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Assessment of urban air quality using geo spatial techniques for sustainable development: case of Tirupur City, India

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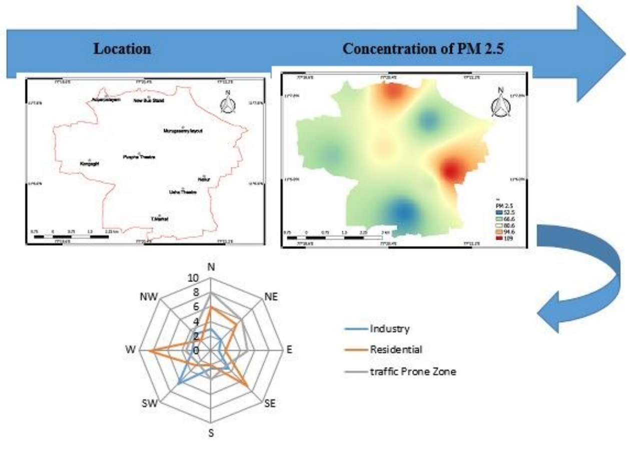
Graphical abstract



Eight-direction radar chart for proximity of industries

Abstract

Rapid urbanisation, industrialization, and population growth have fostered an urgent need for a green, clean-living environment. Among the many pollutants, gaseous pollutants like NO_2, SO_2, and particle pollutants like $PM_{2.5}$ and PM_{10} have a profound negative impact on human health. In this investigation, samples of air pollutants like NO_2, SO_2, $PM_{2.5}$, and PM_{10} were taken at ten different sites inside the Tirupur corporation boundaries. For the locations taken into consideration, the Air Quality Index has been calculated using the Central Pollution Control Board's model. Utilizing inverse weighted distance (IDW), these data are interpolated and integrated into a geographic information system (GIS). It was discovered that the level of secondary industries and the density of automobiles had a substantial impact on air quality. Results indicate that PM_{10} concentrations in the new bus stop and RakkiyapalayamPirivu are 113.7 mg/m3 and 134.73 mg/m3, respectively, which are comparatively higher than the permitted level specified in IS 5182. The areas with the most vehicular traffic and industry include the new bus stop location and RakkiyapalayamPirivu. Thus, the main sources of pollution in the study region are an increase in automobile traffic and industrial development. A clear indication of the area where the concentration of pollutants is high is provided by integrating the pollutant data with geographic information systems, and this enables local government agencies to conduct in-depth environmental evaluations. This aids planners in their decision-making for sustainable development.

Keywords: Urbanization, industrialization, air quality index, geographical information system, inverse weighted distance, sustainable development

1. Introduction

At all scales, the contribution of industrial development to global air pollution is a major concern. Research from around the world shows that air pollution can cause serious respiratory issues from both gaseous and suspended particles, as well as cardiopulmonary death. According the World Health Organization (WHO, 2016), deaths from air pollution diseases approach about 6.5 million with up to 92% of the global population residing in areas of air quality exceeding the WHO limits In India, increased anthropogenic activity-related air pollution has become a contentious issue at all levels. Air pollution in metropolitan areas is caused by ineffective environmental legislation, population increase, and the use of fuels with poor environmental performance, a bad pattern of land use, and the number of motor vehicles (Chattopadhyay and others (2010) Numerous research on air pollution have been conducted in many of India's major cities. But of days, air pollution is a major concern for city planners and residents of even tiny cities. The study uses one such city in western Tamil Nadu, India. Tirupur is an industrial city that mostly exports textiles. The air quality in metropolitan areas needs to be monitored and assessed in order to handle these problems at the territorial level. A district's air quality is mostly determined by its population, rate of urbanisation, car occupancy, and scope of supporting industries (M. Kianisadr *et al.*, 2018). Many industrialised nations have developed the air quality index (AQI) out of social concern. The concept is now successfully used by all countries. The vehicular thickness boundary and their interaction with the selected vaporous toxins, such as NO_2, SO_2, and respiratory suspended particulate (RSPM), were taken into consideration in this study. A GIS-based air pollution surface model that depends on AQI was developed using Inverse Distance Weighted (IDW) techniques. GIS can be a platform for spatio-temporal analysis or for creating connections between standalone modelling tools and the GIS database. Due to the underlying link between various contaminants, modelling air data is typically exceedingly difficult. The results from the various methodologies showed that careful air quality evaluation is necessary for proper air quality management (SubrataChattopadhyay *et al.*, 2010). From a human health perspective, it is vital to quantify and map the spread of air contaminants in high urban sprawl settings (Mohamed Hereher *et al.*, 2022). The goals of this project are to specifically examine the distribution of a few gaseous pollutants, including sulphur dioxide (SO_2), nitrogen dioxide (NO_2), and respiratory suspended particulate matter (RSPM), as well as how these pollutants interact with climatic variables. This study was also conducted to determine whether urbanisation, traffic, and industrialisation are the main causes of the concentration of air pollutants.

