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THE IMPORTANCE OF THE REDUCTION OF AIR POLLUTION IN THE BLACK SEA BASIN

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ABSTRACT

This study will submit to the aspects concerning the need for reducing air pollution in the Black Sea basin, current objective at the global level and European as well, as a result of the effects of the more obvious on global warming, which has a series of indirect watch: extreme weather phenomena, increasing the level of the planetary ocean, the effects to the biodiversity in protected areas, etc. This type of activities shall take place at the global level and are to be found in practice.

To highlight the need to reduce pollution sources, the paper focuses on one of the main factors of air pollution in the Black Sea basin, namely shipping. The paper refers to a series of navigation routes used by ships passing through the Black Sea to reach one of the most important ports on the shores of this hydrographical area.

Keywords: air pollution, Black Sea, emissions from shipping, Danube Delta

1. INTRODUCTION

From a geographical point of view, the Black Sea is one of the world's most particular zones and it represents 3% of the total planetary ocean as a stretch, covering about 423,000 km^2, with a volume of 537,000 km^3 and a depth of up to 2211 m. It is a sealed sea that communicates with the planetary ocean only through the Bosporus Strait, being supplied with fresh water of important rivers, such as the Danube, the Dnieper, the Dniester, the Bug, the Don, the Kulan and other rivers. The Danube River flows into the Black Sea 59 % of the total fresh water by means of the greatest natural delta in Europe, the Danube Delta [3], [5], [7].

The need to reduce emissions from shipping and inland waterway transport is a must in the Black Sea area due to the globalization of shipping, accounting for 90% of the total volume of goods for sale in the geographical area. According to the data provided by Eurostat Russia, the Black Sea represents for EU-28 one of the most important partners in the maritime transport sector, with the largest volume of goods exported to Europe through the Black Sea and the Baltic Sea ports in 2016, liquid goods and, in particular, the oil products and crude oil [2], [17].

Maritime transport is recognized as being the main factor of pollution in the areas in which it is active, but especially in the coastal areas [8], [9], [10]. As compared to classical terrestrial transport systems, it is more efficient in terms of energy efficiency, but NO_x, SO_2 and PM emissions are much higher due to a lack of regulation, the quality of fuels used for combustion and, last but not leas, due to the sizing of these ships [11], [12], [13].

This issue is one of topical interest, being handled with great care at the United Nations through the specialized agency responsible for maritime safety and security, and for the prevention of marine and ocean pollution by ships, IMO (International Maritime Organization) [4].

As proof of the effect of pollution resulting from shipping, emission control areas appeared (ECA). These protected areas were regulated by Marpol Annex VI.

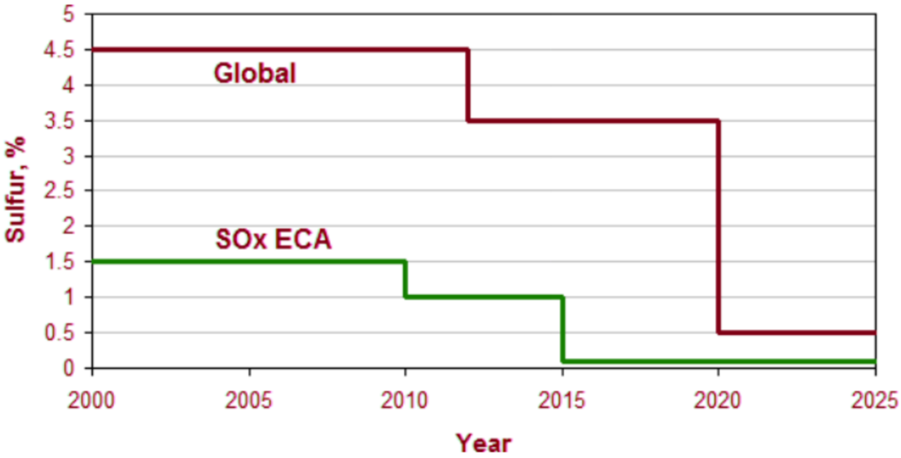

Fig. 1 Marpol annex VI fuel sulfur limits [4]

The EU has adopted directives for the Baltic Sea Area, Sulphur Emission Control Area (SECA). This means that, in these protected areas, by burning fuel, sulfur emissions should not exceed 0.1%. Previous regulation, which was active until 2015, provided 1%. The evolution of these regulations against pollution resulting from shipping is shown in Fig. 1 [4].

