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AIR POLLUTION FROM THE MARITIME TRANSPORT IN THE ROMANIAN BLACK SEA COAST

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ABSTRACT

The economic activities carried out in Romania's Black Sea jurisdiction are numerous and diverse. The water transport activity is highlighted by the important quantities of goods transiting the Romanian ports in the trade between Africa, Asia and Europe. In recent years, is added the exploitation of marine resources on the continental shelf. These activities will permanently involve water transport as an integral part of the logistics chain associated with offshore activities (platform supply, operation and maintenance work etc.).

Therefore, the latest reports from the International Maritime Organization show that these activities are an important source of air pollution, ship's pollutant emissions affecting human health and the environment. Literature mention that more than 70% of ship emissions, especially greenhouse gases, occur in the coastal area in a "band" of up to 20 nautical miles from the coast.

In this context, the paper proposes the implementation of an innovative solution for the monitoring of ship gas emissions, which will allow the management of this problem in the Western Black Sea area. The research conducted has developed a mathematical model and a software solution.

The paper has a complex approach in which a database has been created, with the vessels that have passed through the area under review, a database that can be permanently updated. Centralized information in the database is the input for the software solution, which determines the fuel consumption and emissions of pollutants from the vessels in the area for various analysis periods. All these measures allow the outline of the "footprint" for each polluting vessel. The results obtained can be used both for environmental impact assessment and for setting environmental standards by national regulators, depending on a set of predefined parameters that characterize the ship: tonnage, propulsion power and engine type.

Key-Words: air pollution, maritime transport, monitoring, Black Sea.

AIMS AND BACKGROUND

It is known that between 85-90% of international trade is achieved by means of water transport. This continues to be the cheapest mode of transport, which is at the same time an indispensable factor in meeting demand for goods and services. Naval accidents, collisions or failures, with explosions and fires of tanks and oil platforms, can have a negative impact on the environment. In addition, ship-borne emissions contribute more than 60,000 deaths globally, mainly in coastal and seaside areas (Corbett et al., 2007). The explanation is very simple, maritime transport is characterized by high fossil fuel consumption and, implicitly, a high level of gas emissions. These emissions are mainly represented by: carbon oxides (CO and CO_2), particulate matter (PM), volatile organic compounds (VOCs), nitrogen and sulfur oxides (No_x and SO_x). These atmospheric pollutants have a major impact on the environment and marine and coastal ecosystems, but especially on the populations in these areas (Rosu et al., 2016; Falup et al., 2014). To prevent marine pollution, the International Maritime Organization adopted the International Convention for the Prevention of Pollution from Ships, MARPOL 73/78, and Annex VI to this Convention regulates the issue of air pollutants.

From this perspective, air quality issues related to emissions from shipping have been reported globally (Jalkanen et al., 2012; Mueller et al., 2015; Song, 2014) and regional level (Zis et al., 2014; Nicolae et al., 2015; Im et al., 2013). On the other hand, harbor activity cannot be neglected because the technical means used in port logistics services involve the release of large amounts of emissions into the atmosphere (Maragkogianni, Papaefthimiou, 2015; Nicolae et al., 2014; Zhao et al., 2013).

