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# **Air Pollutant Dispersion Studies using AERMOD for Industrial Area of North- Western Part of Mysuru City**

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**ABSTRACT:** To regulate the effect of industrial emissions on ambient air quality standards, it is important to know about the dispersion of pollutants through air pollution models. In the present study, the information on source emission and meteorological data and the details of study area were collected. The contour maps for the distribution of SO<sub>2</sub> and NO<sub>2</sub> were generated during winter under maximum temperature conditions by using ISCST3 and AERMOD models over a period of five years. AERMOD has been used to analyze 24-hr maximum SO<sub>2</sub> and NO<sub>2</sub> concentrations downwind for all the five major industries studied (near Wipro Infotech Ltd.) over a period of five years during winter season and compared with the values obtained from ISCST3 model under similar conditions. The results indicated that AERMOD is slightly under-predicted the ground level pollutant concentration when compared to ISCST3. This may be due to the fact that unlike ISCST3, AERMOD calculates mixing height and stability class based on meteorological parameters such as; cloud cover, temperature, wind velocity and solar incidence angle and it is not artificially varied or kept constant throughout the model run. Whereas, in ISCST3 model run, the stability class and mixing heights were kept constant throughout.

**KEYWORDS:** Ambient air quality, emission inventory, air quality prediction models, ISCST3.

## **I. INTRODUCTION**

Due to increase in industries as well as automobiles emission, many cities in India are experiencing deterioration of ambient air quality. Air pollution has adverse health effects on human and has threat to children and risk factor for both acute and chronic respiratory diseases. Air quality models are used to quantify the health and environmental risks arising from gases and particulates being released to the air from industrial and other sources. There are large numbers of models like ISCST3, ADMS, AERMOD, CALPUFF and SCREEN models are available for the prediction of air pollutant concentrations in the atmosphere. American meteorological model (AERMOD) is especially designed to support the EPA'S regulatory modeling programs, which is an improved version of Industrial Source Complex Terrain Model (ISCST3). AERMOD model incorporates the effect of air turbulence and dispersion in the planetary boundary layer for flow over the flat and complex terrain, scaling concepts, and surface and elevated sources. The AERMOD modeling system consists of two processors (AERMET and AERMAP). The major purpose of AERMET is to calculate boundary layer parameters for use by AERMOD and major purpose of AERMAP is to calculate terrain heights and receptor grids for AERMOD.

## **II. RELATED WORK**

In the past, many researchers have conducted studies on the dispersion of air pollutants of various towns/cities and to measure the impact of major air pollutants such as SO<sub>x</sub>, NO<sub>x</sub>, SPM and lead on human health. Emission inventory for pollutants such as SO<sub>x</sub>, NO<sub>x</sub>, SPM and lead in various urban cities of India have been reported by numerous researchers (Zade and Ingole, (11), Prakash et al.(6), Prakash et al.(7), vanisa et al.(9) and Saroj et al.(8)). NO<sub>2</sub> emissions from the

