Study on Emissions From Vessel Activities at the Port of Tanjung Perak, Indonesia

ARIF FADILLAH, AUGUSTINUS PUSAKA, SHANTY MANULLANG
Y. ARYA DEWANTO, DANNY FATURACHMAN
Department of Naval Architect
Darma Persada University
Radin Inten street at Jakarta 13450
INDONESIA
arif_fadillah@yahoo.com http://www.unsada.ac.id

Abstract: - This study measures emissions from vessel activities at case of the port of Tanjung Perak. Pollution of the marine environment of the ship in the harbor is a national issue that needs to be addressed; because it is expected of marine pollution will increase in the future. The result of calculations of the emissions from ships in the Port of Tanjung Perak shows that from year to year, either to ship overseas and domestically increased total exhaust emissions from ships.

Key-Words: - Air Pollution, Emissions, Vessel Activities, Tanjung Perak Port

1 Introduction

Port of Tanjung Perak is one of the local movements of goods in Indonesia. Existing facilities at the port of Tanjung Perak, includes shipping lanes, pilot age, bunkers, passenger terminal facilities, container, scouting, and loading and unloading equipment.

With so many ships as well as domestic and foreign-flagged vessels that traverse these waters will have an impact on the increase in emissions that are released by the ship. Improved exhaust emissions are accompanied by a decrease in air quality is believed to have an impact on the quality of human health. Marine vessel traffic is expected to have a role in the deaths of about 60,000 premature infants worldwide [1]. Nitrogen oxides (NOx), carbon monoxide (CO), carbon dioxide (CO2), particulate matter (PM), and sulfur oxides (SOx) are some of the pollutants contained in exhaust emissions from ships. pollutants contained in exhaust emissions from ships.

Figure 1. Ship Turn Round Time at the Port

2 Problem Formulation

In order to measure the exhaust emissions from ships in port activities carried out, both for the main engine and auxiliary engine boats taking into account since the arrival of the vessel (arrival time), loading and unloading activities including ship waiting time until the time of departure of the ship (departure time) on the door harbor known as the Time Round Time (TRT) ship in the port, as shown in Figure 1.

First necessary to determine the operational mode of the ship. When estimating the fuel consumption and emissions, Trozzi *et al*. focuses on three operational modes, namely hotelling, maneuvering, and cruising [2].

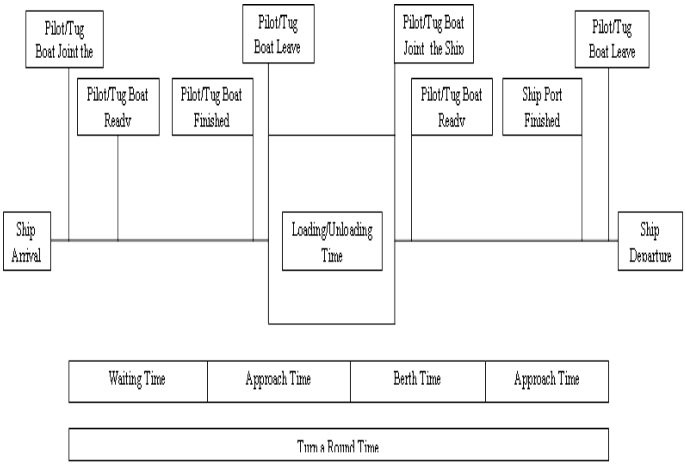

Figure 2. Ship Turn Round Time at the Port

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After the operation mode is known, fuel consumption is calculated by considering the fraction of maximum fuel consumption of each mode of operation of the ship. It is necessary to consider the actual fuel consumption during different phases of ship operations carried out in the port area.

Calculation of emissions is calculated based on the standard European methodology (MEET), Estimates of emissions into account the twelve classes that have a gross tonnage vessels over 100 GT Trozzi, *et al [2][4]*, other data include emissions factors, and specification parameters such as ship fuel consumption, engine type, etc. Trozzi, et al, in a study using a calculation engine fuel consumption of each type of vessel is obtained from a linear regression analysis of fuel consumption to the gross tonnage as shown in Table 1.