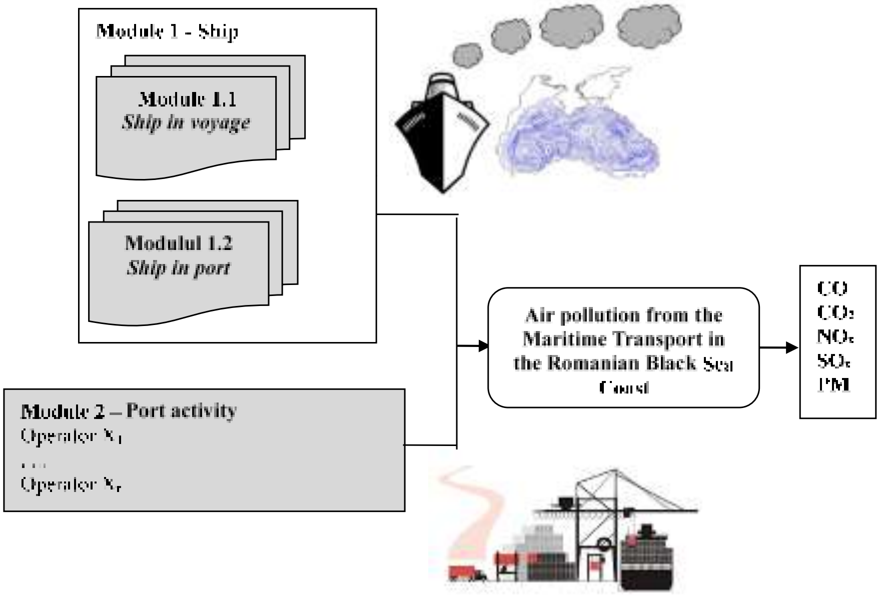

Fig. 1. Solution for monitoring air pollution due to maritime transport in the Romanian Black Sea coast.

The paper proposes an innovative solution for the monitoring of atmospheric pollution due to the maritime transport in the Romanian Black Sea coast, figure 1. The mathematical model and the associated software solution were developed within the project PSCD 143/2016 (SIMEN - Innovative solution for monitoring ship gas emissions) and other previous research.

EXPERIMENTAL

At the design stage of the model, two sources of atmospheric pollution were identified: emissions from ships, module 1 (M_1), and emissions from port activity, module 2 (M_2). In the case of *Module 1 - Ship*, a database was created with the vessels that passed through the area under consideration, containing *Module 1.1 - Ship in voyage* and *Module 1.2 - Ship in port*.

For each ship were centralized the informations that underly the software solution, Figure 2. For the period 2010-2016 the quantities of M_1 pollutants associated with the fuel consumed by the vessels that crossed the Romanian Black Sea coast and/or operated in the port of Constanta were considered.

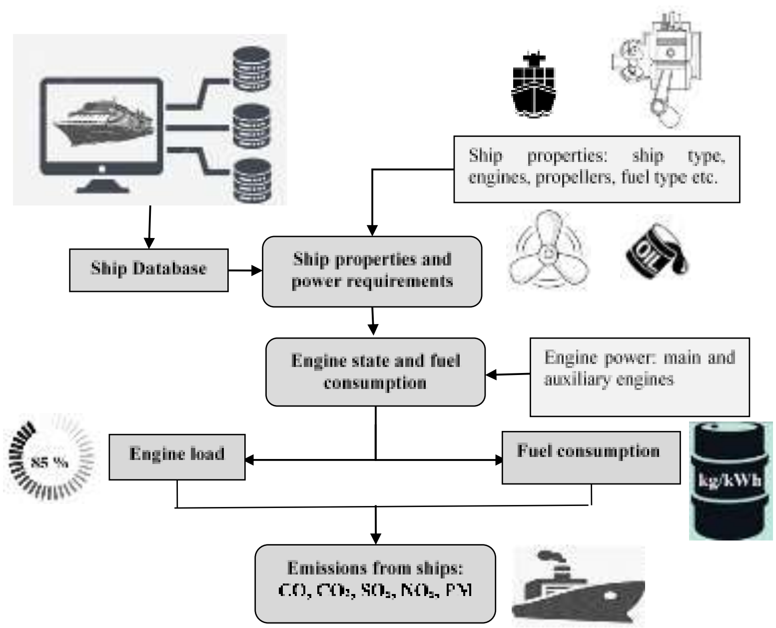

Fig. 2. Module 1 - The ship.

Most ocean-based emission estimation methods are based on models which consider: ship type, characteristics (dimensions, construction elements), distance traveled in the area under consideration, characteristics of the main propulsion system and auxiliary power system characteristics (type of engine, installed power, fuel type, fuel consumption). The information has been integrated into a calculation methodology that allows the determination of the following types of emissions: coastal voyage emissions (last 12 nautical miles before entering port), emissions during ship's stationing in the port area, emissions from Diesel generators and emissions resulting from the loading/unloading of oil tankers.

For *Module 2 - Port Activity*, another database was created, which included the sources of atmospheric pollution present in the port. There were included for each specialized terminal the cargo handling equipment, the associated diesel rail freight, the inland transport system (tractors, trailers, etc.) and auxiliary vessels (harbor tug boats, boats).

