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Analysis and assessment of gaseous pollutants along high traffic roads (NH 948) in Coimbatore city, India

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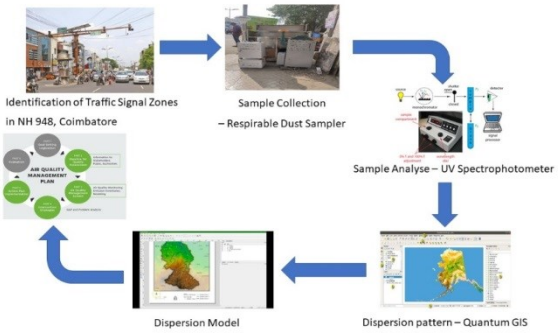
Graphical abstract



Abstract

The growing Urbanization, Industrialization, Institutional, and IT sector development contribute to the exponential growth of motorized road transportation increasing the composition of harmful gaseous pollutants in ambient air. So, it is necessary to analyze and quantify the concentration of pollutants such as CO, NO_x, SO_x, and PM_{10}(for calculating the Air Quality Index) in ambient air at traffic signal zones in National Highway 948 across Coimbatore city and to model its dispersion using Quantum GIS. Usinga Respirable Dust Sampler, the ambient air samplesare collected at various locations based on heavy traffic signals zonesduring the month of December 2022 – March 2023. Quantified data are compared with National Ambient Air Quality Standards (NAAQS) to know about air quality, i.e., Air Quality Index. The dispersion rate in terms of concentration of CO, NO_x, and SO_x in the sampling locations of National Highway 948 revealed that in comparison to other sampling months, the mean NO_x concentration was higher in December at SL1 (78 µg/m³). The mean concentration value of SO_x was high at SL2 (57 µg/m³) in the month of February 2023, and the mean concentration of CO is relatively high at SL1 (1.93 mg/m³) in NH 948. Sampling Locations such as SL1, SL5, SL7, and SL11 fall under the category of Poor compared to other sampling locationsbecause of improper alignment of roadway, Traffic congestion, Liberty, and Violation of Traffic rules, Lack of vehicular maintenance, and End life vehicles. The lack of implementation of environmental regulations contributes to the bad air quality in most Indian cities.

Keywords: Air quality index, Coimbatore, dispersion modelling, roadway, traffic congestion

1. Introduction

One of the most significant risks to humanity is the ongoing contamination of our environment. Governments are passing laws to preserve the environment as people become more aware of pollution's danger (Rajamanickam *et al.*, 2012). According to the Bureau of Indian Standards [BIS], air pollution refers to "the presence of substances in the ambient atmosphere, generally resulting from the activity of man, in sufficient concentration under the circumstances such as to interfere with comfort health or welfare of persons or with reasonable use or enjoyment of property." According to the World Health Organization (WHO) definition, air pollution is the presence of unwanted materials in the ambient air that harm humanity and the environment.

Air is a composition of many gases containing Oxygen and Nitrogen, which are the essential elements for any species to survive on the Earth. Key factors that affect air quality are the type of pollutant, source, dispersion rate, concentration, and duration of existence in highway (ambient) air Rao *et al.* (1986) of various sources contributing to the deterioration of air quality, automobile usage has emerged as a vital source of urban air pollution. The air pollution caused by motor vehicles significantly impacts ambient air quality, and the role of transportation is entirely being highlighted and prolonged.

Numerous atmospheric elements influence the dispersion of pollutants that enter the atmosphere from a source in weather-related aspects—commonly known as meteorological parameters. The key meteorological factors are rainfall and precipitation, high and low atmospheric pressure, heat, solar radiation, temperature, environmental lapse rate, atmospheric stability, wind speed, wind direction, mixing height, moisture, and relative humidity (Vedamadavan *et al.*, 2012). Various levels of air pollution, contaminants, and meteorological factors, including temperature, wind speed, and humidity,

have been studied extensively (Mamta *et al.*, 2010; Samoli *et al.*, 2005).

