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SIMEN - INNOVATIVE SOLUTION FOR MONITORING EXHAUST EMISSIONS FROM SHIPS

Florin-Marius NICOLAE[1]
Ionela BADEA[2]
Andrei BĂUTU[3]
[1]. Associate Professor Ph.D., Department of Naval and Port Engineering and Management, "Mircea cel Bătrân" Naval Academy, Romania, florin.nicolae@anmb.ro
[2] B.Sc. Student, Department of Naval and Port Engineering and Management, Naval Academy "Mircea cel Bătrân", Romania
[3] Lecturer Ph.D., Department of Navigation and Naval Transport, Naval Academy "Mircea cel Bătrân", Romania

Abstract: *The environmental protection is a critical issue for the global maritime industry. Maritime transport contributes significantly to air pollution, especially in coastal areas. Over 70% of emissions from ships, especially greenhouse gases are produced in the coastal zone at a distance of about 400 km from the coast. Air pollution from ships has been at the center stage of discussion by the world shipping community at least during the last decade. The purpose of this paper is to develop an innovative solution for monitoring gas emissions from ships, a software solution for monitoring data on emissions from shipping in the Western Black Sea.*
Keywords: *ships, emissions, monitoring, Black Sea*

Literature review

Shipping transport remains the cheapest way of transport, being an indispensable factor for demand of goods and services, given that it achieves more than 85% of international trade. Therefore, shipping transport is characterized by high fuel consumption and thus a high level of greenhouse gas (Nicolae et al., 2014). According to Annex VI of MARPOL 73/78, these emissions are mainly represented by: diesel exhaust, particulate matter (PM), volatile organic compounds (VOCs), nitrogen oxides (NO_x), ozone and sulfur dioxide (SO_2), (IMO, 2010).

Shipping transport contributes to air pollution, especially in areas near land. Different studies show that approximately 70% of emissions from ships, especially greenhouse gases are produced in the coastal zone in a "strip" of about 400 km from the coast (Corbett et al., 2007).

This statement is particularly important, given that a large part of the main navigation routes are concentrated in the western part of the Black Sea Basin as indicated in Figure 1.

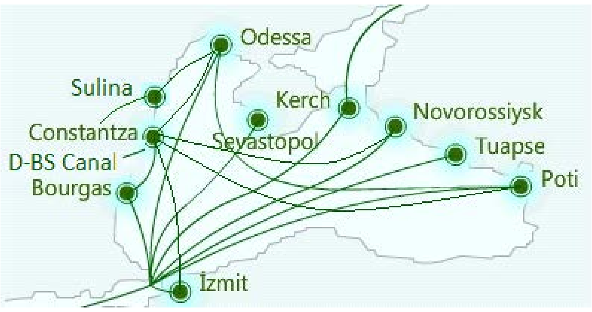


Figure 1. The main shipping routes of the Black Sea (Apetroaiei & Nicolae, 2012)

Several reports assess the emissions released into the atmosphere through shipping in the Black Sea and adjacent areas, Table 1.

Area	NO_x	SO_2	CO_2	HC	PM_{total}	Source
Mediterranean Sea	1,76	1,408	93,6	61	172	ILASA, 2007
Marmara Sea	111	87.2	5450	-	4,8	Deniz & Durmușoglu, 2008
Black Sea	89	65	3,85	3	8	ILASA, 2007
Black Sea	85.5	61.6	4,61	3	7,4	Nicolae, 2012
Black Sea, Constanta	8	77	44	-	0,16	Nicolae, 2014

Table 1. Comparison of emissions of the ships on the Black Sea regions (kilotons/year, kT/y)

Investigation and monitoring sources of pollution from ships is done according to several variables, among them: the seaworthiness of the vessel, type of the ship, type and power of the propulsion system installed, type of fuel used, etc. (Corbett et al., 2004) (Endersen et al., 2005) (Trozzi & Vaccaro, 1998).

A large part of the main navigation routes are concentrated in the western part of the Black Sea Basin (Figure 1). This is a vulnerable ecosystem of the world in terms of air pollution through gases from ships. Because of the shipping transport in Black Sea area, important quantities of greenhouse gas were evacuated: 0.0855 Mt NO_x, 0.0616 Mt SO_2, 4.614 Mt CO_2, 0.003 Mt HC and 0.0074 Mt PM_{total}.