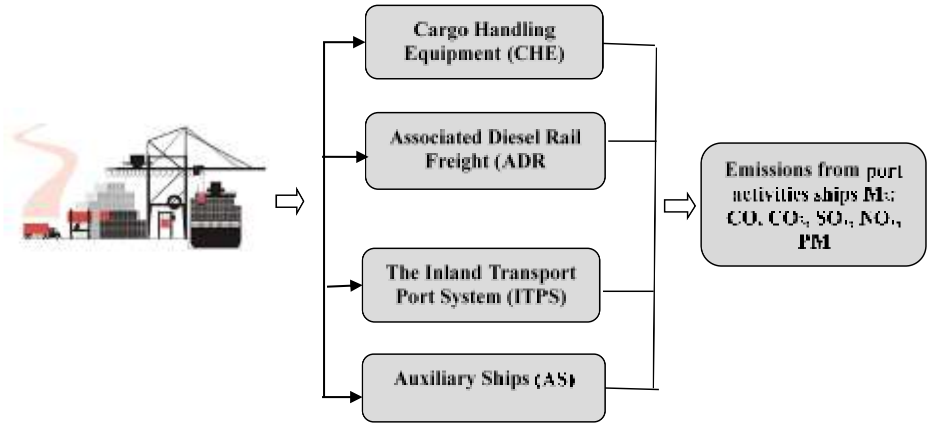

Fig. 3. Module 2 - Port activity.

Further, based on the statistical records for Constanta port, freight traffic was determined for each cargo type (general cargo - 1; container - 2; liquid bulk/ tanker - 3; bulk carrier - 4) and the number of ships operated (N_i), table 1.

Table 1. Traffic by type of goods in Port of Constanta during 2010-2016 (tons) (authors contribution after www.portofconstantza.com).

Year	General cargo		Containers		Liquid bulk		Dry bulk		Total /year	
	Traffic	N_1	Traffic	N_2	Traffic	N_3	Traffic	N_4	Traffic	$\approx N_T$*
2010	3307669	3145	5887879	523	11210940	647	27157391	419	47563879	5202
2011	4105327	2879	6517667	577	10616509	632	24732592	401	45972095	4874
2012	4232871	2692	6680107	651	10014672	673	29657012	439	50584662	5057
2013	3597556	2525	6543354	579	10090966	636	34906181	533	55138057	4833
2014	3680744	2143	6778884	578	12516199	719	32666083	558	55641910	4774
2015	3998471	1971	6849564	610	12203606	668	33285131	589	53336772	4605
2016	3675141	1812	6897354	684	13662917	665	35189409	607	59424821	4331
Total	26597779	17167	46154809	4202	80315809	4640	217593799	3546	370662196	33676

** Remark: From this table, out of the total number of vessels, passenger ships and other vessels not falling under the four types mentioned above have been excluded.*

In the next step, centralized information in the database is the input for the software solution. Using calculation methodology for different analysis periods, fuel consumption, ship emissions and pollution from port activity can be determined.

RESULTS AND DISCUSSION

The research methodology allows assessing the impact of maritime transport activity in the form of air pollution/air pollution for any type of cargo that is operated in the port of Constanta. Table 2 summarizes the results obtained from the two modules in the case of general goods (to which index 1 is allocated). The following are highlighted: the number of general cargo vessels (N_1), annual traffic of goods, the amount of fuel consumed in the analysis area, ship emissions (M_{11}) and port activity emissions (M_{21}).

Table 2. Emissions from general cargo vessels (kilotons/year, kt/yr).

