URBAN LOCAL AIR QUALITY MANAGEMENT (ULAQM) FRAMEWORK FOR NO_2 AND $PM_{2.5}$ USING HYBRID MODELS

SUNIL

DEPARTMENT OF CIVIL ENGINEERING

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URBAN LOCAL AIR QUALITY MANAGEMENT (ULAQM) FRAMEWORK FOR NO_2 AND $PM_{2.5}$ USING HYBRID MODELS

by

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Department of Civil Engineering

Submitted
in fulfillment of the requirements of the degree of

DOCTOR OF PHILOSOPHY

to the

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October, 2015

Dedicated

to

My Parents

&

My Beloved Wife

Mrs. Monika

<u>CERTIFICATE</u>

This is to certify that the thesis entitled "**Urban Local Air Quality Management (ULAQM) Framework for NO_2 and $PM_{2.5}$ using Hybrid Models**" being submitted by **Mr. Sunil** has been prepared under our supervision in conformity with the rules and regulations of the **Indian Institute of Technology Delhi**. We further certify that the thesis has attained a standard required for the award of the degree of **Doctor of Philosophy** of the institute. The work, or any part thereof, has not been submitted elsewhere for the award of any other degree or diploma.

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ABSTRACT

Urban air pollution is one of the major issues throughout the world. In urban areas, wide variety of sources contribute to different types of air pollutants. Among these, the single major source of urban air pollutants is motorized road transportation (Sharma and Khare, 2002; Singh et al., 2007; Ramachandra and Shwetmala, 2009; CPCB, 2010). During peak traffic hours, increase in ambient pollutant concentrations results into *episodic* conditions. These *episodes* are common features particularly at urban *hot spots* i.e. central business districts, intersections and signalized roadways. The users of these urban hot spots are exposed to severe pollution which may affect their health (Kanlindkar, 2007). Low wind speed and mixing height along with temperature inversion are main meteorological factors generating the *episodes* (Gokhale and Khare, 2007). Gaussian based air quality models generally fails in predicting *air pollution episodes (upper percentile range)* due to inherent limitations that they possess (Sharma and Khare, 1999; Nagendra and Khare, 2002). Alternatively, Jakeman et al. (1988); Wordsworth (1990); Gokhale and Khare (2003) have described that statistical distribution models which are *non-causal* and based on historical data, are best suited for accurate predictions of *extreme* concentrations i.e. *episodic*. However, environmental damages are caused by both *extremes* as well as by the sustained *average* ambient pollutant concentrations. Past studies have reported that hybrid modelling techniques an integrated approach which may accurately predict *extreme* as well as *average* pollutant concentrations (Jakeman et al., 1988; Gokhale and Khare, 2003; Sharma et al., 2013c). It combines features of deterministic based model (taking into consideration the sustained average pollutant concentrations) and statistical distributions model (that takes into consideration the *peak* concentrations). The present research, aims to formulate urban local air quality management (ULAQM) framework which is

capable of accurately predicting the *average* as well as *extreme* percentile ranges of NO_2 and $PM_{2.5}$ concentrations using hybrid models developed at selected non-attainment areas (NAAs) in India, i.e. I.T.O. intersection (NAA1) in Delhi city and S.P. Road (NAA2) in Chennai city. At the NAA1 (Delhi), for winter season, the hybridization of AERMOD (deterministic based model) and Lognormal distribution for NO_2 and $PM_{2.5}$ has given satisfactorily predictions with index of agreement, d values of 0.98 to 0.99, respectively. However, during summer season, it has been observed that hybridization of AERMOD and Log-logistic distribution for NO_2 and AERMOD and Lognormal distribution for $PM_{2.5}$ have produced satisfactorily predictions with d values of 0.98 to 0.96, respectively. Further, at NAA2 (Chennai), for winter and summer seasons both, hybridization of AERMOD and Lognormal distribution has predicted $PM_{2.5}$ concentrations satisfactorily with d values of 0.98 and 0.99, respectively. The verification of the developed hybrid models have been carried out using emission and meteorological data of the winter season of year 2009 and year 2008. The results show satisfactorily performance of the developed models with d values ranging from 0.94 to 0.96. Further, the application of the models at two different sites having similar traffic and other surrounding characteristics in Delhi (NAA3) and Chennai (NAA4) cities showed satisfactory performance with a 'd' values, ranging from 0.95 to 0.97. The probability of *exceedences* of pollutant concentrations over specified standards has also been evaluated using the hybrid models. It has been observed that at Delhi site (NAA1), *exceedence* of 1-hour average NO_2 concentrations over specified standards (200µg/m^3) during winter and summer periods are 5.9% and 5.7%, respectively. However, *exceedences* of 1-hour average $PM_{2.5}$ concentrations over specified standard (i.e., 80µg/m^3) are 82.5% and 67.3%, respectively for winter and summer seasons. At

Chennai site (NAA2), the *exceedences* of 1-hour average $PM_{2.5}$ concentrations over standard are 27.5% and 4.9% in winter and summer, respectively.