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cement complex in dry and wet season were found to be within NAAQS in Thailand when AERMOD model was used (9). The study of Nagendra et al. (5) showed AERMOD, ADMS-Urban and ISCST3 perform satisfactory when compared to CALINE4, Delhi Finite Line Source Model (DFLSM) and GFLSM for predicting NO<sub>2</sub> concentrations. Heist et al. (3) have conducted air pollutant dispersion studies using RLINE, AERMOD, ADMS and CALINE models. The results of which have showed the ability to estimate the majority of downwind concentrations within in a factor of two (F2). The results of AERMOD model evaluation showed, there was good agreement between modeled and observed SO<sub>2</sub> concentration for annual and monthly comparison, however, this was not true when estimated hourly for SO<sub>2</sub> concentration in Halifax and Sydney (2). Quantification of contribution of SO<sub>2</sub> and NO<sub>2</sub> from various pollution sources in Jamshedpur region have been studied using emission inventory data and air quality model i.e., ISCST-3 model (1). It was predicted SO<sub>2</sub> and NO<sub>2</sub> concentration in the ambient air during winter season using the ISCST3 model. Further, they showed that, contributions from industrial sources are responsible for more than 50 % of the total SO<sub>2</sub> and NO<sub>2</sub> concentrations. Vehicular activities contributed to about 40 % of NO<sub>2</sub> and domestic fuel combustion contributed to about 38 % of SO<sub>2</sub>. It was showed that low Concentration of SO<sub>2</sub> was observed (Compared with NAAQ Standards) during rainy season near carbon industry in Raigad district, Chattisgarh, India (11). The studies conducted by Khare et al. (4) in Bellary steel industrial area have shown that, CALPUFF performed relatively well compared to Atmospheric Dispersion Modeling System (AERMOD), this may be due to atmosphere calm condition, which was difficult to predict the plume dispersion using AEMOD model. Further, the studies conducted by Prakash et al. (7) using AERMOD model for point source have showed the concentration of PM<sub>10</sub> from industrial emission was less compared to vehicle contribution (68%) From the above discussions, it is observed that most of the investigators have conducted air quality model studies using ISCST3 and AERMOD models for the predictions of as SO<sub>x</sub>, NO<sub>x</sub> and SPM concentrations in ambient air. Faulkner et al. (10) have conducted studies on sensitivity of two air quality dispersion models (AERMOD and ISCST3) for a rural ground-level area source. Concentrations predicted using ISCST3 were shown to be sensitive to changes in wind speed, temperature, solar radiation (as it affects stability class), and at mixing heights below 160 m. Surface roughness also affected downwind concentrations predicted by ISCST3. They also stated, AERMOD was sensitive to changes in albedo, surface roughness, wind speed, temperature, and cloud cover, however, Bowen ratio did not affect the results of AERMOD.

## III. METHODOLOGY

Mysuru industrial area comprises of six industrial areas such as Belagola (Metagally, General and Food), Hebbal (General and Hebbal Electronic City), Hootagally, Belavadi, Pura Angarahally – Mysuru II Phase and Koorgally – Mysuru III Phase. These industrial areas have been developed within a radius of 7 km from Mysuru city. The industrial area of Mysuru city is located at the Northwest part of Mysuru city and the geographical location of the study area is shown in the Figure 1. Information on emission inventory sources and meteorological data were collected and used in the present study. Emission inventory data were collected over period of five years from industrial stacks in Mysuru, these include: M/s J.K Tyre and Industries Ltd, M/s Falcon Tyres Ltd, M/s Hindustan Unilever Ltd, M/s. Automotive Axles Ltd., and M/s Rane (Madras) Ltd.



Fig. 1. Geographical location of the study area

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## Field Data Collection

Meteorological data was collected over a period of five years i.e. 2008 to 2012. Emission data and surface data's were also collected. Wind data's were collected from Meteorological Centre, Naganahalli, Mysuru and Mean Mixing Depth (MMD) values were obtained from a studies conducted by Attri et al., (1). A detailed map of Mysuru Industrial area along with locations of stacks of five major industries is shown in Figure 2. From Figure 2, it is observed that, industrial area in Mysuru is situated in North of Mysuru city, it stretches from west to east over a distance of 10 Kms and forms a belt across the northern limits of Mysuru city. The average width of the industrial area is found to be 4.5 Kms. The industrial area is surrounded by agricultural lands in the North-Eastern part, whereas, South-Western part consists of Hootagally residential layout and South-Eastern part is being city limits. Topo-sheet of the study area has been prepared using Google earth, Surfer11 and Auto CAD, is shown in Figure 3. From the topo-sheet (Figure 3) it is noticed, the two major stacks of J.K.Tyre industry are gently located at an elevated area. However, not much variation in the ground profile was noticed in other parts of industrial area.

