

Environmental Impact of the Marine Transport in Port of Taranto

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Abstract—The purpose of this work is to study and analyze the data associated with the marine traffic operations and to estimate the resulting noxious substances emissions to find a solution for potential pollution reduction. The obtained results provide useful information to assess the cost-effectiveness of possible strategies (such as shore-site electricity) for bringing pollutants down, in order to reach a wealth based on environmental preservation.

Index Terms—Environmental pollution, emission reduction, power supply, environmental monitoring and control systems

I. INTRODUCTION

The emissions in the ports mainly derive from the combustion engine ships, but they can also be associated with evaporation of the products transported (emission evaporative). These emissions are normally divided into emission effects on global scale (CO₂ and other greenhouse gas) and into emissions and effects on local and regional scales (CO, NO_x, HC, SO₂ and PM₁₀).

The Atmospheric Emission Inventory Guidebook of the EEA [1], in the chapter devoted to navigation, provides some useful observations on the contribution of emission due to activities related to maritime traffic.

Globally, it is estimated that NO_x and SO_x emissions due to shipping is responsible for about 5-12% and about 3-4% of the anthropogenic emissions, respectively. Global studies indicate that near land and in ports, shipping emissions of NO_x and SO_x emissions contribute to the formation of photochemical smog and particles. Moreover, human epidemiological studies have linked the diesel exhaust of ship engine with asthma, other respiratory diseases, cardiovascular disease, lung cancer, and premature death [2]; on the other hand, to investigate and diagnose these illnesses medical images are used with additional costs to the community and different methods has been proposed to reduce both the economic impact and radiation doses [4]–[7].

In this context the development of suitable methodology for pollutant reduction is strongly encouraged by the agencies in charge of environmental protection and the by the local government.

Different international regulations have been enacted with the aim to control pollutant emissions taking into account both improvements of engine design and fuel quality. The EU directive 2005/33/EC [3] limits the sulphur content to 0,1 % for marine fuels while docked.

Moreover, the Annex IV of MARPOL 73/78 [8], sets three fixed thresholds for NO_x emissions, depending on marine engine revolutions per minute (rpm) values. In order to properly estimate the shipping emissions it is recommended to adopt a ship movement methodology and then to decompose the ship activities in three main trip phases:

- Cruising (open sea)
- Maneuvering (approaching harbour)
- Hotelling (operations while stationary at dock in port)

In the proposed work the focus will be on the hotelling phase where, in absence of shore-site electricity, the on-board auxiliary diesel engines should be operated to supply electric energy to different systems such as lightning, load movement, air conditioning, control, etc. while the vessel is at the dock. Therefore, hotelling represents the main contribute to air pollution in the harbors.

II. EMISSION ESTIMATION

Marine emissions can be estimate with differ level of complexity depending on the typology of information available (detailed data on the vessels and land-based equipment characteristics and activities, fuels used as well as detailed information on port geography and ship paths within the port).

In the previous work [9] an approximated estimating method based on a linear relationship between Gross Tonnage (GT) and engine power was used to assess the emission of main pollutant during the hotelling. In this work an in-depth analysis of power consumption as function of engine type/fuel and vessel was proposed [9].

The methodology normally used to calculate the total emission from navigation of the commercial vessels is based on the emission sum of three different trip phases during the year [10]:

$$E_{Trip} = E_{Hotelling} + E_{Manouvering} + E_{Cruising} \quad (1)$$

For each trip phase, two different procedures for emission estimating can be applied to evaluate the emissions depending on the known data available: fuel consumptions or engines power.

In particular when fuel consumptions for each phase is known, then the emissions of a given pollutant i can be

Ship category	Main engine power (kW)	
	1997 fleet	2010 fleet
Liquid bulk ships	14.755*GT ^{0.6082}	14.755*GT ^{0.6082}
Dry bulk carriers	35.912*GT ^{0.5276}	35.912*GT ^{0.5276}
Container	1.3284*GT ^{0.9303}	2.9165*GT ^{0.8719}
General cargo	10.539*GT ^{0.6760}	5.56482*GT ^{0.7425}
Ro Ro Cargo	35.93*GT ^{0.5885}	164.578*GT ^{0.4350}
Passenger	1.39129*GT ^{0.9222}	9.55078*GT ^{0.7570}
Fishing	10.259*GT ^{0.6919}	9.75891*GT ^{0.7527}
Other	44.324*GT ^{0.5300}	59.049*GT ^{0.5485}
Tug	27.303*GT ^{0.70}	54.2171*GT ^{0.6420}