Unwanted air pollutants such as Suspended Particulate Matter, measured as PM_{10} and $PM_{2.5}$, Sulphur-dioxide (SO_x), oxides of Nitrogen (NO_x), etc., are brought on by this development and urbanization (Zeka *et al.*, 2005). Particulate Matter (PM) is one of the most severe environmental issues in the world (Brauer *et al.*, 2015, Sarojini *et al.*, 2019). Traffic emission is a significant concern to human society because it is a ground-level source and contains many toxic gases, e.g., PM $_{2.5}$, PM_{10}, CO, O_3, NO_x, SO_x, and aromatic hydrocarbon. In the last two decades, due to changes in the pattern of air pollutant emission, higher impacts of pollutants also have been experienced in rural and remote areas. The uncontrolled use of fossil fuels in industries and the transport sector has increased the concentration of gaseous pollutants in the atmosphere. The strength of emission sources, chemical transformation, and atmospheric conditions influence it.

The air along traffic corridors where most residents in the formal and informal sectors subsist daily to conduct their daily activities could hardlybe regarded as fresh due to automobile emissions from various road activities. Because of such living conditions, the probability of extreme illness because of air pollutants from automobile emissions is very high. A region's economic growth depends on simple and easy access to people and things made possible by transportation technology. Unfortunately, these benefits are connected to environmental damage and health risks (Indusri *et al.*, 2020). Air Quality Index is used to assess the entire ecological condition and its trends with a specific standard. It is based on the lines of the health index and measured by the degree (CPCB, 2015). Sustainability road which covers mainly the green area or green space to have a great potential. Sustainable Developmental Goals interaction says that applying the goals in university had a great ecological potential because of green of development on extensive presence space (Lazzeroni *et al.*, 2021).

2. Materials and methods

2.1 Description of study area

The third largest city of the state, Coimbatore, is one of the most industrialized cities in Tamil Nadu, known as the textile capital of South India. The city is thickly populatedand has a moderately ventilated air basin, polluted due to many activities such as ever-expanding transport, commercial activities, and construction. Hence, it is necessary to forecast the impacts of air pollutants emitted from various sources to derive comprehensive air pollution control strategies. The administrative zones of Coimbatore city (East, West, North, South, and Central) are served by major arterial roads represented in Table 1. Between 35°C and 18°C are the average maxima and minima temperatures. Around 700 mm of rain falls annually, with 47% and 28% coming from the North East and South West monsoons. Since cotton may be grown there, the soil is primarily black. The Class III Seismic Zone encompasses Coimbatore (Vinoth kumar *et al.*, 2021).

2.2 Description of sampling site

Being the nerve center of Coimbatore – Sathyamangalam road (NH948), Saravanampatti is located in the eastern part of Coimbatore, between latitude 11º 05' 24"N and longitude 76º 59' 52"E, about 11.5 km from the City railway junction and 9 km from Gandhipuram Central bus terminus. Accommodating approximately 30000 IT professionals, Saravanampatti has emerged as the "IT corridor of Coimbatore" and is one of the fast-growing locations in Coimbatore city. Also, many educational Institutions, corporate offices, luxury hotels, textile shops, and hospitals are situated around Saravanampatti. Local transportation services will connect Saravanampatti to various parts of the city. The selected sampling locations in the study area starts from Ukkadam Junction to Saravanampatti Junction in NH 948 covering a distance of 12.6 km asrepresented in the Figure 1. Table 2 represents the Latitude and Longitude of each sampling locations. Figure 2 represents the Distance between the sampling locations from SL1 – SL20.