2. Materials and methods

2.1. Study area

Tirupur Corporation, which is located in Tamil Nadu, India, has been chosen as the study area. Geographically, Tirupur is situated at 11.1075°N and 77.3398°E. Tirupur City is located at an elevation of 295 metres above mean sea level. The area of Tirupur Corporation is 159.6 km^2. Figure 1 depicts the area chosen for the investigation. According to data from the 2011 census, Tirupur has 24.8 lakh residents, or 3.44% of the state's total population. Due to the proximity of Coimbatore and Erode, two significant corporations, the city has seen rapid expansion in the textile industrial sector.

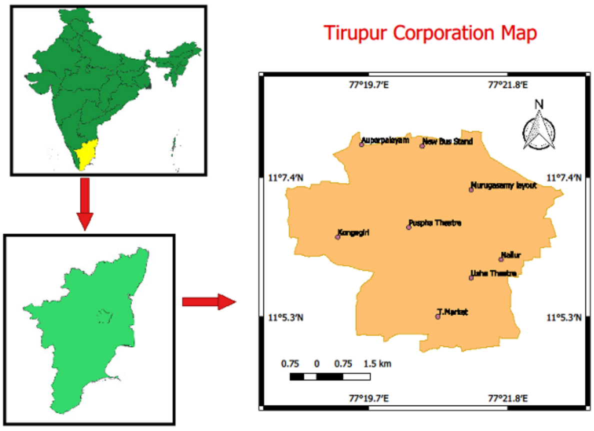


Figure 1. Study area

2.2. Selection of sampling points

The sample location points were chosen from the Tirpur Corporation's 2022 LULC map. Residential, industrial, and traffic-prone zones were chosen as the areas for sampling based on a map of land use and land cover classification. For the purpose of measuring the air quality, a total of 10 locations that included all three zones were randomly chosen. The land use and cover classifications for the sampling site are detailed in Table 1. The sampling locations in the study area are shown in Figure 2.

Table 1. Land use classes of the sampling location

S.No	Sampling Location	Land Use Class
S1	New Bus Stand	Built up Area with high traffic volume
S2	Puspha Theatre	Built up Area with high traffic volume
S3	Anuparpalayam	Industrial area with low traffic volume
S4	Thennampalayam Market	Commercial area with low traffic density
S5	Usha Theatre	Commercial area with low traffic density
S6	RakkiyapalayamPirivu	Built up Area with high traffic volume and Industry
S7	Konganagiri	Industrial area with low traffic volume
S8	Murugasamy Layout	Built up Area with high traffic volume
S9	Sirupooluvapatti	Commercial area with low traffic volume
S10	Kongu Nagar	Industries surrounded by residential area

Table 2. Pollutant concentration at various locations

S.No.	Sampling Location	Concentration in (μg/m³)				
		PM 2.5	PM 10	NO_2	SO_2	AQI
S1	New Bus Stand	102.5	113.7	30.2	51.9	242
S2	Puspha Theatre	83.7	85.23	24.2	40.3	179
S3	Anuparpalayam	71.2	96.4	25.3	41.6	137
S4	Thennampalayam Market	52.5	63.0	21.5	36.1	88
S5	Usha Theatre	73.7	93.9	23.1	42.5	146
S6	RakkiyapalayamPirivu	108.7	134.73	38.6	56.9	262
S7	Konganagiri	63.5	53.5	22.6	37.5	112
S8	Murugasamy Layout	58.7	67.8	24.8	39.5	98
S9	Sirupooluvapatti	50.5	52.8	21.8	38.3	84
S10	Kongu Nagar	103.8	97.5	23.6	35.3	228
Permissible Limit as per IS 5182		60	100	80	80	