TABLE I

INSTALLED MAIN ENGINE POWER AS A FUNCTION OF GT E VESSEL TYPE [1].

evaluated by means of the following expression referred to the hoteling phase [11]:

$$E_{Hotelling_{i,j,m}} = FC_{j,m} \cdot EF_{i,j,m} \quad (2)$$

where

FC is the fuel consumption (tonnes),

EF is the fuel emission factor (kg/tonne),

i subscript indicates the analyzed pollutant.

j subscript indicates the engine type (slow-, medium-, and high-speed diesel, gas turbine and steam turbine).

m subscript indicates the fuel type (bunker fuel oil, marine diesel, oil/marine gas oil -MDO/MGO-, gasoline).

This procedure requires knowledge of detailed information about fuel consumption for each ship/engine type combination in the different trip phases which in the most cases are not available.

Therefore a more used emission estimating technique is based on the evaluation of engine power [11].

$$E_{Hotelling_{i,j,m}} = T \sum_e P_e \cdot LF_e \cdot EF_{i,j,m} \quad (3)$$

where

P is the engine nominal power (kW)

T is the hotelling time

LF is engine load factor (%)

e subscript indicates engine category (main, auxiliary)

With a good approximation it is possible to assume that only auxiliary engines are in operation in the hotelling phase, so that the sum in (3) is reduced to only first addend. The first step to estimate the global emission in the port computing the installed power of main engine as function of gross tonnage by type of vessel referring to Table I.

Successively the power of auxiliary engines is calculated by taking into account the estimate average ratio of auxiliary and main engines by ship type listed in Table II

Once the power of auxiliary engine (P) is obtained the engine load factor representing the percentage of use in the different trip phases is evaluated by the standard values listed in Table III.

Finally the emission factor (EF) is evaluated by using the values listed in the Table IV.

Ship category	1997 fleet	2010 fleet
Liquid bulk ships	0.26	0.35
Dry bulk carriers	0.29	0.39
Container	0.10	0.27
General cargo	0.23	0.35
Ro Ro Cargo	0.17	0.39
Passenger	0.13	0.27
Fishing	0.38	0.47
Other	0.28	0.18
Tug	0.10	

TABLE II

AVERAGE RATIO OF AUXILIARY AND MAIN ENGINES BY SHIP TYPE [1].

Ship activity	Load factor
Hotelling (except tankers)	0.40
Hotelling (tankers)	0.60

TABLE III

ESTIMATED LOAD FACTOR FOR AUXILIARY ENGINE FOR HOTELLING SHIP ACTIVITY [1].

III. CASE OF STUDY: PORT OF TARANTO

The port of Taranto (PoT shown in Figure 1) is the second most important Italian port with a throughput of about 50 million tons in 2006 and an extent which covers a total area of about 3,500,000 square meters [13]. It is mainly dedicated to the service of the industries located in the area and the handling of containers. PoT traffic structure consist of dry bulk and steel products related to the steelmaking activities of steel plant near it, liquid bulks (crude oil and refined products) related to the ENI refinery, cement throughput and general cargo handled at common user commercial berths. A future development plant is to become one of the main Mediterranean logistics platform linked directly with production and transport chains.

The proximity of the port to Taranto city provides an increased health risk due to the pollutants emissions generated by marine activity. Moreover the increasing of manufacturing industries near the city has exposed the population to great environmental stresses. This has lead the local administration to install environmental monitoring stations to assess the status of air quality allowing the development of modeling studies to manage polluting emissions and to forecast emergency events



Fig. 1. Port of Taranto

Engine	phase	Engine type	Engine fuel	NOx [g/kWh]	NMVOC [g/kWh]	PM10	PM2,5 [g/kWh]
auxiliary	Cruise/Manoeuvring/Hotelling	High-speed diesel	BFO	11.2	0.4		0.8
			MDO/MGO	10.5	0.4		0.3
		Medium-speed diesel	BFO	14.2	0.4		0.8
			MDO/MGO	13.2	0.4		0.3