## Source Emission data

In order to determine the contribution of air pollutants from five major industries located in North-West part of industrial area of Mysuru city, the emission inventory data were collected over a period of five years (i.e., from year 2008 to 2012), and used in air quality prediction models. The data's such as; stack height, stack diameter, stack gas exit velocity (m/s), flue gas temperature ( $^{\circ}\text{C}$ ), quantity of flue gas discharged into atmosphere ( $\text{Nm}^3/\text{hr}$ ), concentration of sulphur dioxide ( $\text{mg}/\text{Nm}^3$ ) and oxides of nitrogen ( $\text{mg}/\text{Nm}^3$ ) were collected. The details of total number of major stacks considered during the years 2008 and 2012 are presented in Table 1. From Table 1, it is observed, there is not much increase in the industrial emissions rates from the stakes, as the number of stacks during 2008 to 2012 remains almost same. Table 2 presents the category of industries as well as their activity of the major industries studied. From this Table 2, it is observed that, the natures of industries are in relating to rubber reclamation, food processing and metal bearing industries.

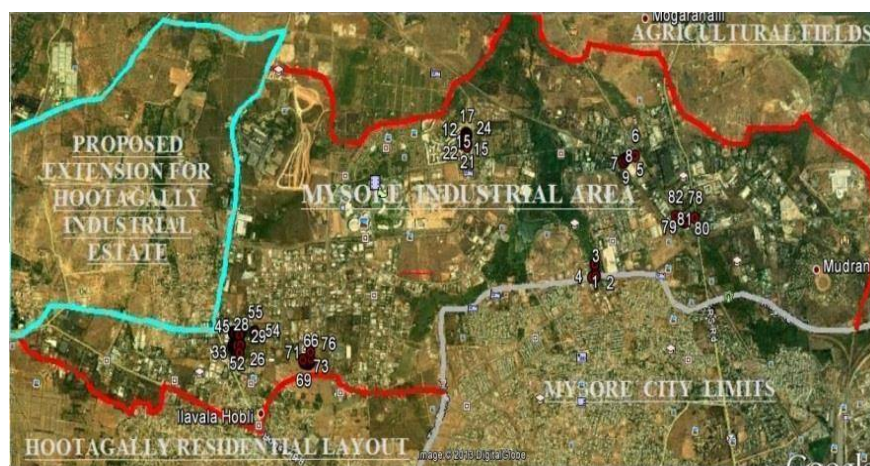


Fig. 2. Map of the study area with locations of major stacks of all the five industries



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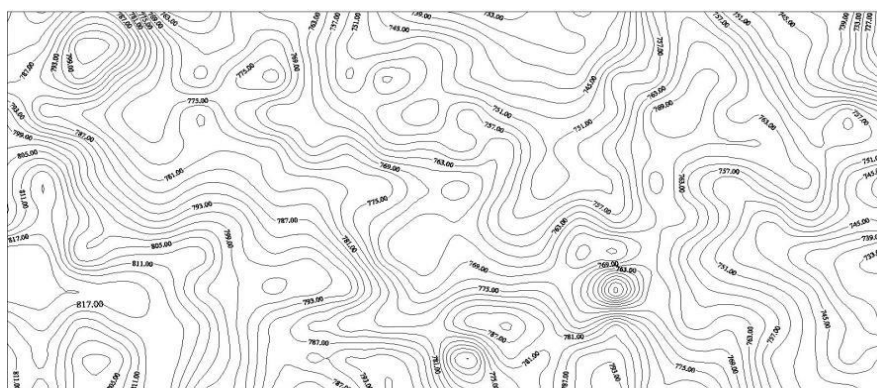


Fig. 3. Topo sheet of Mysuru industrial area

Table. 1. Year-wise variations in number of major industrial stacks in the study area

Year	Total number of stacks working
2008	48
2009	50
2010	48
2011	49
2012	48

Table. 2. General details of industries in Mysuru industrial area

Industry	Category	Activity
Automotive Axles Ltd., Hootagalli, Mysuru	Large- Red	Engineering
Falcon Tyres Ltd., KRS Road, Mysuru	Large- Red	Automobile Tyres
J.K. Industries Ltd., KRS Road, Mysuru	Large- Red	Truck Tyres and tubes
Hindustan Unilever Ltd., Hebbal, Mysuru	Large- Red	Instant Coffee processing
Rane (Madras) Ltd., Hootagalli, Mysuru	Large- Red	Engineering

