Inventory of Exhaust Gas Emissions from Maritime Vehicles in a Bay

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Abstract: An emission inventory was prepared for maritime vehicles in Izmir Bay, Turkey. The emissions were calculated by using emission factors for three vehicle types; the passenger boats, the ferries carrying on-road vehicles and passengers, and the ships used for freight transport. The data of vehicle types and numbers, engine specifications for each vehicle type, fuel consumptions, passenger numbers, freight amounts, etc. for maritime traffic in Izmir Bay were collected. Emissions of NO_x, CO, VOC and PM were estimated using the data collected and the emission factors from EMEP/CORINAIR database. The emissions emitted by the vehicles used for public transport were estimated as 12 tons/year for particulate matter (PM), 112 tons/year for nitrogen oxides (NOx); 60 tons/year for carbon monoxide (CO) and 29 tons/year for volatile organic compounds (VOCs). The emissions emitted by the ships coming to Izmir Harbour for trading were estimated as 24 tons/year for PM, 314 tons/year for NOx, 65 tons/year for CO and 30 tons/year for VOCs. Total emission in the bay were found 36 tons/year for PM, 426 tons/year for NOx, 125 tons/year for CO and 59 tons/year for VOC. The maritime emissions of PM and NOx in the bay are about 58 and 70 times lower, respectively than road transport emissions in the city.

Keywords: Maritime transport, Shipping emissions, Emission inventory, Izmir.

1. INTRODUCTION

Izmir is a coastal metropolitan city at the western part of Turkey with coordinates of longitude between 26°15' and 28°15', and latitude between 37°45' and 39°15', covering a total area of 11891 km^2 (HGM, 2019). Metropolitan center is the third biggest urban agglomeration of Turkey and assumed as the industrial and commercial capital of the Aegean Region. The city with 3.4 million population and sizeable economic activities hosts many industries that are emitting high quantities of air pollutants (Elbir, 2002; Dincer *et al*., 2003; Elbir, 2003).

Maritime transport is a major source for urban air pollution in Izmir. Determination of air pollution arising from maritime transportation in the region has not been studied in detail, yet. Although, in Turkey a study including air pollutant emissions from the ships passing through the Bosphorus and the Dardanelles is available in literature (Kesgin and Vardar, 2001), many studies are available for determination of air pollutant emissions from the port trading in literature (Streets *et al*., 1997; Saxe and Larsen, 2004; Colodner *et al*., 2011; Zhang *et al*., 2016; Sun *et al*., 2018; Liu *et al*., 2018). But, the studies for determination of emissions from only passenger transportation are less. Kesgin and Vardar (2001) predicted NOx emissions from ships passing through the straits as 12818 tons/year. Besides, NOx emissions on the Bosphorus in Istanbul were estimated as 10% of total emissions from highway traffic in the city center.

The emissions from maritime public transport are not widely studied in literature. Cooper (2001) studied the emissions of NO_x, SO_2, CO, CO_2, NMVOC, CH_4, N_2O, NH_3, PM and PAH from maritime vessels by examining the ferries running for passenger transportation in Norway at three categorized groups according to motor specifications and voyage speeds. Cooper and Andreasson (1999) studied NO_x, CO and CO_2 measurements during a year by on-board measurement techniques in a ferry. The emissions emitted from this ferry were calculated for the period of 4618 hours per year and the emission factors were produced. Another study is about determination of air pollution arising from international and intercontinental maritime traffic. SO_2 emissions from maritime traffic carried out between Asia continent countries were calculated (Streets *et al*., 1997). In this study, SO_2 emissions were 236000 tons per year and this amount corresponded to 11% of total SO_2 emissions in Asia Continent.

The aim of this study is to prepare an inventory of the emissions from ships coming for trade purposes and ferries and ships used for public transport in Izmir Bay. The statistical data on vehicle number, vehicle properties, motor specifications, fuel consumptions and voyage numbers etc. belong to maritime traffic in the Izmir Bay were collected.

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2. STUDY AREA

Izmir metropolitan municipality has carried on transportation service in Izmir Bay by passenger ships and ferries since the year 2000. Passenger and vehicle transportation in the inner-bay are carried out by the means of total 24 vessels and 8 ports (Bostanli, Karsiyaka, Bayrakli, Alsancak, Pasaport, Konak, Goztepe and Uckuyular). The routes of ships and ferries in Izmir Bay are given in Figure **1**.