With regard to certain types of ships, they may not descend below a certain level of sulfur emissions, even if they are using alternative fuels with low sulfur content. In order to reduce the emissions of old ships, it is acceptable to install scrubbers or EGR (Exhaust Gas Recirculation) [4].

Outside the areas of the Sulphur Emission Control Areas (SECA), the percentage of sulfur emissions is currently 3.5%, but it is expected to be reduced to 0.5% by 2020, a matter that will be decided most likely in 2018.

Marine diesel engines generate significant emissions of NO_x, fine particulate matter ($PM_{2.5}$) and sulfur oxides (SO_x) [4].

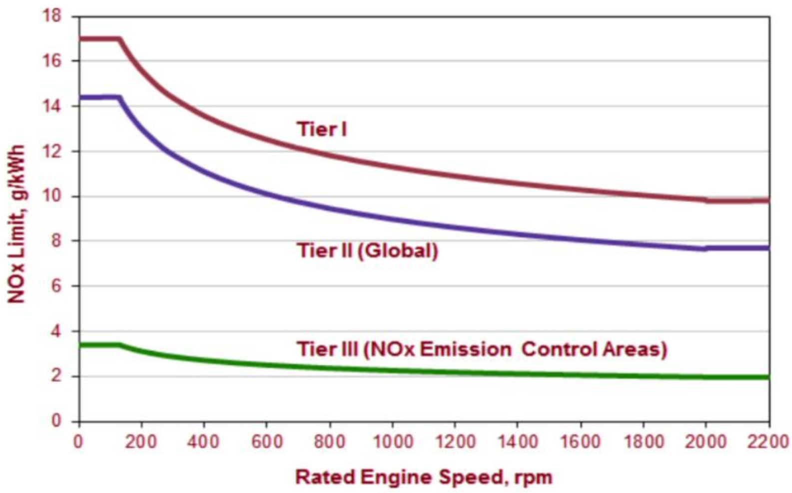

Fig. 2 Marpol annex VI NOx emission limits [4]

Since 2000, nitrogen emissions have been regulated in Marpol (Annex VI), so ships builded after January 1, 2000, have to comply with certain Tier I emission limits, for the specifications shown in Fig 2. In 2011, there was a new threshold, which regulates these emissions, which has been globally adopted, namely Tier II [4]. Starting from 2016, a new threshold was proposed and adopted, thus, a much more drastic emission reduction intended for protected areas.

2. UNESCO PROTECTED AREAS

Starting from 1990, the area of Danube Delta becomes an UNESCO "Biosphere Reserve". For this reason, the Danube Delta has been declared part of the universal natural heritage. This implies a protected area of more than 340,000 hectares, which represents the natural habitat for many species of birds and fish. Thus, more than 300 species of birds and 45 fish species are to be found in this protected area. Furthermore, the Danube Delta is the greatest natural delta in Europe [17].

The Srebarna Nature Reserve is a lake of freshwater close to the Danube River, ~~whith~~ having a surface larger than 600 ha. This place represents the natural habitat of almost 100 bird species that are usually nesting in this area, many of them being also very rare. Other more than 80 species of birds migrate and ~~and~~ find a home in this particular place in the wintertime. It may be also highlighted that the Dalmatian pelican, great egret, night and purple herons, glossy ibis and white spoonbill can be considered among the most rare and interesting species of birds that are living in the Srebarna Nature Reserve [17].

T**he Western Caucasus** is among the few large mountain areas of Europe that were not significantly affected by the human touch**.** This mountain chain extends along aproximately 275,000 ha and are located about 50 km north-east of the Black Sea. Wild animals are to be met in its subalpine and alpine areas covered by large mountain forests that have many features which are unique in Europe. There is also a wide ecosystem diversity, with many rare plants and fauna, and that is why this also represents not only one of the places of origin, but also the place where the European bison subspecies was reintroduced [17].