Table 1. Ship Type and Fuel Consumption (ton/day)

Ship Type	Fuel Consumption (ton/day)
Solid Bulk	C_{jk} = 20.1860 + 0.00049 × GT
Liquid Bulk /Tanker	C_{jk} = 14.6850 + 0.00079 × GT
General Cargo	C_{jk} = 9.8197 + 0.00143 × GT
Container	C_{jk} = 8.0552 + 0.00235 × GT
Ro-Ro Cargo	C_{jk} = 12.8340 + 0.00156 × GT
Passenger	C_{jk} = 16.9040 + 0.00198 × GT
High Speed Ferry	C_{jk} = 39.4830 + 0.00972 × GT
Inland Cargo	C_{jk} = 9.8197 + 0.00143 × GT
Sail Ship	C_{jk} = 0.4268 + 0.00100 × GT
Tugs	C_{jk} = 5.6511 + 0.01048 × GT
Fishing	C_{jk} = 1.9387 + 0.00448 × GT
Other Ships	C_{jk} = 9.7126 + 0.00091 × GT

In addition, exhaust emissions are calculated by considering factors such as the engine and fuel type and mode of operation of the vessel as shown in Table 2.

Table 2. Ship Emission Factor

Mode	Engine / Fuel	NO_x	CO	CO_2	VOC	PM	SO_x
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
Manoeu vering	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 BFO = Bunker Fuel Oil PM = Particulate Matter VOC = Volatile Organic Compound							
MSD = Medium Speed Diesel Engine MDO = Marine Diesel Oil							
HSD = High Speed Diesel Engine							

Calculation of total emissions of a pollutant from the main engine is shown in the following equation Trozzi, [2]:

$$E_i = \Sigma_{jklm} E_{ijklm} \quad (1)$$

$$E_{ijklm} = S_{jkm}(GT)\, t_{jklm}\, F_{ijklm} \quad (2)$$

where i = pollutant; j = type of fuel; k =ship type; l = engine type; m = vessel operating mode; Ei = total emissions pollutans i; E_{ijklm} = Total emissions of pollutant i, type of fuel is j, type of ship is k and l is type of engine and m is vessel operating mode. F_{ijklm} = average emission factor of fuel pollutant i, and type of fuel is j, types of vessel is k and engine type is m. S_{jkm} (GT) = Daily fuel consumption by type of fuel j, type of ship is k, with the vessel operating mode m by using the function GT. t_{jklm} = navigation of the ship type k with the type of engine is l, the type of fuel is j and ship operation mode is m.

While to estimate the fuel consumption of auxiliary engines obtained from the following equation Ishida [3].

$$f = 0{,}2\ x\ O\ x\ L \quad (3)$$

where: f = fuel consumption (kg/ship/h), O = rated output (PS/engine), L = load factor (crusing: 30%, hotelling (tanker): 60%, hotelling (other ship): 40% and 50% maneuvering

3 Problem Solution

Table 3 shows the ship call in unit ship at the port of Tanjung Perak. Data from 2009 to 2013 shows the number of ship visits increased from year to year, both for foreign and domestic vessels.

Table 3. Ship Call at Tanjung Perak Port (unit Ship)

	2009	2010	2011	2012	2013
Foreign Ship	2.435	2.114	2.220	2.194	2.063
Domestic Ship	12.629	12.084	11.908	12.579	12.135
Total	**15.064**	**14.198**	**14.128**	**14.773**	**14.198**

Table 4 shows the ship call in GT ship at the port of Tanjung Perak. Data from 2009 to 2013 shows the number of ship visits in gross tonnage (GT) increased from year to year, both for foreign and domestic vessels.

Table 4. Ship Call at Tanjung Perak Port (GT Ship)

	2009	2010	2011	2012	2013
Foreign Ship	29.522.768	30.558.087	33.238.190	34.743.877	36.446.922
Domestic Ship	33.725.382	36.398.221	36.463.733	38.378.303	39.846.779
Total	**63.248.150**	**66.956.308**	**69.701.923**	**73.122.180**	**76.293.701**

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Table 5 and tabel 6 shows domestic and foreign ship services at the port of Tanjung Perak Port from 2009 to 2013 both for foreign and domestic vessels seems fluktuative.
In Domestic ship services the longest waitingtime happen in 2009 but in Foreign Ship happen in 2012.