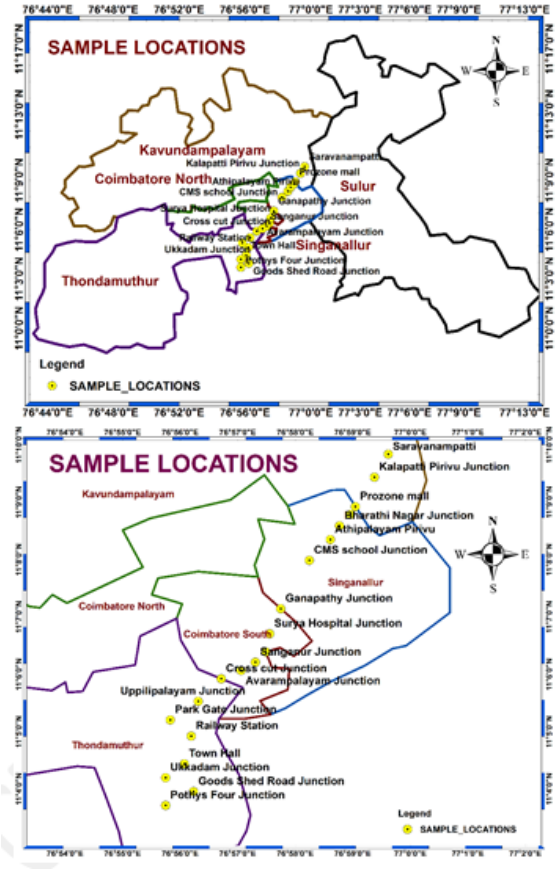


Figure 1. Sampling Location Point in the Study Area

The criteria for the selection of sampling sites include the following

- Presence of households, shops, school
- Traffic density
- Area of population exposure
- Wind direction
- Humidity level

Table 1. High Traffic roads across Coimbatore City

Road	Administrative zone	National Highway	Connectivity
Avinashi Road	Central and East	NH 544	Bangalore and Chennai
Trichy Road	Central–southeast	NH 81	Trichy and Thanjavur
Mettupalayam Road	North - South	NH 181	Ooty, Gudalur
Sathy Road	South–northeast	NH 948	Sathyamangalam, Chamrajnagar, Mysore
Pollachi Road	North–South	NH 83	Palani, Dindugal

Table 2. Sampling Location Site

Sampling Location (*SL)	Latitude (N)	Longitude (E)	Sampling Location (*SL)	Latitude (N)	Longitude (E)
SL1	10.987718	76.961581	SL11	11.033783	76.978448
SL2	10.993519	76.960823	SL12	11.036059	76.978078
SL3	10.99658	76.968017	SL13	11.038819	76.979478
SL4	11.00275	76.967954	SL14	11.040462	76.982132
SL5	11.017231	76.968548	SL15	11.044673	76.985427
SL6	11.021184	76.971061	SL16	11.046895	76.988098
SL7	11.036015	76.978036	SL17	11.051287	76.991427
SL8	11.040462	76.982132	SL18	11.055027	76.995096
SL9	11.044673	76.985427	SL19	11.075025	77.002118
SL10	11.055027	76.995096	SL20	11.078758	77.003617