TABLE IV

ESTIMATED LOAD FACTOR FOR AUXILIARY ENGINE FOR HOTELLING SHIP ACTIVITY [12]. (BFO-BUNKER FUEL OIL, MDO-MARINE DIESEL OIL, MGO-MARINE GAS OIL)

Dock	2-year period number of vessels	Mean time of hotelling [h]	Vessel per day [n°/day]
Quay #1	35	1 122	0.0
Pier #1 - Seaward end	14	507	0.0
Pier #1 - West side	215	10 425	0.3
Quay #2	182	8 415	0.2
Pier #2 - East side	464	21 600	0.6
Pier #2 - Seaward end	10	423	0.0
Pier #2 West side	150	6 048	0.2
Quay #3	147	6 708	0.2
Pier #3 - East side	586	22 575	0.8
Pier #3 - Seaward end	80	2 688	0.1
Pier #3 - West side	644	30 444	0.9
Quay #4	2	108	0.0
Pier #4 - East side landward	116	4 746	0.2
Pier #4 - East side	183	9 711	0.3
Oil Terminal	975	41 490	1.3
Buoy Moorings	54	2 229	0.1
Pier #5	1164	40 233	1.6
Multipurpose Pier	1154	41 238	1.6
Quay #5	83	3 324	0.1

TABLE V
TRAFFIC DATA FOR EACH DOCK.

ship type	GT [tonne]	number of ships	mean hotelling time [h]	mean engine speed [knots]
liquid bulk	5.001	1	3	13.4
liquid bulk	5.001	3	9	13.4
liquid bulk	5.001	51	18	13.4
liquid bulk	5.001	49	36	13.4
liquid bulk	5.001	6	72	13.4
liquid bulk	7.501	1	3	14.1
liquid bulk	7.501	2	9	14.1
liquid bulk	7.501	28	18	14.1
liquid bulk	7.501	33	36	14.1
liquid bulk	7.501	8	72	14.1
liquid bulk	7.501	1	48	14.1
liquid bulk	15.001	1	3	14.5
liquid bulk	15.001	1	18	14.5
liquid bulk	15.001	10	36	14.5
liquid bulk	15.001	2	72	14.5
liquid bulk	15.001	1	48	14.5
liquid bulk	35.000	3	3	15
liquid bulk	35.000	1	9	15
liquid bulk	35.000	3	18	15
liquid bulk	35.000	14	36	15
liquid bulk	35.000	118	72	15
liquid bulk	35.000	32	48	15
liquid bulk	75.001	1	3	16
liquid bulk	75.001	1	18	16
liquid bulk	75.001	6	36	16
liquid bulk	75.001	27	72	16
liquid bulk	75.001	55	48	16
Tugs	15.001	3	3	9.6
Tugs	15.001	1	36	9.7
Tugs	15.001	1	72	9.8

TABLE VI
TRAFFIC DATA FOR PIER #3 - EAST SIDE DOCK.

[14], [15].

In order to estimate the effect of environmental pollution due to PoT activities, the data about the marine traffic a two-years period (2010-2012) have been analyzed. Table V summarizes the traffic data for each dock and allows highlighting the docks having main time of hotelling.

To evaluate the total amount of power demand a detailed analysis of fleet characteristics for each dock has been performed. As an example Table VI lists the value about Pier #3 - East side dock which exhibits high marine traffic. Therefore combining the data listed in the table I-III the amount of power engine has been calculated.

By means of Table IV, the emissions of main pollutants due to PoT activities have been evaluated. As regard to the fuel type data required in the table, it is worth highlighting that normally marine diesel is predominant for both propulsion and auxiliary power generation. Therefore in first approximated phase the MDO engine fuel has been considered in the performed analysis.

IV. CONCLUSIONS

Ship emissions are a significant source of air pollution degrading the sustainable development of areas near ports.

In this study a methodology for estimating emissions from marine traffic was proposed in accordance with the

EMEP/EEA air pollutant inventory guidebook.

The real case of port of Taranto was analyzed by estimating for each dock the emission contribution as function of ship typology in terms of gross tonnage, engine and fuel type.

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