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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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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). 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 September 2, 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%.

Keywords : *Ship emissions, Distribution of emissions, AIS, MEET methodology, Gaussian Puff Model, programming, Straits of Malacca and Singapore*

1.0 INTRODUCTION

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. 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.

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The Straits of Malacca and Singapore are 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), the Strait play role in producing of shipping emission and contributed to air pollution.

Previous attempts, Street et al (1997) by using ATMOS (Atmospheric Transport Modeling System) showed that shipping emission of sulfur oxide (SO2) on the Strait of Malacca almost the same in Sumatra, Indonesia (32,000 t SO_2 of Strait of Malacca and 52,000 t SO_2 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).

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 objective of this study is to estimate the air pollution such as SOx, Nox, CO, CO_2 and Particulate Matter (PM) resulting from the marine traffic in the Strait of Malacca and Singapore areas using Automatic Identification System (AIS) data. The same method previously have conducted by Jalkanen et al (2009; 2011), Perez et al (2009) and Pitana (2010). AIS data are used as an initial data (raw data), it can identify Maritime Mobil Service Identity (MMSI) of ship, ship speed, initial position and type of ship. The such 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. Once emission is calculated, an emissions dispersion model of the Gaussian Puff Model is used to estimates the concentration of emission in several areas around the Strait which caused by distribution of the emissions. In addition, a programming using Microsoft Visual Studio 2010 is built to ease the calculation of emission and the distribution by the reason of using several variations of rime release on calculation of the Gaussian Puff Model.

2.0 LITERATURE REVIEW

Over the years, there were many study efforts in emission's estimations fields such as Jaswar et al (2002), Wang et al (2007), Lucialli et al (2007), Meyer et al (2007), Eyring et al (2010) and Matthias et al (2010). Wang et al (2007) estimated emissions of 172,000 ship voyages to and from North American ports in 2002 by using Ship Traffic, Energy, and Environment Model (STEEM) and also evaluated the energy use. Lucialli et al (2007) estimated NOx and PM10 emission from marine traffic in the Italian harbor of Ravenna by using Transport. Emissions and Energy Consumption Methodology (MEET Methodology). Ship's data taken by considering the number of ships in the harbor. The study also evaluated the contribution of emission to air quality by using ADMS-URBAN model, Atmospheric Dispersion Modelling System (ADMS) is a dispersion model of pollutants released into the atmosphere from industrial, domestic and traffic sources in urban areas. Meyera et al (2007) estimated the atmospheric emissions from international shipping (carbon dioxide, sulfur dioxide and nitrogen oxides) in the Belgian area of the North Sea for a one year period. Eyring et al (2009) estimated emission of exhaust gases and particles from seagoing ships as globally. They use different approach to estimate the emission such as Top-down approaches to calculate the fuel consumption, Bottom-up approaches to estimate shipping and route specific emissions based on ship movements, ship attributes and ship emission factors, Ship Traffic, Energy and Environment Model (STEEM) and geographic information system (GIS) technology is used to solves routes automatically at a global scale, following actual shipping routes. The ship's data taken by considering the number of oceangoing fleet of ships for the year 2001 from Lloyd's Maritime Information System (LMIS) (2002). Matthias et al (2010) evaluated the impact of ship emission in coastal areas of the North Sea under conditions of the year 2000. Estimation of ship emission on this study using approach on the basis of ship movement data together with average engine loads and emission factors. To simulate the atmospheric transport and transformation of air pollutants, they used A three-dimensional Eulerian chemistry transport model. The vessel database was purchased from Lloyds Marine Intelligent Unit (LMIU). It consists of a vessel characteristic database and a vessel movement database and it includes all commercial vessels equal to or greater than 100 gross tonnages (GT). The Strait of Malacca and Singapore is one of the world's most congested straits used for international shipping.

The Straits are one of the heavy marine traffic. Consequently, that it causes air pollution levels are high. Street et al (1997) estimated sulfur dioxide from international shipping in Asian waters. They estimated sulfur dioxide in sea line by using The RAINS-ASIA project methodology and estimated the emission in major ports by considering the number of ships from 12 different ports in Asia waters, assumed that the typical ship is a 70,000 dwt cargo vessel averaging 11 knots and 18 t of oil consumption per day and traveling in the port vicinity for 6 h and calculated using a method for port emissions found in the literature is a reference in CONCAWE (1993). The approach for deposition of this sulfur was calculated using the ATMOS model of atmospheric transport and deposition. The result of this study for The Straits of Malacca areas, showed that land areas most heavily affected are those bordering the Strait of Malacca, where portions of Sumatra, peninsular Malaysia, and Singapore have contributions from shipping in excess of 10% of total sulfur deposition. Emissions within the Strait of Malacca, measured from the northwestern tip of Sumatra (4S"N latitude, 93.5"E longitude) to Singapore, are estimated to be 39,400 t SO_2 per year. As compared to Arndt et al., (1996) and Bhatti et al., (1992) showed that 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.

Initially, Automatic Identification System (AIS) has been used to comply security regulations since September 11, 2001, functioning as traffic management, collision avoidance, and other safety applications. However, today, Automatic Identification System (AIS) be able used to estimate ships emissions. Jalkanen et al (2009) purposed a modeling system for maritime traffic exhaust emissions of NOx, SOx, and CO_2 in the Baltic Sea area based on data obtained from AIS receivers. The approach for estimating emission of by using ship Traffic, Energy, and Environment Model (STEEM). In the year of 2011, Jalkanen et al extends the research for ship emission of particulate matter (PM) and carbon monoxide (CO) and presented Ship Traffic Emissions Assessment Model (STEAM2) as a method for estimation of ship emissions. Perez et al (2009) uses AIS by combining with Geographic Information System (GIS) to spatially analyze the emissions of marine vessels. However, AIS doesn't provide completeness of ship information such as main engine power, auxiliary engine power, and gross tonnage. Therefore, additional of ship information is needed from ship database as Lloyd's Register. The study propose for estimated the emission of nitrogen oxides (NOx), carbon monoxide (CO), non-methane volatile organic compounds (NMVOC), sulfur dioxide (SO_2), ammonia (NH_3), particulate matter less than or equal to 10 µm (PM10), particulate matter less than or equal to 2.5 µm (PM2.5), and several significant hazardous air pollutants for Texas State waters for ship that recorded in years of 2007 by using Swedish Methodology for Environmental Data's (SMED) Methodology for calculating emission from ships. Pitana et al (2010) estimated the ship emission level of nitrogen oxides (NOx), sulfur oxides (SOx), particulate matter (PM), carbon monoxide (CO) and carbon dioxide (CO_2) in the Strait of Madura, Indonesia by using Automatic Identification System (AIS) receiver to obtain ship data. The study used a combination of GIS and AIS data to evaluate ship traffic patterns and combining AIS data with ship databases for retrieving gross tonnage (GT) information of ship which is then used to estimate the ship's emission. Emission estimates are based on the standard European (MEET) methodology, which is adopted from Trozzi et al (1998; 1999).