## IV. AIR QUALITY DISPERSION MODELS

To regulate the effect of industrial emissions on the air quality standards, it is important for us to understand the dispersion of pollutants through air pollution dispersions models. Modeling provides an estimate of what the air quality will be as the result of various natural and non-natural processes. Air quality modeling is used to quantify the health



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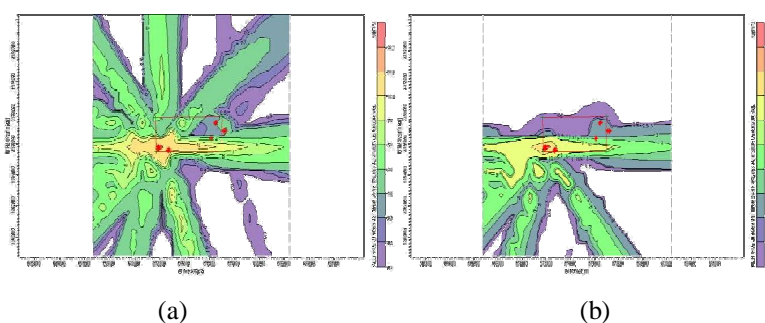
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## V. EXPERIMENTAL RESULTS AND DISCUSSION

### Seasonal Variations of Pollutants Concentrations Predicted by AERMOD Air Quality Model

and environmental risks arising from gases and particulates being released to the air from industrial and other sources. Air quality models are used to estimate the pollutant concentrations at a downwind receptor location. Fundamentally different models have been developed in the way they parameterize the physical and chemical processes. They have been developed for different scales from trans-boundary air pollution, to urban background and street scale, and for different sources such as traffic and industrial sources (Hung, 2010). The AERMOD is an air quality dispersion which consists of three separate components such as: AERMOD (AERMIC Dispersion Model), AERMAP (AERMOD Terrain Preprocessor), and AERMET (AERMOD Meteorological Preprocessor). AERMET is a meteorological preprocessor for the AERMOD. To run of AERMOD the input data required are hourly cloud cover observations, surface meteorological observations and upper air soundings data. Output data include surface meteorological observations, pollution parameters and vertical profiles under various atmospheric stability conditions. The AERMAP preprocessor is a terrain preprocessor designed to simplify and standardize the input of terrain data for AERMOD. The AERMOD version 8.2.0 was used in the present study to predict the downwind pollutant concentrations. AERMET which uses .sfc and .pfl file formats and later AERMET was incorporated into AERMOD for generating Planetary Boundary Layer parameters. AERMOD was run for critical winter season over a period of five years. For winter season the emission was categorized as sulphur dioxide and nitrogen dioxide from all sources (DG sets, process and boilers). The meteorological data required to run AERMOD are ambient temperature, wind velocity and its direction and cloud cover. AERMOD calculates mixing height using these meteorological data unlike ISCST3 and the model considers bowen and albedo ratios in its dispersion algorithms. AERMOD was run for winter and maximum hourly, 24-hr and monthly concentration contours were obtained.

In the present study, American Meteorological Society and the United States Environmental Protection Agency Dispersion Model (AERMOD) air quality model was run for critical period (winter season) under maximum atmospheric temperature conditions for over a period of five years (2008 to 2012). The AERMOD has been run for SO<sub>2</sub> and NO<sub>x</sub> distribution with 24-Hr maximum concentration and concentration contours were obtained. Figure 4 (a-e) and Figure 5 (a-e) shows the concentration contours for SO<sub>2</sub> and NO<sub>2</sub>, respectively during winter, over a period of five years. From these Isopleths plots, it is observed that, the highest pollutants concentrations predicted by AERMOD was near the major source (i.e., Automotive Axles Ltd.) and a maximum of 174.8 µg/m<sup>3</sup> of SO<sub>2</sub> and 147.1 µg/m<sup>3</sup> of NO<sub>2</sub> was noticed during winter in 2011. It is also observed that, the maximum pollutants concentrations for all other years were found to be below the prescribed NAAQS of 80 µg/m<sup>3</sup> for both SO<sub>2</sub> and NO<sub>2</sub> near the source.



