ESTIMATION AND DISTRIBUTION OF EXHAUST SHIP EMISSION FROM MARINE TRAFFIC IN THE STRAITS OF MALACCA AND SINGAPORE USING AUTOMATIC IDENTIFICATION SYSTEM (AIS) DATA

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Special dedication to my beloved family

Mama, Papa, Rian, Dedi, and Dea…..

Thanks for your valuable sacrifice

Love you all…

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ABSTRACT

Global warming and air pollution have become one of the important issues to the entire world community. Exhaust emissions from ships has been contributing to the health problems and environmental damage. This study focuses on the Strait of Malacca area because it is one of the world's most congested straits used for international shipping where located on the border among three countries of Indonesia, Malaysia and Singapore. The study seeks to estimate of the exhaust emission and to know the concentration of emission to several areas around. This is accomplished by evaluating the density of shipping lanes in the Straits of Malacca by using the data which obtained by Automatic Identification System (AIS). To show the movement patterns of ships, operational mode and influence of the ship movement to the distribution of emissions are integrating of AIS data and GIS software. MEET methodology is used to estimate emissions from ships and Gaussian Puff Model used to estimates the concentration in several areas around the Strait. The results show 813 total number of ships through the Strait of Malacca on 2 September 2011 at 07.00 am-08.00 am produces exhaust emission for NOx, CO, CO2, VOC, PM and SOx are about 13715.51 g/second, 25461.525 g/second, 11092.99 g/second, 5858.216 g/second, 415.304 g/second and 6921.746 g/second, respectively. The ships under the Singapore flag contribute approximately 22.72% of total emissions in the Strait of Malacca followed by Panama and Liberia flag approximately 21.32%, 12.89%, respectively. Ships under Malaysia and Indonesia rank of sixth and seventh respectively of the emission rates. The most high-risk areas which affected by the emissions are Sentosa Island (Singapore), Port of Pasir Gudang (Malaysia) and Jurong Island (Singapore) with approximately contaminated about 47.33%, 21.68% and 17.69%, respectively of total emission and other areas around the Strait represent below 1%.

ABSTRAK

Masalah pemanasan global dan pencemaran udara telah menjadi salah satu daripada isu-isu yang penting kepada masyarakat seluruh dunia. Pelepasan ekzos dari kapal telah menyumbang kepada masalah kesihatan dan kerosakan alam sekitar. Kajian ini difokuskan kepada kawasan Selat Melaka kerana ia adalah salah satu selat di dunia yang paling sesak digunakan untuk pelayaran antarabangsa di mana terletak di sempadan tiga negara antara Indonesia, Malaysia dan Singapura. Kajian ini bertujuan untuk menghitung keluaran emisi dan untuk mengetahui kepekatan keluaran emisi seperti SOx, Nox, CO, CO2 dan PM kepada beberapa kawasan sekitarnya. Ini dapat dicapai dengan menilai trafik laluan kapal di Selat Melaka dengan menggunakan data yang diperolehi dari Automatic Identification System (AIS). Untuk menunjukkan corak pergerakan kapal, mod operasi kapal dan pengaruh pergerakan kapal kepada taburan emisi dengan mengintegrasikan data AIS dan perisian GIS. Kaedah MEET Methodology digunakan untuk menghitung keluaran emisi daripada kapal dan Gaussian Puff Model digunakan untuk menghitung kepekatan emisi di beberapa kawasan di sekitar Selat. Hasilnya menunjukkan 813 jumlah kapal yang berlayar di Selat Melaka pada 2 September 2011 pada 07:00-08.00 dan menghasilkan keluaran emisi NOx, CO, CO2, VOC, PM dan SOx kira-kira 13715.51 g/second, 25461.525 g/second, 11092.99 g/second, 5858.216 g/second, 415.304 g/second and 6921.746 g/second. Kapal-kapal di bawah bendera Singapura mewakili hampir 22.72% daripada jumlah pelepasan diikuti oleh kapal-kapal di bawah bendera Panama dan Liberia dengan jumlah masing-masing 21.32%, 12.89%. Kapal di bawah Malaysia dan Indonesia menduduki tempat keenam dan ketujuh dari kadar pelepasan. Pulau Sentosa (Singapura), pelabuhan Pasir Gudang (Malaysia) dan Pulau Jurong (Singapore) adalah kawasan tertinggi terjejas oleh pelepasan dengan kira-kira 47.33%, 21.68%, 17.69% dari jumlah kepekatan emis daripada trafik kapal dan kawasan lain di sekitar Selat terjejas dibawah 1%.

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LIST OF ABBREVIATION

AIS	-	Automatic Identification System
IMO	-	International Maritime Organization
SOLAS	-	Safety of Life at Sea
CO	-	Carbon Monoxides
CO_2	-	Carbon Dioxides
g	-	Gram
g/s	-	gram per second
H_2S	-	Hydrogen Sulphide
HNO_3	-	Nitric Acid
km	-	Kilometer
km^2	-	Kilometre square
m	-	Meter
m/s	-	Meter per second
NO	-	Nitric oxide
N_2O_2	-	Dinitrogen dioxide
N_2O_3	-	Dinitrogen trioxide
NO_2	-	Nitrogen Dioxides
NOx	-	Nitric Oxides
N_2O	-	nitrous oxide
N_2O_4	-	Dinitrogen tetroxide
N_2O_5	-	dinitrogen pentoxide
O_2	-	Oxygen
O_3	-	Ozone

PM	-	Particulate matter
SO_2	-	Sulphur Dioxides
SO3	-	Sulphur Trioxides
SOx	-	Sulphur Oxides
VOC	-	volatile organic compunds
WHO	-	World Health Organization
$\mu g/m^3$	-	microgram per meter cube