3.0 METHODOLOGY

The methodology of the study indicates stages of the working process of the study. The study framework started from an investigation of AIS raw data to be several databases such as information relating to ship speed and locations (longitude & latitude), MMSI number of ships, ship departure and arrival speeds, types and names of ship, etc. could be obtained. In addition, for calculation using the Gaussian Puff Model needs AIS data relating to MMSI number, receive time and positions of shipment for each proposed time release. Ship data of Gross Tonnage (GT) that could not be obtained from AIS receivers were extracted from free ship databases, such as marinetraffic.com, maritime-connector.com, equasis.org, vesseltracker.com and Equasis.org. In order to evaluate ship traffic patterns, AIS data is input into the ArcGIS software suite. Ship traffic patterns are useful when evaluating ship operational modes, such as maneuvering, hotelling and cruising which are necessary for determining their emission factors. Figure 1 shown overall framework of the study.

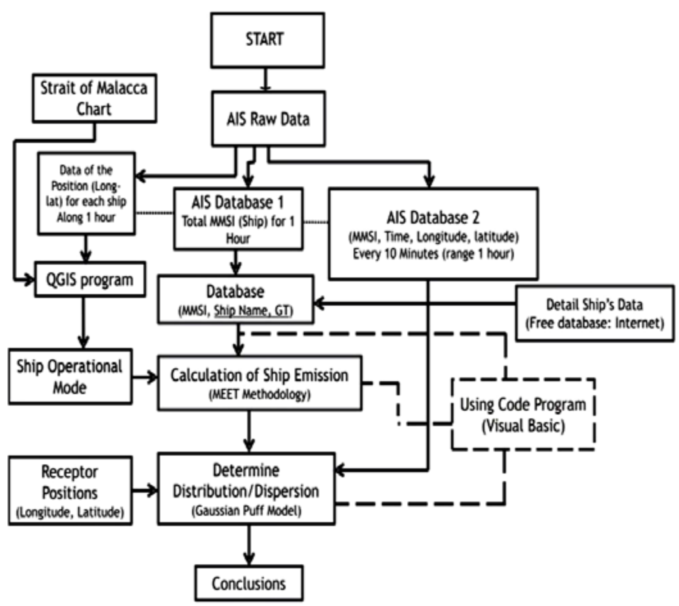

Figure 1 : Framework of the study

3.1 Overview of AIS Installation

Primary data of ships which obtained from an AIS receiver in the study are MMSI of the ship, IMO number, receive time, the position of the ship (longitude and latitude), speed of ground (SOG) and COG. These all the data obtained from an AIS receiver installed in Marine Technology Laboratory (Marine Technology Center (MTC), Faculty of Mechanical Engineering, Universiti Teknologi Malaysia (UTM) as shown in the Figure 2. The AIS data collected was simultaneously stored and updated in a hard disk on the Personal Computer (PC). Once recorded, such data could be utilized by other users using local network or the internet.

Figure 2 : AIS Installation in the UTM, Marine Technology Center

Automatic identification systems (AIS) are designed to be capable of providing information about the ship to other ships and to coastal authorities automatically for ship 300 gross tonnage and above engaged on international voyages, cargo ships of 500 gross tonnage and upwards not engaged on international voyages and all passenger ships irrespective of size (IMO, 1998). IMO Resolution MSC.74 (69) requires each ship included in the regulation shall provide information including the ship's identity, type, position, course, speed, navigational status and other safety-related information. Information update rates of AIS also includes on the IMO (1998). AIS information of every ship is needed to update at specified time frame. The different information types are valid for a different time period and thus need a different update.

i. Static information shall update at every 6 min and on request
ii. Dynamic information shall update dependent on speed and course alteration according to the Table 1
iii. Voyage related information shall update at every 6 min, when data have been amended and on request
iv. Safety-related message shall update as required

Table 1 : Information updates rates for AIS dynamic information

Type of ship	Reporting interval
Ship at anchor	3 min
Ship 0 - 14 knots	12 sec
Ship 0 – 14 knots and changing	4 sec
Ship 14 – 23 knots	6 sec
Ship 14 – 23 knots and changing	2 sec
Ship > 23 knots	3 sec
Ship > 23 knots and changing	2 sec

3.2 Analysis of AIS Data

To identify the ship traffic in the Strait of Malacca, a program of the MySQL Database Management is used to obtains required data for the purposes of emissions calculation and the distribution assessment. Trozzi et al (1998; 1999) mentioned that air pollution emissions are influenced by the traffic density, ship types and ship operational modes. From the emissions point of view, operational modes considered are the maneuvering phase, hotelling phase and cruising phase.

Figure 3 and 4 shows the traffic density data recorded on September 2011 and September 2, 2011 in term of average number of ships per day and per hour, respectively.

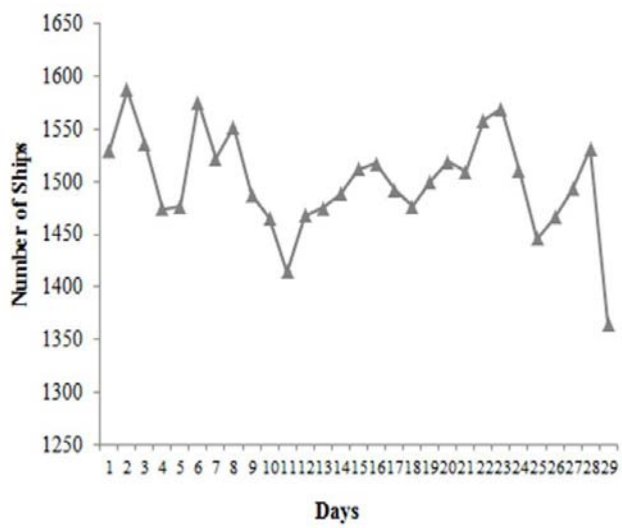

Figure 3 : Number of ships recorded on September 2011

From Figure 3 shows the total number of ships on September 2011. For instance, there were about 1530 ships and 1474 ships recorded during days on September 1 and September 6, respectively. The figure shows the lowest marine traffic density was recorded on September 29 by the total number about 1364 ships while the densest occurred on September 2 by the total number about 1587 ships during the day.

