ISOMAse
International Society of Ocean, Mechanical and Aerospace Scientists and Engineers

Journal of Ocean, Mechanical and Aerospace
-Science and Engineering-
30th March 2019. Vol.63 No.1

March 30, 2019

Estimation of Single Hour Emission Rate From Marine Traffic In Batam-Singapore Waterways Using Automatic Identification System (AIS) Data

Hendra Saputra, [a,*] Nidia Yuniarsih, [a] ,Naufal Abdurrahman, [a] Mufti Fathonah Muvariz, [a]
Sapto Wiratno S, [a] and Tri Ramadani Arjo, [b]

[a)] *Department of Ship Planning and Construction Engineering, Politeknik Negeri Batam, Indonesia*
[b)] *Department of Information Engineering, Politeknik Negeri Batam, Indonesia*

*Corresponding author: hendrasaputra@polibatam.ac.id

Paper History

Received: 14-November-2018
Received in revised form: 20-January-2018
Accepted: 30-March-2018

ABSTRACT

This paper focuses on estimation of single hour emission rate from ships traffic in the Batam-Singapore waterways as it is one of the congested narrow straits area used for international shipping. MEET methodology is used to estimate emissions from ships.There were 1326 total number of ships through the strait at 22.00 on September 4, 2018 produces total exhaust emission for NOx, CO, CO2, VOC, PM and SOx were about 48,716.48 kg/hour, 62,297.39 kg/hour, 3,541,656.53 kg/hour, 14,751.79 kg/hour, 1,339.14 kg/hour and 22,319.03 kg/hour, respectively. This paper also try to compare the result of emission calculated on previous research of single hour emission rate on 2011, 2014 and the current results. The result of comparison shows that there is a significant difference of CO2 emission results.

KEY WORDS: *AIS (Automatic Identification System), Ship Emission, Marine Traffic*

NOMENCLATURE

AIS	*Automatic Identification System,*
MMSI	*Maritime Mobile Service Identity*
GT	*Gross Tonnage*
SSD	*Slow Speed Diesel Engine*
MSD	*Medium Speed Diesel Engine*
HSD	*High Speed Diesel Engine*
BFO	*Bunker Fuel Oil*
MDO	*Marine Diesel Oil*
VOC	*Volatile Organic Compound*
PM	*Particulate Matter*
NOx	*Nitrogen Oxide*
SOx	*Sulfur oxides*
CO	*Carbon Monoxide*
CO_2	*Carbon Dioxide*

1.0 INTRODUCTION

Strait of Malacca is one of the most congested port in the word especially in Singapore and Indonesia waters border. The daily traffic shown approximately 1500 ships passing through the strait both for national and international shipping [1] [2] [3] [4]. Compared to one of the busiest port in Indonesia, Madura Strait only has the heaviest density of 120 ships per day [5]. By large number of ship in the Strait, its play role in producing of shipping emission and contributed to air pollution.

This paper focuses on estimating of exhaust gas emission rate in the Strait of Batam-Singapore waterways using single hour data of Automatic Identification System (AIS) at highest density on September 4, 2018. The methodology used to estimate emission such as SOx, Nox, CO, CO2 and Particulate Matter (PM) by using MEET methodology.

An automatic identification system (AIS) is a system which has capability to provide information of ships and broadcast the information between ships and coastal automatically. The AIS system used on ships for identifying and locating vessels by electronically exchanging data with other nearby ships, AIS base

ISOMAse
International Society of Ocean, Mechanical and Aerospace Scientists and Engineers
Journal of Ocean, Mechanical and Aerospace
-Science and Engineering-
30th March 2019. Vol.63 No.1

March 30, 2019

stations, and satellites. A vessel carrying AIS equipment (AIS transponder) can communicate automatically to a neighbouring vessel and nearby station by VHF radio.