This paper proposes a software solution for monitoring data emissions from shipping in the Western Black Sea. For this, it was created a database which can be continuously updated and contains vessels that sail in this area. The centralized information from the database represent entries for SIMEN software solution, which are used to determine fuel consumption and the emissions from ships in the area, for various periods of analysis.

Database of ships sailing in the western Black Sea

To identify and locate vessels in Western Black Sea we will use the Automatic Identification System (AIS) that allows monitoring ships and centralization of information relating to the identification, location, position and speed of the ships.AIS automatically transmits information from navigation sensors of ships through a VHF built in transmitter. Regularly, other information is transmitted, such as: vessel name or call sign.

All these signals are received by AIS receivers mounted either on another vessel or on land systems. The information received can be displayed graphically and the positions of other vessels can be visualized as on a radar screen. These data is also collected by other entities for various purposes. Some companies offer commercial services for fleet monitoring via internet sites like www.marinetraffic.com or www.fleetmon.com. These sites provides essential information about the ships: name, type of the vessel, length, width, statute, speed, tonnage, flag, year of construction, vessel position, information about voyage and history of itineraries.

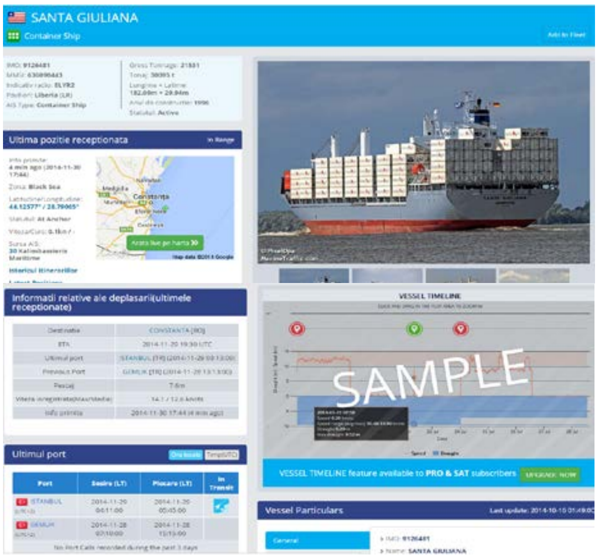


Figure 2: Example of information available about ships

Data was retrieved from such sites through a HTTP request to a specific URL address. Data is encoded using JavaScript Object Notation (JSON) format that uses human readable text to transmit data between a server and a web client. This is an independent format data and libraries for encoding and decoding JSON data are available in many programming languages. In order to process the JSON data retrieved about vessels and create the database, we used PHP programming language. The main functions used to implement the program that process the data are:

- file_get_contents – this is the simplest method to read the contents of a file (or URL address) into a string.
- json_decode - converts the JSON text into PHP data
- file_put_contents - write a string to a file.

The processed data were saved into comma separated files that were then imported into Microsoft Excel (Figure 3). Every file contains various data about ships activity: the ID of the vessel on Marine Traffic website (column A), latitude (column B), longitude (column C), ship name (column D), home country (column H), timestamp of data observation, and other information less relevant to this study.

	A	B	C	D	E	F	G	H
1	460736	4.250.468	2.759.143	MSC JAPA	7	113	2	PA
2	758726	4.319.017	2.764.733	MSC EQU/	7	272	0	LR
3	701995	4.319.153	2.766.175	SEA SHARI	7	0	1	CK
4	348079	4.318.773	2.767.765	AVANGAR	7	36	0	RU
5	21068	4.265.958	2.774.031	2070417	0	0	0	BG
6	299676	4.318.938	2.775.227	ARROW	7	131	0	PT
7	350930	4.318.861	2.775.635	PROFESSC	3	8	0	RU
8	125148	4.319.878	2.777.962	ISLANDCH	8	171	0	CY
9	765547	4.320.129	2.779.793	LADY MAF	7	354	0	TG
10	335007	4.256.617	277.985	FAHRI EKS	7	229	84	TR
11	120786	4.319.879	2.788.156	RK4	2	339	0	BG
12	21066	4.302.375	278.874	2070415	0	0	0	BG
13	467241	4.320.051	2.788.976	ARVELOR	7	136	0	VC
14	415879	4.319.553	2.789.912	ST ROSSA	7	11	0	PA
15	686675	4.318.623	2.790.018	CHERRY P(	7	102	0	HK
16	343534	4.505.901	2.790.176	SLAVUTICI	7	188	54	UA
17	21067	4.285.429	2.790.233	2070416	0	0	0	BG

