PHYSICAL MODELING AND NUMERICAL SIMULATION STUDY OF LINE SOURCE DISPERSION IN URBAN STREET CANYONS

by

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Air pollution - Urban Street canyons
Pollution dispersion Phenomena - Urban Study
Urban Environment - traffic Effect - Numerical simulation.

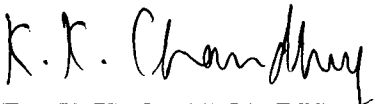
Dedicated

to

My Family

CERTIFICATE

This is to certify that the thesis entitled "**Physical modeling and Numerical simulation Study of Line Source Dispersion in Urban Street Canyons**" being submitted by **Ms. Seema Awasthi**, has been prepared under my supervision in conformity with the rules and regulations of the **Indian Institute of Technology, Delhi**. I further certify that the thesis has attained a standard required for the award of a degree of **Doctor of Philosophy** of the institute. This work, or any part thereof, has not been submitted elsewhere for the award of any other degree or diploma.



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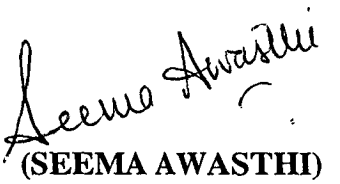

(SEEMA AWASTHI)

ABSTRACT

Air pollution from motor vehicles is one of the most serious and rapidly growing problems in various urban centres of the world. From the population exposure point of view, study of air quality in urban street canyons is of paramount importance, since the highest pollution levels and considerably larger environmental impacts have often been observed in these situations. In order to chalk out effective counter measures for achieving sustainable street air quality, there is a need to comprehensively analyse the pollution dispersion phenomenon within the street canyon.

Predicting the distribution of pollutants under various urban conditions such as urban street canyon is extremely complex involving a variety of physical and meteorological factors including vehicle emissions, wake effects, canyon wind flows and turbulent dispersion. Over the past two decades, significant progress has been made in understanding and modelling vehicular pollution dispersion phenomena under these urban environmental conditions by using Environmental Wind Tunnel (EWT) technique. In the EWT, the emission conditions, different meteorological situations, terrain and topographical features can be changed at will and useful data translatable to the real - life situations can be obtained. These EWT studies carried out over the last ten years have greatly helped in determining the pollutant concentrations under various urban street canyon conditions as a function of building dimensions, upwind building configuration, wind direction with respect to building configuration and roof geometry. These studies have further shown that the street canyon configuration, its aspect ratio, external wind speed and its direction and traffic produced turbulence are some of the important factors influencing pollutant dispersion in urban areas.

In the present study, physical modelling of various street canyon configurations in EWT facility at the Indian Institute of Technology (IIT) Delhi has been carried out to study the heterogeneous traffic-induced effects on pollutant dispersion in street canyon. Effects of aspect ratio of street canyon and wind orientations have also been studied. In addition, an attempt has been made to find out the extent of application of Computational Fluid Dynamics (CFD) code FLUENT in

the pollution predictions within urban street canyons for the three-dimensional case. The numerical simulation has been done using standard, RNG (Renormalized Group) and realisable k-ε turbulence models.

The study has indicated that under perpendicular and oblique wind directions, pollution distribution in the urban street canyon is affected by the central vortex whereas during parallel wind flow, the pollution gets dispersed due to channelling of the flow. It has been found that while increase in traffic results in an increase in the pollutant levels in the street canyon, the effect of increased pollution level, to a certain extent is offset by the increased traffic produced turbulence (TPT) generated by these vehicles.

The effect of TPT is significantly reduced with height (z/H). The effect of the vehicle - induced mixing has been found to be maximum at the pedestrian level, while at sampling locations close to the top edge, the effect of vehicle- induced mixing of pollution was found to be almost negligible. Further, the pollution level in street canyon has also been found to be affected by aspect ratio and traffic volume.

A comparison of each set of data from wind tunnel experiments with the numerical simulation reveals that the CFD code FLUENT, can predict many of the wind tunnel results for average flow field and concentrations by choosing appropriate boundary condition, grid resolution and turbulence model. It has been found out that for separated flows, the RNG k-ε turbulence model works best whereas, for normal flows without any separation, the predictive capability of standard k– ε turbulence model is better than the RNG and realizable k– ε turbulence models.