2.0 AUTOMATIC IDENTIFICATION SYSTEM

2.1 Development of AIS System in Batam-Singapore Waterways

Data of AIS in this paper was obtained by system which developed for education purpose and installed in Politekni Negeri Batam. The current feature of the AIS system is for record, decode and visualize of AIS message sent by ships passing through Batam-Singapore waterways.

The system consist of AIS receiver equipments, AIS record and decode software & web based interactive visualization application to visualize the vessels traffic. The main AIS receiver is installed in Politeknik Negeri Batam as AIS receiver station.

Table 1: AIS Station Devices

No	Devices	Remarks
1	AIS Receiver	AMEC CYPHO-150
2	AIS Antenna	VHF antenna
3	Personal Computer (PC)	Mini PC Model: Intel NUC NUC5CPYH

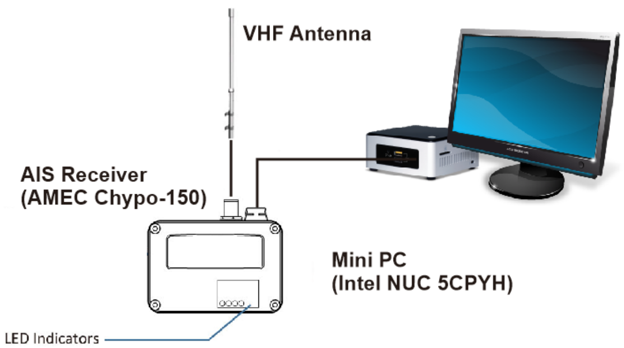


Figure 1: AIS Sytem Connection Diagram

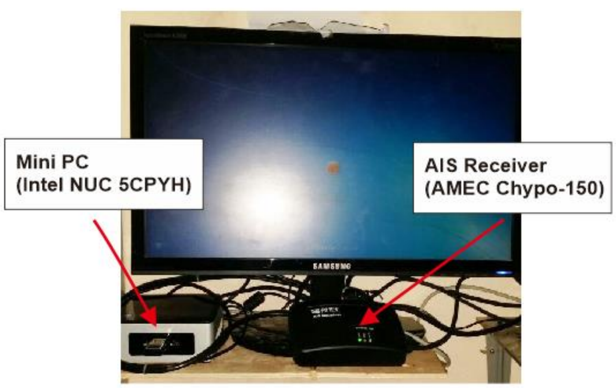


Figure 2: AIS station devides

2.2 Overview of AIS System

Installed AIS receiver station is used to record AIS data sent by ship which passing through nearby the station. Once recorded, the AIS data will be simultaneously decoded and stored in the hardisk of PC. Both system of record and decode the AIS data was develop using LabView as shown in figure 3 and 4.

The information obtained from AIS decoded consist of Tanggal (Date), Jam (time), Packet Type, Channel, AIS Type, Repeat Indicator, MMSI, Navigation Status, Rate of Turn, Speed Over Ground, Position Accuracy, Longitude, Latiitude, Course Over Ground, True Heading, Time Stamp, and Maneuver Indicator.

