MODELLING OF VEHICULAR EXHAUST EMISSIONS FOR ASSESSING THE AIR QUALITY NEAR URBAN ROADS USING ARTIFICIAL NEURAL NETWORK

by

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Submitted
in fulfillment of the requirements of the degree of Doctor of Philosophy
to the

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Dedicated
to
My Parents

WORK IS WORSHIP

Basavanna, 12^{TH} Century

कर्मण्येवाधिकारस्ते मा फलेषु कदाचन ।
मा कर्मफलहेतुर्भु र्मा ते संगोऽस्त्वकर्मणि ।।

karmany eyvādhikāras te
mā phalesu kadācana
mā karma - phala-hetur bhur
mā te sango 'stv akarmani

You have a right to perform your prescribed duty,
but you are not entitled to the fruits of action.
Never consider yourself the cause of the result of your activities,
and never be attached to not doing your duty.

BHAGAVAD-GITĀ (II-47)

CERTIFICATE

This is to certify that the thesis entitled **"Modelling of Vehicular Exhaust Emissions for Assessing the Air Quality near Urban Roads using Artificial Neural Network"** being submitted by **Mr. Shiva Nagendra, S. M.**, 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.

31/12/02

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ABSTRACT

Movement of traffic on the urban roads along with other roughness elements surrounding an air quality control region (AQCR)*, add more complexities in vehicular exhaust dispersion modelling studies. The conventional modelling approach using deterministic Gaussian based models may not able to explain variations in meteorological and traffic parameters, and so affecting their prediction efficiency. Stochastic approach of vehicular exhaust emission (VEE) modelling may have some advantages in explaining non-linearity (randomness) in data i.e. extraction of predictable movements, trends and serial correlations present in the observed data. However, the variations in air quality data are so complex and non-linear in nature that it requires prior assumptions concerning their distribution. Artificial neural networks (ANNs) appear to be useful alternatives to deterministic and stochastic techniques to explain these gaps.

ANN is capable of capturing highly non-linear phenomena than commonly used deterministic and stochastic modelling approaches. The study addresses the development of 1- and 8-hour average ANN based carbon monoxide (CO) and 24-hour average ANN based nitrogen dioxide (NO_2) models using back-propagation training algorithm. These models have been formulated with ten meteorological and six traffic characteristic variables. The performance of 1-, 8- and 24-hour average ANN based VEE models have been evaluated on unseen test data. Degree of agreement (d) and other descriptive statistics have been used for model performance evaluation at two AQCRs. The forecast

* It may be defined as fixed boundaries / areas where local authorities have been entrusted with the responsibility for assessing and reviewing the local air quality in conformity with the national ambient air quality standards (NAAQS).

performance of 1-hour average ANN based CO models with meteorological and traffic characteristic variables, as inputs, has been found to be satisfactory, explaining 78 % (d=0.78) predictions as error free at AQCR1 and 67 % (d=0.67) at AQCR2. The models with regular meteorological inputs only, indicate significant decrease in their performance at AQCR1. The forecast performance of 8-hour average ANN based CO models (with meteorological and traffic and only meteorological inputs, respectively) and 24-hour average NO_2 models, have also been found to be satisfactory. The ANN based VEE models could also identify and explain the complex dispersion phenomena generated as a result of 'traffic wake' (Rao et al., 1979, Sedefian et al., 1981) in the near-field region of the roadways (< 3 m from the line source). The results show poor performance of ANN based CO models, when only meteorological data have been used as input to the model, without considering any traffic data.

ANN based persistence factors (ANNPFs) have also been developed to forecast maximum 8-hour average CO concentration from predicted worst-case 1-hour average CO concentration data. The ANNPFs derived for 2 PM to 10 PM show best performance, having 'd' value of 0.71 at AQCR1 and 0.68 at AQCR2 for the critical period data (21^{st} to 31^{st} December, 1999). The results are comparable with U.S. Environmental Protection Agency findings (EPA, 1978).

The comparative evaluation of 1-hour average ANN based CO models with univariate stochastic and deterministic model predictions show poor performance of deterministic (d =0.43 for AQCR1 and d= 0.41 for AQCR2) and univariate stochastic (d =0.49 for AQCR1 and d= 0.43 for AQCR2) models. It indicates their inability to take into account the 'lag effect' during inversion conditions (Khare and Sharma, 1999). On the contrary, the ANN based VEE models could successfully take into account the complex phenomena of 'lag effect' during after hours (after 10 PM) when meteorological conditions are stable and traffic is 'trickle'. With the result, it could explain 67 % of CO prediction as error free at AQCR1 (d= 0.67) and 69 % at AQCR2 (d= 0.69). It demonstrates that ANN based VEE models are viable when compared to deterministic and statistical modelling approach.

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