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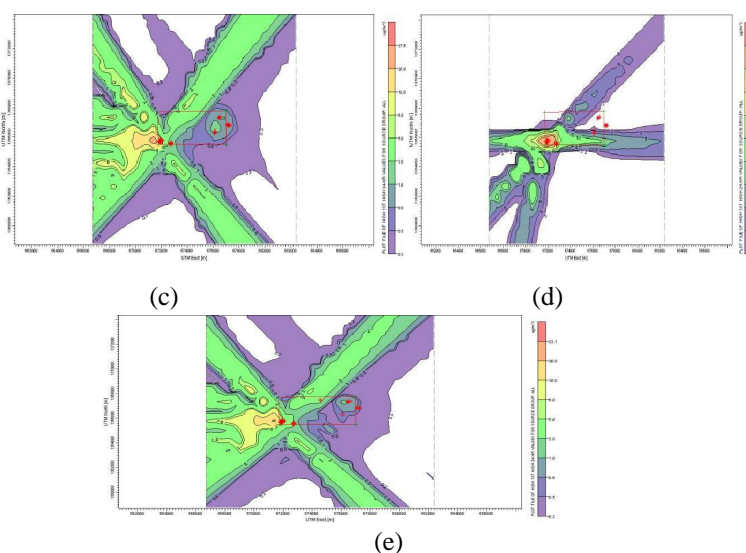


Fig .4. AERMOD predicted maximum 24-hr  $\text{SO}_2$  concentration (in  $\mu\text{g}/\text{m}^3$ ) during winter (a) 2008 (b) 2009 (c) 2010 (d) 2011 (e) 2012

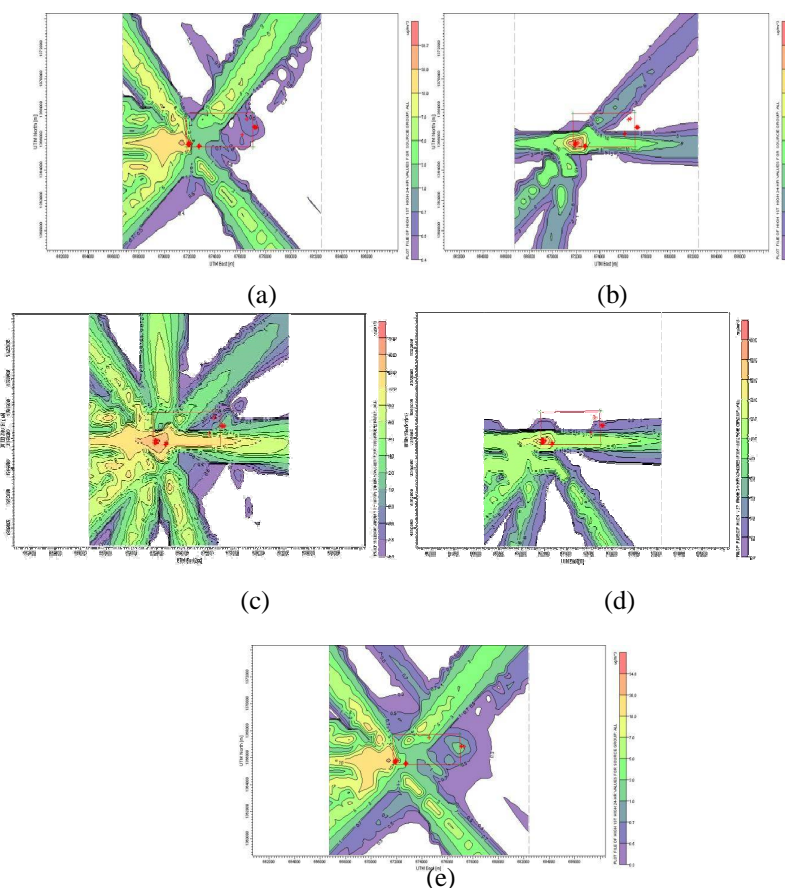


Fig. 5. AERMOD predicted maximum 24-hr  $\text{NO}_2$  concentration (in  $\mu\text{g}/\text{m}^3$ ) during winter (a) 2008 (b) 2009 (c) 2010 (d) 2011 (e) 2012