The vessels directly belonging to the Municipality and the vessels rented from two companies travelled about average 5000 voyages and 26000 miles (1 miles = 1852 meters) per month in 2005 (IBB, 2006). The total distances for months in Izmir Bay are given in Table **1**.

The total fuel consumed by the vessels in the bay is given in Table **2**. Fuel consumptions are individually given for each vessel. The vehicles named Esenkoy,

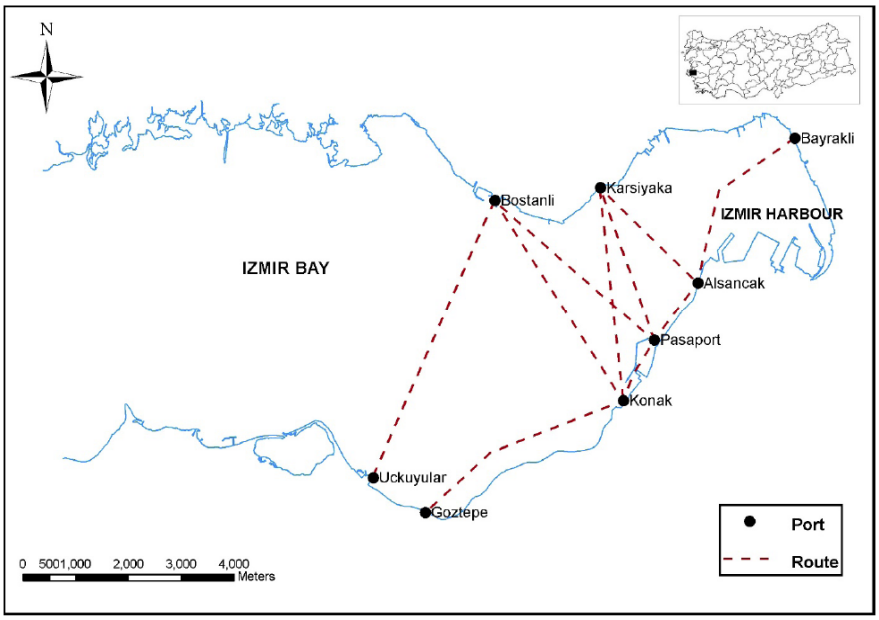

Figure 1: The ports and the routes for ships and ferries in Izmir Bay.

Table 1: Total Distances Travelled by Ships and Ferries in Izmir Bay

Years / Months	2001	2002	2003	2004	2005
January	27216	30551	29708	29681	26182
February	23786	28021	25859	27471	23501
March	26714	30538	29590	30212	27330
April	26070	30243	28926	29178	26271
May	29347	31496	30340	30002	26703
June	29350	29912	29524	29013	27366
July	30085	32142	31093	29268	28071
August	30609	32379	30524	28932	28478
September	28750	27826	29324	26968	26889
October	31158	30088	29941	26944	26656
November	29522	29014	28307	25811	24700
December	30410	29445	30056	27485	27176
Total	343017	361655	353192	340965	319323

Eminonu and Salacak are ferries and the others are passenger ships. Total fuel consumed was 3100 m³ per year (IBB, 2006).

Maritime traffic caused by big transport ships coming to Izmir Harbour for trade purposes is also available in the bay. The numbers of transport ships coming to the harbour between years of 2000 – 2005 and their total weights are shown in Table **3**.

3. MATERIALS AND METHODS

Many vessels traveling for national and international trading are available in Izmir Bay. Another important traffic is from the vessels making public transportation. These vessels used public transportation in the routes of Karsiyaka-Konak, Bostanli-Konak, Bayrakli-Konak, Bostanli-İnciralti, Karsiyaka-Pasaport and Bostanli-Pasaport have worked from early morning hours to late night hours in all days. In this study, amounts of