Table 5. Domestic Ship Services at Tanjung Perak Port

Domestic Ship	2009	2010	2011	2012	2013
Waiting time	1,23	1,40	1,33	1,38	2,09
Postpone time	8,60	6,16	9,32	11,02	10,62
Approach time	2,24	2,17	2,09	2,00	4,37
Berthing time	34,40	29,39	29,65	28,47	29,64
Turn Round Time	46,46	39,12	42,38	42,87	46,72

Table 6. Foreign Ship Services at Tanjung Perak

Foreign Ship	2009	2010	2011	2012	2013
Waiting time	1,12	1,04	0,93	0,85	1,26
Postpone time	4,67	3,11	6,75	7,00	6,81
Approach time	2,55	2,54	2,53	2,40	4,57
Berthing time	50,33	41,76	49,51	50,39	51,42
Turn Round Time	58,67	48,45	59,71	60,63	64,05

Port

In this study ships services owned by port operator and consists of a tugboat, pilot boat and boat mooring. Figure 3 shows the fuel consumption for foreign ships services at Port of Tanjung Perak, Surabaya from 2009 to 2013. The result of fuel consumption shows that the highest fuel consumption is tugboat follows pilot boat and mooring boat. Fuel Consumption of Foreign ship services are fluctuating, where the largest fuel consumption occurred in 2013 with a total value of 12,179 tons of fuel, with the user details tugboat consumming of fuel about 11,339 tons, 561 tons of pilot boat, and 280 Tons for mooring boat.

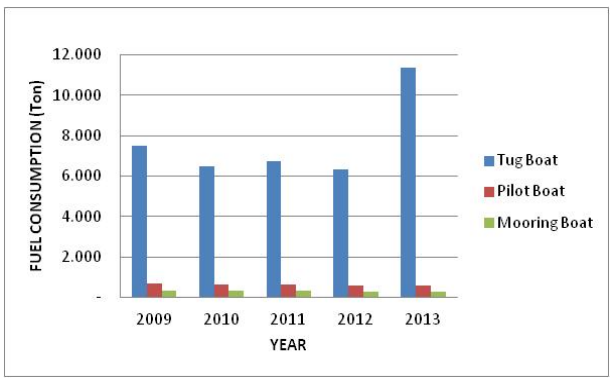


Figure 3. Foreign Ships Services Fuel Consumption

Meanwhile in Figure 4 shows the results of fuel consumption for domestic ship services at the Port of Tanjung Perak. Fuel consumption of ships services are fluctuating where the largest fuel consumption occurred in 2009 with total fuel consumption about 38,796 tons, where the fuel consumption of tugboat, the pilot boat and mooring boat consumes about 33,999 tons, 3,200 and 1,596 tons.

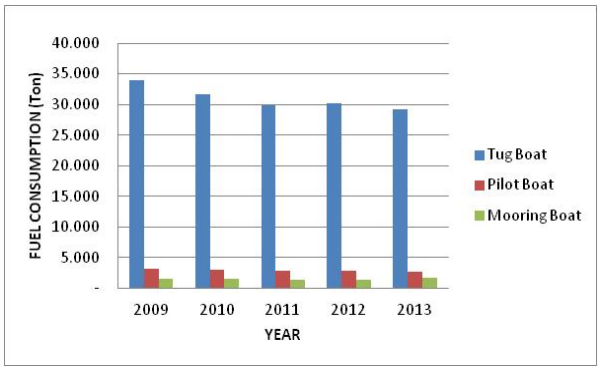
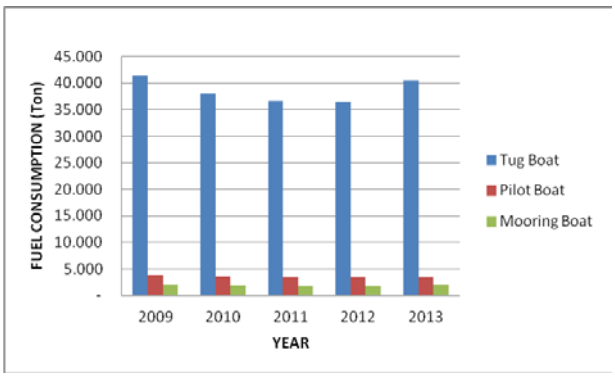


Figure 4. Domestic Ships Services Fuel Consumption

The total fuel consumption of the ship services owned by port operator for both domestic and foreign ship at the Port of Tanjung Perak from 2009 to 2013 is shown in Figure 5. Fuel consumption was greatest in 2009, whereas in 2013 the fuel consumption for tug boat, pilot



boat and mooring boat as follows 40,501 tons, 3,306 tons and 1,924 tons.