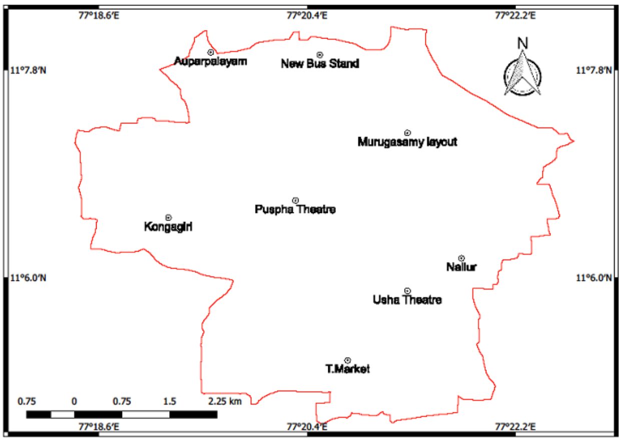


Figure 2. Location of sampling station

2.3. Acquisition of air pollution data

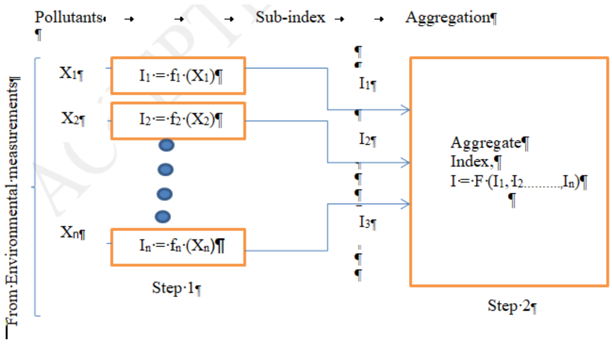
Using an air dust sampler for 24 hours, the air pollutant parameters NO_2, SO_2, PM $_{2.5}$, and PM $_{10}$ were measured in 10 different places within the Tirupur Corporation. For standard system pollutant detection, a large volume sampling was used. The technology filters the airborne impurities using glass fibre paper. The stream's filtration rate was maintained at 1-1.5 m^3/min. With the use of a twister separator, the sampler separates particle problems larger than 10 m from the air stream. Before separating on glass fibre channel paper, the particle problems are isolated. Additionally, air was allowed to pass through two encroachments with specific SO_2 and NO_2 retention agents. Table 2 depicts the pollutant concentration.

2.4. Meteorology

Both during the pre-monsoon and post-monsoon seasons, the temperature, wind speed, and wind direction were measured at each sampling station. Wind speed and direction were measured in the sampling location using a digital anemometer and a wind vane. It was noted that the wind primarily blew from the North-East, South-East, and South-West during the pre-monsoon season. The contaminants appeared to be spreading out more in these directions from the polluted area. South, South-West, and North wind directions were the most common. Therefore, the extremely contaminated area had caused the exact opposite dispersion of contaminants.

3. Air quality index (AQI)

The weighted estimations of each parameter linked to air contamination constitute the AQI. The Central Pollution Control Board's definition of particulate matter includes instances of sulphur dioxide (SO_2), nitrogen dioxide (NO_2), and particulate matter less than 10 microns (PM_{10}) (MamtaPandey, 2013). The conclusion of the analysis is the aggregate index value, which depends on the previously specified observed parameters. The block diagram illustrates the weighted aggregate-based calculation of the air quality index.



Air quality rating is calculated for each parameter by using the observed data for each zone (Elbir *et al*., 2010)

q = 100x (V/Vs);

Where q = rating of the quality index;

V = Value of the observed parameter;

Vs = value corresponding to that parameter.

The geometric mean for 'n' number of parameters was calculated by the equation given below, if 'n' parameters are involved in air quality monitoring,

g = anti log {(log a + log b + ... log x)/n};

Where g = geometric mean; a, b, c, d, x = different values of air quality rating; and n = number of values of air quality rating, log = logarithm (Figure 3).