In this research, we focus on September 2, 2011 as the dentest period of marine traffic, as shown in the Figure 4. On that day, it can be seen that the busiest periods occurred around the hours of 0400, 0800 and 0900. We selected 0800 which showed the highest level of marine traffic. There were recorded about 1173 ships passing through the

Strait of Malacca during 0800 (0700-0800) on September 2. For the purposed of calculation and the distribution of emissions, only selects 813 numbers of ships from the total 1173 ships that occurred on that day. The remaining number of ships can not being used in the calculation because there were invalid data of the ships that recorded by AIS receiver. The invalid data were often occurring on MMSI number and IMO number, the invalid data cannot be used to find additional of ships data on free database. Table 2 shows the total number of ships by type during 0800 on September 2, it can be seen that there were about 360 unknown or invalid ships.

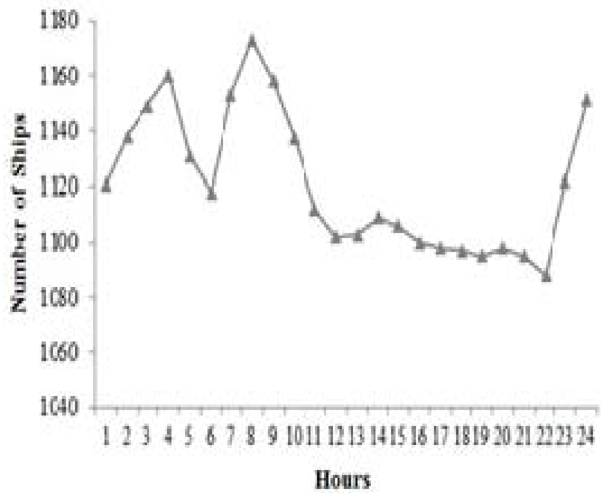

Figure 4 : Number of ships recorded on September 2, 2011

Table 2 : Total number of ships (by type)

Type	Number of Ship
Solid Bulk	49
Liquid Bulk	372
General Cargo	51
Container	124
Ro-Ro Cargo	3
Passenger	12
High speed ferries	1
Tugs	138
Fishing	1
Other	62
Unknown/invalid ships	360
Total Number of Ship	1173
Total correspondent ship	813

In addition to the marine traffic density data, it is very important to analyze the ship types as shown in the Figure 5(a) since the ship types influence emission factors (Trozzi et al. 1998; 1999). Figure 5 (a) and Table 2 shows that the majority of ships recorded at 0800 on September 2 were Solid Bulk, tug boat and container, followed by other ships, general cargo, solid bulk, passenger, ro-ro cargo, high speed ferries and fishing vessel.

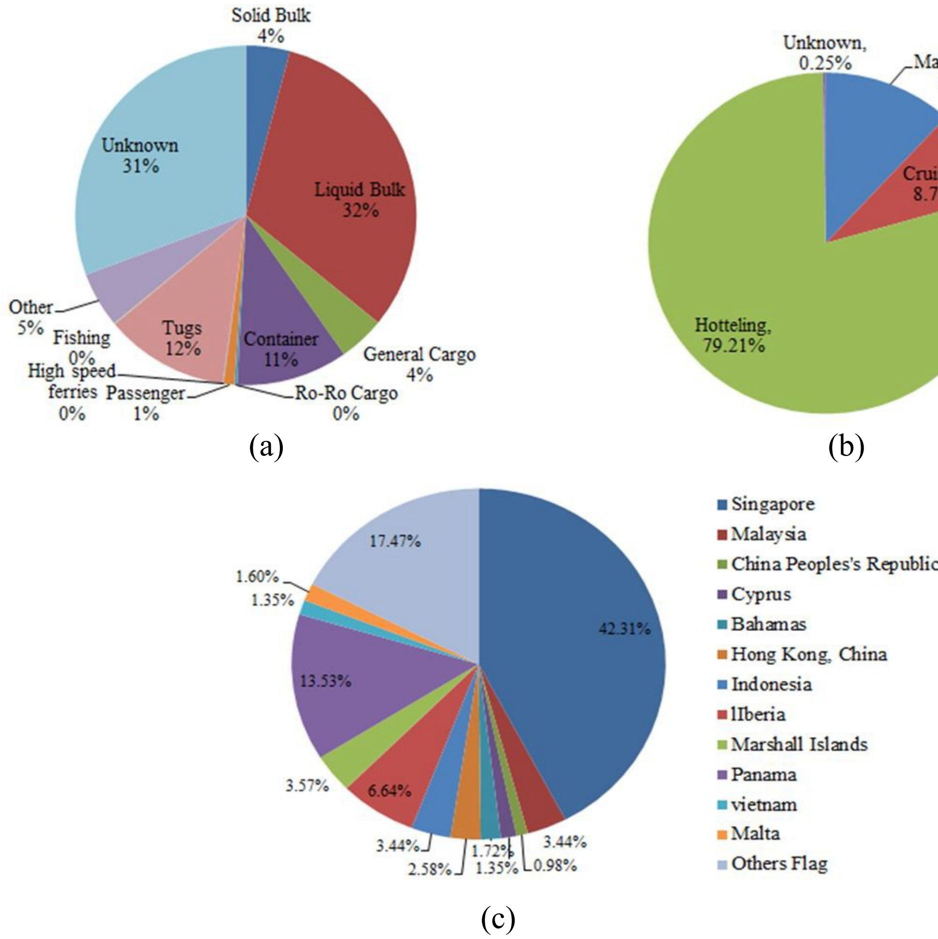

Figure 5 : Total number of ships on September 2, 2011 (a) by type (b) by mode operation (c) by flag registered.

Figure 5(b) shows the majority of ships by mode operational recorded on that day were hotelling, maneuvering and cruising. Figure 5(c) shows the majority of flag registered ship recorder at 0800 on September 2, it can be seen the highest number of ships were by flag of Singapore, others flag, Panama and Liberia, followed by the Marshall Islands, Malaysia, Indonesia, Hong Kong, China, Bahamas, Malta, Cyprus, Vietnam and China Peoples's Republic.

3.2 Emission Assessment Assumption

The calculation of emission is calculated based on the standard European (MEET) methodology which is primarily based on the work Trozzi et al (1998; 1999) and UNECE/EMEP (2002) and also used by Pitana et.al (2010). There are 12 class of ships which considered on the assessment that have gross tonnage in excess of 100 GT, using appropriate emission factors, and specific ship parameters such as engine type, time spent in port, fuel consumption and gross tonnage.