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## Seasonal Variations of Pollutants Concentrations Predicted by ISCST3 Air Quality Model

In the present study, the isopleths plots for winter season have been made for the year 2008 to 2012 for  $\text{NO}_2$  and  $\text{SO}_2$  are shown in Figure 6 (a-e) and Figure 7(a-e) respectively. From these Isopleths plots, it is observed that, the spatial distributed (i.e., North-East direction) over study area and a maximum of  $48 \mu\text{g}/\text{m}^3$  of  $\text{SO}_2$  and  $52 \mu\text{g}/\text{m}^3$  of  $\text{NO}_2$  was noticed during winter in 2008. It is also observed that, the maximum pollutants concentrations during entire study period found to be below the prescribed NAAQS of  $80 \mu\text{g}/\text{m}^3$  for both  $\text{SO}_2$  and  $\text{NO}_2$  near the source.

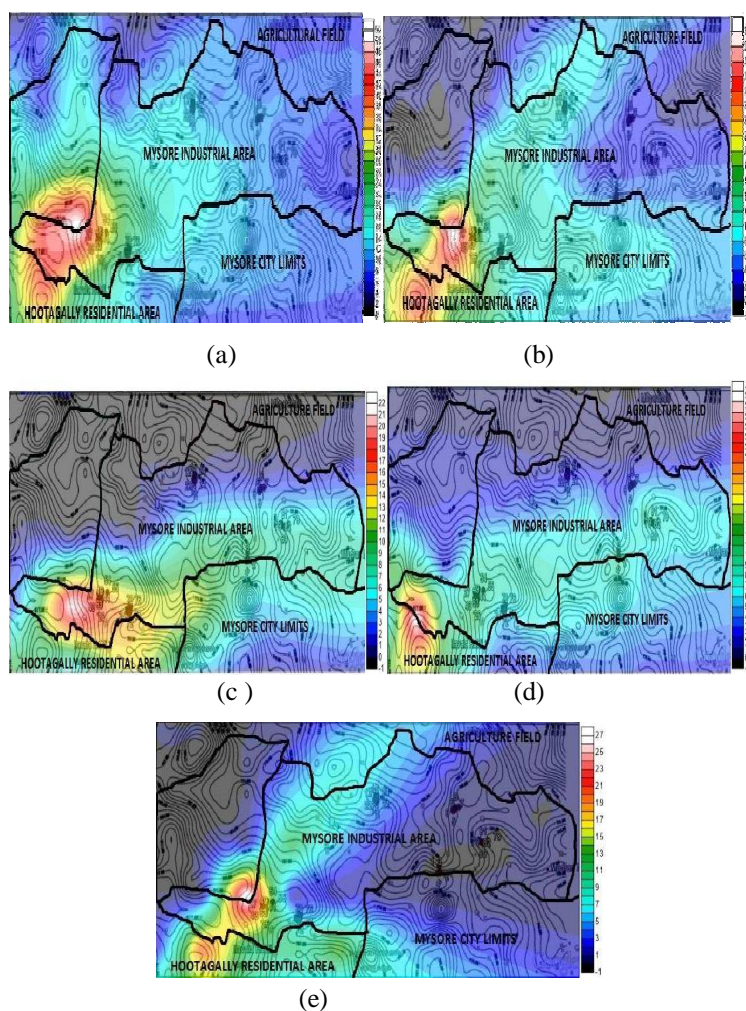


Fig. 6. ISCST3 predicted maximum 24-hr  $\text{SO}_2$  concentration (in  $\mu\text{g}/\text{m}^3$ ) during winter (for maximum temperature) (a) 2008 (b) 2009 (c) 2010 (d) 2011 (e) 2012