*SL- Sampling Location

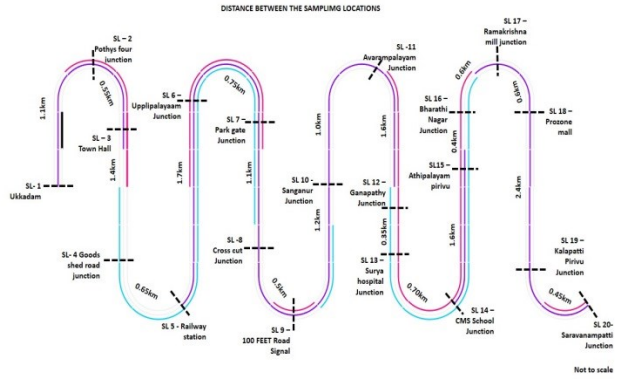


Figure 2. Distance between Sampling Locations

2.3 Methodology

Previous research on the seasonal variation of Suspended Particulate Matter in Coimbatore city regarding wind direction reveals that the SPM concentration is higher from January to March due to high humidity and low wind velocity **(**Saravanakumar *et al.*, 2016). This sampling investigation was carried out in December 2022 to March 2023. The dispersion of air pollutants on the highway is significantly influenced by the wind's velocity, direction, relative humidity, atmospheric pressure, temperature, and terrain types. Atmospheric conditions and meteorological details were obtained from the continuous ambient air quality monitoring station of the pollution control board. The sampling and analysis of the gaseous pollutant have been done per Indian Standard Methods of Measurement of Air pollution: IS 5182 (Part IV) 1973. Concentrations of NO_x, CO, PM_{10} and SO_x were determined from Respirable Dust Sampler manufactured by Envirotech APM 460 DXNL. The constant running flow rate for monitoring of particulate matter and gaseous pollutant in Respirable dust sampler must be maintained as 16.1 lpm (CPCB 2011). The equipment should be placed at 10 feet from the ground level at every sampling location. The Particulate Matter samples are collected in the filter paper. The filter papers were placed in a Desiccator before and after collection of sample at room temperature (27º C) in order to remove moisture content. For a sampling of gaseous pollutants, ambient air directly enters the inlet of each impingers, bubbles through the absorbing region, and exhausts through the blower. It has been provided with a gas manifold and Rotameter to set independent sampling rates. The gaseous sampling attachment can be easily detached from the main sampler and transported and stored independently. The following reference methods were used for the determination of gaseous pollutants:

- Particulate Matter – Gravimetric Method
- Sulfur dioxide – UV Fluorescence
- Carbon Monoxide – UV Spectrophotometer
- Oxide of Nitrogen – Chemiluminescence

2.4 Modelling using quantum GIS (QGIS) dispersion software

Particulate Matter Pollutant $PM_{10}$and Gaseous pollutant levels of CO, NO_x and SO_x in ambient air along the traffic signals in Highway NH 948 of Coimbatore City have been assessed from December 2022 to March 2023. Based on the traffic density in NH 948, the prone locations (SL 1 to SL 20) were identified, and 8 hours of sample monitoring were carried out from 8.00 a.m. to 4.00 p.m.in all sampling locations as per National Ambient Air Quality Standards (NAAQS). The results were compared with National Ambient Air Quality Standards (NAAQS). The dispersion of the mean concentration of monitored gaseous pollutants is modelled using Quantum GIS (QGIS).

The function of QGIS is as follows:

Dispersion modelling for any point source is done by Arc-GIS, AERMOD, Quantum GIS (Geographic Information System), Land Use Regression (LUR), Computational Fluid Dynamics (CFD) model, and HYSPLIT transport & dispersion model. The Air quality modelling has been performed using the mapping software called Arc Map 10.1.

2.4.1 Quantum GIS (QGIS)

QGIS is a useful tool of increasing utility for spatial visualization and analysis, making it a viable alternative to other expensive software packages. This software helps to render the modelling for easy understanding. The map shows the dispersion of air quality in the collected sample locations and its effect in and around the sampling locations. The samples were collected in 20 locations and using the ground control points the locations were plotted in the map. Base information such as temperature, humidity, wind speed, NO_x, SO_x, PM_{10}, CO, and air quality index were fed as input. Before modelling the sampling size was verified using a semivariogram which shows the fairness of the sample location. Since no outliers were found the modelling was continued using the IDW technique.

2.4.2 Geostatistical deterministic interpolation

The fundamental steps in geostatistical interpolation, which we will assume to be Ordinary Kriging for the time being, are nearly identical to those in deterministic interpolation, namely interpolation using radial basis functions (Karthikeyan *et al.*, 2023). The values at unsampled (grid) points are computed as a simple linear weighted average of nearby measured data points, where the (optimal) weights are derived from the fitted variogram rather than by the user. For a specific grid point, p, with the condition that the weights must add up to 1:The weights in Kriging might be either positive or negative. A procedure of re estimating the mean value at each new site is identical to the requirement that the weights must add up to 1. Therefore, Ordinary Kriging is just Simple Kriging with a location-dependent mean. It should be noted that while it is assumed that the mean value is fixed inside the computation window, this allows for fluctuation of the mean value from place to site. Alternative approaches, like Universal Kriging, should be taken into consideration if the mean values significantly vary over extremely short distances.