Methodologies for estimating air pollutant emissions from ships used to estimate of consumption and emissions based on present day statistics of ship traffic (Trozzi et al, 1998; 1999) and UNECE/EMEP (2002). Fuel consumption of any type of ship are obtained from a linear regression analysis of fuel consumption to gross tonnage as shown in the Table 3. Calculation of emissions rate defined as:

$$Ei = \Sigma jklm \,.\, Eijklm \quad (1)$$

with:

$$Eijklm = Sjkm(GT) \,.\, tjklm \,.\, Fijlm \quad (2)$$

Where

i : pollutant
j : fuel type
k : ship class for use in consumption classification
l : engine type class for use in emission factors characterization
s : reference reduction scenario (low, medium, high) Ei: total emissions of pollutant i
Eijklm: total emissions of pollutant i from use of fuel j on ship class k with engines type l in mode operation m
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
Fijlm: average emission factors of pollutant i from fuel j in engines type l in mode m

Table 3 : Ship class and fuel consumption factors

Ship types(code)	Consumption at full power (t/day) as function of gross tonnage
Solid Bulk (SB)	Cjk = 20.1860 + 0.00049 × GT
Liquid Bulk /Tanker (LB)	Cjk = 14.6850 + 0.00079 × GT
General Cargo (GC)	Cjk = 9.8197 + 0.00143 × GT
Container (CO)	Cjk = 8.0552 + 0.00235 × GT
Ro-Ro Cargo (PC)	Cjk = 12.8340 + 0.00156 × GT
Passenger (PA)	Cjk = 16.9040 + 0.00198 × GT
High Speed Ferry (HS)	Cjk = 39.4830 + 0.00972 × GT
Inland Cargo (IC)	Cjk = 9.8197 + 0.00143 × GT
Sail Ship (SS)	Cjk = 0.4268 + 0.00100 × GT
Tugs (TU)	Cjk = 5.6511 + 0.01048 × GT
Fishing (FI)	Cjk = 1.9387 + 0.00448 × GT
Other Ships (OT)	Cjk = 9.7126 + 0.00091 × GT

For auxiliary engine (generator) Trozzi (1998; 1999; 2010) use the following equation which got from EPA (1985). The equation has adopted by Ishida (2003) to estimate air pollution and greenhouse gases from ships. The equation is defined as:

$$f = P \times L \quad (3)$$

where

f: Auxiliary engine fuel consumption P: Auxiliary engine rated output
L: Load factor

Trozzi et al (2010) update them research towards the methodology for estimating emissions from navigation in the frame of maintenance of the EMEP/EEA air pollutant emission inventory. In the Table 4, Trozzi et al (2010) reported the results of the non-linear regression procedure applied to installed main engine power by considering several ship classes as a function of gross tonnage. In this study, the table is used to estimate the power of the main engine. Power of auxiliary engine is calculated by using the vessel ratio of Auxiliary Engines / Main Engines as shown in Table 5, once the power of the main engine is calculated from Table 4. Load factor used for estimates of auxiliary engine fuel, based on Table 6 given by trozzi et all (2010).

Table 4 : Installed main engine power as a function of gross tonnage (GT)

Ship categories	2010 World fleet	1997 World fleet	Mediterranean Sea fleet (2006)
Liquid bulk ships	$14.755*GT^{0.6082}$	$29.821*GT^{0.5552}$	$14.602*GT^{0.6278}$
Dry bulk carriers	$35.912*GT^{0.5276}$	$89.571*GT^{0.4446}$	$47.115*GT^{0.504}$
Container	$2.9165*GT^{0.8719}$	$1.3284*GT^{0.9303}$	$1.0839*GT^{0.9617}$
General Cargo	$5.56482*GT^{0.7425}$	$10.539*GT^{0.6760}$	$1.2763*GT^{0.9154}$
Ro Ro Cargo	$164.578*GT^{0.4350}$	$35.93*GT^{0.5885}$	$45.7*GT^{0.5237}$
Passenger	$9.55078*GT^{0.7570}$	$1.39129*GT^{0.9222}$	$42.966*GT^{0.6035}$
Fishing	$9.75891*GT^{0.7527}$	$10.259*GT^{0.6919}$	$24.222*GT^{0.5916}$
Other	$59.049*GT^{0.5485}$	$44.324*GT^{0.5300}$	$183.18*GT^{0.4028}$
Tugs	$54.2171*GT^{0.6420}$	$27.303*GT^{0.7014}$	

Table 5 : Estimated average vessel ratio of Auxiliary Engines / Main Engines by ship type

Ship category	2010 World fleet	Mediterranean Sea fleet (2006)
Liquid bulk ships	0.3	0.35
Dry bulk carriers	0.3	0.39
Container	0.25	0.27
General cargo	0.23	0.35
Ro Ro Cargo	0.24	0.39
Passenger	0.16	0.27
Fishing	0.39	0.47
Others	0.35	0.18
Tugs	0.1	

Table 6 : Estimated % load of MCR (Maximum Continuous Rating) of Main and Auxiliary Engine for different ship activity

Phase	% load of MCR Main	% time all Main Engine	% load of MCR
Cruise	80	10	30
Manoeuvring	20	10	50
Hotelling (except tankers)	20	5	40
Hotelling (tankers)	20	10	60

3.3 Definitions of hotelling, maneuvering and cruising

The operational mode of the ship is used to measure emission resulting from ship activities. Mode operational ships of hotelling, maneuvering and cruising are used when estimating fuel consumption and emissions (Trozzi et al, 1998; 1999; 2010) and UNECE/EMEP (2002). When the ships spend approaching, docking and departing the harbor called as maneuvering. Hotelling refers to operations taking place while ships are berthed alongside piers, while ships traveling at a constant speed are said to be cruising (Pitana et al, 2010). Mode operational of the ships is shown in Figure 6.

