_2 emissions

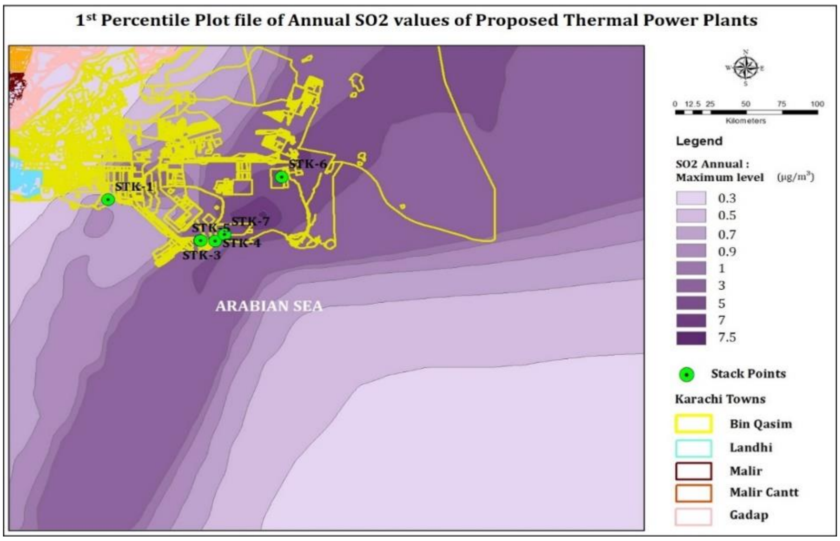


Figure 8: Annual averaged SO_2 emissions

4. CONCLUSION

Air contamination influences are a reality across the globe, this CIA study shows negligible impacts because of prevailing meteorological conditions within the modeling domain *i.e.,* wind speed (5-8 m/s) and wind direction as shown in Figure 2 (a to l) have a substantial impact on the air flow field, which results in lowering the ground level concentrations of the pollutants in the study area but the results are higher from the baseline concentration as shown in Table 1. Furthermore, strong sea breeze from the Arabian Sea is responsible for lowering the emissions limits in the study area which is termed as a blessing to the nearby residents. The primary purpose was to develop a practical CIA tool, based on a standard procedure to be used by Sindh Environmental Protection Agency to assess the cumulative impacts and guide future industrial developments to submit CIA assessment as a legal requirement. Although the selected parameters concentrations are complying, however, the importance of cumulative impact assessment can't be ignored in Pakistan because of an increasing trend of air pollution in the city of Karachi. Another reason is that only thermal power plant emissions were considered in this study apart from other emissions sources like transport, fertilizers, ship operations and textile units in the study are and no specific SO_2 and NOx emissions reduction initiatives in the Vision of 2025 planned by Sindh Government. As a result, the planned operation of thermal power plants in the future and the pollutants they will produce could seriously affect Karachi's air quality, raising several health risks in the research region.

5. REFERENCES

Alam, K.; Blaschke, T.; Madl, P.; Mukhtar, A.; Hussain, M.; Trautmann, T.; Rahman, S., (2011). Aerosol size distribution and mass concentration measurements in various cities of Pakistan. J. Environ. Monit., 13: 1944-1952**.**

BCME, (2009). Air quality objectives and standards. British Columbia Ministry of Environment.

https://www2.gov.bc.ca/gov/content/environment/air-land-water/air/air-quality-management/regulatory-framework/objectives-standards

Braback, L.; Breborowicz, A.; Dreborg, S.; Knutsson, A.; Pieklik, H.; Björkstén, B., (1994). Atopic sensitization and respiratory symptoms among Polish and Swedish school children. Clin. Exp. Allergy 24(9): 826-835.

Braun-Fahrlander, C.; Vuille, J.C.; Sennhauser, F.H.; Neu, U.; Künzle, T.; Grize, L.; Gassner, M.; Minder, C.; Schindler, C.; Varonier, H.S.; Wüthrich, B., (1997). Respiratory health and long-term exposure to air pollutants in Swiss schoolchildren. Am. J. Respir. Crit. Care Med. 155(3): 1042-1049.

Col Beck, I.; Nasir, ZA.; Ahmad, S.; Ali, Z., (2011). Exposure to PM_{10}, $PM_{2.5}$, PM_1 and carbon monoxide on roads in Lahore, Pakistan. Aerosol Air Qual. Res. 11: 689–695.

EIU, (2017). The global liveability report 2017; A free overview. Economist Intelligence Unit.

https://www.eiu.com/public/topical_report.aspx?campaignid=Liveability17

EMCPL, (2016). EIA of 660 MW coal-fired power plant. Sindh Environmental Protection Agency, Government of Sindh. Environmental Management Consultancy Pakistan (Pvt.) Limited.

Faiza Ilyas, (2018). Concerns related to serious environmental degradation affecting the federally administered Port Qasim area dominated the proceedings of a public hearing held at a hotel on Thursday October 26, 2018 DAWN. https://www.dawn.com/news/1441362

Fajersztajn, L.; Saldiva, P.; Pereira, LAA.; Leite, VF.; Buehler, AM., (2017). Short-term effects of fine particulate matter pollution on daily health events in Latin America: a systematic review and meta-analysis. Int J Public Health 2017; 62: 729-38.