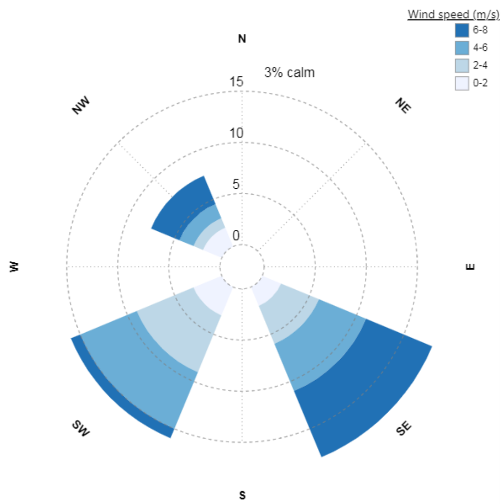


Figure 3. Wind rose diagram

4. Integration of air pollutant data and GIS

Base map for the study region is taken from the toposheet of Tirupur region. The base map was geo referred to utilizing ground control focuses gathered utilizing Garmin hand held GPS. The area subtleties alongside air quality parameters and their fixations were imported as spatial information to the base map. The spatial interpolation was conducted using the Inverse Distance Weighted (IDW) interpolation available in the ArcGIS geo statistical analyst toolbar. IDW interpolation is a technique, which is largely used in mapping of variables. It is an exact and convex interpolation method that fits only the continuous model of spatial variation. The basic principle of IDW interpolation is using a weighted linear combination set of sample points, it counts on the two statistical and mathematical methods in order to create surfaces and calculate the predictions of unmeasured points. The general equation used for the IDW is given below

$$\hat{Z}(x_0) = \sum_{i=1}^{n} z(x_i).d_{ij}^{-p} / \sum_{i=1}^{n} d_{ij}^{-p}$$

Where, Z is the interpolated value of a grid node, Zi are the neighbouring data points, dij are the distances between the grid node and data points.

5. Results and discussion

Spatial interpolation has been carried out for pollutants such NO_2, SO_2, PM $_{2.5}$, and PM_{10}. Figures 4–7 depict the pollutants' concentrations throughout the Tirupur Corporation. The pollution pattern is also evident in the Air Quality Index (AQI). Figures 8 and 9 depicts the AQI variance in the research area. The outcome makes it abundantly evident that there is a high concentration of air pollution at RakkiyapalayamPirivu, which is mostly caused by the movement of numerous vehicles and small-scale industries. Additionally, statistics from Tirupur's regional transport office clearly demonstrates the rise in both commercial and non-commercial vehicles. Due to the trading that takes place in this area, the amount of vehicular movement is relatively considerable. This location provides raw materials to the entire Tirupur for the knitting and dyeing industry. The second-highest concentration of air pollution is seen in the area of Kongu Nagar and New Bus Stand. Because there are so many knitting businesses in Kongu Nagar, there is a high concentration of PM 2.5 there. Due to heavy automotive traffic, there is a significant concentration in the area around the new bus stop, and it also exceeds the standard value shown in Figures 10 and 11. Due to the dense vegetation and numerous trees at Konganagiri, Sirupooluvapatti, and Thenampalayam Market, the concentration of air pollutants is also low in those locations.

The distributions of air pollutants and emission patterns in the city of Tirupur were studied. The results clearly indicates that textile industry is the most polluting sector for SO_2 contributing to about 81% of total emissions while residential region is the most polluting sector for PM_{10} and $PM_{2.5}$ contributing to 44% of total emissions. Traffic is the most polluting sector for NO_2 with the contributions of 80%, in the study area. Several knitting and weaving industries are the major contributors to PM_{10} and $PM_{2.5}$ emissions in the study area. The contribution of each pollutant and its factors are given as a chart in the Figure 9.

The study area is divided into eight directions including E, SE, S, SW, W, NW, N, and NE. Through the radar chart of proximity for both highly concentrated pollutant stations, it clearly shows the high value of PM $_{2.5}$ and PM $_{10}$ is due to the vicinity of textile industry and the more congested traffic area. Figures 12 and 13 shows the radar chart of proximity at highly concentrated sampling station S1 and S6.

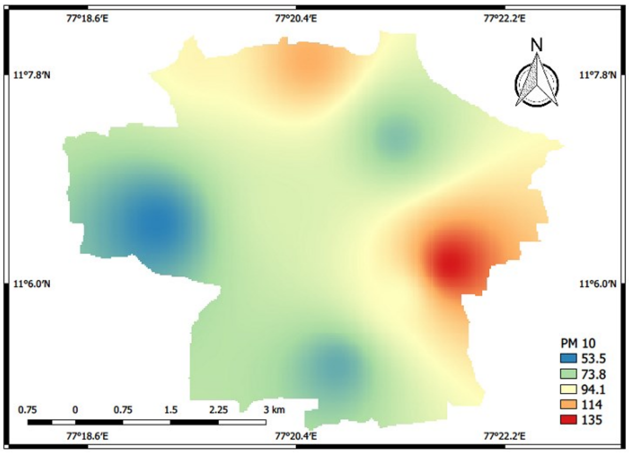


Figure 4. Concentration of PM $_{10}$ (µg / m^3)

