

Performance Study of Modelling Urban Traffic Air Pollution Dispersion

H. C. Chowde Gowda¹, Dr. Mahalingegowda R. M²

^{1,2}Department of Civil Engineering, P. E. S. College of Engineering Mandya –571401, Karnataka, INDIA

Abstract – Currently, in India, air pollution is widespread in urban areas where vehicles are the major contributors and in a few other areas with a high concentration of industries. Vehicular emissions are of particular concern since these are ground level sources and thus have the maximum impact on the general population. Also, vehicles contribute significantly to the total air pollution load in many urban areas. In most of the countries exist many buildings (obstacles) along the road ways which are densely populated, this is typically common in urban areas. The transport and dispersion of vehicular exhaust released into atmosphere governed by the air flow near the ground, which depend on the existing geometry and arrangement of buildings. The entrainment of pollutant concentration emitted from line sources (vehicular exhaust emission) into the near field wakes of group of buildings in the near- field of highway can result in maximum concentration that are significantly greater than those found for similar sources in the open terrain

Key Words: Pollution, dispersion, array of building Obstacles, emission, etc

1. INTRODUCTION

The movement of pollutants in the atmosphere is caused by transport, dispersion, and deposition. Transport is movement caused by a time-averaged wind flow. Dispersion results from local turbulence, that is, motions that last less than the time used to average the transport. Deposition processes, including precipitation, scavenging, and sedimentation, cause downward movement of pollutants in the atmosphere, which ultimately remove the pollutants to the ground surface. This chapter deals only with transport and dispersion. Further, the dispersion is dependent on various source parameters and surface layer micro-meteorological parameters such as wind speed, wind direction, roughness conditions etc. In addition, the influence of the nearby buildings and other structures of varying terrain categories cause further complexity in the dispersion phenomenon. During the past decade, the complexities of transport and dispersion of airborne pollutants associated with vehicular emissions have been studied with elaborate field and modeling experiments. In the first part of this article, the terms used in the study of transport and dispersion of pollutants and the scales of motion (time and distance) over which vehicular emissions may affect air quality, precipitation quality, or both, are defined. Since pollutants can travel distances from meters to hundreds of kilometers, the relative scales of motion

involved in distinguishing transport phenomena from dispersion phenomena may vary from problem to



Fig -1: vehicular air pollution

2. DOMINANT SOURCES OF AIR POLLUTION

One of the dominant sources of air pollution affecting environmental living quality in urban areas is road traffic-induced air pollution providing information about traffic air pollution and finding out its distribution is therefore a crucial starting point for planning effective measures to improve air quality. Such information helps decision makers to optimize e.g. urban design.

However, the phenomenon of road traffic air pollution shows considerable variation within a street canyon as a function of distance to the source of pollution, therefore, the levels and consequently the effected number of inhabitants varies. The location of hot spots of high pollution levels that exceed a certain threshold has besides a horizontal also a vertical dimension; the latter is usually neglected. The little attention to the vertical variation is mainly caused by the fact that urban environmental policy standards only demand monitoring and therefore modelling of pollution levels at a specific measurement height (e.g. 3.5 m above ground), ignoring that below this measurement level but also offering no specific information to inhabitants living on upper floors of high rise buildings.

To fill this information gap a variety of micro-scale air dispersion models have been developed in the past years. Such models provide information about the horizontal as well as vertical variation of air pollution levels, including a Discrimination of most common pollutants (e.g. CO₂, NO₂, PM₁₀) that have different spatial spreading behaviors'. Most dispersion models have a special output formats e.g. tabular outputs, but unfortunately do not integrate the information into a spatial database in conjunction with contextual information of the street canyon which would allow urban planners and decision makers to easily access and interpret the information.

Linking up dispersion models with a GIS environment is a mean to resolve this shortcoming. Modelling pollution dispersion with a GIS platform is also a powerful way of making the modelled results user-friendly and easily understandable for local authorities as well as the public. Several researches have been studied that aimed at linking dispersion models with a GIS system.