GEMSL, (2017). EIA of 2X450 RLNG Based Power Plant. Sindh Environmental Protection Agency, Government of Sindh. Global Environmental Management Services (Pvt.) Limited.

Hashmi, D.R.; Shaikh, G.H.; Usmani, T.H., (2005). Air quality in the atmosphere of Karachi city-an overview. Jour. Chem. Soc. Pak., 27: 6–13.

HBPL, (2016). EIA of 110-120 MW FFBL Coal Based Power Plant. Sindh Environmental Protection Agency, Government of Sindh. Hagler Bailly Pakistan (Pvt.) Limited.

HBPL, (2015). EIA of 450 MW RNLG Power Plant, Sindh Environmental Protection Agency, Government of Sindh. Hagler Bailly Pakistan (Pvt.) Limited.

HBPL, (2014). EIA of 2X660 MW Coal Based Power Plant. Sindh Environmental Protection Agency, Government of Sindh. Hagler Bailly Pakistan (Pvt.) Limited.

Higgins, B.G.; Francis, H.C.; Yates, C.J.; Warburton, C.J.; Fletcher, A.M.; Reid, J.A.; Pickering, C.A.; Woodcock, A.A., (1995). Effects of air pollution on symptoms and peak expiratory flow measurements in subjects with obstructive airways disease. Thorax 50(2):149-155.

Hoek, G.; Brunekreef, B., (1993). Acute effects of a winter air pollution episode on pulmonary function and respiratory symptoms of children. Arch. Environ. Health 48(5):328-335.

K-Electric, (2016). K-Electric reiterates its commitment to meet city's growing power demand September 28, 2016. https://www.ke.com.pk/k-electric-reiterates-its-commitment-to-meet-citys-growing-power-demand

Karachi Metropolitan Corporation, (2017). Government of Sindh.

http://www.kmc.gos.pk/Contents.aspx?id=14

National Power Policy, (2013). Government of Pakistan.

http://www.ppib.gov.pk/National%20Power%20Policy%202013.pdf

Newell, K.; Kartsonaki, C.; Lam, KBH.; Kurmi, O., (2018). Cardiorespiratory health effects of gaseous ambient air pollution exposure in low- and middle-income countries: a systematic review and meta-analysis. Environ Health 2018; 17: 41.

Pakistan Bureau of Statistics, (2017). Government of Pakistan.

http://www.pbs.gov.pk/sites/default/files/PAKISTAN%20TEHSIL%20WISE%20FOR%20WEB%20CENSUS_2017.pdf

Pakistan Bureau of Statistics, (1998). Government of Pakistan.

http://www.pbs.gov.pk/sites/default/files//tables/City%20District%20Karachi%20at%20a%20glance.pdf

Peters, A.; Dockery, D.W.; Heinrich, J.; Wichmann, H.E., (1997). Short-term effects of particulate air pollution on respiratory morbidity in asthmatic children. Eur. Respir. J. 10(4):872-879.

Rajak, R.; Chattopadhyay, A., (2019). Short and long-term exposure to ambient air pollution and impact on health in India: a systematic review. Int J Environ Health Res., 30(6):593-617.

Saric, M.; Fugas, M.; Hrustic, O., (1981). Effects of urban air pollution on school-age children. Arch. Environ. Health 36(3): 101-108.

Schwartz, J.; Dockery, D.W.; Neas, L.M.; Wypij, D.; Ware, J.H.; Spengler, J.D.; Koutrakis, P.; Speizer, F.E.; Ferris Jr, B.G., (1994). Acute effects of summer air pollution on respiratory symptoms reporting in children. Am. J. Respir. Crit. Care Med. 150(5): 1234-1242.

Soyseth, V.; Kongerud, J.; Broen, P.; Lilleng, P.; Boe, J., (1995). Bronchial responsiveness, eosinophilia, and short-term exposure to air pollution. Arch. Dis. Child., 73(5): 418-422.

Stebbings Jr, J.H.; Hayes, C.G., (1976). Panel studies of acute health effects of air pollution: I. Cardiopulmonary symptoms in adults, New York, 1971-1972. Environ. Res., 11(1): 89-111.

Tanveen, A.; Rasheed, M.; Imran, A.; Azra Parveen, Azad., (2018). Impacts of downtown developments to facilitate environmental sustainability and presence of core and frame: a case study of Saddar, Karachi, Pakistan. J. Basic Appl. Sci., 14: 23-31.

USEPA, (2021). Nitrogen Dioxide (NO_2) Pollution

https://www.epa.gov/no2-pollution/basic-information-about-no2#Effects

Vedal, S.; Schenker, M.B.; Munoz, A.; Samet, J.M.; Batterman, S.; Speizer, F.E., (1987). Daily air pollution effects on children's respiratory symptoms and peak expiratory flow. Am. J. Public Health 77(6): 694-698.