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Environmental Impact Assessment and Determination of Air Quality Study in Chennai Region, Tamilnadu, India.

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ABSTRACT
Urban air pollutants, pose a major health problem in most developing countries, especially India. Prolonged exposure presents a significant carcinogenic risk. This study analyzes NO_2, SO_2, $PM_{2.5}$-bound heavy metals and $PM_{2.5}$-bound PAHsin108samplescollectedduring 2018-2019 at a suburban industrial site in the Chennai, Tamil Nadu. NO_2 and SO_2 were found to be within acceptable levels but $PM_{2.5}$ exceeded the limits of both CPCB and WHO guidelines. The NWR plots used for pollutant source contributions pointed to high probabilities for local pollutant sources at low wind speeds (< 5m/s). The levels of heavy metals in $PM_{2.5}$ and the diagnostic ratios of $PM_{2.5}$-bound PAH further confirmed vehicular and industrial emissions to be the sources. The 96-h back trajectory and cluster analysis showed the air masses from the South-Western and North Eastern directions influencing the pollutant levels at the monitoring site. Health Risk Assessment showed varying levels of risk for various pollutant constituents. The Incremental upper-bound Lifetime Cancer Risk (ILCR) via inhalation exposureto$PM_{2.5}$-boundPAHwasatthe‗low'risklevel($15.4x10^{-5}$).To improve air quality, close attention should be paid to controlling vehicular and thermal plant emissions.
Keywords: Gaseous Pollutants, Particulate Pollutants, Outdoor Air quality, Chennai.

1.INTRODUCTION

Urban air quality poses a serious threat to human health. As they are home to densely packed populations and pollutant levels regularly exceed them and values (Kumaretal.2015;Singhetal.2021;Badida et al. 2023). Gaseous pollutant emissions in urban areas are known to cause environmental and concerns related to public health (Brauer et al. 2012; Kim et al. 2013). Nitrogen dioxide and sulphur According to Mustafic et al. (2016), carbon dioxide is a priority gaseous air pollution that is harmful to both human health and the ecosystem. In South Africa, reports have indicated the impact of extended exposure to NO_2 on respiratory mortality. (Naidoo et al. 2008), China(Tao et al. 2012; Yang et al. 2015),India (Maji et al. 2017) and Iran (Vahedian et al. 2017). Exposure to NO_2 and SO_2 can lead to bronchial reactivity (Happoetal.2010; Ko&Hui2012),pulmonary inflammation (Ko & Hui 2012) and inflammation of blood vessels (States and EPA 2019).

Atmospheric Particulate Matter (PM) can be defined as a heterogeneous mixture Comprising polycyclic aromatic hydrocarbons, elemental and other organic carbon, and heavy metals (PAHs), sulphate and nitrate salts and water (Ghasemi et al. 2020). $PM_{2.5}$is considered the fifth leading risk factor worldwide and the third leading risk factor in India (Collaborators2015). The health risks of gaseous pollutants and $PM_{2.5}$ to human health have been well-established (Newell et al. 2017). $PM_{2.5}$ has the ability to absorb potentially hazardous elements "such as heavy metals, polycyclic aromatic hydrocarbons, and polychlorinated biphenyls amongst others (Guo et al.2003; Islam et al. 2020).Among these, heavy metals in $PM_{2.5}$ area major health threat as they caused verse effects on prolonged exposure. These enter the human body via inhalation, ingestion or dermal contact and cause potential carcinogenic effects (Wang et al. 2014). The level of heavy metal in $PM_{2.5}$ is influenced by natural processes, such as" erosion and long-range transport, as well as anthropogenic activities, including vehicular emissions, industrial activities and fuel combustion (Titos et al. 2014).

PAHs released into incomplete combustion of fossil fuels, which occurs in automobiles, oil refineries, the coke and steel industry, and waste incineration, produces the atmosphere. (Callén et al. 2014; Liu et al. 2018c). PAHs are hydrophobic, bind easily to particles (Cai et al. 2007), and are resistant to degradation (Liu et al. 2018c), making them suitable for easy long-range transport. Hence, it is crucial to assess the health risk posed by gaseous pollutants and fine particulate matter by analysing their concentration and potential sources in order to efficiently control air pollution.