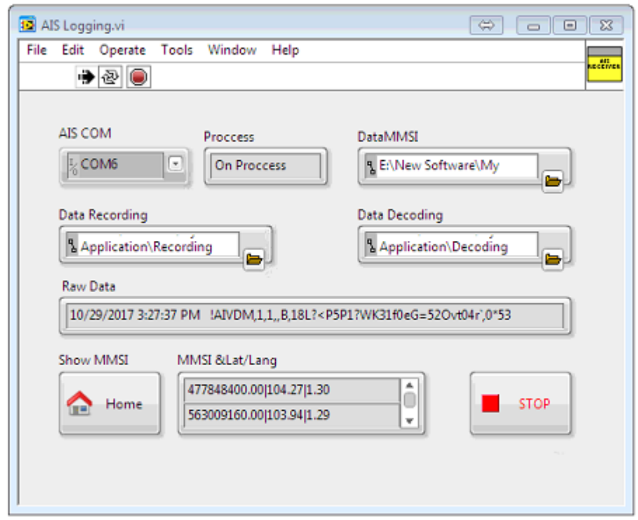


Figure 3: The AIS record and decode

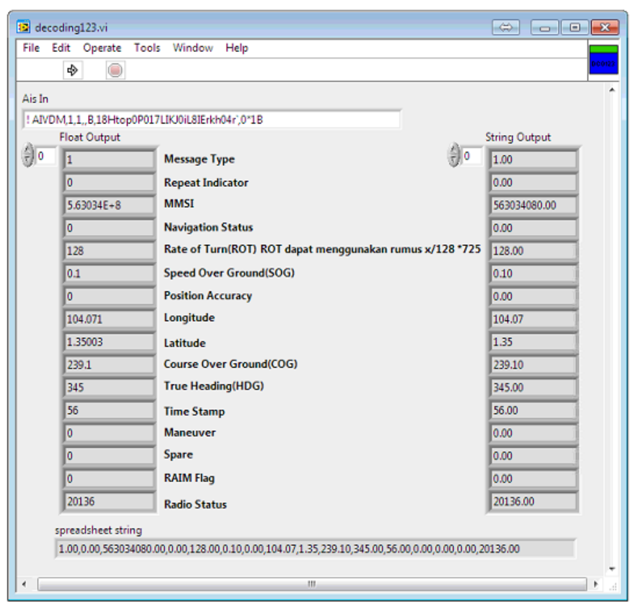


Figure 4: Decode process shown on the application

2.3 AIS Data Overview

In this paper, the AIS data obtained from AIS system installed in Politeknik Negeri Batam station. The traffic density used for emission calculation is the highest density on September 4, 2018 as shown on figure 5.

JOMAse | Received: 14-November-2018 | Accepted: 30-March-2019 | [(63) 1: 1-6]
Published by International Society of Ocean, Mechanical and Aerospace Scientists and Engineers, www.isomase.org., ISSN: 2354-7065 & e-ISSN: 2527-6085

Journal of Ocean, Mechanical and Aerospace
-Science and Engineering-
30th March 2019. Vol.63 No.1

Table 2: Traffic Density on September 4, 2018

Time	No of MMSI	Individual Vessel (Ship Station)	Invalid
00.00	1147	1104	43
01.00	1135	1092	43
02.00	1117	1075	42
03.00	1125	1079	46
04.00	1143	1098	45
05.00	1177	1133	44
06.00	1236	1191	45
07.00	1280	1237	43
08.00	1261	1220	41
09.00	1286	1243	43
10.00	1304	1260	44
11.00	1291	1248	43
12.00	1276	1235	41
13.00	1286	1243	43
14.00	1255	1213	42
15.00	1249	1206	43
16.00	1201	1159	42
17.00	1222	1173	49
18.00	1213	1170	43
19.00	1200	1158	42
20.00	1222	1179	43
21.00	1270	1220	50
22.00	1382	1326	56
23.00	1367	1316	51
Average	**1235**	**1191**	**44**

Table 2 shows that the highest ship density occurred at 22.00 on September 4, 2018. There were 1326 of individual ships passing through the Batam-Singapore Strait while the average ships hourly for individual vessels (ship-station) about 1191 vessels.