Table 2: The Fuel Amounts used in Ships and Ferries for 2005 in the bay, m³

	PASSENGER SHIPS								FERRIES				
Months	**YALOVA 1**	**KORDON**	**9 EYLÜL**	**ALAYBEY**	**BERGAMA**	**İ.ALYANAK**	**GÖLCÜK**	**TOTAL**	**ESENKÖY**	**EMİNÖNÜ**	**SALACAK**	**TOTAL**	**GENERAL TOTAL**
January	31.4	9.8	29.6	25.9	7.6	0.1	23.8	128.1	73.9	1.0	42.4	117.2	245.4
February	32.9	27.7	11.3	23.8	7.4	0.1	17.7	120.9	72.1	0.2	41.9	114.1	235.1
March	36.4	36.1	29.6	26.2	9.0	0.1	4.6	142.1	87.7	0.0	47.7	135.4	277.4
April	37.5	32.8	28.2	0.1	9.4	0.0	26.1	134.1	81.0	0.2	38.9	120.1	254.1
May	22.2	31.2	26.9	0.2	7.5	1.2	30.9	119.9	75.8	35.6	13.6	125.0	244.9
June	26.2	31.8	23.0	0.0	9.5	7.6	28.5	126.7	78.5	47.8	0.0	126.4	253.1
July	13.8	34.4	25.9	1.0	10.2	12.1	26.5	123.8	52.6	52.6	27.8	133.0	256.8
August	41.6	15.6	11.6	26.1	12.0	11.6	27.7	146.1	20.8	51.3	54.6	126.7	272.8
September	27.5	31.3	26.6	27.9	7.1	4.0	0.9	125.2	81.7	32.8	19.0	133.6	258.8
October	27.5	30.2	25.8	26.4	8.0	0.0	1.5	119.3	91.7	13.9	41.3	146.9	266.2
November	28.8	27.3	7.6	24.4	2.2	2.4	13.0	105.6	104.5	28.8	15.2	148.5	254.1
December	39.8	30.3	0.2	28.0	11.6	0.0	17.4	127.3	97.1	30.4	26.3	153.8	281.1
Total	365.6	338.4	246.3	209.9	101.4	39.1	218.4	1519.1	917.4	294.6	368.7	1580.7	3099.8

Table 3: The Numbers and Weights of the Ships Coming to Izmir Harbour

	2000	**2001**	**2002**	**2003**	**2004**	**2005**
Numbers of Ships	2757	2574	2645	2628	2644	2461
Total Weights (Gross Tonnage)	21811056	22388615	26614773	29139815	32175714	29048146

Table 4: Baseline Emission Factors for Uncontrolled Diesel Engines (EEA, 2005), g/kWh

POLLUTANT (g/kWh)	**Power Range in kW**							
	0-20	**20-37**	**37-75**	**75-130**	**130-300**	**300-560**	**560-1000**	**>1000**
NO_x	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4
CO	8.4	6.4	5.1	3.8	3.0	3.0	3.0	3.0
NMVOC	3.8	2.9	2.3	1.7	1.3	1.3	1.3	1.3
PM	2.2	1.8	1.5	1.2	1.1	1.1	1.1	1.1

Table 5: Bulk Emission Factors for Diesel Engines, g/kg fuel (EEA, 2005)

Diesel Engines (g/kg fuel)	NOx	NM-VOC	CO	PM
Inland waterways	42.50	4.72	10.90	4.12

emissions of air pollution arising from all these vessels were estimated throughout a year.

The data including vessel numbers, vessel properties, engine specifications, fuel consumptions, voyage periods, voyage numbers, cargo weights, etc. were collected. Emissions of NO_x, CO, VOC and PM were calculated by using the data collected and the emission factors from EEA/CORINAIR databaser (EEA, 2005). Selected emission factors are given Tables **4** and **5**.

4. RESULTS AND DISCUSSIONS

The emissions caused by ships and ferries making public transportation in Izmir Bay are calculated by emission factors. Total monthly emissions calculated for 2005 are given in Figure **2**.

The total emissions emitted from the ships coming to Izmir harbour were calculated by using emission factors given according to engine power range. It is assumed that the engine powers of the ships coming to the harbour were bigger than 135 kW. Figure **3** shows total emissions due to national and international trading.

The maritime traffic was studied in two groups. Ships and ferries making public transportation as the first group and big transport ships coming for trade purposes to Izmir Harbour as the second group were determined. Some personal vessels belong to private sectors and fishing boats in Izmir Bay were not included in the study due to lack of data. When the emissions from these vehicles are added, total emissions in the bay will increase a little.