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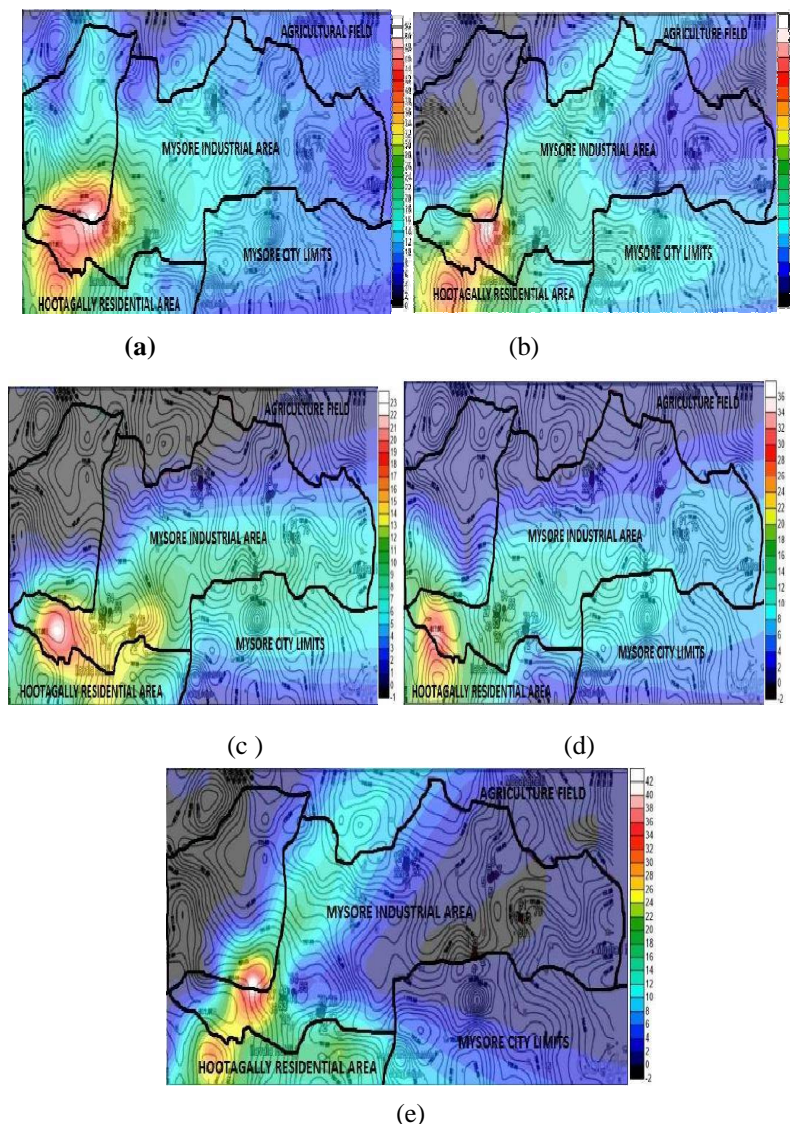


Fig. 7. ISCST3 predicted maximum 24-hr NO<sub>2</sub> concentration (in µg/m<sup>3</sup>) during Winter (for maximum temperature) (a) 2008 (b) 2009 (c) 2010 (d) 2011 (e) 2012