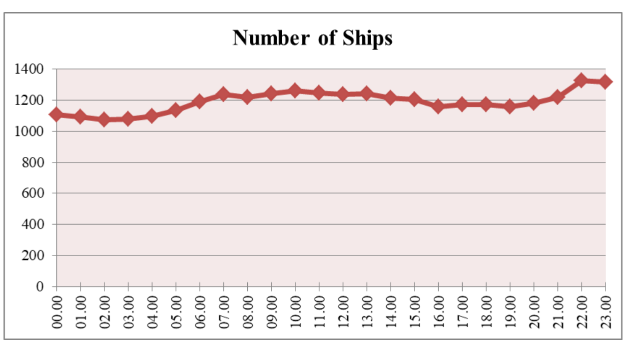
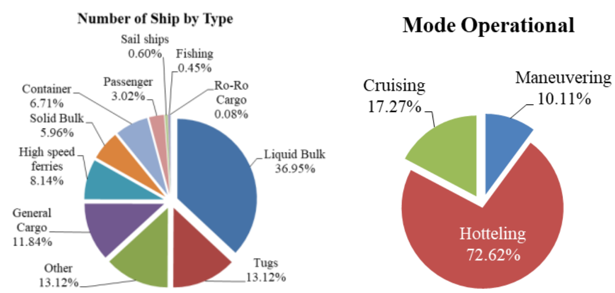


Figure 5: Number of Individual Vessels (Ship Station) on September 4, 2018

The data used in this paper focuses on individual vessel (ship station). It is indicated by MMSI (Maritime Mobile Service Identity) structure of $M_1I_2D_3X_4X_5X_6X_7X_8X_9$. The values of first 3 digits of MID that identified as individual vessels (ship station) between 200 to 799. This values also indicates country code of the vessels. The values excluding on the MID limits of individual vessels (ship station) was identified as others type of MMSI. This can be identified as group of vessels, shore station or group of shore stations, SAR aircrafts and navigation aids.

Table 3: Number of Ship by Type

No	Ship Type	Number
1	Liquid Bulk	490
2	Tugs	174
3	Other	174
4	General Cargo	157
5	High speed ferries	108
6	Solid Bulk	79
7	Container	89
8	Passenger	40
9	Sail ships	8
10	Fishing	6
11	Ro-Ro Cargo	1
Total		**1326**



(a) (b)

Figure 6: Number of Ships at 22.00 on September 4, 2018 (a) ship type (b) by mode operational

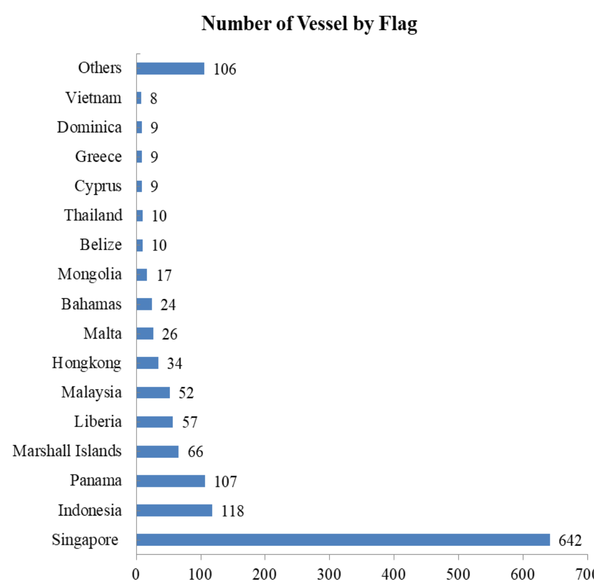


Figure 7: Number of Ships at 22.00 on September 4, 2018 by flag

Analyze the ship type and mode operational is very important when calculating the ship emission since the emission factors are influences by ship type and mode operational. Figure 6 shown that the majority of ships recorded at 22.00 on September 4, 2018, were liquid bulk, tugs, other ship types, general cargo and high-speed ferries followed by other types such as solid bulk,

JOMAse | Received: 14-November-2018 | Accepted: 30-March-2019 | [(63) 1: 1-6]
Published by International Society of Ocean, Mechanical and Aerospace Scientists and Engineers, www.isomase.org., ISSN: 2354-7065 & e-ISSN: 2527-6085

ISOMAse International Society of Ocean, Mechanical and Aerospace Scientists and Engineers
Journal of Ocean, Mechanical and Aerospace
-Science and Engineering-
30th March 2019. Vol.63 No.1

container, passenger, sail ships, fishing and ro-ro cargo. The majority of ship by mode operational were hotteling, cruising and Maneuvering. Figure 7 shown the three highest number of ship by flag register were Singapore, Indonesia and Panama.