These three natural areas, which are protected by UNESCO, are graphically indicated on the map in Fig. 3 as green dots, having in proximity ~~find~~ their names, for an easy identification [17].

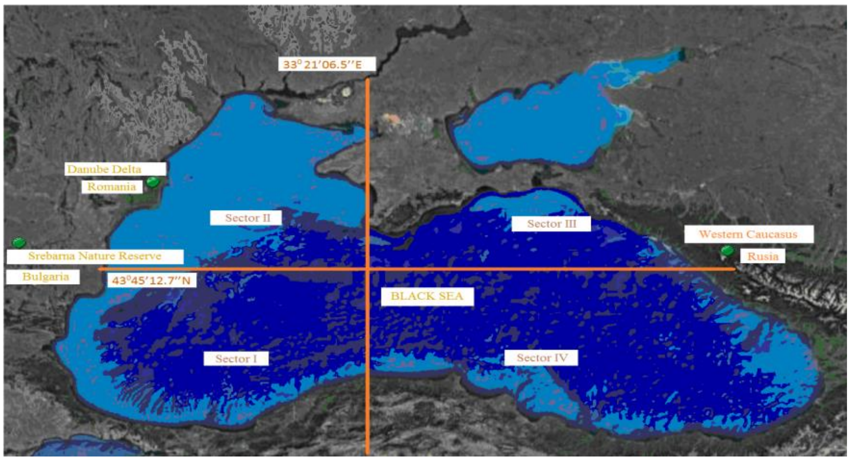

Fig. 3. Main four sectors in Black Sea and natural UNESCO protected areas location

3. WIND DIRECTION IN BLACK SEA BASIN

Figures 4 to 10 show a graphical representation of the air streams above the Black Sea, as generated by www.windfinder.com, for each day of the interval 05.06.2017-11.06.2017.

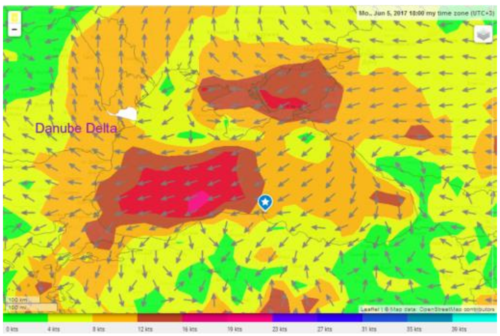

Fig. 4. Wind direction in Black Sea (05.06.2017)

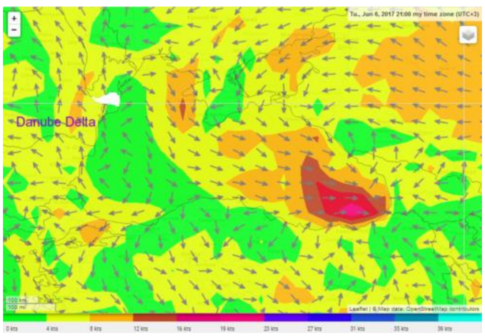

Fig. 5. Wind direction in Black Sea (06.06.2017)

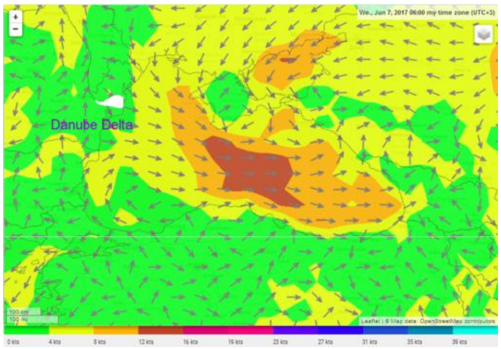

Fig. 6. Wind direction in Black Sea (08.06.2017)

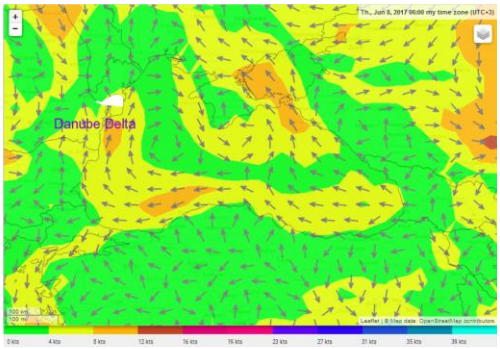

Fig. 7. Wind direction in Black Sea (07.06.2017)