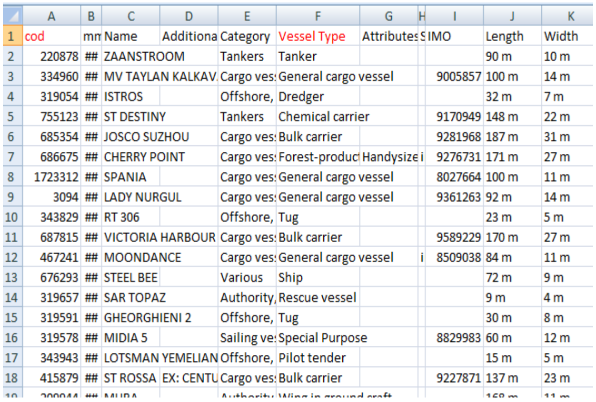
Figure 3: Example of data retrieve from www.marinetraffic.com using the program

The calculation of discharged emissions using the program requires knowing some basic information about ships such as tonnage of the vessel, type of ship, distance traveled, and type of engine.

Using the coordinates collected via AIS in the database at various moments in time (every 12 hours during the months of February and March), we calculated the distance traveled by ship according to the following PHP code:

```
$a = cos($lat1)*cos($lat2)*cos($long1-$long2);
$b = sin($lat1)*sin($lat2);
$c = acos($a+$b);
$distance = $c * 6371; // 6371 km = radius of the Earth
$total_distance = $total_distance + $distance
```

The rest of the information needed to calculate emissions (type of vessel, deadweight, gross tonnage, engine description) was retrieved using another program from the site http://www.fleetmon.com and save them also in an Excel file.



	A	B	C	D	E	F	G	H	I	J	K
1	cod	mn	Name	Additiona	Category	Vessel Type	Attributes	S	IMO	Length	Width
2	220878	##	ZAANSTROOM		Tankers	Tanker				90 m	10 m
3	334960	##	MV TAYLAN KALKAV.		Cargo ves:	General cargo vessel			9005857	100 m	14 m
4	319054	##	ISTROS		Offshore,	Dredger				32 m	7 m
5	755123	##	ST DESTINY		Tankers	Chemical carrier			9170949	148 m	22 m
6	685354	##	JOSCO SUZHOU		Cargo ves:	Bulk carrier			9281968	187 m	31 m
7	686675	##	CHERRY POINT		Cargo ves:	Forest-product	Handysize	i	9276731	171 m	27 m
8	1723312	##	SPANIA		Cargo ves:	General cargo vessel			8027664	100 m	11 m
9	3094	##	LADY NURGUL		Cargo ves:	General cargo vessel			9361263	92 m	14 m
10	343829	##	RT 306		Offshore,	Tug				23 m	5 m
11	687815	##	VICTORIA HARBOUR		Cargo ves:	Bulk carrier			9589229	170 m	27 m
12	467241	##	MOONDANCE		Cargo ves:	General cargo vessel		i	8509038	84 m	11 m
13	676293	##	STEEL BEE		Various	Ship				72 m	9 m
14	319657	##	SAR TOPAZ		Authority,	Rescue vessel				9 m	4 m
15	319591	##	GHEORGHIENI 2		Offshore,	Tug				30 m	8 m
16	319578	##	MIDIA 5		Sailing ve:	Special Purpose			8829983	60 m	12 m
17	343943	##	LOTSMAN YEMELIAN		Offshore,	Pilot tender				15 m	5 m
18	415879	##	ST ROSSA	EX: CENTU	Cargo ves:	Bulk carrier			9227871	137 m	23 m

Figure 4: Example of data retrieved from http://www.fleetmon.com using the program