## AERMOD versus ISCST3

Present study mainly focused on the development of contour maps on the distribution of SO<sub>2</sub> and NO<sub>2</sub> which were generated during winter under maximum temperature conditions using ISCST3 and AERMOD models over a period of five years. AERMOD has been used to analyses 24-hr maximum SO<sub>2</sub> and NO<sub>2</sub> concentrations downwind from all five major industries (near Wipro Infotech Ltd.) over a period of five years during winter season and compared with the values obtained from ISCST3 model under similar conditions. Figure 4 (a-e) and Figure 5 (a-e) depicts the AERMOD predicted 24-hr SO<sub>2</sub> and NO<sub>2</sub> concentrations during winter under maximum temperature over a period of five years. Figure 6 (a-e) and Figure 7 (a-e) shows ISCST3 model predicted maximum 24-hr SO<sub>2</sub> and NO<sub>2</sub> concentrations, respectively during winter over a period of five years. By comparing, SO<sub>2</sub> and NO<sub>2</sub> concentrations contours obtained from ISCST3 and AERMOD models, it is observed that, AERMOD is slightly under-predicted the ground level pollutant concentration when compared to ISCST3 and this can be further justified from the Table 3. Further, this may

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also due to the fact that, unlike ISCST3, AERMOD calculates mixing height and stability class based on meteorological parameters such as; cloud cover, temperature, wind velocity and solar incidence angle and it is not artificially varied or kept constant throughout the model run.

However, in ISCST3 model run, the stability class and mixing heights were kept constant throughout. Faulkner et al. (11) have revealed that, AERMOD is more sensitive to small changes in surface roughness and wind speed and the model also considers bowen ratio and albedo unlike ISCST3 in its dispersion modeling algorithms. They also stated that AERMOD is increasingly sensitive relative to ISCST3 as wind velocity is below 3 m/s. In present study the following conditions have been adopted while running the ISCST3 and AERMOD model.

- Common and lowest mean mixing depth and stability class was considered to run ISCST3 for all five years.
- ISCST3 and AERMOD air quality prediction models cannot be correlated though the downwind concentrations which were well simulated by both the models. Since, for ISCST3 model run, mixing heights and stability class were kept constant which plays a major role in dispersion of pollutants.
- Hourly meteorological data was unavailable for Mysuru region, hence daily meteorological data was converted to hourly data.
- AERMOD calculated mixing heights with basis of other meteorological parameters such as cloud cover, temperature, wind velocity and solar incidence angle unlike ISCST3, which is a major drawback of ISCST3 model.

Table 3. Pollutants concentrations predicted downwind by ISCST3 and AERMOD

Year (winter)	ISCST3		AERMOD	
	SO <sub>2</sub> , µg/m <sup>3</sup>	NO <sub>2</sub> , µg/m <sup>3</sup>	SO <sub>2</sub> , µg/m <sup>3</sup>	NO <sub>2</sub> , µg/m <sup>3</sup>
2008	8	10	6	10
2009	4	6	2	6
2010	6	4	5	1
2011	6	6	3	5
2012	1	2	1	1

## VI. CONCLUSIONS

Comprehensive emissions inventory of an industrial area in Mysuru city has been predicted using AERMOD and ISCST3 air quality models for the dispersion of SO<sub>x</sub> and NO<sub>x</sub> in the atmosphere. The results of output of ISCST3 model isopleths showed, the pollutants traversing towards NE of the study area with SO<sub>x</sub> and NO<sub>x</sub> concentrations were well below NAAQ standards of 80 µg/m<sup>3</sup>. Further, the results of output of AERMOD revealed that, during 2011 maximum SO<sub>x</sub> and NO<sub>x</sub> concentrations near the source was found to be 174.8 µg/m<sup>3</sup> and 147.1 µg/m<sup>3</sup>, respectively, which is found to be greater than NAAQ standards. This may be due to the fact that unlike ISCST3, AERMOD calculates mixing height and stability class on the basis of cloud cover, temperature, wind velocity and solar incidence angle and it is not artificially varied or kept constant throughout the model run. AERMOD and ISCST3 Model have maximum 24-hr averaged Ground Level Concentrations (GLCs) of SO<sub>2</sub> and NO<sub>2</sub> contributed from the five major industrial sources were observed to be near Automotive Axles Ltd, which is located in the south-western part of the industrial area. Further, the model value of 24-hr maximum SO<sub>2</sub> and NO<sub>2</sub> concentration downwind from all five major industries was observed over a period of five years during winter indicate the AERMOD is slightly under-predicted when compared to ISCST3 air quality model.

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