LIST OF SYMBOL

%	-	Percent
Cr	-	Concentration of emission
Q	-	Emission rate
Δh	-	Effective stack height
Δt	-	Length of time of the release itself
σy	-	Horizontal standard deviation
σz	-	Vertical standard deviation
α	-	Wind direction
Ei	-	total emissions of pollutant *i*
f	-	Auxiliary engine fuel consumption
Fijlm	-	Average emission factors of pollutant *i* from fuel *j* in engines type *l* in mode *m*
i	-	Pollutant
j	-	Fuel
k	-	Ship class
L	-	Load factor
P	-	Auxiliary engine rated output
s	-	Reference reduction scenario
Sjkm (GT)	-	daily consumption of fuel *j* in ship class k as a function of gross tonnage
tjklm	-	days in navigation of ships of class *k* with engines type *l* using fuel *j* in mode operational *m*
U	-	Wind speed
xr, yr, zr	-	Cartesian coordinates downwind of the puff

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Global warming and air pollution have become one of the important issues to the entire world community. About 80% of the international trade and movement of goods carried by ship through the sea (UNCTAD, 2010) cause exhaust emission from marine traffic which contribute to the global warming and air pollution problems. Exhaust emission from ship consisted of sulfur oxides (SOx), Nitrogen oxides (NOx), Green House Gas (GHG) or CO2, Particulate Matter (PM), hydrocarbons (HC) and carbon monoxide (CO) have been contributing to the health problems and environmental damage. For instance, Corbett et al (2007) estimated 64.000 cardiopulmonary, lung cancer mortalities and 92% premature death as globally caused by Particulate Matter (PM) from ship traffic. This emission effect arises especially in inland seas, territorial waters, canals, port region, and Straits area.

The Straits of Malacca and Singapore is one of the most important shipping channels in the world connecting the Indian Ocean with the South China Sea and the Pacific Ocean. The Straits remains as one of the world’s most congested straits used for international shipping. Approximately over 60,000 vessels pass through The Straits annually (Mihmanli, 2011) and recorder over 74,000 vessels in 2010 (Khalid, 2011), the Strait play role in producing of shipping emission and contributed to air pollution. Previous attempts, showed by Street et al (1997), shipping emission of sulfur oxide (SO2) on the Strait of Malacca almost the same in Sumatra, Indonesia (32,000 t SO2 of Strait of Malacca and 52,000 t SO2 per year of Sumatra) and approximately one-quarter of the total emissions in each of Singapore and Malaysia (Arndt et al, 1996 and Bhatti et al., 1992).

The Strait of Malacca is a narrow stretch of water lying between the east coast of Sumatra Island in Indonesia and the west coast of Peninsular Malaysia, and is linked to the Straits of Singapore at its Southeast end. Approximately 990 kilometers long and 2.7 kilometers wide, the Straits of Malacca connects The Indian and Pacific Ocean and it's recognized as one of the most economically, strategically and the busiest shipping lanes in the world.

This study focuses on the Strait of Malacca and Singapore area because it is one of the world’s most congested straits used for international shipping where located on the border among three countries of Indonesia, Malaysia and Singapore. The strait of Malacca is a narrow strait where major hub is to be found and it is one of the heavy marine traffic.

The objective of this study is to estimate the air pollution (SOx, Nox, CO, CO2 and Particulate Matter) resulting from the marine traffic in the Strait of Malacca and Singapore areas using Automatic Identification System (AIS) data. The same method, previously conducted by Jalkanen et al (2009; 2011), Perez et al (2009) and Pitana (2010). AIS is used as an initial data, it is can identify Maritime Mobil Service Identity (MMSI) of ship, ship speed, initial position and type of ship. This data is used to evaluate the traffic density of the Strait of Malacca and Singapore area. The initial data will combine with ship database to obtain gross tonnage (GT) of the ship for emission estimation consideration.

1.2 PROBLEM STATEMENT

The Strait of Malacca and Singapore is one of the world's most congested straits used for international shipping, a narrow Strait where major hub to be found and it is one of the heavy marine traffic. Consequently, that it may cause air pollution levels are high. Previous studies of ship emissions in the Malacca Strait, performed by the Street (1997), the study only measured levels of sulfur oxides (SOx) using ATMOS (Atmospheric Transport Modeling System) as dispersion model for emission. This project will try to find out how the air emission (SOx, NOx, CO, CO2 and particulate matter) from the ships in the Strait currently.

In addition, because the Straits located on the border among three countries of Indonesia, Malaysia and Singapore, so it is necessary to know how the dispersion and how big influence of its emission on border countries alongside the coast of The Strait of Malacca and Singapore.

1.3 OBJECTIVE

The objectives of this study are:

i. To estimate of exhaust gas emission that is produced by ships which is passing through The Strait of Malacca and Singapore.

ii. To estimate the distribution of its emissions from ships on hoteling, maneuvering and cruising mode operation.

iii. To determine the distribution's effect of its emission to several territories along the coast of the Straits of Malacca and Singapore by using the Gaussian Puff Model.

1.4 SCOPE OF STUDY

The scopes of this thesis are:

i. The estimation of exhaust ship emission will focuses on the Strait of Malacca and Singapore area because it is one of the world's most congested straits used for shipping.

ii. An analysis of actual vessel data will focus only data which are detected by AIS receiver installed at the Marine Technology Department, Faculty of Mechanical Engineering, UTM Skudai, Johor Bahru, Malaysia.

iii. The Estimation of exhaust ship emission will focuses on one certain day which is occurred the highest traffic in the last one year (2011/2012).

iv. Analysis of the range of the most congested shipping hour of choosing a day that occurs highest traffic in the last one year (2011/2012).

v. Analysis of emission effects of air pollution only on areas which is passed by ships which is detected by AIS receiver.

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