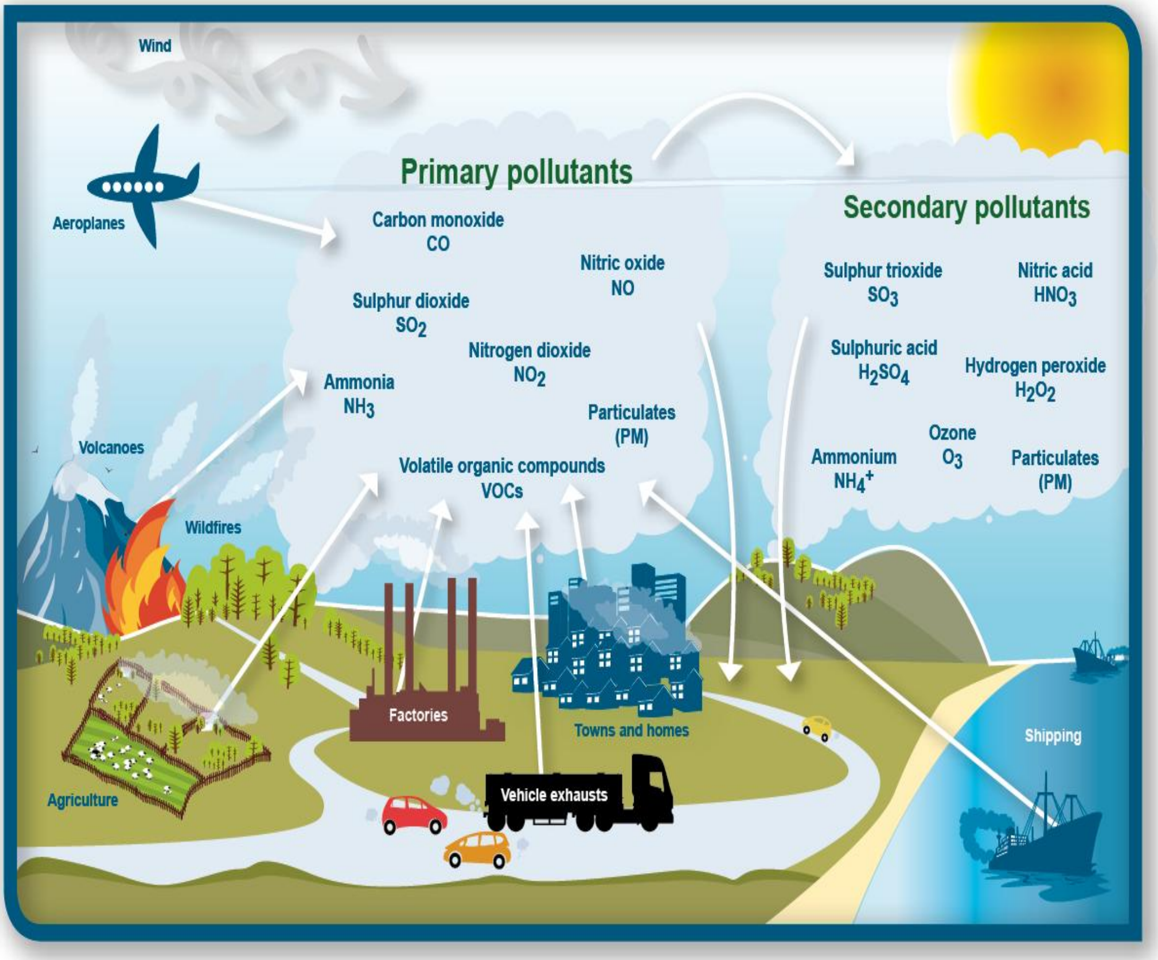

Figure 1.Air pollution status of Chennai city

The capital of Tamil Nadu, Chennai, is India's fourth-biggest city. Due to rapid industrialisation and urbanisation, Chennai records high environmental pollutant levels. Though many studies have analysed the levels of particulate matter and gaseous pollutants, very few reports have comprehensively examined the metals and PAHs that are linked to $PM_{2.5}$. Actually, as far as we are aware, only Mohanraj et al. (2011) investigated the differences in $PM_{2.5}$ and $PM_{2.5}$-bound PAH in Chennai in 2010.There are no Additional research that examines the dangers to human health that the Chennai Metropolitan Region poses from exposure to gaseous pollution, $PM_{2.5}$-bound heavy metals, and PAH. Therefore, the main objectives of this study are to: i) thoroughly analyse the concentrations of NO_2, SO_2, $PM_{2.5}$-bound heavy metals, and $PM_{2.5}$-bound PAHs and identify their possible sources; ii) use correlation studies to ascertain and elucidate the relationship between the pollutants and weather conditions; iii) assess the risk to human health posed by prolonged inhalation of NO_2, SO_2, $PM_{2.5}$-bound heavy metals, and $PM_{2.5}$-bound PAHs; and iv) use back trajectory analysis to identify the regional sources of air masses using the HYSPLIT model.

