UNIVERSITI PUTRA MALAYSIA

MODEL DEVELOPMENT AND INTEGRATED ANALYSIS OF THE IMPACT OF TRAFFIC EMISSIONS ON AIR QUALITY IN URBAN AREAS IN JAKARTA, INDONESIA

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By

DOLLARIS RIAUATY SUHADI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirement for the Degree of Doctor Philosophy

June 2007

DEDICATION

TO MY BELOVED HUSBAND AND MY SONS

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

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Chairman: **Professor Muhamad Awang, PhD**

Faculty: **Environmental Studies**

This research aims to assess air quality status in the urban area of Jakarta and evaluate the effect of traffic emissions control of selected air pollutants by employing a Gaussian-plume dispersion model developed in Delphi. Sources of air pollutants were divided into point, line, and area sources representing three contributing sectors, i.e. industry, transport, and household. Input data for the model was obtained from the government statistics and industrial and traffic surveys conducted in other previous studies. Improvement of the model run-time was done by developing a parallel implementation coded in a data-parallel approach. The dispersion model performed reasonably in estimating the concentrations of SO_2 and NO_x. Testing of the model resulted in the relative standard errors of estimates of below 50% indicating the model could be reproducible. However, the simulation of PM_{10} concentration resulted in underestimation. The cause for this was the exclusion of other significant sources of PM_{10} beside three contributing source categories under study.

Prediction of future emissions using the 2002 emission data and socio-economic factors which affect air quality revealed that the emissions of SO_2, NO_x, and PM_{10} would increase by a factor of 1.64, 1.48, and 1.64, respectively in 2010 if control of the pollutants emissions was not taken. Similarly, simulation of future air quality under business-as-usual scenario resulted in increased pollutant concentrations. The number of grids exceeding the annual NO_x ambient standard in 2010 was twice the number of grids exceeding the standard in 2002. Under the scenario with control measures, the concentrations of pollutants, particularly the transport-contributed PM_{10} were reduced by 44%. The reduction of PM_{10} concentration was a result of simulated implementation of vehicle inspection and maintenance. Updating the emissions inventory to include other pollutant contributing sources, and continued improvement of the dispersion model to fit the best conditions of the urban area are suggested.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PEMBANGUNAN MODEL DAN ANALISIS INTEGRASI TERHADAP KESAN SISA PELEPASAN KENDARAAN KEATAS KUALITI UDARA DI KAWASAN BANDAR JAKARTA DI INDONESIA

Oleh

DOLLARIS RIAUATY SUHADI

Juni 2007

Pengerusi: **Profesor Muhamad Awang, PhD**

Fakulti: **Pengajian Alam Sekitar**

Kajian ini bertujuan untuk menilai tahap kualiti udara di sekitar bandaraya Jakarta serta penilaian implikasi kawalan pelepasan pencemar udara trafik dengan penggunaan model dispersi Gaussian yang dibangunkan oleh Delphi. Sumber bahan pencemar udara telah di bahagikan kepada sumber titik, garisan dan kawasan mewakili tiga sektor penyumbang iaitu, industri, pengangkutan dan rumah kediaman. Data yang digunakan untuk model ini diperolehi dari statistic kerajaan dan kajiselidik industri dan trafik beberapa kajian sebelum ini. Peningkatan waktu simulasi model telah dilakukan dengan pembinaan kod implementasi sejajar dalam pendekatan data sejajar. Pencapaian model dispersi untuk menganggar kepekatan SO_2 dan NO_x adalah memuaskan. Hasil ujian ke atas model ini pula menghasilkan sisihan lazim di bawah 50% dan ini menunjukkan model ini boleh diterima. Walau bagaimanapun, simulasi kepekatan PM_{10} menghasilkan keputusan kurang dari jangkaan. Ia adalah

berpunca dari terkeluarnya sumber penyumbang PM_{10} yang lain selain dari tiga kategori sumber pencemar yang dikaji.

Ramalan pelepasan pencemar masa hadapan dengan menggunakan data pelepasan dan faktor sosio-ekonomi yang mendatangkan kesan pada kualiti udara mendapati bahawa pelepasan SO2, NO_x dan PM_{10} meningkat masing-masing pada faktor 1.64, 1.48, dan 1.64 pada tahun 2010 sekiranya tidak ada kawalan pada pelepasan pencemar ini. Pada keadaan yang sama, simulasi kualiti udara masa hadapan pada senario 'perniagaan seperti biasa' masih menunjukkan peningkatan kepekatan pencemar. Bilangan grid melampaui standard ambien NO_x tahunan pada tahun 2010 iaitu dua kali ganda bilangan grid melampaui standard tahun 2002. Di bawah senario dimana adanya langkah-langkah kawalan, kepekatan pencemar, terutamanya pelepasan PM_{10} berpunca dari pengangkutan, menurun sebanyak 44 %. Penurunan kepekatan PM_{10} adalah hasil dari implementasi pemeriksaan dan penjagaan kenderaan. Adalah dicadangkan untuk masa-masa hadapan, inventori pelepasan pencemar perlulah merangkumi sumber-sumber penyumbang pencemar yang lain disamping pembaikan beterusan pada model dispersi bersesuaian dengan keadaan yang terbaik di kawasan bandaraya.

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I certify that an Examination Committee has met on 25 June 2007 to conduct the final examination of Dollaris Riauaty Suhadi on her Doctor of Philosophy thesis entitled "Model Development and Integrated Analysis on The Impact of Traffic Emission on Air Quality in Urban Areas in Jakarta, Indonesia " in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that candidate be awarded Doctor of Philosophy.

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This thesis submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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Date: 13 September 2007

DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institution.