Column E (Vessel type) include general cargo vessels, tanks, tugs, bulk carriers, transient, fishing vessels, Ro-Ro, vessels for the transport of liquefied gases, container ships, which are grouped in 5 categories that emissions calculation program makes available: solid bulk carriers, liquid bulk carriers, container ships, Ro-Ro / general cargo, and other vessels.
Depending on the characteristics of the engine taken from the site, they were grouped into categories: fast diesel, medium speed diesel, and slow diesel.
The database obtained was used by and existing program to calculate emissions. For vessels monitored during the analysis (in this case the analysis period was two months) we will know the amount of emissions produced and hence the volume of emissions from ships that contribute to air pollution.

Software solution for monitoring exhaust emissions in Western Black Sea

The calculation algorithm underlying the two methods for assessing the exhaust emissions from ships was developed by Trozzi and Vaccaro and applied in a number of projects and studies for the Black Sea (Nicolae 2012, Nicolae 2014). The simplified method is used to assess fuel consumption and emissions based on statistical evidence of vessel traffic on certain routes navigation. The detailed method uses databases on fuel propulsion systems and associated emission factors. To achieve software solution authors choose a tool easy to use and understand, to facilitate the construction of graphs and tables with the results. Therefore the software solution was based on Microsoft Excel platform.

Exhaust emissions calculation using the simplified method

If we want to use the simplified method to calculate the emissions we will select the button to the left and thereby opens the Excel sheet with the interface from Figure 5.

Simplified method needs the following inputs to calculate the emissions from ships:

1) Type of the vessel: solid bulk carrier, liquid bulk carrier, containership, Ro-Ro / general cargo, other ships;
2) The gross tonnage of the vessel;
3) Mileage (Nm);
4) Engine type: slow Diesel, medium speed Diesel, fast Diesel.

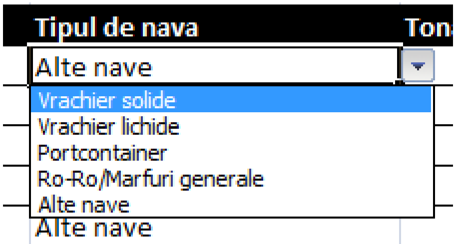


Figure 6: Selecting the type of vessel

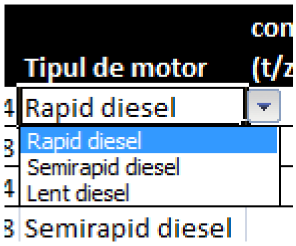


Figure 7: Selecting the engine type

Once entered all data entry the program will automatically calculate the value for fuel consumption in tones / day and the emissions, and displays them as shown in Figure 8.
After determining emissions from a ship or more ships we can do graphics for a better representation of the results. To illustrate this, we will consider three ships with the input data listed in Table 2.

Name of the vessel	Type of the vessel	Gross tonnage	Mileage	Type of the engine
FURTH	Containership	10308	738.71	Medium speed Diesel
DAY	Ro-Ro/General cargo	2516	139.66	Slow Diesel
WAPPEN VON STUTTGART	Liquid bulk carrier	5145	90.77	Fast Diesel

Table 2: Input data for ships taken as an example

For these vessels we will obtain the following results for fuel consumption and for the emissions of CO_2, CO, VOC, NO_x, SO_x and PM (Table 2). The results can be plotted as in Figure 9.

Fuel consumed (tons/day)	Quantity of NOx emissions (kg)	Quantity of CO emissions (kg)	Quantity of CO_2 emissions (kg)	Quantity of VOCs (kg)	Quantity of PM emissions (kg)	Quantity of SO_x emissions (kg)
32.29	56.96	7.39	3.20	2.40	1.20	55.96
16.76	9.88	0.84	0.36	0.27	0.14	6.36
18.75	6.71	0.86	0.31	0.29	0.14	5.37