2.METHODOLOGY

2.1.Study Site Characteristics

The southern part of the Indian Peninsula is home to Chennai, the fourth-largest metropolitan area. It has a population of 7.45 million and is very densely populated (26,553persons/KM^2) (IndiaCensus2011). It is hometoa large number of industries, of which automobile manufacturing is the most prominent. The city's northern region is home to a number of sectors that produce a lot of pollution, including thermal power plants, petrochemicals, and iron and steel facilities. The Central Pollution Control Board has designated the Manali Industrial Cluster in this area as seriously contaminated due to the high levels of pollution. (CPCB 2009).

2.2.Analysis of Air Pollutants

The chemicals required for SO_2 analysis were prepared in the laboratory according to Indian Standard IS 5182 (Part 2):2001 (IS 5182, 2001). The SO_2-absorbing solution (0.04M potassium tetracholomercurate) was prepared by dissolving10.86g mercuricchloride,0.066g of potassium chloride and 6.0 g of EDTA in distilled water. One litre of the resultant solution was prepared in a volumetric flask. This solution was stored for up to 6 months under refrigeration. To determine the SO_2 levels,0.6% 0.6 g was dissolved in 100 mL of distilled water to create sulfamic. 0.2% Formaldehyde was prepared by diluting 5 mL of the 36-38% formaldehyde solution to 1 litre in a volumetric flask. The purified pararosaniline solution (0.2% Nominal) was made by dissolving 0.500g of pararosaniline that has been properly purified in 100 millilitres of distilled water. To prepare the working pararosaniline solution, 10 ml of the above-mentioned purified pararosaniline solution was pippeted out into a 250-mL volumetric flask, and 15 ml concentrated hydrochloric acid was added. The solution was finally diluted to a final volume of 250 ml and used for further analysis.

The gaseous pollutants ($NO_2$and SO_2) were sampled using an APM 433 gaseous sampler (Envirotech Instruments Pvt Ltd). SO_2 from the air stream was absorbed using the potassium tetrachloro mercurate (TCM) solution and analysed colorimetrically by the West and Gaeke (West &Gaeke 1956) methadone UV-visible spectrophotometer, which was calibrated at the wavelength of 560 nm.

2.3.Standard preparation and standard curve for SO_2

To prepare the standard solutions for SO_2 detection, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, and 3.5 millilitres of land Separate 25 mL volumetric flasks were filled with 4.0 mL of the working sulphite TCM solution. The volume was raised to 10 ml by adding enough TCM solution. At the same time, 10 millilitres of absorbing solution were made as a reagent blank. With absorbance on the Y-axis and concentration on the X-axis, the absorbance values of the standards and reagent blank were displayed. After drawing the best line of fit, its slope was ascertained. The Calibration Factor (CF) was the reciprocal of this slope.

2.4.Quality Control (QC) / Quality Assurance (QA) for SO_2

"Very strict quality control and quality assurance protocols were implemented at every stage to ensure accuracy and reliability of the air sampling and analysis procedures. These include maintenance of protocols at equipment calibration, field samples, Lab blank testing and field blank analysis. A flow meter was used for the calibration of all employed air pumps. During SO_2 measurements, field blanks and laboratory blanks (10 ml of unexposed absorbing solution) were also analyzed for SO_2 in the same manner as the actual samples. Distilled water was used as the optical reference. SO_2 samples with absorbance greater than 1.0 were reanalyzed after diluting the aliquot of collected samples with an equal volume of unexposed SO_2-absorbing reagent."

2.5.Reagent preparation and NO_2 measurement

"For the preparation of the NO_2-absorbing solution, in accordance with Indain Standard IS 5182 (IS 5182,2006), 4.0 gram of sodium hydroxide was dissolved in distilled water. Sodium arsenite (1.0 gram) was then added to the solution. The resultant solution was diluted to 100 ml in a volumetric flask. For the preparation of the sulphanilamide solution, 20.0 gram of sulphanilamide was dissolved in 700 ml of distilled water. To this solution, 50 ml of 85% phosphoric acid was added and, the resultant solution was made up to 1000 ml and stored in a refrigerator. Next, 0.2 ml of 30% hydrogen peroxide (H_2O_2) was dissolved in 250 ml of distilled water. The stock nitrite solution was prepared by dissolving sufficient dessicated sodium nitrite (> 97%) in 1000 ml of distilled water."

NO_2 from "the air stream was absorbed using the sodium arsenite-sodium hydroxide mixture and analysed colorimetrically by the modified Jacobs-Hochheiser method (Jacobs & Hochheiser 1958) at the wavelength of 540 nm. The flow rate was maintained at 1 L/min during the collection of both gaseous pollutants."