2.4 Ship Emission Methodology

Previous research carried out by the author has implemented for estimating ship emission based on standard European (MEET) methodology [6] [7]. The methodology used to estimate daily fuel consumption and emission of 12 class of ships by consider the gross tonnage which in excess of 100 GT. The method also need to consider the three different condition of ship operation, those are maneuvering, hotelling, and cruising phase.

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 [8].

Calculation of emissions rate produced by main engine of ship defined as:

$$\boldsymbol{Ei = \sum_{jklm} . E_{ijklm}} \tag{1}$$

$$\boldsymbol{E_{ijklm} = S_{jkm}(GT) . t_{jklm} . F_{ijlm}} \tag{2}$$

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
- E_{ijklm} : total emissions of pollutant i from use of fuel j on ship class k with engines type l in mode operation m
- $S_{jkm}(GT)$: daily consumption of fuel j in ship class k as a function of gross tonnage
- t_{jklm} : days in navigation of ships of class k with engines type l using fuel j in mode operational m
- F_{ijlm} : average emission factors of pollutant i from fuel j in engines type l in mode m

The equations used to calculate the emission is shown in table 4 and the emission factor produced by each ships shown in table 5.

Table 4: Ship classes and fuel consumption factor (ton/day)

Ship Class	Fuel Consumption as function of GT (Gross Tonnage)
Solid Bulk	Cjk = 20.1860 + 0.00049 × GT
Liquid Bulk	Cjk = 14.6850 + 0.00079 × GT
General Cargo	Cjk = 9.8197 + 0.00143 × GT
Container	Cjk = 8.0552 + 0.00235 × GT
Ro-Ro Cargo	Cjk = 12.8340 + 0.00156 × GT
Passenger	Cjk = 16.9040 + 0.00198 × GT
High Speed Ferry	Cjk = 39.4830 + 0.00972 × GT
Inland Cargo	Cjk = 9.8197 + 0.00143 × GT
Sail Ship	Cjk = 0.4268 + 0.00100 × GT
Tugs	Cjk = 5.6511 + 0.01048 × GT
Fishing	Cjk = 1.9387 + 0.00448 × GT
Other Ships	Cjk = 9.7126 + 0.00091 × GT

Table 5: Emission factor (kg emission/ton fuel)

Phases	Engine/fuel type	Nox	CO	CO2	VOC	PM	SOx
Cruising	SSD/BFO	87	7.4	3200	2.4	1.2	60
	MSD/BFO	57	7.4	3200	2.4	1.2	60
	HSD/MDO	70	9	3200	3	1.5	20
Manoeuvring	SSD/BFO	78	28	3200	3.6	1.2	60
	MSD/BFO	51	28	3200	3.6	1.2	60
	HSD/MDO	63	34	3200	4.5	1.5	20
Hotelling	SSD/BFO	35	99	3200	23.1	1.2	60
	MSD/BFO	23	99	3200	23.1	1.2	60
	HSD/MDO	28	120	3200	28.9	1.5	20

SSD = Slow Speed Diesel Engine
MSD = Medium Speed Diesel Engine
HSD = High Speed Diesel Engine
BFO = Bunker Fuel Oil
MDO = Marine Diesel Oil
VOC = Volatile Organic Compound
PM = Particulate Matter

For estimate fuel consumption of euxiliary engine by using the following equation [9]

$$f = 0.2 \times O \times L \tag{3}$$

Where:

- f : fuel consumption (kg/ship/hour)
- O : rated output (PS/engine)
- L : Load factor (cruising: 30%, hotelling (tanker): 60%, hotelling (other ships, excluding tankers): 40% and maneuvering: 50%)

3.0 RESULT AND DISCUSSION

The results of emission by using standar European (MEET) methodology as explained previously, it was found the emission rate at 22.00 on September 4, 2018 is as shown in in tabel 6 and 7.