TABLE OF CONTENTS

CERTIFICATE	(i)
ACKNOWLEDGEMENTS	(iii)
ABSTRACT	(v)
TABLE OF CONTENTS	(vii)
LIST OF FIGURES	(xi)
LIST OF PLATES	(xviii)
LIST OF TABLES	(xix)
LIST OF ABBREVIATIONS	(xx)
LIST OF NOTATIONS	(xxii)
1. INTRODUCTION	1-8
1.1 General	1
1.2 Statement of the problem	2
1.3 Motivation for the present study	3
1.4 Scope of the present study	5
1.5 Objectives of the present study	6
1.6 Overview of the thesis	7
2. REVIEW OF THE LITERATURE	9-78
2.1 General	9
2.2 Physical modelling in Environmental Wind Tunnel (EWT)	10
2.2.1 Advantages of wind tunnel modelling	11
2.2.2 Atmospheric Boundary Layer (ABL)	13
2.2.3 Important features of ABL	15
2.2.4 Similarity criteria	21

2.2.5 ABL simulation techniques in EWT using passive devices 25

2.2.6 Limitations of physical modelling in EWT 27

2.3 Flow measuring techniques in physical modelling 28

2.4 Dispersion mechanism in street canyon 31

2.4.1 Street canyon configurations 33

2.4.2 Effects of wind direction and aspect ratio 35

2.4.3 Effects of shape and length of buildings 41

2.5 Effects of vehicle-induced turbulence 43

2.5.1 Field Studies of turbulence statistics 51

2.6 Computational Fluid Dynamics (CFD) modelling 54

2.6.1 Turbulence modelling in CFD 57

2.6.2 Basic structure of CFD codes 63

2.6.3 Solution convergence and grid sensitivity 65

2.6.4 Street canyon dispersion studies using CFD techniques 67

2.6.5 Performance evaluation of models used in the FLUENT 75

3. EXPERIMENTAL SETUP AND METHODOLOGY 79-113

3.1 General 79

3.2 Brief description of EWT Facility at IIT, Delhi 80

3.2.1 Simulation of neutrally stabilized ABL in the EWT 83

3.2.2 Flow measurements in the EWT 84

3.2.3 Mean Velocity Profile 84

3.2.4 Turbulence intensity measurements 86

3.2.5 Flow uniformity along transverse direction 87

3.2.6 Estimation of surface layer roughness parameters 88

3.3 Simulation of scaled model of urban street canyon 90

3.4 Simulation of Line Source for tracer gas emission 92

3.5 Simulation of Model Vehicle Movement System (f-MVMS) 94

3.6 Simulation of traffic volume and speed 96

3.7 Tracer gas dispersion experiments in the wind tunnel 98

3.8 Test parameters used in the study 102

3.9 Numerical simulation using CFD code FLUENT 107

3.9.1 Description of numerical calculations 107

3.9.2 Boundary conditions used in the study 110

3.9.3 Street canyon configurations simulated in FLUENT 113

4. RESULTS AND DISCUSSION 114-181

4.1 General 114

4.2 Physical modelling study 114

4.2.1 Dispersion mechanism for parallel wind orientation 115

4.2.2 Effect of traffic volume at parallel wind orientation 123

4.2.3 Dispersion mechanism for perpendicular wind orientation 128

4.2.4 Effect of traffic volume at perpendicular wind orientation 135

4.2.5 Dispersion mechanism for oblique wind orientation 140

4.2.6 Effects of traffic volume at oblique wind orientation 146

4.2.7 Effects of wind direction 151

4.3 Numerical simulation using CFD code FLUENT 155

4.3.1 Performance evaluation through statistical analysis 156

4.3.2 Parametric investigation of dispersion mechanism 162

5. CONCLUSIONS 182-188

5.1 General 182

5.2 Conclusions based on the physical modelling study 182

5.2.1 Effects of wind direction 182

5.2.2 Effects of aspect ratio 183

5.2.3 Effects of traffic Volume 183

5.3 Conclusions based on the numerical modelling study 184

5.4 Contributions of the present study 185

5.5 Scope for the future work 186

REFERENCES 189

APPENDIX I 206

APPENDIX II 211

BIO-DATA OF THE AUTHOR 214