2.6.Quality Control (QC) / Quality Assurance (QA) for NO_2

To guarantee the precision and dependability of the air sampling and analysis processes, extremely stringent quality control and quality assurance systems were put in place at every turn. These consist of field samples, lab blank testing, field blank analysis, and equipment calibration protocol maintenance. Every air pump that was utilised was calibrated using a flow meter. Field blanks and laboratory blanks (10 mL of unexposed absorbing solution) were also examined for NO_2 during NO_2 measurements in the same way as the real samples. The optical reference was distilled water. After diluting the aliquot of collected samples with an equivalent volume of unexposed NO_2-absorbing reagent, NO_2 samples with absorbance greater than 1.0 were reanalysed.

2.7.Sampling of $PM_{2.5}$

"$PM_{2.5}$ levels in the ambient air were measured using an APM 550 Mini Fine Particulate Sampler (Envirotech Instruments Pvt. Ltd)."The air mass was allowed to enter the sampler at the rate of 16.67

LPM. Theparticles ≥ 10 microns were filtered in the WINS impactor. The air sample and fine particles coming out of the WINS impactor were deposited on 47mm PTFE filter papers (Merck Life Sciences Pvt. Ltd.). The filter papers were weighed using a microbalance (Shimadzu AUX220).

3.RESULTSANDDISCUSSION

3.1.Gaseous Pollutants

The annual mean concentration of NO_2 was19.34 μg/m^3 and for SO_2 it was 8.20 μg/m^3. Both the gaseous pollutants did not exceed NAAQS standards. NO_2 averaged 26.9 μg/m^{3}during the summer, 24.01 μg/m^3 during monsoon and10.24μg/m^{3}during the winter, whereas SO_2 averaged 8.44μg/m^3 during summer season,4.38μg/m^{3}during monsoon and12.69 μg/m^3 during the winter season. Figure 3.5 shows the trend of gaseous pollutants observed at the study site.NO_2 showed statistically significant positive correlation values for temperature "(R=+0.5,p<0.01), and wind speed R = 0.29, p < 0.01). SO_2 on the other hand showed statistically insignificant negative correlation values for temperature (R=-0.18) and wind speed (R = -0.17) and a positive correlation for relative humidity (R = 0.07)." High concentration of NO_2 can be primarily attributed to incomplete combustion, industrial emissions and local area emissions. Also, NO emitted from vehicular and industrial sources in presence of sunlight can undergo heterogeneous reaction producing NO_2 (Tajudinetal.2019). High concentrations observed in summer season during the study period can be attributed to this reason. Similar Pearson correlation values were (R=-0.14,p=0.15) reported by Bhutiani etal. (2021) and Dandotiya et al. (2020).

Coal fired power plants & petrochemical refineries and Complex are the predominant source of SO_2. The level of SO_2 was well below NAAOS standards due to installing flue gas desulfurization equipment in thermal power stations and having the Tamilnadu Pollution Control Board (TNPCB) closely monitor emissions. For the duration of the investigation, there has been a negative association between NO2 and SO2. Mann-Kendall approach was utilized for statistically determining trends for gaseous pollutants. A statistically significant positivetrendwasfoundforNO_2 (18.01μg/m^3/year) whereas a negative trend was observed for SO_2 (5.25 μg/m^3/year), "Table 3.3 shows the values of fine particulate matter and gaseous pollutants."

3.2.Fine Particulate Matter ($PM_{2.5}$)

During the study year, the average annual PM2.5 concentration was 109.69μg/m^3·This isnearly10timeshigher than WHO guidelines (10μg/m^3) and also exceeds NAAQS standards of 40 μg/m^3 given by CPCB. The trend of $PM_{2.5}$ observed at the study site. If seasons are considered, the $PM_{2.5}$ averaged 107.27 μg/m^3 in the summer, 100.43 μg/m^3 during monsoon and 123.42 μg/m^3 during the winter season. Wintertime high PM2.5 levels can be ascribed to lower wind seeds and high relative humidity, which results in its accumulation at ground level (Gadi Ranu et al. 2019). These meteorological conditions coupled with anthropogenic activities such as high vehicular pollution, fireworks and emission from surrounding industriesledtohigh$PM_{2.5}$levelsespeciallyduring yearend. The brief dip of $PM_{2.5}$ levels observed during months of November and December can be attributed to North East monsoon rains. Sampling campaign was briefly suspended during this period, due to rains.