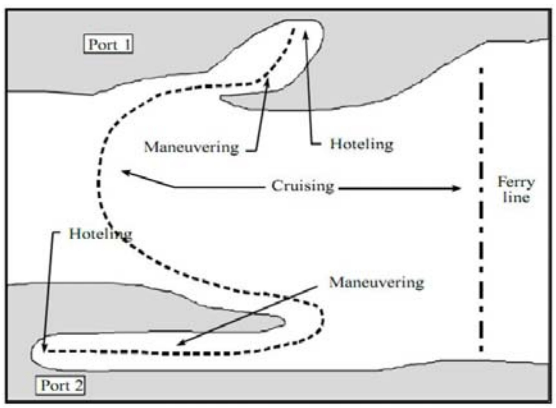

Figure 6 : Ship movement characteristics

3.4 Assumption on Assessment of Emissions Distribution

The Gaussian puff model is used to estimates the concentration of emission and its more likely to be an instantaneous release rather than a continuous emission. The way to use the Gaussian puff model gas adopted by Allen et al (2006) and Long et al (2007). The Gaussian puff model is defined as:

$$Cr = \frac{Q.t/t}{(2\pi)1.5\ \sigma X \sigma y \sigma z}.exp\left(\frac{-(xr-Ut)^2}{2\sigma X^2}\right).exp\left(\frac{-(Zr-He)^2}{2\sigma z^2}.exp\left(\frac{-Yr^2}{2\sigma y^2}\right)exp\left(\frac{Zr-He)^2}{2\sigma z^2}\right)r + exp\left(\frac{-(Zr+He)^2}{2\sigma x^2}\right)\right) \quad (4)$$

where:

Cr : the concentration at receptor
(xr, yr, zr) : the Cartesian coordinates downwind of the puff
Q : the emission rate
Ut : the wind speed
Δt : the length of time of the release itself,
σx, σy, σz : the standard deviations of the concentration distribution in the x-, y-, and z-directions, respectively

The Gaussian model is an analytical solution to the 3D advection-dispersion equation with the following assumptions [Altwicker 2000]:

i. Wind speed is constant,
ii. The system is at steady state,
iii. Diffusion in the x-direction is ignored and the other diffusion coefficients are anisotropic,
iv. The plume can be reflected from the ground when an image source is added and mass is conserved
v. Contaminant is conservative,
vi. Gas is assumed to be ideal and inert.

Pingjian et al (2006) use Gaussian model and do the transfer coordinate to get the real value of x asshown in Figure 7. The wind direction is x in Gaussian puff equations (equation 4). The transfer coordinates equation defined as:

$$x = x0 * (\cos\theta/\cos\beta) \quad (5)$$

$$y = y0 * (\sin\theta/\sin\beta) \quad (6)$$

$$\alpha = \beta + \theta \quad (7)$$

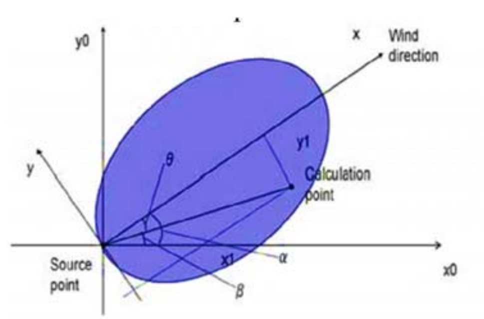

Figure 7 : Transfer coordinates (Pingjian et al, 2006)

In the equation of the Gaussian puff model (equation 4), standard deviation σx, σy, σz depend on the downwind distance and the atmospheric stability class. The uncertainty of the vertical dispersion coefficient, σz, was varied with downwind distance and stability class in a manner consistent with the fundamental form of the Pasquill-Gifford functions (Turner 1970). These coefficients in meters can be obtained from the equations utilized by the Industrial Source Complex (ISC). Dispersion Model developed by USEPA (1995):

$$\sigma y = 465.11628\,(x)\tan(TH) \quad (8)$$

where:

$$TH = 0.01745\,[\,c - (d)\ln(x) \quad (9)$$

$$\sigma z = a.x \quad (10)$$

The formula and corresponding parameter values for determining the lateral diffusion coefficient for a Gaussian plume as shown in Equation 8, 9 and 10 by using the fundamental form of the Pasquill-Gifford functions (Turner 1970; USEPA, 1995).

Once known amount of emission released by the respective ships passing through the Strait of Malacca, the next step is calculated distribution of the emission. The total emission of ships will be seen in several areas around the Strait of Malacca. The areas are figured as a point which has a position of longitude and latitude and called as "receptor". There are 51 points of receptor around the Strait which to be placed as a reference point to know the distribution of the emission as shown in Figure 8.

Figure 8 : 51 points of receptor surrounding the Strait of Malacca areas

In this study, time release of the emission is varied by 6 range of time. At time of 10 minutes, 20 minutes, 30 minutes, 40 minutes, 50 minutes and 59 minutes. Time reference is 60 minutes because all the calculation only at1 hour (08.00am on September 2, 2011). Thus, time releases is obtained at $\Delta t.1 = 50$ min, $\Delta t.2 = 40$ min, $\Delta t.3 = 30$ min, $\Delta t.4 = 20$ min, $\Delta t.5 = 10$ min and $\Delta t.6 = 1$ min

3.5 Calculation by Programming

Calculation of emission and the concentration are performed by using programming. The high number of calculation and output of the calculation becomes an issue when it calculated by manually. The programming which used for this step is Microsoft Visual Studio 2010.

4.0 RESULT AND ANALYSIS

4.1 Programming Overview

Calculation of emission and the distribution will generate a huge number of calculations and result. This happens because of the usage Gaussian Puff Model which considers several of time release. There are 6 time release are considered in this study, thus generates results in huge of number. Because of the issue, thus made a program using Microsoft Visual Studio 2010 (Visual Basic 2010) program as shown in Figure 9.

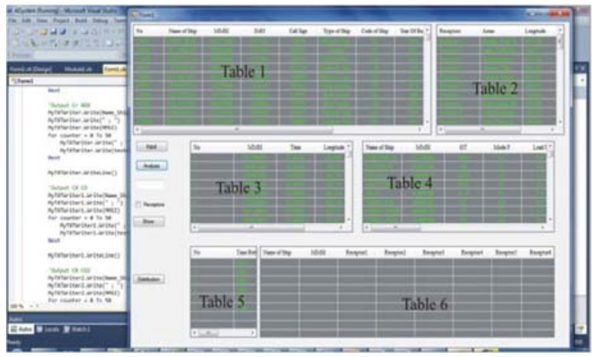

Figure 9 : Programming of emission calculation and the distribution

Encoding functions to calculate emission rates of ships is based on equation 1, 2 and 3. The result shows fuel consumption of fuel main engine, auxiliary engine and emissions rate each ship showed in table 4 by programming. Encoding functions to calculate the concentration of emission for every point of receptors based on Equation 4-10. The result will show the concentration rate of emission to each receptor by programming. The total output of result is formatted in the form of text file and saved on the local computer drive. The output is resulted for every time release showed in table 6 by programming and one text file format for each emission. The programming needs an input data in Microsoft excel format and containing several data of AIS and the additional data, receptor data, ship position (longitude and latitude) for every time release and time release data.