Based on the above analysis, the ULAQM framework has been developed and evaluated to *attain* the hourly average NO_2 and $PM_{2.5}$ concentrations within specified standards.

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ADMS	Atmospheric Dispersion Modelling System
AD	Anderson Darling test
AERMOD	The **A**MS/**E**PA **R**egulatory **Mod**el
APINA	Air Pollution Information network Africa
AQA	Air Quality Act
AQLV	Air Quality Limit Values
AQMA	Air Quality Management Area
AQMP	Air Quality Management Plan
AQM	Air Quality Model
AURN	Automatic Urban and Rural Network
CALINE4	**Ca**lifornia **Line** Source Dispersion Model version 4
CERC	Cambridge Environment Research Center
CO_2	Carbon Dioxide
CO	Carbon Monoxide
CPCB	Central Pollution Control Board
CNEMC	China National Environmental Monitoring Center
CAA	Clean Air Act
CAI	Clean Air Initiative
CBL	Convective Boundary Layer
CMAQ	Community Multi-scale Air Quality
CNG	Compressed Natural Gas
COPERT	Computer Programme to Calculate Emission from Road Transport
d	Index of Agreement
DEAT	Department of Environment Affairs and Tourism
DEFRA	Department of Environment, Food and Rural Affairs
DFLSM	Delhi Finite Line Source Model
e-UAQMP	Episodic Urban Air Quality Management Plan
EEA	European Environment Agency
EU	European Union
FB	Fractional bias
FRAME	Fine Resolution Atmospheric Multi-Pollutant Exchange
GFLSM	General Finite Line Source Model
HGV	Heavy Goods Vehicle
ITO	Income Tax Office
I/M	Inspection and Maintenance
ITS	Intelligent Transport System
ISCST3	**I**ndustrial **S**ource **C**omplex for **S**hort **T**erm version **3**
KEI	Korea Environmental institutes
KS	Kolmogorov-Smirnov test
LGV	Light Goods Vehicle
LAQMP	Local Air Quality Management Plan
LCN+	London Cycle Network Plus

MG	Geometric Mean
MORTH	Ministry of Road Transport and Highways
MOVES	Motor Vehicle Emission Simulator
MPI	Multi Pollutant Index
NAMS	National Air Quality Monitoring Station
NAQS	National Air Quality Standards
NAAQS	National Ambient Air Quality Standards
NAEI	National Atmospheric Emission Inventory
NMB	Normal Mean Bias
NMIM	National Mobile Inventory Model
NMSE	Normal Mean Square Error
NRC	National Research Council
NAA	Non-Attainment Area
NAME	Numerical Atmospheric Modelling Environment
NO_X	Oxide of Nitrogen
OAQPS	Office of Air Quality Planning and Standards
O_3	Ozone
PBL	Planetary Boundary Layer
pdf	Probability density function
PM	Particulate Matter
$PM_{2.5}$	Particulate Matter (Dia. Size <2.5 micron)
PAMS	Photochemical Assessment Monitoring Station
SBL	Stable Boundary Layer
SP	Sardar Patel
SPMS	Special Purpose Monitoring Station
SCOOT	Split Cycle Offset Optimization Technique
SLAMS	State and Local Air Monitoring Station
SIP	State Implementation Plan
SEI	Stockholm Environment institute
SO_2	Sulphur Dioxide
SPM	Suspended Particulate Matter
TNPCB	Tamil Nadu Pollution Control Board
TSP	Total Suspended Particle
TRL	Transport Research Laboratory
UAP	Urban Air Pollution
UAQMP	Urban Air Quality Management Plan
UAQMS	Urban Air Quality Management System
ULAQM	Urban Local Air Quality Management
VG	Geometric Variance
VOC	Volatile Organic Compound
WHO	World Health Organization
WHO-AQG	World Health Organization-Air Quality Guidelines
$\bar{\mathbf{O}}$	Mean of observed concentration
$\bar{\boldsymbol{p}}$	Mean of predicted concentration
$\boldsymbol{\sigma_o}$	Standard deviation of observed concentration
$\boldsymbol{\sigma_p}$	Standard deviation of predicted concentration