During the study period, a negative and statistically insignificant correlation has been found between temperature and $PM_{2.5}$.Thisindicatesthat temperatures help in accumulation of $PM_{2.5}$ especially during winter. "The same trend has been reported in literature also (Bhutiani et al. 2021; Maraziotis et al. 2008; Tyagi et al. 2012). A statistically insignificant weak positive correlation was observed between $PM_{2.5}$ and relative humidity (R=+0.076, p = 1.043) for the entire study period. The possible reason can be attributed to increased formation of secondary PM with high amounts of gas-phased chemical pollutants"(Huang et al. 2015). Also, high RH levels favour increased nucleation of Sulphuric Acid during exhaust dilution, resulting in formation of Particulate Matter (Morawska et al. 2008; Zalakeviciute et al. 2018). This suggests that source of pollution of $PM_{2.5}$ is traffic based. A negative & insignificant correlation has been found between $PM_{2.5}$& wind speed (R = -0.029) indicating the role of wind in dispersing $PM_{2.5}$.Previous studies have reported similar results (Bhutiani et al. 2021; Martuzevicius et al. 2004). A non-parametric Mann-Kendall approach used via Thielsen function in Openair was utilized to statistically determine whether a trend is significant or not.A positive trend was found for $PM_{2.5}$ (9.44 μg/m^3/year). Figure S42 shows the Thielsen plot of $PM_{2.5}$ at the monitoring site.

3.3.Chemical Analysis

3.3.1.$PM_{2.5}$bound heavy metals

A total of 7 heavy metals in $PM_{2.5}$ were quantified. Mercury (Hg) & Chromium (Cr^{6+}) were found to be Below Detection Limit (BDL) in the $PM_{2.5}$ samples for the entire study duration. The annual and seasonal variations"of $PM_{2.5}$ bound heavy metals are shown in Table.1. The range of concentration of metals were

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(Iron (Fe) (98 – 12,370 ng/m^3), Lead (Pb) (1 - 590 ng/m^3), Arsenic (As) (0.2 - 135 ng/m^3), Nickel (Ni) (0.19 - 40 ng/m^3) and Cadmium (Cd) (0.1 – 18.5 ng/m^3) respectively. The mean concentration of heavy metals were ranted in the order of Fe>Pb>As>Ni>Cd. The highest mean concentration of metals was detected in winter followed by monsoon. The minimum levels were detected in summer season. Fe had highest conc. Among stall metals. Presence of Fe in $PM_{2.5}$ can be attributed to local/regional soil as well as road dust suspension, lubricating oil and tail pipe emissions from automobiles (Bi et al. 2020; Faraji et al. 2020). Heavy metals such as Pb, As & Cd have been distinguished as tracers for coal combustion (Dai et al. 2015; Liu et al. 2018)."

Positive correlation has been found between Lead, Cadmium and Arsenic ($0.7 \leq K \leq 0.74$) suggesting a common combustion source (coal combustion and traffic emissions). Nickel in $PM_{2.5}$ can be attributed to industrial processes and heavy oil combustion (Duan et al. 2021; Liu et al. 2018).

3.3.2.$PM_{2.5}$ bound PAHs

The average concentration of $PM_{2.5}$ bound PAHs (TPAH) for the entire study period was determined to be 8.03 ng/m^3 ranging from 0.16 to 74.8 ng/m^3. The range of identified TPAH s in descending order(µg/m^3) was.

Benzo (a) Anthracene (2.65±8.32) > Chrysene (1.78±4.92) > Indeno (1,2,3-cd) Pyrene(1.07±1.356) > Benzo (a) Pyrene (0.811±1.71) >Benzo (b) fluranthene (0.660±0.954) >Benzo (ghi) Perylene (0.554±0.547) >Dibenz (a,h) Anthracene (0.498±0.459).

The concentration of TPAH was 2.5 times higher in winter when compared to annual PAH levels. Further a non-significant negative correlation (R=-0.18, p = 0.28) was observed between TPAHs and temperature for the entire study. This suggests that temperature inversions and lower Weak dispersion caused by various layer heights causes PAHs to accumulate and enrich in wintertime particulate phases. (Zhang et al. 2020). In summer season, PAHs are seen to easily be transferable to the atmosphere and therefore do not attach themselves efficiently to $PM_{2.5}$(Heetal.2014;Liu et al. 2017).

A very weak positive correlation was observed between TPAHsand relative humidity (R = 0.094, p = 0.57).This can be attributed to wet depositional effects of gaseous PAHs on particulate PAHs (Ali-Taleshi et al. 2021; Khan et al. 2018; Moein).