Table 3: The results obtained for the example considered

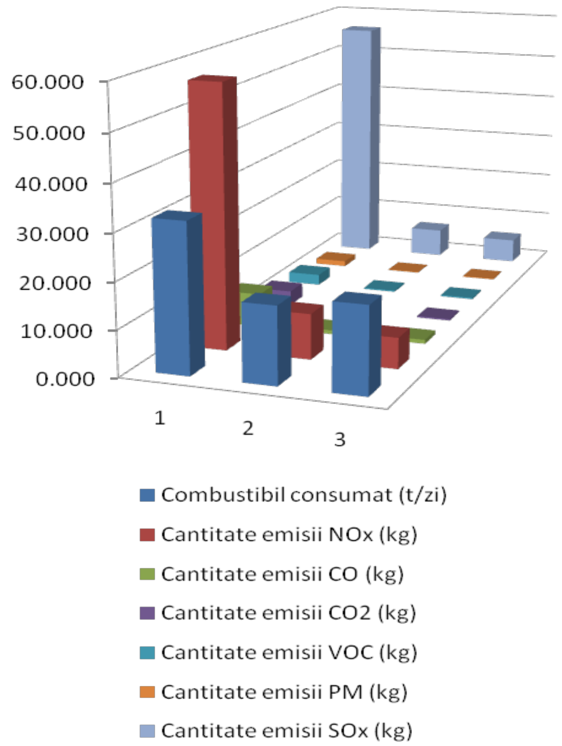


Figure 9: Graphical representation of the results

Exhaust emissions calculation using the detailed method

To calculate consumption and emissions with the detailed method we select the right button and open the Excel sheet from Figure 10.

To obtain results through detailed method we need the following inputs:

1) Type of vessel - we can select one of the following types: cargo ship, ferries with high speed, sailing vessel, passenger vessel, fishing vessel, containership, tug, Ro-Ro / general cargo, solid bulk carrier, liquid bulk carrier, other ships, all ships.
2) The gross tonnage;
3) Days of residence;
4) Type of stationary engine;
5) Days of maneuver;
6) The engine type for maneuver;
7) Days of voyage;
8) The engine type for voyage.

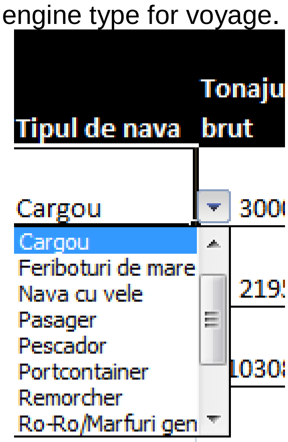


Figure 11: Choosing the vessel type

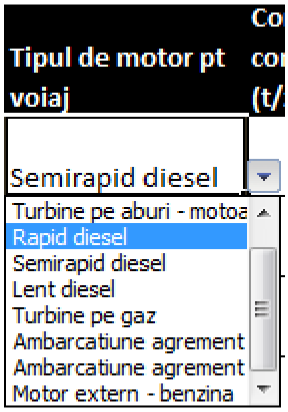


Figure 12: Choosing the engine type

As in simplified method by introducing input data we obtain values for fuel consumption (tons / day) and for the quantities of NO_x emissions (kg), CO (kg) CO_2 (tons) VOC (kg), PM (kg) and SO_x. The program offers the possibility of adding up the results. For a fleet of N ships we can calculate the total amount of fuel consumed and also the total quantities of each type of emissions.

CONCLUSIONS

The program developed is easy to use and can be used both in Windows, and in Mac OS systems. To facilitate interpretation of the results we can make graphics for fuel consumption and emissions. The results obtained using this program can be used to monitor emissions from shipping in different areas of analysis. The program can be used as a management tool in making decisions on the adoption of measures to reduce emissions from ships.

The database created and attached to the simplified method of the program is an important step in developing a monitoring solution. This database was created by recording ships which were sailing in the Western Black Sea during the analysis (in this case the analysis period was two months). For these ships we saved the necessary information to calculate fuel consumption and exhaust emissions, with the possibility of recalculating these parameters, depending on the changes made (mileage, speed etc).
The scientific approach can be improved by creating a database for the detailed method of calculation which requires more information: stationary days, maneuvering days, voyage days, several types of engines etc.