4.2 Total emissions

The estimation results for NOx, CO, CO_2, VOC, PM and SOx emissions from ships is shown in Table 7. The results show that NOx, CO, CO_2, VOC, PM and SOx rates were 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. In addition, the highest emissions rate of NOx, CO, CO_2, VOC, PM and SOx for a single hours were emitted by liquid bulk (tanker), which contributed 4353.872 g/second, 11212.623 g/second, 4549.125 g/second, 2590.807 g/second, 170.592 g/second and 2843.203 g/second, respectively at 0800 September 2, 2011. It is also possible to estimate exhaust emission by considering the vessel's flag of registry, as shown in Tables 8. These tables show that the most significant contributions to emissions were from ships registered under the flag of Singapore. They also show that NOx, CO, CO_2, VOC, PM and SOx emissions were 2641.152 g/second, 6226.438 g/second, 2513.719 g/second, 1441.283 g/second, 94.157 g/second and 1569.275 g/second, respectively

Table 7 : Estimates of NOx, , CO, CO_2, VOC, PM and SOx during thedensest marine traffic conditions in the Strait of Malacca area at 08.00 September 2, 2011.

Type of ships	NOx	CO	CO_2	VOC	PM	Sox
(g/ton of fuel) per-second						
Solid Bulk	824.00	1458.41	729.93	340.95	27.37	456.21
Liquid Bulk	4353.87	11212.62	4549.13	2590.81	170.59	2843.20
General Cargo	302.81	729.96	305.84	166.21	11.47	191.15
Container	7023.11	8846.59	4220.97	2019.17	157.71	2628.53
Ro-Ro Cargo	31.16	59.80	28.23	12.82	1.06	17.65
Passenger	40.39	119.30	45.10	27.00	1.69	28.19
High speed ferries	2.34	10.08	3.26	2.35	0.12	2.04
Tugs	474.47	1353.90	524.53	311.42	19.56	326.03
Fishing	6.14	26.45	8.55	6.17	0.32	5.34
Other	657.23	1644.42	677.47	381.31	25.41	423.42
Total	13715.52	25461.53	11093.00	5858.22	415.30	6921.75

Table 8 : Estimation of NOx, , CO, CO_2, VOC, PM and SOx based on the flag of registry in g/second at 0800 September 2, 2011

Flag	Number of Ship	Nox	CO	CO_2	VOC	PM	Sox
(g/ton of fuel) per-second							
Singapore	344	2641.152	6226.438	2513.719	1441.283	94.157	1569.275
Malaysia	28	234.967	312.137	183.373	72.352	6.877	114.608
China Peoples's	8	172.100	298.238	151.466	70.841	5.680	94.666
Cyprus	11	305.070	353.822	206.808	79.026	7.755	129.255
Bahamas	14	452.886	745.208	384.639	166.968	14.424	240.399
Hong Kong,	21	838.589	930.120	523.411	209.325	19.628	327.132
Indonesia	28	142.083	459.815	163.281	106.754	6.123	102.050
lIberia	54	2231.697	2867.265	1440.845	648.188	53.457	890.950
Marshall	29	628.918	1458.934	566.050	331.188	21.227	353.781
Panama	110	3005.009	5381.394	2346.478	1251.927	87.993	1466.549
vietnam	11	86.531	262.653	96.492	61.209	3.618	60.307
Malta	12	221.020	453.423	189.227	104.324	7.096	118.267
Others Flag	142	2755.495	5712.079	2327.211	1314.832	87.270	1454.507
Total	813	13715.516	25461.526	11092.999	5858.216	415.305	6921.747

4.3 Concentration of Emission on Surrounding Areas of Malacca Strait

There are 51 points of receptor around the Strait which to be placed as a reference point to know the distribution of the emission at 0800 September 2, 2011 as shown in Figure 8. The receptor point divided into 4 major area includes Indonesia areas (14 receptors), Malaysia areas (15 receptors) Singapore areas (10 receptors) and open sea areas on around the Malacca Strait (12 receptors). Figure 10-15 shows concentration of emission for NOx, CO, CO2, VOC, PM and SOx emission on the surrounding Strait of Malacca areas. The distribution of ships emission were calculated on all ships movement includes hotteling, cruising and maneuvering condition. These conditions are considered by the current possition of ship for each time release which converted from Lat- Long to UTM (Universal Transverse Mercator) coordinate.

The result shows that NOx, CO, CO2, VOC, PM and SOx were concentrated on areas of Singapore and Malaysia. The most high-risk areas which affected by the emissions are Sentosa Island (Singapore), Port of Pasir Gudang (Malaysia) and Jurong Island (Singapore). Sentosa Island (Singapore) contaminated by NOx, CO, CO2, VOC, PM and SOx emission were 8.51441E-06 µg/m3, 7.24214E-07 µg/m3, 3.13174E-06 µg/m3, 2.3488E-07µg/m3, 1.1744E-07 µg/m3 and 1.95734E-06µg/m3, respectively at 0800 September 2, 2011 at a time release of 10 minutes on Gaussian Puff Model calculations. Concentration of NOx, CO, CO2, VOC, PM and SOx emission in the Port of Pasir Gudang (Malaysia) were 4.60077E-07, 5.97293E-08, 2.58289E-07, 1.93717E-08, 9.68583E-09 and 1.61431E-07 µg/m3, respectively and in the Jurong Island (Singapore) were 1.19104E-07, 5.12661E-07, 1.65709E-07, 1.19621E-07, 6.21408E-09 and 1.03568E-07 µg/m3, respectively for NOx, CO, CO2, VOC, PM and SOx emission at 0800 September 2, 2011 at a time release of 10 minutes.