Figure 5. Total of Foreign and Domestic Ships Services Fuel Consumption

Fuel consumption by foreign ship at the Port of Tanjung Perak from 2009 to 2013 is shown in Figure 6. Fuel Consumption seen to fluctuate with the greatest fuel consumption in 2009 amounted to

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1,822 tons, decreasing fuel consumption in the year 2010 compared to the year 2009, while in 2011 to 2013 the consumption of fuel for foreign ship has increased.

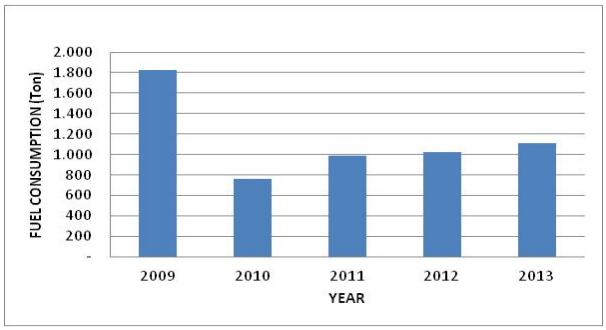

Figure 6. Foreign Ships Fuel Consumption

The total fuel consumption of domestic ships at the Port of Tanjung Perak from 2009 to 2013 is shown in Figure 7, with the largest fuel consumption in 2009 amounted to 1,550 tons. Fuel consumption for domestic shipping from 2009 to 2013 has increased significantly.

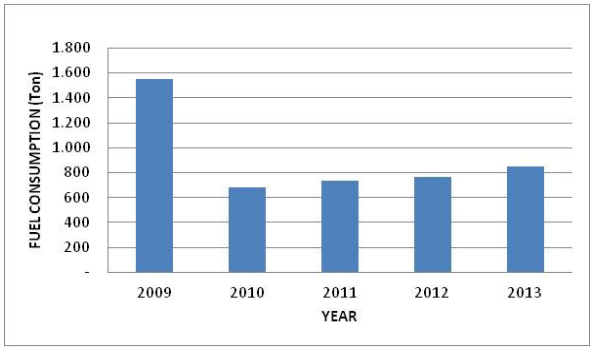

Figure 7. Domestic Ships Fuel Consumption

Total fuel consumption foreign & domestic shipping at the Port of Tanjung Perak during 2009 to 2013 shown in Figure 8. Total fuel consumption in 2013 about 1,967 tons. Where fuel consumption for domestic shipping about 853 tons and foreign shipping fuel consumption about 1,114 tons.

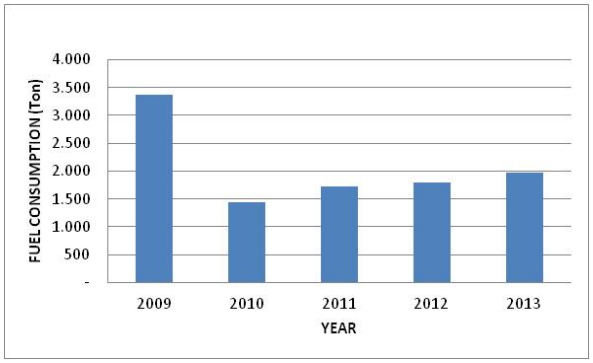

Figure 8. Foreign and Domestic Ships Fuel Consumption

Figure 9 shows the exhaust emissions of foreign ships at the port of Tanjung Perak. Exhaust emissions are NOx, CO, CO2, VOCs, PM and SOx, from the picture shown that CO2 exhaust gas emissions are among the highest exhaust emission of other exhaust gases. The entire exhaust emissions that occur in the service of the ship is very dependent on fuel consumption. In 2013 exhaust emissions were highest this year, and in 2009 to 2012 fluctuations and exhaust emissions rose dramatically in 2013

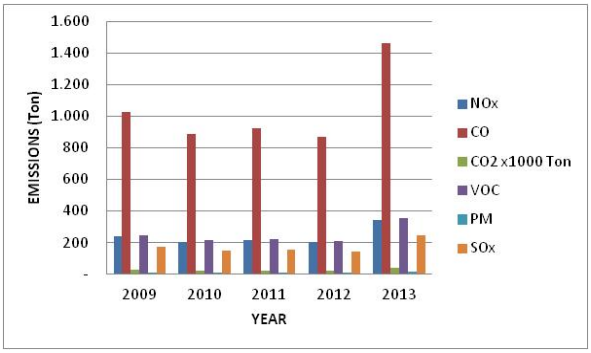

Figure 9. Foreign Ships Services Emissions

In the Figure 10 shows the exhaust emissions in domestic ships service at the Port of Tanjung Perak. Exhaust emissions produced between 2009 to 2013 has fluctuated, with the largest exhaust emissions are CO2, with exhaust emissions were highest in 2009, with a value of CO2 emissions by 5,000 tons, followed by the CO of 186 tons, followed by VOCs by 45 tons, 43 tons of NOx, SOx by 31 tons and PM about 2 Ton.