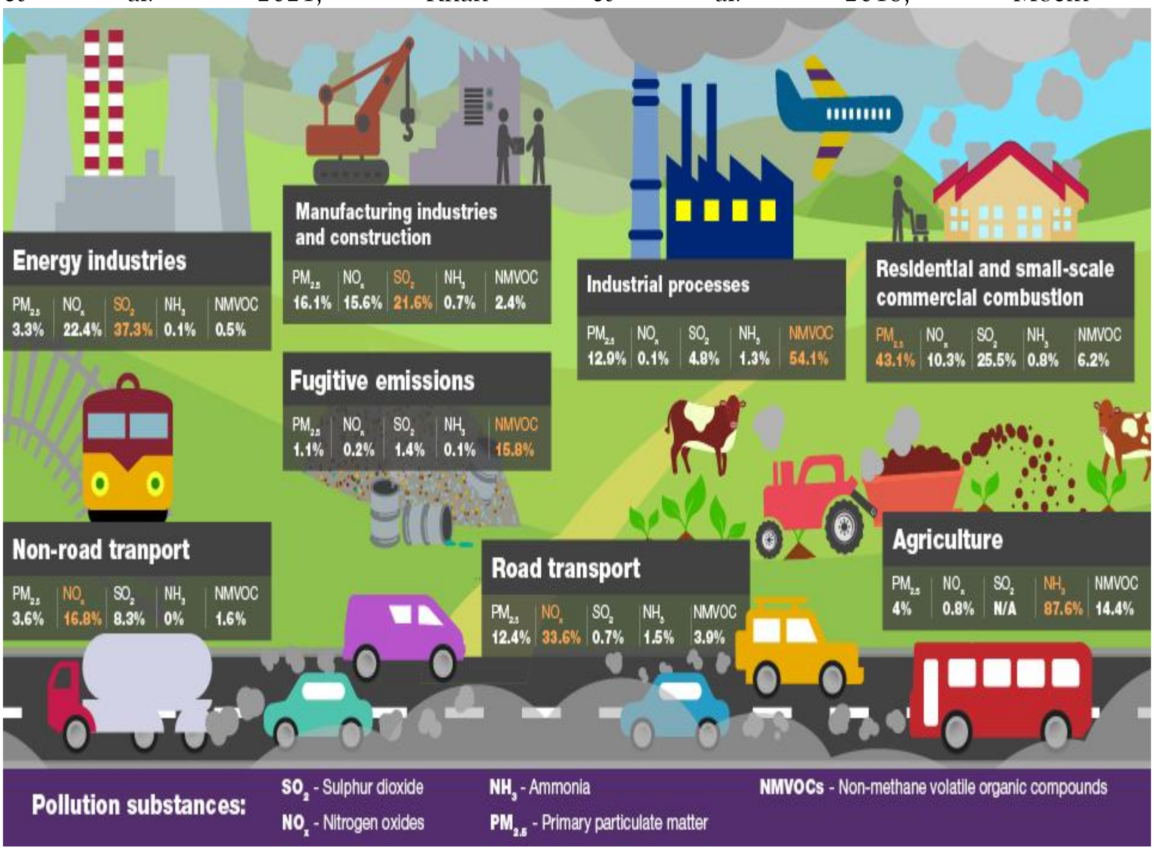
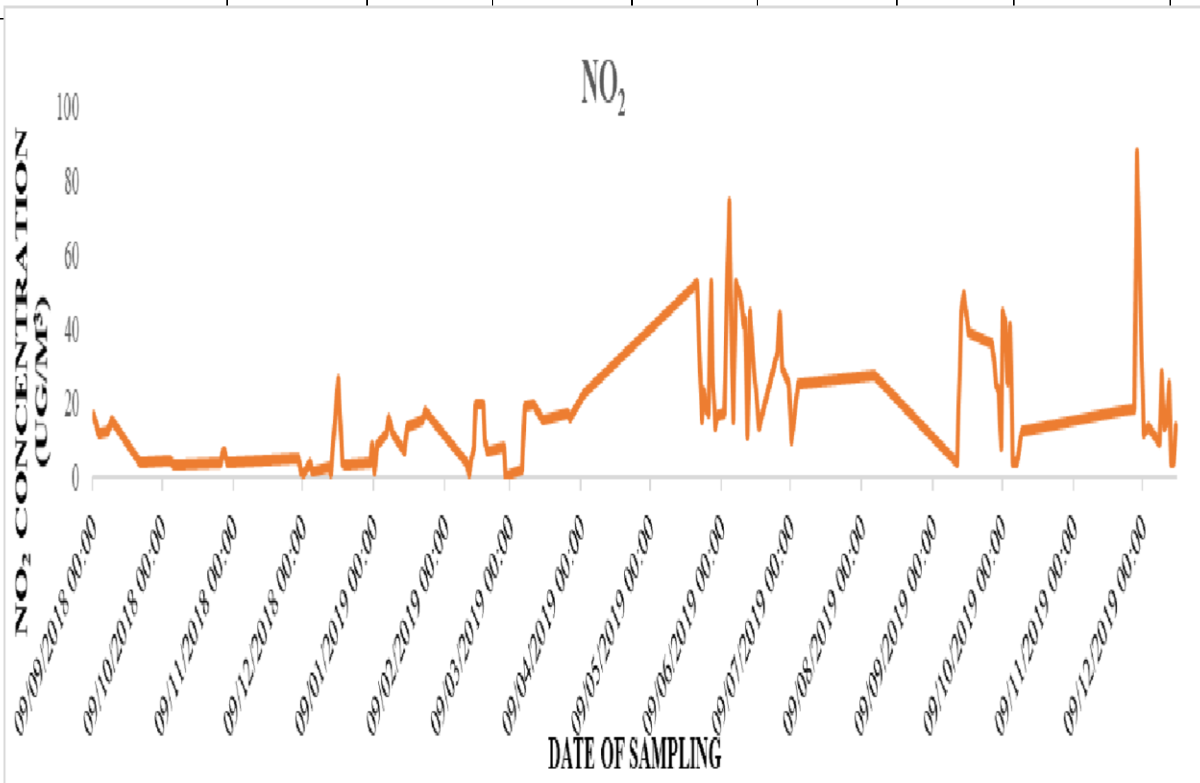