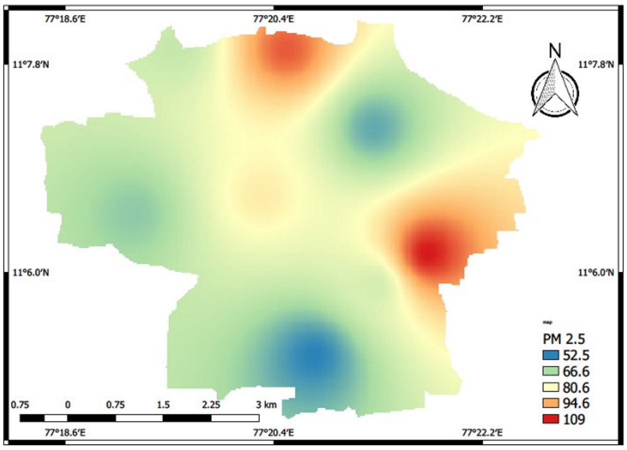


Figure 5. Concentration of PM $_{2.5}$ (µg / m^3)

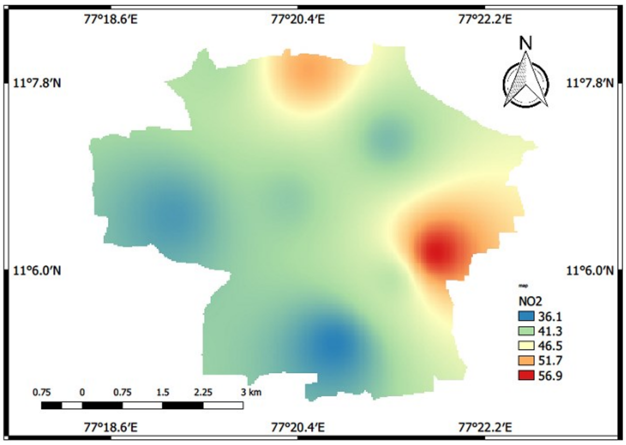


Figure 6. Concentration of NO_2 (µg / m^3)

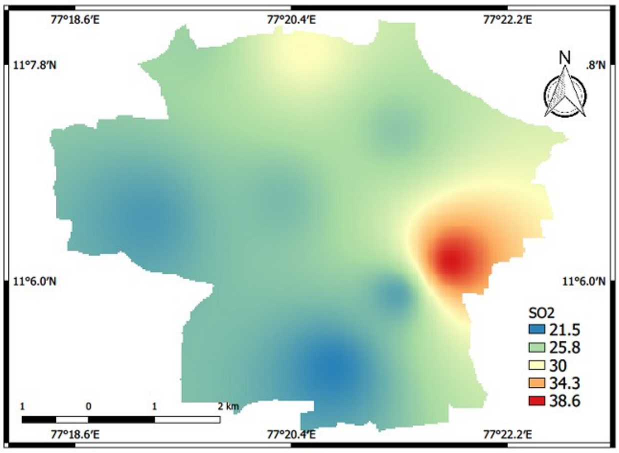


Figure 7. Concentration of SO_2 (µg / m^3)