The emissions emitted by the ships and the ferries making public transportation were estimated as 12 tons/year for PM, 112 tons/year for NOx, 60 tons/year for CO, 29 tons/year for VOC. On the other hand, emissions caused by the transport ships coming to Izmir Harbour were estimated as 24 tons/year for PM, 314 tons/year for NOx, 65 tons/year for CO and 30 tons/year for VOC. Total emissions emitted to the atmosphere in 2005 were found 36 tons/year for PM, 426 tons/year for NOx, 125 tons/year for CO and 59 tons/year for VOC.

Emissions emitted by road transportation in the emission inventory prepared for Izmir Metropolitan area in 2000 (Elbir and Müezzinoğlu, 2004) were founded as 2081 tons/year for PM, 2519 tons/year for SO_2 and

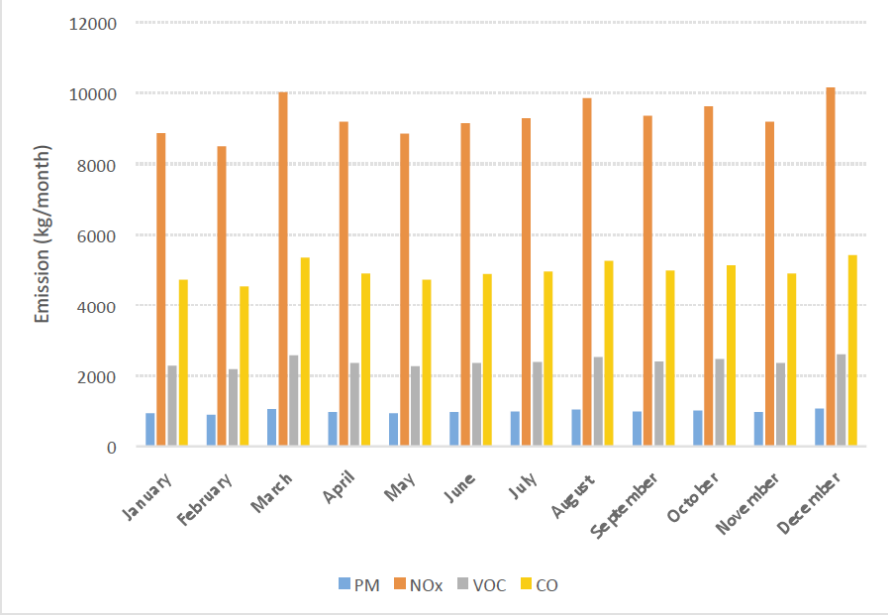

Figure 2: Total emissions emitted by ships and ferries making public transportation in Izmir Bay, kg/month.

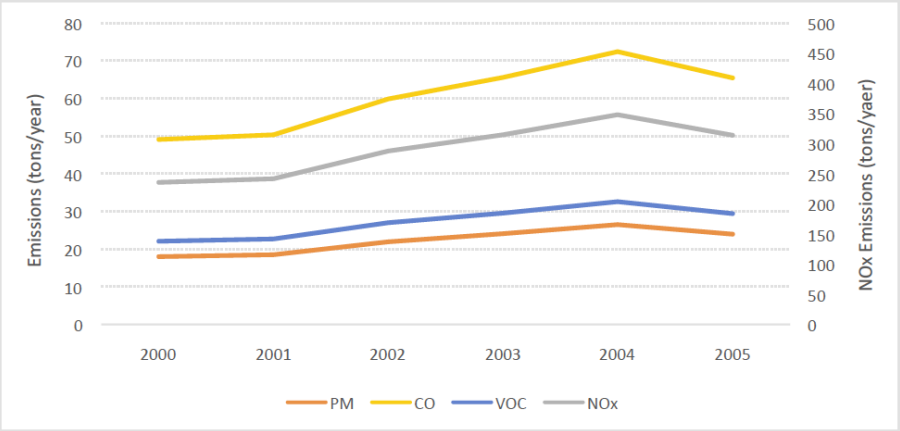

Figure 3: Total emissions due to transport ships coming to Izmir harbour, tons/year.

29711 tons/year for NOx. It is seen that emissions of PM and NOx are about 58 and 70 times respectively higher than maritime emissions in the city. This is expected situation in a city which provides transport with road and has 3 million populations.

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