Figure 2.Analysed Pollutants in Chennai region

Table 1 Annual and seasonal concentrations of NO_2, SO_2 and $PM_{2.5}$ (in µg/m^3) and the concentration of heavy metals and PAH in $PM_{2.5}$ (ng/m^3). Values in bold indicate exceedance above WHO and CPCB guidelines

Pollutant	Annual		Summer		Monsoon		Winter	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev	Mean	Std. Dev
SO_2	8.20	7.66	8.44	6.172	4.384	4.06	12.69	9.72
NO_2	19.34	16.55	26.90	17.44	24.01	19.36	10.24	7.58
$PM_{2.5}$	**109.69**	**71.66**	**107.267**	**61.78**	**100.43**	**55.845**	**123.42**	**94.24**
$PM_{2.5}$-boundheavymetals(ng/m^3)								
Species								
Lead	109.36	145.967	63.73	43.11	74.376	24.49	226.1	263.424
Arsenic	**18.89**	**41.56**	0.484	0.283	1.068	0.872	**73.02**	**56.23**
Nickel	8.472	26.412	0.802	0.442	12.266	37.708	9.93	12.966
Iron	1651.32	3237.94	821.36	630.922	482.235	539.525	4781.778	5481.64
Cadmium	3.661	4.76	2.14	0.736	3.107	4.498	6.4	6.777
$PM_{2.5}$-boundPAH(ng/m^3)								
Species								
chrysene	**1.784**	**4.92**	0.199	0.0959	0.335	0.389	**5.14**	**8.09**
benz(a)anthracene	**2.653**	**8.32**	0.1649	0.0792	0.274	0.225	**8.08**	**13.87**
benzo(a)pyrene	0.811	1.71	0.3371	0.157	0.268	0.203	**1.96**	**2.81**
benzo(b)fluranthene	0.660	0.954	0.248	0.0904	0.313	0.281	**1.48**	**1.397**
benzo(ghi)perylene	0.554	0.547	0.3269	0.2008	0.388	0.583	0.97	0.487
dibenz(a,h)anthracene	0.498	0.458	0.3951	0.2317	0.390	0.418	0.808	0.610
indeno(1,2,3-cd)pyrene	**1.07**	**1.355**	0.2354	0.1267	0.458	0.639	**2.62**	**1.39**
$\sum PAH$	8.03	9.97	1.906	0.398	2.43	1.117	21.07	16.44