3 Results and discussion

3.1 Carbon Monoxide (CO)

Internal combustion gasoline-powered engines produce high carbon monoxide concentration. It was found that 9% of CO emissions in terms of tonnes/year came from transportation. Before the catalytic converter, the exhaust stream from even an adequately designed gasoline engine will contain more than 30,000 parts per million (ppm) of Carbon Monoxide (CO) (Karishma *et al.*, 2021)**.** From the study conducted, it is assessed that the mean CO concentration was high at SL1, SL2, SL7, and SL11 were 1.93 mg/m³, 1.41 mg/m³, 1.58 mg/m³, 1.38 mg/m³ respectively, compared to that of other sampling locations in the month of December. In the month of January 2023, it was found that the average concentration of CO was high at SL1 (1.38 mg/m³), SL7 (1.25 mg/m³) and SL 11(1.27 mg/m³) and In case of February month, The sampling location was quite high at SL1 (1.48 mg/m³), SL2 (1.23 mg/m³), SL4 (1.31 mg/m³), SL7 (1.45 mg/m³) and SL11 (1.49 mg/m³). For the month of March 2023, it was found that SL1, SL2, SL7, SL11 has the mean concentration of 1.31 mg/m³, 1.11 mg/m³, 1.19 mg/m³, 1.23 mg/m³ compared to that of other sampling location. The concentration of CO was high in the sampling location because it emits excessive CO if the vehicles are faulty, either airflow restricted, the carburettorrunning rich, choke applied, or the fuel injection is defective. The dispersion pattern for the Mean Concentration of Carbon Monoxide in term of mg/m³ was described in the Figure 3.

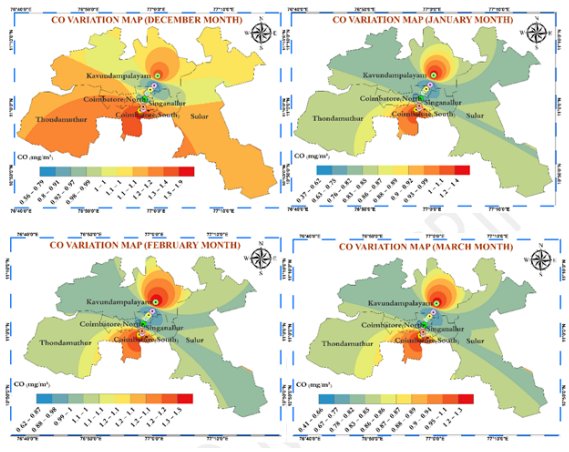


Figure 3. Dispersion pattern of CO for the Month of December'22 – March'23

3.2 Oxides of Nitrogen (NO_x)

Nitrogen makes up over 80% of the air used in combustion processes. A group of gases called Nitrogen Oxides (NO_x) is created when fuel and air are burned at high temperatures. The primary sources of emissions include major plants that use combustion processes, household heating systems, and automobile exhaust fumes. High concentrations of NO_x have been linked to detrimental health effects, including airway inflammation and weakened lung function. Nitrogen Oxides are drawn out of a sodium hydroxide solution to create stable sodium nitrite. A photometric calculation is used to determine the Nitrite ion generated (Sarojini *et al.*, 2019). The mean concentration value of NO_x was high at SL1 (78 µg/m³), SL7 (77 µg/m³), and SL11 (74 µg/m³) compared to other sampling locations in NH 948 for the month of December. It was found that the concentration of NO_x for the Month of January 2023 was high in the SL 1(61 µg/m³), SL 7(59 µg/m³) and SL 11(58 µg/m³) compared to other sampling location. For the month of February SL 1, SL7 and SL11 has the high concentration as 65 µg/m³, 68 µg/m³ and 69 µg/m³ respectively compared to other sampling location. The mean concentration of NO_x for the month of March was high in SL 1 & SL11 as 56 µg/m³ & 56 µg/m³ respectively compared to other sampling site. The concentration of NO_xispromptly increasing due to faulty

and low-maintained vehicles, end-life vehicles, contamination of fuels, poor traffic administration, narrowed roadway, and violation of traffic rules. The following Figure 4 represents the Dispersion pattern of Mean concentration of NO_x for Month of December'22, January'23, February'23 and March'23