JOMAse | Received: 14-November-2018 | Accepted: 30-March-2019 | [(63) 1: 1-6]
Published by International Society of Ocean, Mechanical and Aerospace Scientists and Engineers, www.isomase.org., ISSN: 2354-7065 & e-ISSN: 2527-6085

ISOMAse
International Society of Ocean, Mechanical and Aerospace Scientists and Engineers

Journal of Ocean, Mechanical and Aerospace
-Science and Engineering-
30th March 2019. Vol.63 No.1

Table 6: Emission rate of NOx, CO, CO2, VOC, SOx and PM (kg/hour) by Ships Flag at 22.00 on September 4, 2018

No	Flag	Number of Ships	Nox	CO	CO2	VOC	PM	SOx
1	Singapore	642	18,202.97	21,990.70	1,327,174.04	5,199.43	499.68	8,327.98
2	Indonesia	118	1,015.97	2,030.20	94,663.65	475.93	35.50	591.65
3	Panama	107	4,844.03	5,448.28	317,590.29	1,286.99	123.85	2,064.23
4	Marshall Islands	66	4,708.43	8,191.98	388,715.73	1,923.78	150.04	2,500.72
5	Liberia	57	4,988.60	4,744.15	310,374.47	1,141.21	116.39	1,939.84
6	Malaysia	52	673.08	1,406.48	63,694.92	329.54	23.89	398.09
7	Hongkong	34	2,701.93	3,164.30	200,185.74	757.44	75.07	1,251.16
8	Malta	26	1,999.40	2,090.55	133,109.90	494.36	49.92	831.94
9	Bahamas	24	1,295.24	1,336.20	95,936.41	323.78	35.98	599.60
10	Mongolia	17	138.91	421.52	15,810.54	98.48	5.93	98.82
11	Belize	10	419.99	185.47	26,152.05	46.70	9.81	163.45
12	Thailand	10	319.11	661.58	27,771.50	155.82	10.41	173.57
13	Cyprus	9	208.64	368.81	18,506.86	87.55	6.94	115.67
14	Greece	9	597.22	881.00	49,501.24	210.35	18.56	309.38
15	Dominica	9	154.21	207.11	12,368.48	49.30	4.64	77.30
16	Vietnam	8	171.62	214.77	13,461.64	51.60	5.05	84.14
20	Other	128	6,277.10	8,954.26	446,639.09	2,119.53	167.49	2,791.49
Total		**1326**	**48,716.48**	**62,297.39**	**3,541,656.53**	**14,751.79**	**1,339.14**	**22,319.03**

Note: Others flag is total of 51 flags register with under 5 vessel each flags

Table 7: Emission rate of NOx, CO, CO2, VOC, SOx and PM (kg/hour) by Ships Type at 22.00 on September 4, 2018

No	Ship Type	Number of Ship	Nox	CO	CO2	VOC	PM	SOx
1	Liquid Bulk	490	12,503.94	23,037.32	1,126,954.71	5,433.56	422.61	7,043.47
2	Tugs	174	7,160.32	10,250.53	587,081.92	2,442.02	220.16	3,669.26
3	Other	174	1,944.85	4,988.60	203,193.07	1,167.83	76.20	1,269.96
4	General Cargo	157	5,733.35	5,064.03	407,409.06	1,223.74	152.78	2,546.31
5	High speed ferries	108	2,399.43	3,262.63	192,278.24	738.10	72.10	1,201.74
6	Solid Bulk	79	3,198.91	3,252.63	235,912.12	785.45	88.47	1,474.45
7	Container	89	14,806.97	11,532.32	718,981.04	2,744.24	280.64	4,677.30
8	Passenger	40	935.76	794.55	65,811.42	190.49	24.68	411.32
9	Sail ships	8	5.31	18.21	644.17	4.18	0.24	4.03
10	Fishing	6	13.47	35.47	1,416.18	7.93	0.53	8.85
11	Ro-Ro Cargo	1	14.19	61.09	1,974.61	14.25	0.74	12.34
Total		**1326**	**48,716.48**	**62,297.39**	**3,541,656.53**	**14,751.79**	**1,339.14**	**22,319.03**