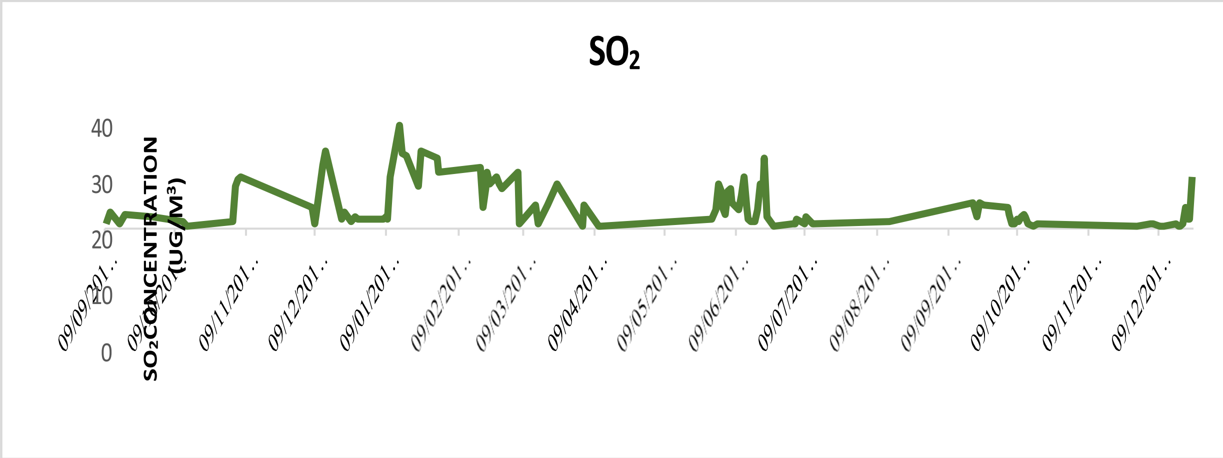


Figure.1 The trend of gaseous pollutants at the monitoring site

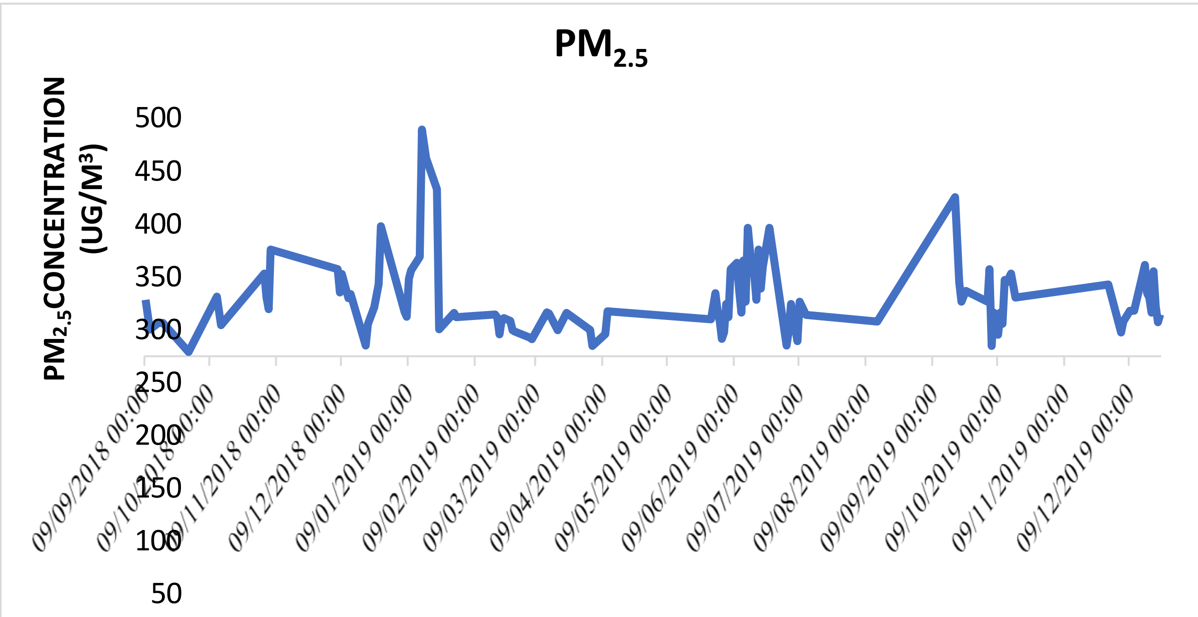


Figure2. The trend of $PM_{2.5}$ and gaseous pollutants at the monitoring site

4.CONCLUSION

This study provides information on the trends and concentration of key gaseous pollutants and fine particulate matter in an industrial suburb of the Chennai Metropolitan Region. NO_2, SO_2 and $PM_{2.5}$ levels were measured from September2018 and December 2019. The gaseous pollutants were within the permissible limits mandated by WHO and CPCB. However, $PM_{2.5}$ exceeded both CPCB and WHO standards. The gaseous pollutants in the study area do not seem to pose any non-carcinogenic risks"(HI < 1) for both children and adults. The heavy metals in $PM_{2.5}$-were discovered to be mostly caused by coal burning and vehicle pollution. The non-carcinogenic dangers that adults and children face while inhaling were found to be higher than the acceptable limits. $PM_{2.5}$-bound arsenic posed the highest carcinogenic risk. These results are expected to help local pollution control authorities toward developing targeted air pollution control strategies and thereby, reduce the negative health effects of PM2 and gaseous pollution exposure. 5. To identify the local and transported sources of PM2.5, long-term research is required in Chennai Metropolitan region in order to reduce its ambient levels in atmosphere and associated health risks.

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