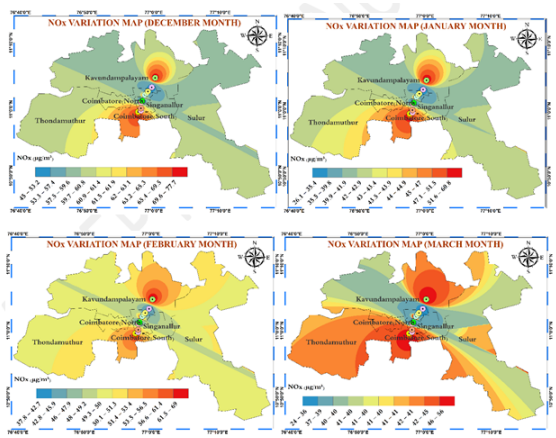


Figure 4. Dispersion Pattern of NO_x for the Month of December'22 – March'23

3.3 Sulphur di Oxide (SO_x)

In an internal combustion engine's combustion chamber, sulphur compounds in all petroleum-based fuels are easily converted to sulphur dioxide (SO_x). The most significant health risk from sulphur dioxide is too young children and asthmatics because it can react in the atmosphere to generate tinyparticles. Oxides of sulphur are also a precursor to secondary PM_{10}. Health effectson humans can range from mild eye and respiratory tract irritation after a brief exposure to bronchial constriction after continuous exposure to even low concentrations (Cannistraro *et al.*, 2016). From the study conducted, it was assessed that the mean concentration level of SO_2 was less compared to the emission level of CO and NO_x. The mean concentration of Sulphur dioxide (SO_x) was found to be relatively high at SL1 (48 µg/m^3) and SL7 (47 µg/m^3) for the month of December compared to other sampling locations. However, the average level of SO_x was below the permissible limit (80 µg/m^3) prescribed by NAAQS at all eleven sampling locations. For the month of January '23, SL 7 (38 µg/m^3), February '23 SL 2 (57 µg/m^3), March '23 SL2 (41 µg/m^3) has been found that the concentration of $SO_x$was very high at the above sampling sites, It was due to more traffic congestion, entry and exit of buses to and from the bus terminals, the low ratio of the road width to the traffic volume, and high vehicle idling duration. Figure 5 illustrates the Dispersion pattern for the month of December '22 – March '23 for SO_x.

3.4 Air quality index (AQI)

The overall state of the environment and trend analysis is done using the Air Quality Index (Zlauddin *et al*., 2006). The Air Quality Index is a factor that the Environmental Protection Agency created with a set of statistics in it. The criticalparameter determining AQI is the concentration of CO, NO_x, SO_x, and PM_{10}. In this study for calculating the Air Quality Index, the mean concentration of PM_{10} was also analysed in all sampling locations. The concentration of PM_{10} ranges from 166 – 297 (µg/m^3), 121- 271(µg/m^3), 143 - 267(µg/m^3) and116 – 264 (µg/m^3) for the month of December 2022, January '23, February'23 and March '23 respectively. The various categories of the AQI and its range are listed in Table 3. The Air Quality Index for the sampling locations from SL1 to SL 20 for the month of December '22 – March '23 is shown in Figure 6. It indicates that SL1 (248), SL5 (257), SL7 (232), and SL 11 (241) fall under the Poor categoryfor the month of December '22, which may cause discomfort to people on prolonged exposuresto polluted air and people with heart diseases. Roadway alignment issues, traffic law violations, poor vehicle maintenance, and end-lifevehicles contribute to the poor air quality index. In the month of January '23, the AQI (221) was Poor at SL 11. The AQI for the month of February was poor at the sampling location SL1 (217), SL7 (208), SL11 (241). Whereas AQI was poor at the sampling location SL 11(214) in the month of March '23.