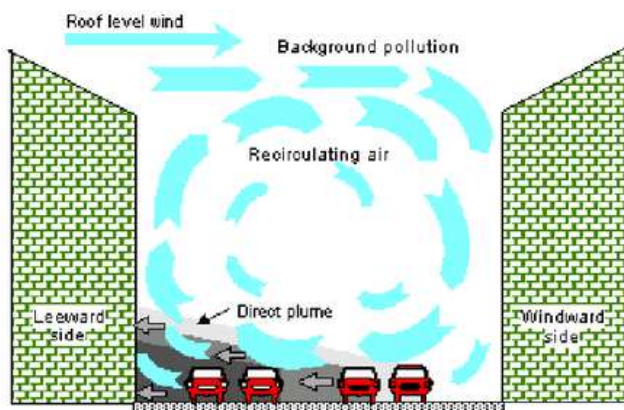


Fig -2: Modelling Urban Traffic Air Pollution Dispersion

Transport and Dispersion: Theory and Applications, outlines the observational information on transport and dispersion, describes the theoretical tools that have been used to simulate the transport of vehicular emissions, identifies the limitations of these tools, and recommends specific areas for further research. Mathematical formulations of transport and dispersion are developed only as needed to identify the parameters of interest.

3. URBAN AIR QUALITY

Urban air pollution involves physical and chemical process ranging over a wide scale of time and space. The urban scale modeling systems should consider variations of local scale effects, for example, the influence of buildings and obstacles, downwash phenomena and plume rise, together with chemical transformation and deposition. Atmospheric boundary layer, over 10 to 30 km distances, governs the dispersion of pollutants from near ground level sources.

Vehicular emissions are one the major pollution source in urban areas. Ultrafine particles are formed at the tailpipe due to mixing process between exhaust gas and the atmosphere. Processes at urban scale provide momentum sink, heat and pollutant source thereby influencing the larger regional scale (up to 200 km). Atmospheric flow and microclimate are influenced by urban features, and they enhance atmospheric turbulence, and modify turbulent transport, dispersion, and deposition of atmospheric pollutants. Any urban scale modeling systems should consider effects of the various local scales, for example, the influence of buildings and obstacles, downwash phenomena and plume rise, chemical transformation and deposition. The modelling systems also require information on emissions from various sources including urban mobile pollution sources. Simple dispersion air quality pollution transport models and complex numerical simulation model require wind, turbulence profiles, surface heat flux and mixing height as inputs. In urban areas mixing height is mainly influenced by the structure heights and construction materials.

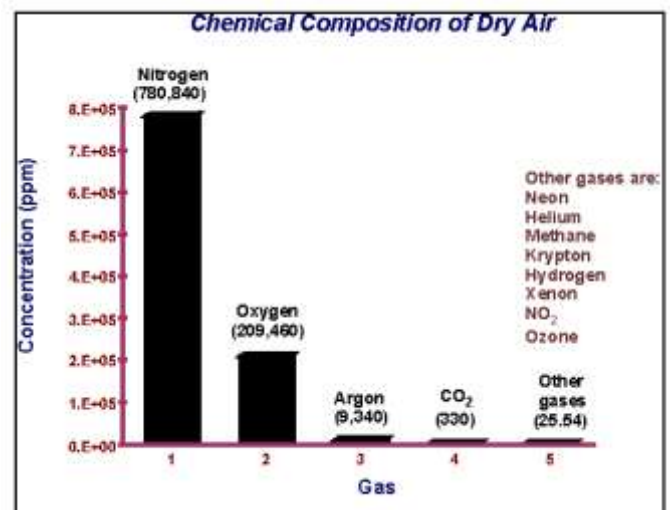


Fig -3: Chemical composition of dry Air

There are two basic physical forms of air pollutants. The first is gaseous form. For example, sulfur dioxide, ozone and hydro-carbon vapors exist in the form of a gas. The gases lack definite volume and shape and the molecules are widely separated. The second form of air pollution is particulate matter such as smoke, dust, fly ash and mists.