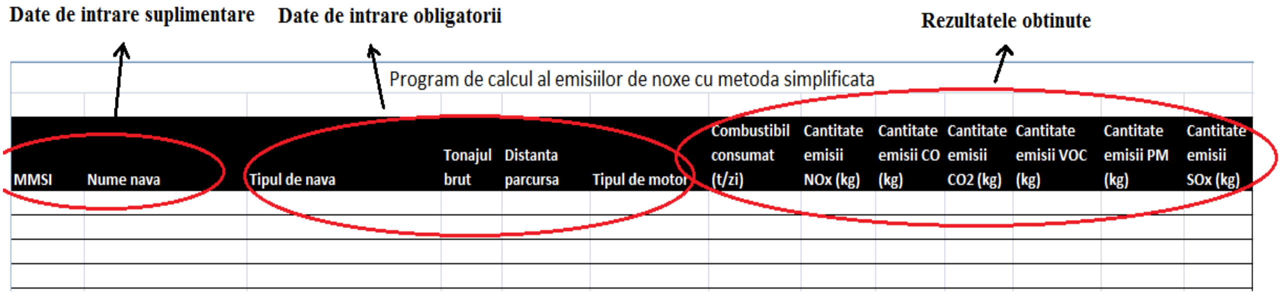


Figure 5: The program interface for simplified method

Program de calcul al emisiilor de noxe cu metoda simplificata

Nume nava	Tipul de nava	Tonajul brut	Distanta parcursa	Tipul de motor	Combustibil consumat (t/zi)	Cantitate emisii NOx (kg)	Cantitate emisii CO (kg)	Cantitate emisii CO2 (kg)	Cantitate emisii VOC (kg)	Cantitate emisii PM (kg)	Cantitate emisii SOx (kg)
MEDUZA 3	Alte nave	117	1.226270744	Rapid diesel	9.819	0.05	0.01	0.00	0.00	0.00	0.04
EMELYAN PUGACHEV	Alte nave	182	9.958016458	Semirapid diesel	9.878	0.33	0.04	0.02	0.01	0.01	0.33

Figure 8: Showing results for fuel consumption and emissions in simplified method

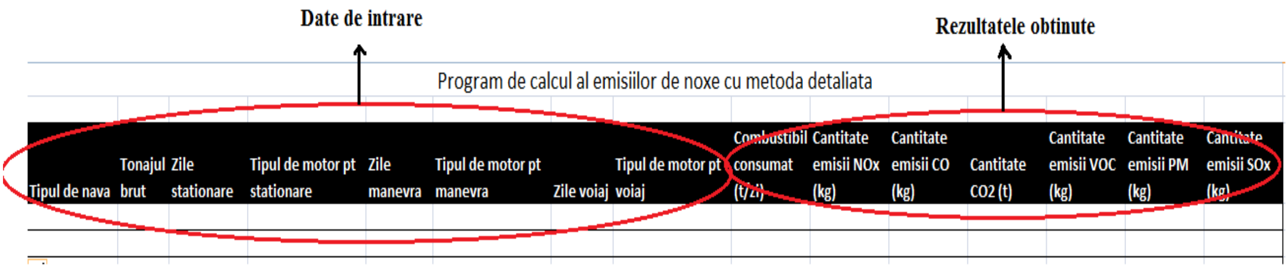


Figure 10: The program interface for detailed method

Tipul de nava	Tonajul brut	Zile stationare	Tipul de motor pt stationare	Zile manevra	Tipul de motor pt manevra	Zile voiaj	Tipul de motor pt voiaj	Combustibil consumat (t/zi)	Cantitate emisii NOx (kg)	Cantitate emisii CO (kg)	Cantitate CO2 (t)	Cantitate emisii VOC (kg)	Cantitate emisii PM (kg)	Cantitate emisii SOx (kg)
Vrachier solide	3000	2	Lent diesel	2	Rapid diesel	30	Rapid diesel	21.659	37.782	6.125	1.747	1.838	0.816	30.565
Remorcher	4500	3	Semirapid diesel	4	Semirapid diesel	15	Turbine pe aburi - motoare MDO	52.811	8.999	5.883	2.400	1.353	1.458	41.995
Total								**74.470**	**46.781**	**12.008**	**4.146**	**3.191**	**2.274**	**7[illegible]1**

Figure 13: Showing results for fuel consumption and emissions in detailed method

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