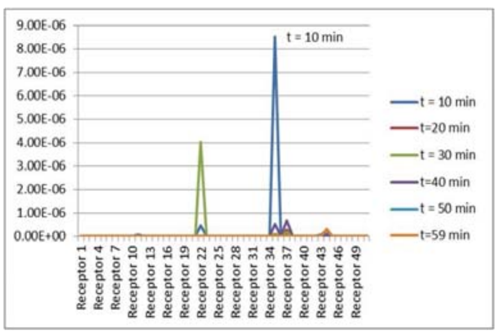

Figure 10. Concentration of NOx emission

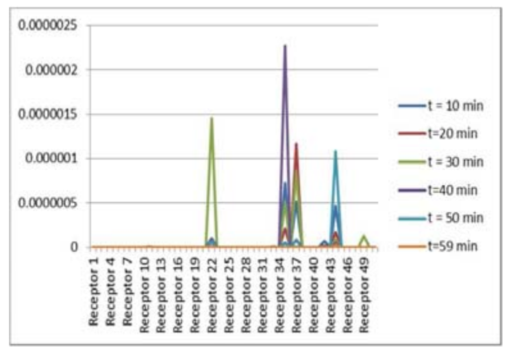

Figure 11. Concentration of CO emission

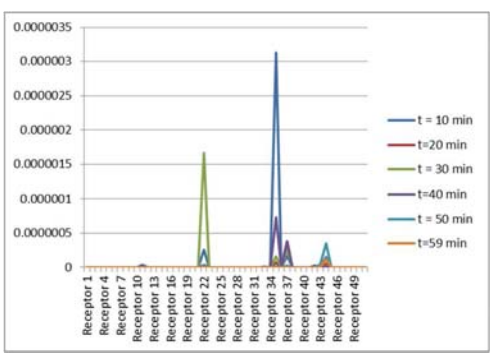

Figure 12. Concentration of CO2 emission

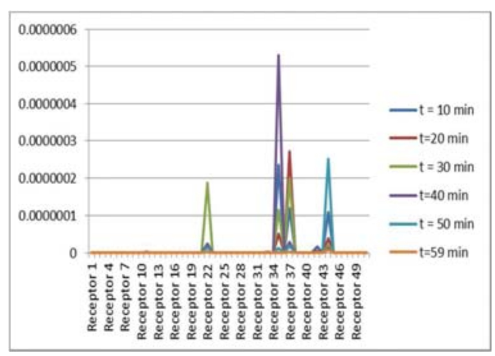

Figure 13. Concentration of VOC emission

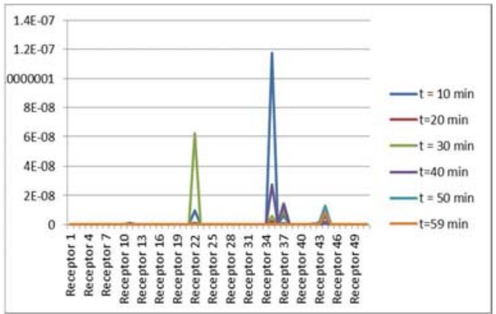

Figure 14 : Concentration of PM emission

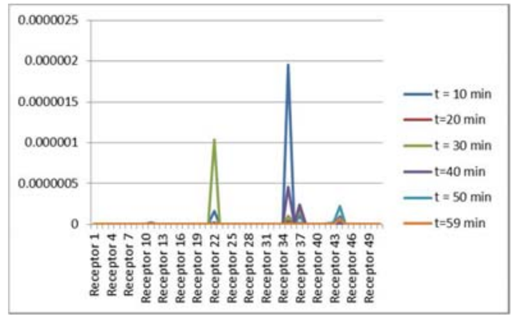

Figure 15 : Concentration of SOx emission

5. 0 CONCLUSIONS

This work demonstrated that it is possible to use AIS data to estimate NOx, SOx, PM, CO and CO2 emissions and distribution of the emission from shipping activities. In additions, the distribution can be seen through amount of concentration of emission in several areas around the ship traffic as an emission source. This study also demonstrated that possibility of calculating the distribution of emission by all mode operational of ships (Manoueuvring, cruising and hoteling), not only one of them.

The exhaust emission rates which produced through this study may used for evaluating the impact of marine traffic on air quality, the greenhouse effect and could be used when establishing government policy in relation to ratification of international maritime conventions, such as MARPOL 73/78 Annex VI (Pitana et al, 2010).

This work show the total amount of emission NOx, CO, CO_2, VOC, PM and SOx emission were 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. It also showed that the highest contribution of emission per hour from liquid bulk (tanker), which contributed 4353.872 g/second, 11212.623 g/second, 4549.125 g/second, 2590.807 g/second, 170.592 g/second and 2843.203 g/second at 0800 September 2, 2011, respectively. In addition, this study also determined possibility to evaluate the emissions by considering the vessel's flag of registry. Furthermore, our study showed that the total distribution of emission surrounding areas of the Malacca Strait.

There are 51 areas that we consider in this paper, but only 3 areas were shown in this result of the paper as the highest-affected areas of emission from marine traffic in the Strait of Malacca on 0800 September 2, 2011. The most high-risk areas which affected by the emissions in that hour 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%. We also consider wind direction on exhaust gas emission to calculate the distribution of emission according to the wind direction that occurs in the Strait of Malacca on 0800 September 2, 2011 which the data was obtained from the Malaysian Meteorological Department (2011). Calculation of the emission distribution using the Gaussian Puff Model enables to find out the total concentration of emission at specified time intervals and predetermined distance. Result of total emission distribution by the usage of the model shown a tendency to decline over time. For example, Figure 16 and 17 are the total of distribution of NOx emission at release time t=20 minutes and t=50, respectively. These Figure shows a tendency of the concentration from 4.35216E-08 µg/m3 at t=20 to 6.94188E-10 µg/m3 at t=59. It is caused by several factors when emission was distributed over time influenced by wind direction and time release emitted.

This study only determines exhaust emission and distribution. The impact of such emissions on human beings was not evaluated. In additions, additional database of ships as complementary AIS Data to get complete data of the ship, in the future research will be necessary.