Yr/Var.	Unit	2010	2011	2012	2013	2014	2015	2016	Total
General cargo (1)									
N_1	-	3.145	2.879	2.692	2.525	2.143	1.971	1.812	17.167
Traffic	kt	3.308	4.106	4.233	3.598	3.681	3.999	3.675	26.599
Fuel	kt/yr	166	152	142	132	113	102	99	906
Emissions from ships M_{11}									
CO	kt/yr	12	10.9	10.2	9.93	9.27	9.06	8.79	70.15
CO_2	kt/yr	51.57	64..21	63.17	53.6	54.2	59.3	53.31	399.36
SOx	kt/yr	90.24	111.9	116.34	98.6	99.2	107.4	99.03	722.71
NO_x	kt/yr	9.19	8.41	7.87	7.1	6.9	7.03	6.98	53.47
PM	kt/yr	0.19	0.26	0.27	0.21	0.22	0.24	0.22	1.61
VOC	kt/yr	0.38	0.47	0.45	0.39	0.41	0.43	0.38	2.91
Emissions from port activities M_{21}									
NO_x	kt/yr	4.67	4.23	3.87	3.62	3.51	3.57	3.56	27.03
PM	kt/yr	0.04	0.06	0.06	0.03	0.03	0.04	0.04	0.66
VOC	kt/yr	0.58	0.72	0.69	0.57	0.59	0.6	0.56	4.31

Total emissions, for all ships and all goods operated, were determined using the M_1 and M_2 modules, and centralized in table 3.

Table 3. Emissions from all ships (kilotons/year, kt/yr).

Yr/Var.	Unit	2010	2011	2012	2013	2014	2015	2016	Total
N	-	5.202	4.874	5.057	4.833	4.774	4.605	4.331	33.676
Traffic	x 10^6 kt	≈ 47.56	≈ 45.97	≈ 50.58	≈ 55.13	≈ 55.64	≈ 53.33	≈ 59.425	≈ 370.662
Fuel	kt/yr	≈ 620	≈ 593	≈ 611	≈ 581	≈ 577	≈ 569	≈ 546	≈ 4.097
Emissions from ships M_1									
CO	kt/yr	2.06	1.93	2.019	1.91	2.008	1.987	1.716	13.63
CO_2	kt/yr	632.7	592.97	615.47	588.01	584.75	575.18	527.25	4.166.33
SOx	kt/yr	10.1	9.465	9.823	9.534	8.931	8.847	8.416	65.116
NO_x	kt/yr	17.17	16.091	16.703	15.957	15.868	15.609	14.308	111.706
PM	kt/yr	1.42	1.37	1.41	1.36	1.35	1.29	1.21	9.41
VOC	kt/yr	0.442	0.416	0.429	0.410	0.408	0.401	0.379	2.885
Emissions from port activities M_2									
NO_x	kt/yr	4.37	4.22	4.65	5.06	5.12	4.93	5.46	33.81
PM	kt/yr	0.534	0.515	0.567	0.618	0.624	0.598	0.666	4.122
VOC	kt/yr	0.612	0.591	0.652	0.709	0.715	0.686	0.764	4.729

The results show that it can be determined the quantity of emissions corresponding to sea transport, relative to one ton of cargo passing through the port, table 4.

Table 4. The footprint of shipping over a ton of cargo carried.

Emissions corresponding to sea transport	Traffic	CO	CO_2	SO_x	NO_x	PM	VOC
	x 10^6 kt/yr	kt/yr	kt/yr	kt/yr	kt/yr	kt/yr	kt/yr
2010							
2010	47.56	2.06	632.7	10.1	21.54	1.954	1.054
Footprint	-	0.043E-6	13.303E-6	0.279E-6	0.453E-6	0.041E-6	0.022E-6
2016							
2016	59.425	1.716	527.25	8.416	18.868	1.876	1.143
Footprint	-	0.029E-6	8.873E-6	0.142E-6	0.317E-6	0.031E-6	0.019E-6

CONCLUSIONS

The results show a relative stagnation of emissions from maritime transport for the period 2010-2016. This is partly due to the fact that from 2010 to 2016 the number of ships operated or in transit through Constanta port is decreasing. The explanation is quantitative, the number of general cargo ships declining year by year, while the number of other types of vessels is slightly increasing (container ship, tanker, bulk carrier). However, the volume of goods transported is on an increasing trend. Thus, the footprint associated with maritime transport reflects the impact that it has on the environment. Research shows that from a qualitative point of view, measures are needed to reduce emissions of pollutants for all vessels located in the port area. In this regard, naval/port authorities should promote administrative measures to facilitate monitoring of ship emissions and identification of substandard, highly polluting ships. The same measures should also apply to port operators in reducing the amount of pollutants released into the atmosphere.

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