The results show that NOx, CO, CO2, VOC, SOx and PM emission rate were 48,716.48 kg/hour, 62,297.39 kg/hour, 3,541,656.53 kg/hour, 14,751.79 kg/hour, 1,339.14 kg/hour and 22,319.03 kg/hour, respectively.

The highest emission rate by ship type were emitted by liquid bulk, tugs, other ships type, general cargo and high speed ferries followed by solid bulk, container, passenger, sail ships, fishing and ro-ro cargo as shown in table 7. The highest emission rate by ship flag were contributed by ships registered under the flag Singapore, Indonesia and Panama as shown in table 6.

The results of total emission rate for NOx, CO, CO2, VOC, SOx and PM emission rate shown in table 8.

Table 7: Contribution of NOx, CO, CO2, VOC, SOx and PM in total emission rate

No	Emission	Total Emission Rate		% Contribution
		kg/hour	g/second	
1	Nox	48,716.48	13,532.36	1.32%
2	CO	62,297.39	17,304.83	1.69%
3	CO_2	3,541,656.53	983,793.48	95.95%
4	VOC	14,751.79	4,097.72	0.40%
5	PM	1,339.14	371.98	0.04%
6	SOx	22,319.03	6,199.73	0.60%

JOMAse | Received: 14-November-2018 | Accepted: 30-March-2019 | [(63) 1: 1-6]
Published by International Society of Ocean, Mechanical and Aerospace Scientists and Engineers, www.isomase.org., ISSN: 2354-7065 & e-ISSN: 2527-6085

ISOMAse
International Society of Ocean, Mechanical and Aerospace Scientists and Engineers

Journal of Ocean, Mechanical and Aerospace
-Science and Engineering-
30th March 2019. Vol.63 No.1

4.0 CONCLUSION

In this paper, we demonstrated that the use of AIS data is possible to estimate emission rate on single hour from marine traffic in Batam-Singapore waterways. The estimation of single hour of emission rate of NOx, CO, CO2, VOC, SOx and PM from marine traffic in the Batam-Singapore waterways using AIS data recorded at 22.00 on September 4, 2018 by consider mode operational of ship (Manoueuvring, cruising and hoteling), ship type and engine/fuel type.

This paper also compare result of emission calculated on different time as results of previous research on single hour emission rate on 2011, 2014 and current result. The comparison shows that there is a significant difference of CO_2 emission result as shown in table 8 and figure 8.

Table 8: Comparison of Single Hour Emission Rate on 2011, 2014 and Current Results

No	Emission	Total Emission Rate (g/sedond)		
		at 22.00 on September 4, 2018 (current resluts)	**at 06.00-08.00 September 27, 2014** [10]	**at 08.00 September 2, 2011** [3]
1	Nox	13,532.36	12,595.35	13,715.52
2	CO	17,304.83	25,725.19	25,461.53
3	CO_2	983,793.48	11,832.31	11,093.00
4	VOC	4,097.72	5,973.23	5,858.22
5	PM	371.98	443.71	415.31
6	SOx	6,199.73	22,185.57	6,921.75
Number of Ships used on estimation		1326	1269	813

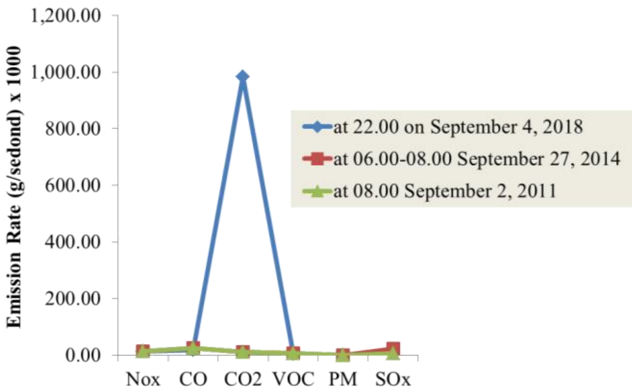


Figure 8: Comparison Graph of Single Hour Emission Rate on 2011, 2014 and Current Results

This difference results significantly occurred by two factors those are different use of CO2 emission factor and use of equation to estimate fuel consumption of auxiliary engine.