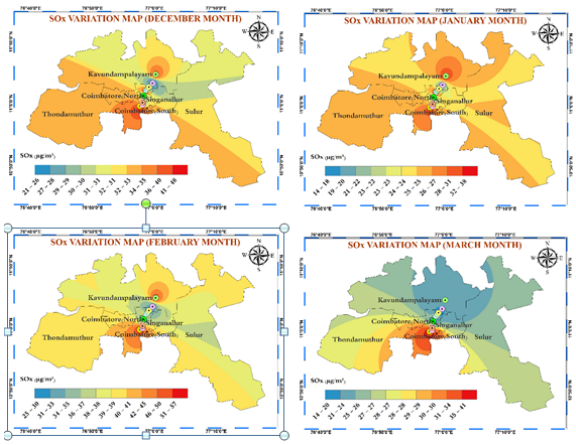


Figure 5. Dispersion Pattern of SO_x for the Month of December'22 – March'23

Due to the disregard for environmental laws, poor air quality is a concern in many Indian cities. Many outdoor activities take place in the major cities of developing countries (Rajkumar *et al.*, 2023). People finish jobs or promote their wares on congested highways. People who visit or work in shops, establishments, and institutions adjacent to the road may have unfavourable health effects due to increased gaseous pollutants from vehicle traffic (S.M. Shiva Nagendra *et al.*, 2007).

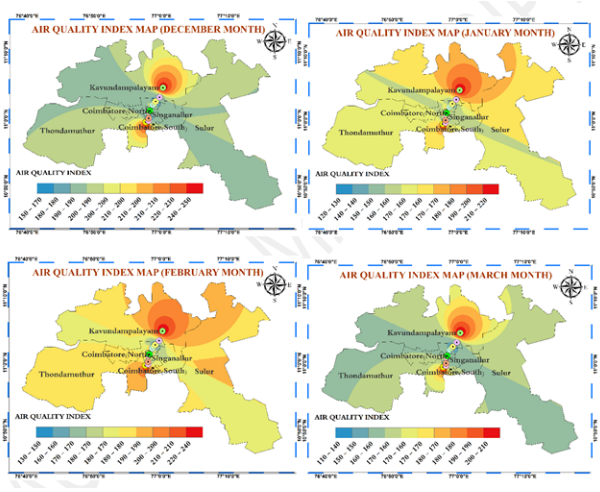


Figure 6. AQI MAP for the Month of December'22 – March'23

Table 3. Air quality categories based on Air Quality Index

Air Quality Index	Levels of Health Concern
0 – 50	Good
51 – 100	Moderate
101 – 150	Unhealthy for sensitive groups
151 – 200	Unhealthy
201 – 300	Very Unhealthy
301 & Above	Hazardous

3.5 Variation in concentration due to meteorological parameters

The meteorological parameters such as Temperature, Relative Humidity and Wind Speed plays an vital role in the dispersion pattern of gaseous pollutants such as CO, NO_x, SO_x. Meteorological parameters decide the fate of particulates once they are released to the atmosphere. Micro scale meteorology is the study of short-lived atmospheric phenomena smaller than mesoscale, about 1 km or less (Sadheesh *et al.*, 2023). The factors that effects the dispersion of particulates in the air are -

- Wind Speed and Direction
- Ambient air temperature and stability class
- Relative humidity
- Barometric pressure

The average monthly temperature in Coimbatore ranges from 24 to 33 degrees Celsius, with the wind speed varying from 8 to 17 km/h, the humidity varying from 45 to 83%, and the atmospheric pressure varying from 1012 to 1023 mbar. Data on rainfall ranges from 570 to 985 mm. Over the course of the study period, Coimbatore's monthly average values for the main gaseous pollutants and climatic factors were calculated. The results of analyzing the seasonal fluctuation of air pollutants in Coimbatore revealed that modifications in climatic parameters have a direct impact on the concentration and dispersion of pollutants throughout the year. Figure 7 represents the Variation of Pollutant concentration with respect to Temperature, Relative Humidity and Wind speed