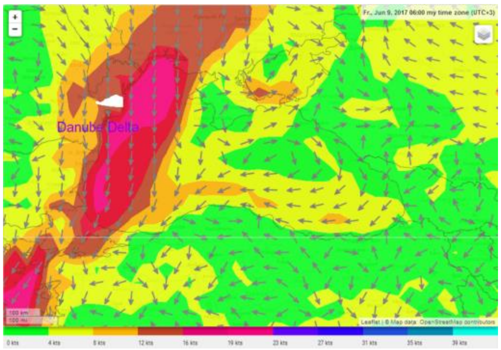

Fig. 8. Wind direction in Black Sea (9.06.2017)

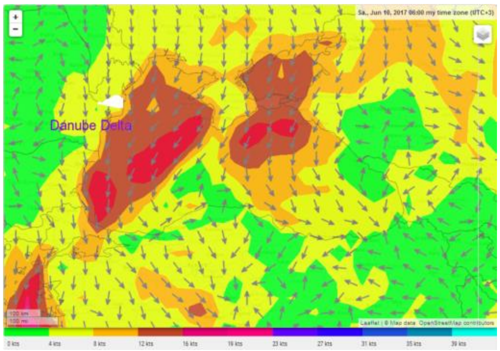

Fig. 9. Wind direction in Black Sea (10.06.2017)

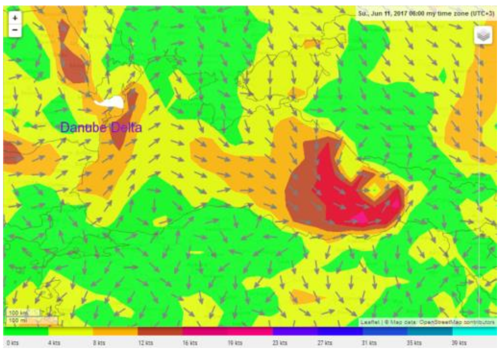

Fig. 10. Wind direction in Black Sea (11.06.2017)

The wind direction in the Black Sea basin was studied for 7 days, between 05.06.2017 and 11.06.2017, and the results graphically interpreted are as follows in Fig. 11. The result shows that, in more than half of the time studied, the Danube Delta protected area is affected to a lower or greater extent by the currents carrying the emissions from the combustion of diesel engines of vessels operating in the Black Sea, particularly in the sector II, related to the distribution in Fig. 3.

The Srebarna Nature Reserve may be affected in a lower proportion, as less than 50% of the winds could direct the toxic emissions to this protected area, but also the greater distance, over 100 km; shipping routes makes this area be naturally protected from the anthropogenic effects of shipping [14], [15], [16]. The Western Caucasus can be affected according to the graphical study in Fig. 11, in less than 15% of cases, the presence of the Caucasus Mountains creates an atmospheric air front that generally prevents air circulation in the E or N-E directions, in the third and fourth sectors, as delimited in Fig. 3.

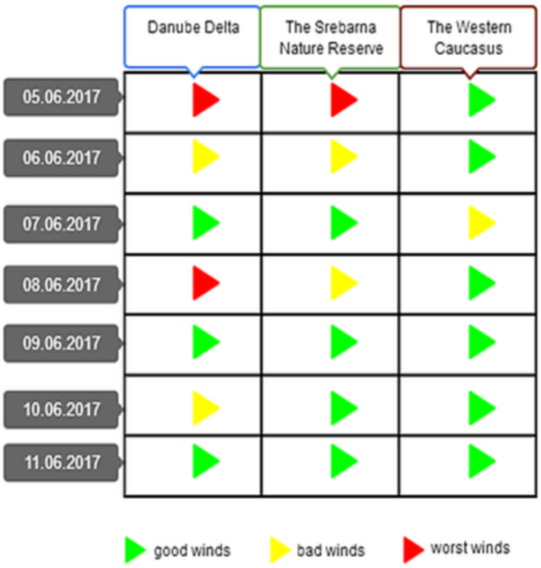

Fig. 11. Grafic of wind influence in the UNESCO protected areas.

