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HUMAN EXPOSURE TO STREET LEVEL AIR POLLUTANTS IN COLOMBO AND EXPLORATION OF MITIGATION OPTIONS USING CFD MODELING

Being a dissertation submitted in partial fulfillment of the requirements of
The Degree of Master of Philosophy

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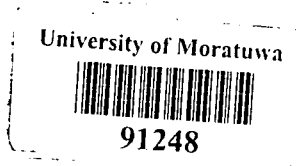
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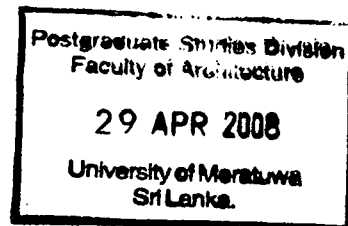
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DEDICATION

*This dissertation is dedicated to my beloved husband Sumal and
my child Sithika*



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DECLARATION

I hereby declare this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material, which to substantial extent, has been accepted for the award of any other academic qualification of a University or any other Institute of higher learning except where acknowledgement is made in the text.

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ABBREVIATIONS

AAS	Atomic Absorption spectrometry
AEA	Atomic Energy Authority
AirMAC	Air Resource Management Centre
Al	Aluminum
ATS-DLD	American Thoracic Society, Division of Lung Diseases WHO
Br	Bromine
C	Carbon
Ca	Calcium
CAI-Asia	Clean Air Initiatives for Asia
Cd	Cadmium
CEA	Central Environmental Authority
CFC	Chlorofluorocarbons
CH ₄	Methane
CI	Confident Interval
CISIR	Ceylon Institute for Scientific and Industrial Research
Cl	Chlorine
CMA	Colombo Metropolitan Area
CMR	Colombo Metropolitan Region
CO	Carbon monoxide
CO ₂	Carbon dioxide
COI	Cost of Illness
Cr	Chromium
CTMs	Chemical/Transport Models
Cu	Copper
df	degree of freedom
ENVI-met	Environmental Meteorology
EPA	Environmental Protection Agency
ESP	Environment Systems Products
Fe	Iron
GIS	Geographic Information System
H ₂ O ₂	Hydrogen Peroxide



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HC	Hydro Carbon
HCFC	Hydrochlorofluorocarbons
HEI	Health Effects Institute
HFC	Hydrofluorocarbons
HM	Heavy Metals
HNO ₃	Nitric acid
I/M	Inspection and Maintenance
IR	Infrared
ISB	Industrial Service Bureau
ITI	Industrial Technology Institute
K	Potassium
Mn	Manganese
MS	Mean square
MTBE	Methyl Tertiary Butyl Ether
N ₂ O	Nitrous Oxide
Na	Sodium
NBRO	National Building Research Organization
NEA	National Environmental Act
NEDA	(1-Naphthyl)-ethylenediamine dihydrochloride
Ni	Nickel
NMHC	Non-Methane Hydrocarbons
NO	Nitrogen monoxide
NO ₂	Nitrogen dioxide
NO _x	Oxides of Nitrogen
O ₃	Ozone
OH	Hydroxyl
OR	Odd Ratio
Pb	Lead
PM	Particulate Matter
PM ₁₀	Particulate matter less than 10 microns (μm) in diameter)
PM _{2.5}	Particulate matter less than 2.5 microns (μm) in diameter- fine
PMV	Predicted Mean Vote
POPs	Persistent Organic Pollutants
ppb	parts per billion



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RPM	Respirable Particulate Matter
S	Sulfur
Si	Silica
SLAQI	Sri Lanka Air Quality Index
SO ₂	Sulfur Dioxide
SS	Sum of squares
Ti	Titanium
TSP	Total Suspended Particulates
UNEP	United Nations Environmental Programme
UOM	University of Moratuwa
USEPA	United States Environmental Protection Agency
VET	Vehicle Emission Testing
WHO	World Health Organization
XRF	X-Ray Fluorescence
Zn	Zinc



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ABSTRACT

Human exposure to street level air pollutants in Colombo and exploration of mitigation options using CFD modeling was studied. To fulfill the requirement, present study was designed to gather baseline air pollution data, health risk assessment data and computer modeling was subsequently applied to a selected urban area and urban school to minimize the air pollution. For the purpose of estimating the air quality effects of land use and planning variables, a free-ware model named ENVI-met was used. ENVI-met is a numerical, 4 dimensional (three spatial plus the time dimension) microclimate free ware model which can simulate the microclimate within street canyons through the solution of the physical basic equations for the wind current, the thermodynamics and the radiation balance of surfaces. In order to estimate the effect of land use and urban planning variables, several ENVI-met simulations were run: change of street vegetation, change of soil conditions and building geometry. Measured Respirable Particulate Matter (RPM) values were used to calibrate the simulation cases. It was found that the high risk urban location had RPM of $437\mu\text{g}/\text{m}^3$ whereas low risk village had $212\mu\text{g}/\text{m}^3$. Total Suspended particulate mater (TSP) levels during peak hours (7.30am-8.30am and 2.00pm-3.00pm) exceeded the Sri Lankan standard ($>538\mu\text{g}/\text{m}^3$ against $500\mu\text{g}/\text{m}^3$). The data also revealed that apart from the number of vehicles, meteorological factors such as high temperature and low relative humidity increased the Respirable Particulate Matter. A significant different in aerosol exposure levels was resulted in urban and rural dwellers for SO_2 and NO_2 . Similarly exposure levels of urban & rural school children were resulted for SO_2 and NO_2 . Simulations carried out at the urban area and school area clearly showed that the increasing greenery and banning of vehicles from busy sub roads with paving resulted the decreasing of particulate matter

concentration. On the other hand, high rising buildings resulted the increase of particulate matter concentration heavily in the urban area and urban school respectively. Compared to the Base Case, results have shown that marked decrease of PM concentration has occurred by the suggested Best Case and for the Worst Case considerable increase of PM₁₀ concentration in the urban area and urban school respectively. Best city design with minimum air pollution can be modeled using the ENVI-met computer modeling software with minimum cost. Therefore possibility of using this model in planning stage of new cities as well as redesigning of cities is highlighted.



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