For further research, need to consider the distribution of the emission to know how it is emission impacted to shoreline and its influence to air quality towards the environment on certain reception point.

ACKNOWLEDGEMENTS

The authors would like to convey a great appreciation to Ristekdikti and Politeknik Negeri Batam for this research.

REFERENCE

1. Mir'atul Khusna Mufida, Hendra Saputra, Ardian Budi Kusuma Atmaja, and Wenang Anurogo, "Monitoring Marine Traffic Applying Automatic Identification System (AIS) Data by Interactive Visualization Approach," in *Proceeding 4th International Conference on Technical and Vocation Education and Training (4th ICTVET)*, vol. 4, Padang, 2017, pp. 248-254.
2. Hendra Saputra, Ardian Budi Kusuma Atmaja, Didi Istardi, and Sapto Wiratno Satoto, "Penggunaan Data Automatic Identification System (AIS) untuk Mengetahui Pergerakan Kapal," *Jurnal Integrasi*, vol. 8, no. 2, Oktober 2016.
3. Hendra Saputra, Adi Maimum, Jaswar Koto, and Mohammad Danil Arifin, "Estimation and Distribution of Exhaust Ship Emission from Marine Traffic In the Straits Of Malacca and Singapore Using Automatic Identification System (AIS) Data," *The 8th International Conference on Numerical Analysis in Engineering*, pp. 131-142, 2013.
4. Hendra Saputra et al., "Development of Automatic Identification System (AIS) for Vessels Traffic Monitoring in the Strait of Singapore and Batam Waterways," *Journal of Ocean, Mechanical and Aerospace -Science and Engineering- (JOMAse)*, vol. 51, pp. 7-13, Januari 2018.
5. Emmy Pratiwi, Bagus Dinariyana, Trika Pitana, Agoes A. Ketut Buda Artana, "Enhancement on Methodology for Estimating Emission Distribution at Madura Strait by Integrating Automatic Identification System (AIS) and Geographic Identification System (GIS)," *Proceedings of the 3rd International Symposium of Maritime Sciences Nov. 10-14, 2014, Kobe, Japan*, November 2014.
6. C., Vaccaro, R. Trozzi, "Methodologies for estimating future air pollutant emissions from ships," *Techne Report MEET RF98b, 1998*.
7. UNECE/EMEP, "Group 8: Other Mobile Sources and Machinery, in EMEP/CORINAIR Emission Inventory Guidebookthird ed," *October 2002 Update (Technical Report no. 30)*.
8. Trika., Kobayashi, Eiichi., Wakabayashi, Nobukazu Pitana, "Estimation of Exhaust Emissions of Marine Traffic Using Automatic Identification System Data (Case Study: Madura Strait Area, Indonesia)," in *OCEANS 2010 IEEE* , Sydney, NSW, Australia, 2010.
9. T Ishida, "Emission of Estimate Methods of Air Pollutants and Greenhouse Gases from Ships," *J. Jap. Inst. Mar. Eng., 37(1)*, 2003.
10. Hendra Saputra, Mufti Fathonah Muvariz, Sapto Wiratno Satoto, and Jaswar Koto, "Estimation of Exhaust Ship Emission from Marine Traffic In the Straits of Singapore and Batam Waterways Using Automatic Identification System (AIS) Data," *Jurnal Teknologi*, vol. 77 Nomor 23, November 2015.