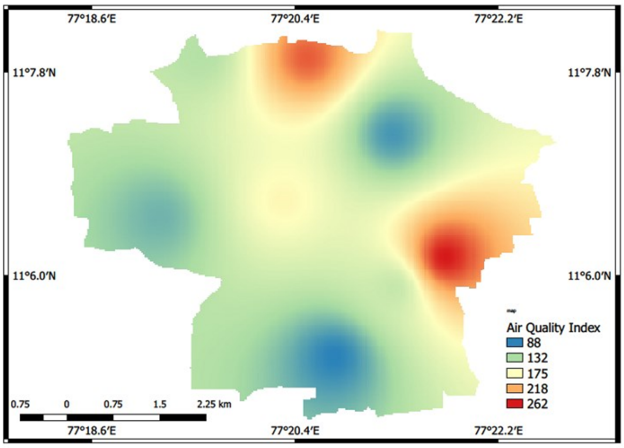


Figure 8. Air Quality Index

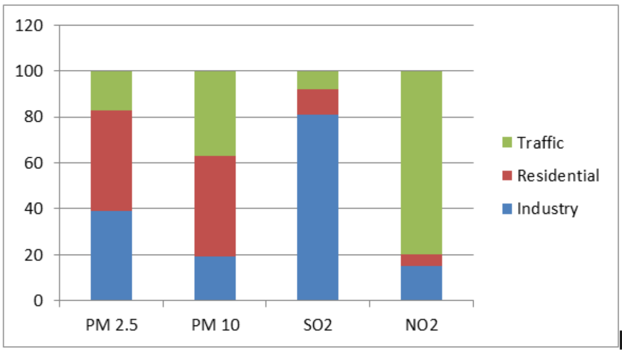


Figure 9. The emission contributions of each pollutant sector

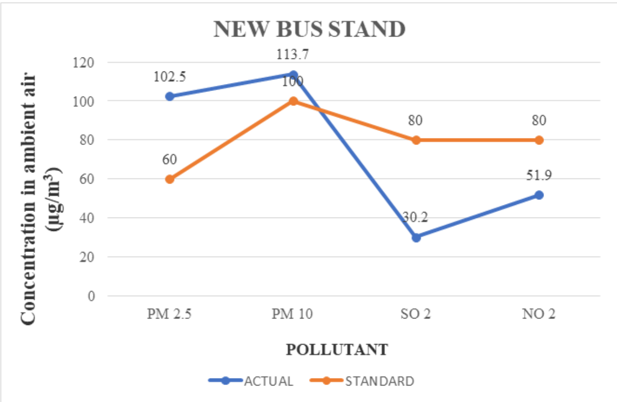


Figure10. Concentration of air pollutants in station S1

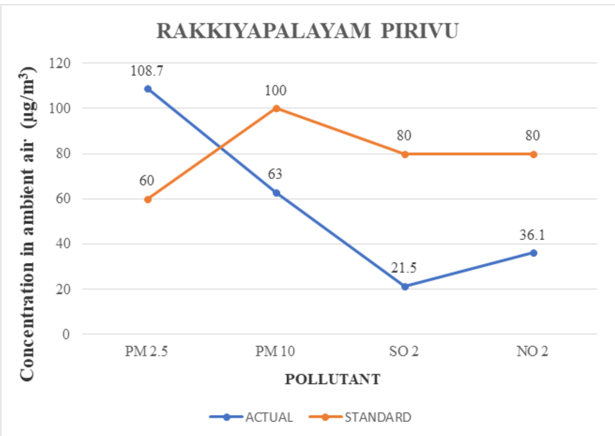


Figure 11. Concentration of air pollutants in S6

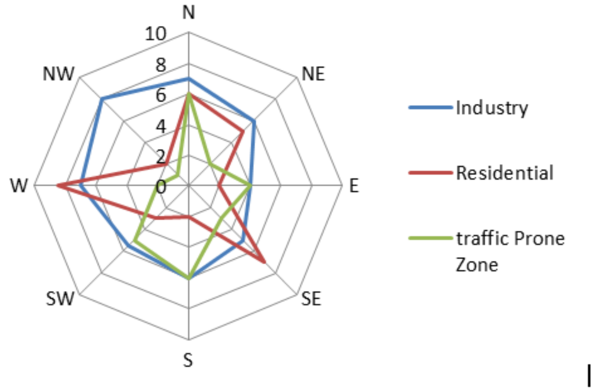


Figure 12. Eight-direction radar chart for proximity of industries at S1

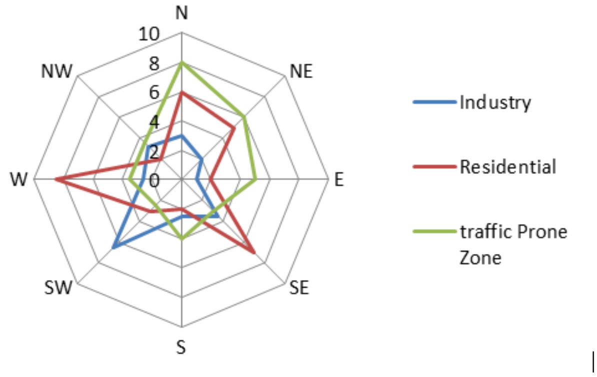


Figure 13. Eight-direction radar chart for proximity of industries at S6

6. Conclusion

There is a lack of employment in rural areas nowadays, and the majority of the population is moving to urban areas in quest of work. On the other hand, a lot of global corporations are moving their industries to India. As a result, urban regions see a rise in population and traffic. One such industrial hub is selected for the examination in this investigation. Using geospatial methods, the air quality in Tirupur Corporation has been researched. Based on the AQI, high pollution areas like RakkiyapalayamPirivu and the new bus stop have been identified from the study. The industries and traffic flow in the area are to blame for the pollution. By creating new strategic legislative controls for industrial emissions, air pollution can be reduced. People ought to opt for public transit and electric vehicles.In future study, periurban area can be included for the study.

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