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DOLLARIS RIAUATY SUHADI

Date: 13 September 2007

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LIST OF ABBREVIATIONS

ADO	Automotive Diesel Oil
BAPEDAL	Badan Pengendalian Dampak Lingkungan
BAU	business-as-usual
Bodetabek	Bogor Depok Tangerang Bekasi
CEA	Cost-effectiveness Analysis
CNG	Compressed Natural Gas
CO	carbon monoxide
CO_2	carbon dioxide
CORINAIR	Coordination Information on the Environment in the European Community – Air)
EMEP	European Monitoring and Evaluation Program
GDP	Gross Domestic Product
GIS	Geographic Information System
g	gram
g/lit	gram per liter
GRDP	Gross Regional Domestic Product
HC	hydrocarbons
HSD	High Speed Diesel
IDO	Industrial Diesel Oil
IPCC	Intergovernmental Panel on Climate Change
IPPS	Industrial Pollution Projection System
Jabodetabek	Jakarta Bogor Depok Tangerang Bekasi
JICA	Japan International Cooperation Agency

JMDPR	Jabotabek Metropolitan Development Plan Review
kg	kilogram
kL	kiloliter
LPG	Liquified Petroleum Gas
LPS	Large Point Source
m^3	cubic meter
min	minute
MFO	Marine Fuel Oil
MoMR	Ministry of Mining & Natural Resources
MTBE	methyl tetra buthyl ether
NMSE	Normalized Mean Square Errors
NO_x	nitrogen oxides
PM_{10}	particulate matter with diameter up to 10 microns
SEE	Standard Errors of Estimates
SO_2	sulphur dioxide
toe	ton oil equivalent
TSP	Total Suspended Particulates
U.S.EPA	United States of Environmental Protection Agency
μg	microgram
UTM	Universal Transverse Mercator
VKT	Vehicle Kilometer Traveled
VOC	Volatile Organic Carbon
WHO	World Health Organization

CHAPTER 1

INTRODUCTION

1.1 Framing the Problem

Road transport is a significant source of air pollution in urban centers (Johansson, 1995; Chin, 1996). The impact of its exhaust emissions on human health and the environment has raised much concern worldwide. Road transport, like any other modes of transport has been partly responsible for greater atmospheric impacts such as acid deposition, stratospheric ozone depletion, and climate change (Colville *et al*, 2001). To date, urban traffic air pollution continues to be the focus of many air quality reviews and studies despite the growing interest shown in global air pollution issues over the last decade.

For many years efforts to reduce traffic air pollution have been made through various control measures including the introduction of vehicle technology, improvement of transport system and fuel quality. As a result, traffic emissions have been reduced substantially and some countries, mostly developed countries, reported that their nation's urban air quality has been improved (U.S.EPA, 2002; European Environment Agency, 2005). In developing countries, however, with accelerating urban growth likely to cause great increase in car ownership and use, efforts to reduce traffic emissions remain to be seen. The challenge for the authority will be whether to act upon control measures now to prevent air quality from getting more severe in the future or to delay the implementation further until the damage costs in health, productivity, and economy become enormous.

Many developing countries have developed their own air quality policy and strategy based on their needs for improved air quality and relative findings of the status of air quality and level of emissions. In many cases, the common strategy is often derived from other countries' experience, which has been proved to be successful. While it is not necessary for a developing country to start from "the scratch" in finding what control options work best for the country, the adoption should be done in a careful manner because a control measure is country-specific. It may work in a certain country but may not work in other country or may require modification to make it workable.

Indonesia, for example, first embarked its air pollution agenda in 1992 with the issuance of "Blue Sky" program aimed at reducing air pollution in target provinces. Air quality-related regulations have been revised or newly issued since then, including the revision of the national ambient standard and the establishment and continued improvement of emissions standards for both mobile and stationary sources. Control measures for traffic-related emissions as stated in the program provisions, which are also in line with recommendations from previous foreign-funded studies include emission regulations through inspection and maintenance, phase-out of leaded gasoline, reduction of sulfur content in diesel fuel, introduction of clean vehicle technology and use of smokeless oil for two-stroke vehicles (Shah *et al*, 1997; Japan International Cooperation Agency – JICA and Environmental Impact Control Agency – BAPEDAL, 1997a).

Despite the availability of regulatory instruments and proposed action plans for Indonesia, implementation has not begun until today. Lacks of public and political wills are the major factor, which contributes to the implementation failure of many

regulations. Provisions with regard to institutional resources, technical procedures, and detailed administration of the regulations are not clearly defined. Unclear lines of authority and responsibility of government agencies have often attributed to the delay of the formulation of these implementing provisions (D. Kuper, personal communication, October 2, 1996). Other shortcomings, in general, include lack of control and law enforcement and shortage of well-trained personnel (Shah *et al*, 1997).

The newly enacted Regional Autonomy Law No. 22/1999 that stipulates in its provisions an extended transfer of environmental policy resources and regulatory authority from the central government to local governments is significant for the interest of air pollution control efforts. Some areas of many environmental problems will be addressed by local governments. Such transfer would pose a potentially formidable test for both the local government and the public as they become much closer to the real problem and are more challenged to tackle the problem. Public participation is central that will help the local government to move forward to formulate and execute its action plans without further delay (Shah, 2004).

The Provincial Government of Jakarta, in this regard, has taken initiative and advanced into setting up a coordinating body that will oversee the implementation of emission regulations in the Province of Jakarta. The approach is directed towards achieving air quality objectives (air quality standards) and economic objectives (reduction of damage costs) by implementing cost-effective air pollution control measures in line with the national pollution control strategy. Road transport is being the target source of control. Through active role of advocacy groups and other interest groups in Jakarta, air