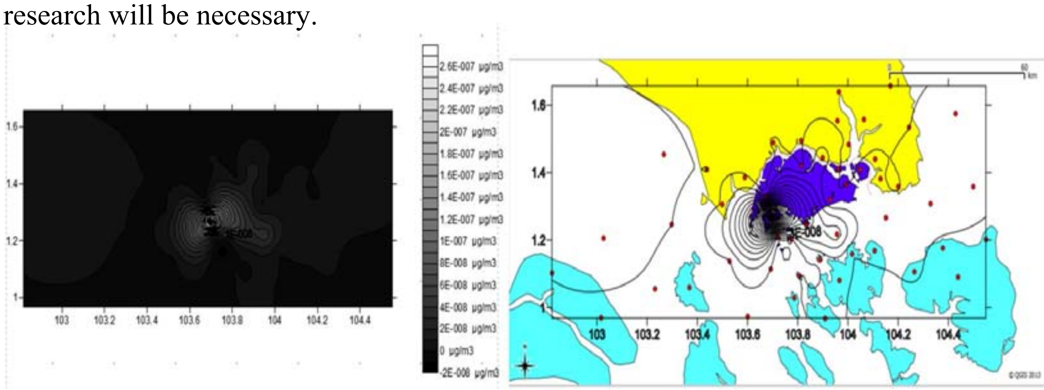

Figure 16 : Distribution of NOx emission by Surfer.8 at t=20 minute

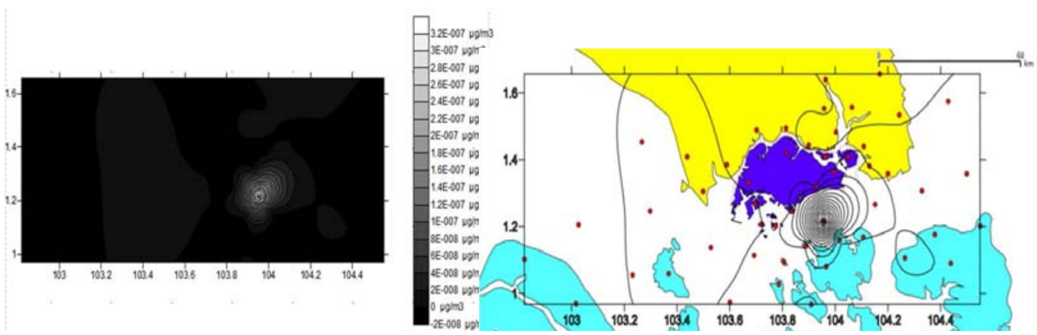

Figure 17 : Distribution of NOx emission by Surfer.8 at t= 59 minutes

REFERENCES

1. Allen, C. T., G. S. Young, and S. E. Haupt. (2006). Improving Pollutant Source Characterization by Optimizing Meteorological Data with a Genetic Algorithm, Submitted to Atmos. Environ.
2. Arndt R.L., Carmichael G.R., Streets D.G. and Bhatti N. 1996. Sulfur dioxide emissions and sectorial contributions to sulfur deposition in Asia. Atmospheric Environment 31, 1553-1572.
3. Bhatti N., Streets D.G. and Foe11 W.K. 1992.Acid rain in Asia. Environmental Management 16, 541-562.EPA. 1985. Compilation of Air Pollutant Emission Factors: Volume II: Mobile Sources - Vessels. AP-42, Fourth Edition, September 1985.
4. Eyring, Veronika.,S.A.Isaksen, Ivar., Berntsen, Terje., J.Collins, William., et al. 2010. Transport impacts on atmosphere and climate: Shipping. Atmospheric Environment44(2010)4735–4771.
5. IMO (International Maritime Organization).1998. IMO Resolution MSC.74 (69). "Recommendation on Performance Standards for A Universal Shipborne

Automatic Identification System (AIS)".

6. Jalkanen, J.-P., Johansson, L., Kukkonen, J., Brink, A. ., Kalli, J., Stipa, T. 2011. Extension of an assessment model of ship traffic exhaust emissions for particulate matter and carbon monoxide. Atmos.Chem.Phys.Discuss., 11, 22129–22172.
7. Jaswar, Y.Ikeda. (2002). A feasibility Study on a Podded Propulsion LNG Tanker in Arun, Indonesia-Osaka, Japan, Proceeding ISOPE, 12.
8. Long, K.J., S.E. Haupt, G.S. Young, and C.T. Allen, 2007: Characterizing Contaminant Source and Meteorological Forcing using Data Assimilation with a Genetic Algorithm, Fifth Conference on Artificial Intelligence Applications to Environmental Science at AMS Annual Meeting, San Antonio, TX, Jan. 16, Paper number 4.3.
9. Lucialli, P., Ugolini, P., Pollini, E., Harbur of Ravenna: The Contribution of Harbour Traffic to Air Quality. Atmos. Environ., vol. 41, pp. 6421-6431, 2007.
10. Matthias, Volker.,Bewersdorff, Ines., Aulinger, Armin., Quante, Markus. 2010. The contribution of ship emissions to air pollution in the North Sea regions. Environmental Pollution 158 (2010) 2241 – 2250.
11. Meyer, D.P., Maes, F., Volckaert, A., Emission from international shipping in the Belgian part of the North sea and the Belgian seaports, J. Atmos.Environ., vol 42, pp. 196-206, 2007.
12. Mihmanli, Ege. 2011. Research Report : Combating Piracy in the Strait of Malacca. MUNDP 2011 – Asia and the Pacific.
13. Perez, M., Chang, R., Billings, R., Kosub, T.L.,. 2009. Automatic Identification System (AIS) data use in marine vessel emission estimation. 18th Annual International Emission Inventory Conference.
14. Pitana, Trika., Kobayashi, Eiichi., Wakabayashi, Nobukazu. (2010). Estimation of Exhaust Emissions of Marine Traffic Using Automatic Identification System Data (Case Study: Madura Strait Area, Indonesia). OCEANS 2010 IEEE – Sydney, E-ISBN : 978-1-4244-5222-4, Print ISBN: 978-1-4244-5221-7.
15. Streets, D.G., Carmichael, G.R., Arndt, R.L., .1997. Sulfur dioxide emissions and sulfur deposition from international shipping in Asian waters. Atmospheric Environment 31,1573-1582.
16. Trozzi C. (2010). Update of Emission Estimate Methodology for Maritime Navigation, Techne Consulting report ETC.EF.10 DD, May 2010.
17. Turner, D. (1970). Workbook of atmospheric dispersion estimates (Revised). US EPA: Office of Air Programs, Research Triangle Park, N.C. Pub. No. AP-26.
18. UNECE/EMEP. (2002). Group 8: Other Mobile Sources and Machinery, in EMEP/CORINAIR Emission Inventory Guidebook-third ed., October 2002 Update (Technical Report no. 30).
19. UNCTAD. 2010. Review of Maritime transport 2010. New York and Geneva : The United Nations Conference on Trade and Development Secretary.
20. USEPA (1995). User's guide for the Industrial Source Complex (ISC3) Dispersion Models. US EPA: Office of Air Quality Planning and Standards Emissions, Monitoring, and Analysis Division, Research Triangle Park, N.C. Vol. 2,EPA-454/B-95-003b.
21. Wang, C., Callahan, J., Corbett, J.J.,. 2007. Geospatial Modeling of Ship Traffic and Air Emissions, Proceeding of ESRI International Conference.