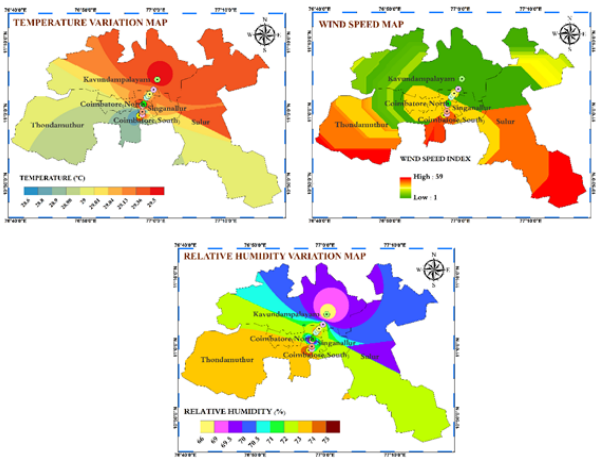


Figure 7. Variation in concentration due to Temperature, Wind Speed and Relative Humidity

3.6 Correlation between Pollutants and Meteorological Parameters

The standard way to gauge a linear correlation is the Pearson correlation coefficient (r). The link between two variables' strength and direction is represented by a number between -1 and 1. The influence on the pollutant with respect to the Meteorological parameter are studied. The Negative correlation indicates that the accumulation, dilution and deposition of the pollutants. Table 4 represents the Pearson's Coefficient Correlation for the study period from December '22 – March '23. Most of the Pollutants are negatively correlated ($r < 0$) with Relative Humidity, Humidity plays an important role in deposition of pollutants on surfaces. The reason for this is, during colder month fuel consumption by vehicle engine is high which causes increased emissions. Besides, colder region amounts for various biomass burning activities for heating requirements. In comparison to the other seasons, studies reveal that average particulate matter concentrations were higher in winter, the season with the lowest ventilation capabilities. This is reinforced by the fact that lower temperatures, high relative humidity, accessible organics produced from automobiles and decreased air mixing height promote particle production (Somuri, 2011).

Table 4. Pearson's Correlation coefficient

	Relative Humidity	NO_x	CO	SO_x	PM_{10}	Temperature	Wind Speed
Relative Humidity	1						
NO_x	-0.116	1					
CO	-0.017	0.935	1				
SO_x	-0.115	0.847	0.829	1			
PM_{10}	-0.365	0.697	0.686	0.859	1		
Temperature	-0.832	-0.168	-0.202	0.0618	0.354	1	
Wind Speed	-0.370	-0.195	0.0209	-0.060	0.105	0.586	1

4. Conclusion

The study as performed to assess the gaseous pollutants and SPM (Suspended Particulate Matter) in the ambient air particularly in the traffic signal zone of National Highway 948, Coimbatore. The Respirable Dust sampler was used for analyzing the gaseous pollutants such as CO, NO_x, SO_x and SPM in ambient air at Traffic Signal zone. Spectrophotometer was used for measurement of gaseous pollutants. The twenty sampling locations were

identified in NH 948 and sampling was done from the month of December 2022 – March 2023. The ambient air quality was analyzed with the ambient air quality standards of NAAQS. The variation of pollutant concentration with respect to changes in meteorological parameters and category of AQI was identified. The concentration of both gaseous pollutants and Suspended Particulate Matter was high, because of the heavy traffic prone area, Presence of Bus terminals, Construction of Flyovers which cause congestion of traffic, increasing due to faulty and low-maintained vehicles, end-life vehicles, contamination of fuels, poor traffic administration, narrowed roadway, and violation of traffic rules. The Quantum GIS software was used to identify the pollutant dispersion under various meteorological parameters. The dispersion pattern results also agrees to that of experimental analysis, if the concentration of pollutant increases with respect to meteorological parameter, the dispersion range of pollutants also raise gradually. A thorough extension of the research to several different regions can provide accurate maps of ambient air pollutant concentrations that can later assist various authorities in managing the pollution on the roads owing to traffic and also account for effective infrastructure management and sustainable environment (Alvarez-Risco *et al.*, 2021).

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