The pollutants are also classified as primary pollutants and secondary pollutants. The primary pollutants remain in the same chemical form as they are released from a source directly into the atmosphere. For example: sulfur dioxide and hydrocarbons. The secondary pollutants are a result of chemical reaction among two or more pollutants. The production of PAN (Peroxyacetyl Nitrate) during

photochemical reactions is an example of secondary pollutant.

Considered. Elevated (nonsurface) emissions from sources such as smokestacks (point sources) are of little importance in the field of vehicular emissions except perhaps when comparing the relative human exposure resulting from surface versus nonsurface emissions on urban and regional scales.

4. Method and Validation

This study used the Eulerian method to model the air pollutant dispersion. Compared with the Lagrangian method, which considers the species as a discrete phase, the Eulerian method considers phases as continuum and is solved based on a control volume, which is similar in form to that for the fluid phase (Wang, Lin, & Chen, 2012; Zhang & Chen 2006). Wang, Lin and Chen (2012) compared the performance of Reynolds-averaged Navier-Stokes (RANS) model with Eulerian method and Large Eddy Simulation (LES) model with Lagrangian methods. The later one is more accurate but also with higher computational cost. Zhang and Chen (2006) used a user-defined function in Fluent to calculate the pollutant concentration, because the lagrangian method does not directly output the concentration value. Therefore, the Eulerian method is more convenient for calculating the air pollutant concentration, which was the index that this study used to evaluate air pollutant dispersion[4].

In this study, the wind tunnel data provided by Niigata Institute of Technology was used to validate the Eulerian method. The effects of the different turbulence models on air pollutant dispersion simulation were also investigated in this validation study. RANS and LES models were included in the validation study. In RANS models, the standard and realizable model. The model configurations were set to match those in the wind tunnel experiment too. The H/W and H/L aspect ratios were set to 1.0 and 0.5, respectively, where H is the building height, W is the width of the street, and L is the length of the canopy. All modeling settings followed the Architectural Institute of Japan (AIJ) guidelines.

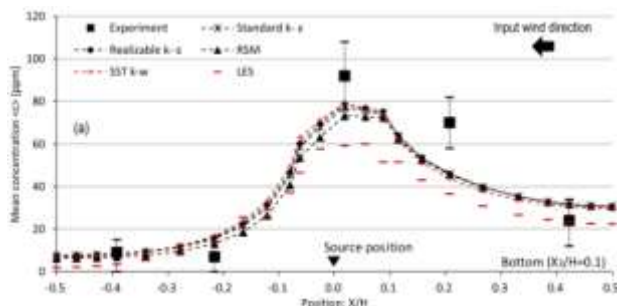


Fig -3: Cross-comparisons of time-averaged concentrations

The simulation results of the different turbulence models were collected at two test lines and cross-compared in Figure 3. The simulation results were closer to the experiment data particularly near ground ($X/H=0.1$, X is the height of the test line). However, compared with LES model with best accuracy, all RANS models overestimated the concentrations at upper lines ($X/H=0.5$, for example), particularly at the windward side of the street canyon. Among the RANS models, the SST $\kappa\omega$ model best performed in terms of air pollutant modeling at the windward side. The special near-wall region (the shear layer) treatment by the standard $\kappa-\omega$ model (Menter, Kuntz, & Langtry, 2003) was considered helpful for estimating the air pollutant concentration near surface regions[5]. Balancing the computational cost and accuracy, for this study, the SST $\kappa-\omega$ model was selected as the preferred turbulence model to simulate the air pollutant dispersion in the parametric study.

5. CONCLUSION

The concentrations of pollutants that would be expected in the absence of moving vehicles are determined by emissions rates and the complex wind flow and turbulence produced by the interaction of the local wind with complex structures (for example, buildings, sound barriers, other vehicles). Weather plays a role in most of these components, generally causing higher emission rates at lower temperatures, diluting pollutants at higher wind speeds, mixing pollutants vertically during unstable thermal conditions, and influencing the rates of homogeneous and heterogeneous chemical reactions and the rate of scavenging of pollutants from the atmosphere by precipitation and dry deposition.

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