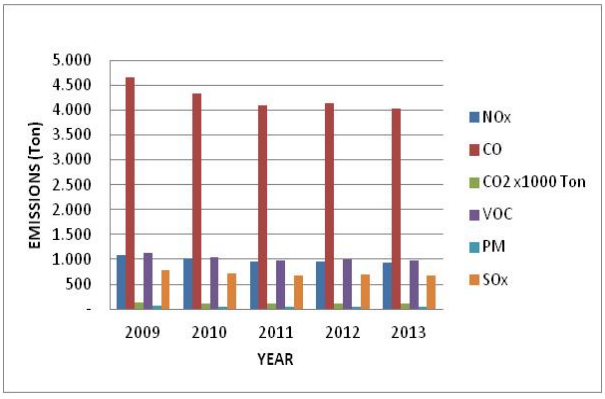

Figure 10. Domestic Ships Services Emissions

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Figure 11 shows that the exhaust emissions produced by foreign ships at the Port of Tanjung Perak. Exhaust emissions that are generated NOx, CO, CO2, VOCs, PM and SOx. Exhaust emissions were highest in 2009, and experienced a significant decline in 2010 and the trend in the years subsequent to rise. The highest exhaust emissions produced is CO2, which in 2009 resulted in CO2 emissions by 6,000 tons.

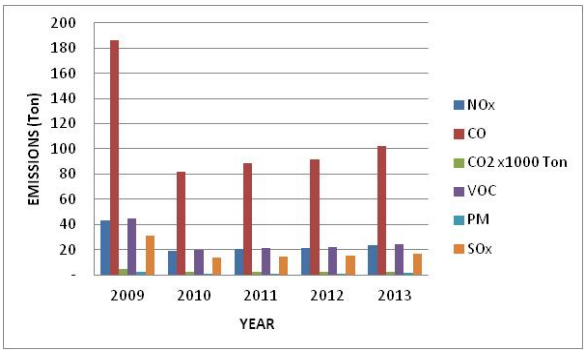

Figure 11. Foreign Ships Emissions

Figure 12 shows that the exhaust emissions produced domestic ship at the Port of Tanjung Perak. Exhaust emissions were highest in 2009, decreased in 2010 and the trend decline in subsequent years. Exhaust emissions in the year 2013 is a gas produced by 939 tons of NOx, CO of 4,026 tons, 107,000 tons of CO2, VOC of 970 Ton, 50 Ton PM and SOx by 671 tons.

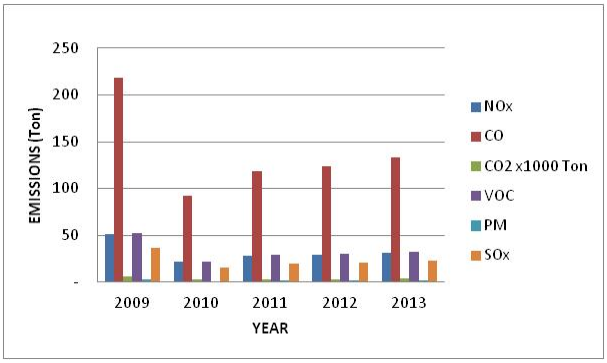

Figure 12. Domestic Ships Emissions

4 Conclusion

Based on data collection, discussion and analysis of data, the study on emissions from vessel activities at the Port of Tanjung Perak, Indonesia obtained the following conclusions:

1. The number of ship visits at the port of Tanjung Perak in unit and gross tonnage (GT) increased from year to year, both for foreign and domestic vessels.
2. The average of Turn Round Time (TRT) ship for domestic shipping is about 44 hours, meanwhile for foreign shipping is about 58 hours. In this point of view the port should have development to decrease the waiting time at the port.
3. The bigest fuel consumption by ship services owned by port operator, such as: tug boat, pilot boat and mooring boat. Meanwhile the ships at the ports for both foreign and domestic shipping not use the main engine or in other words, only use the auxiliary engines while in port.
4. Exhaust gas emissions produced by ship services greater than foreign and domestic shipping due to the fuel consumption.

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