4. SHIPPING ROUTES IN BLACK SEA

Using the satellite navigation tracking service, published by www.marinetraffic.com, the maritime traffic density was extracted between 2015-2016 in the Black Sea and coastal areas [6]. In Fig. 12, we plotted the main routes on deep sea water, used during this time span of the Black Sea area. It should be noted that coastal navigation is very active, but it can not be clearly represented as the navigable route and can be deduced from the map on the left side of Fig. 12.

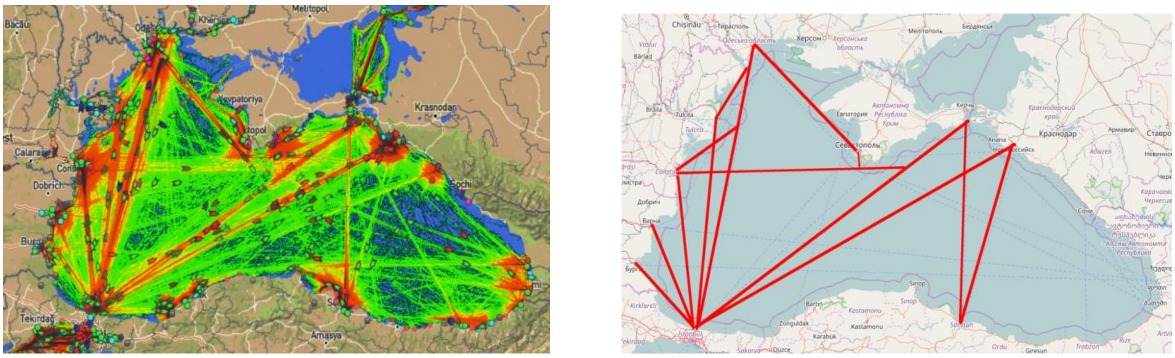

Fig. 12 Shipping routes in Black Sea, using traffic density in the period 2015-2016 [6]. Color code: Red – very high shipping density, Orange - high shipping density, Yellow - Average density of sea traffic, Green - Low Density of Maritime Traffic.

Using the information from the graphical representation in Fig. 12, the main sea routes in the Black Sea were drawn, taking into account the coastal navigation areas, whose density is very high, covering the shores in their entirety. The main waterways link the following points of interest, depending on the sectors delineated in Fig. 3: Sector I: Bosphorus Strait, Burgas, Varna; Sector II: Constanta, the navigable Danube, Odesa, Sevastopol; Sector III: Kerch Strait, Novosibirsk; Sector IV: Samsun, Trabzon, Poti.

4.1 Ships operating in Black Sea

In order to carry out a calculation of the emissions of chemical compounds of nitrogen and sulfur in the air, resulting from the combustion of naval diesel engines, the total number of vessels having certain characteristics in two different days (13.06.2017 and 15.06.2017) what appeared in the Black Sea basin, has been checked, in accordance with the data submitted by the marinetraffic.com [6].

Filters were applied on both days (Figs. 13 and 14), in which the length of the ships to be displayed was not less than 50 meters, or less than 2000 tones deadweight. Thus, in the Black Sea basin, there were about 740 active vessels on 13.06.2017 and 700 vessels on 15.0 6.2017 that were operating in the same geographical area.

Fig. 13. Filter used in marinetraffic.com 13.06.2017 [6]

Table 1. Ships operating in Black Sea, random chosen (13.06.2017) [6]

No.	Flag	Name	Type	L x B	Deadweight	Build
1	Grecia	Providence	Oil/Chemical Tanker	103x16	6450	2009
2	Sierra Leone	Princess H	General Cargo	92x14	2934	1985
3	Panama	Ibrahim Konan	General Cargo	108x18	8107	2006
4	Turcia	Nazlim	General Cargo	146x19	11300	1978
5	Rusia	Mekhanik Kharitonov	Tanker	141x16	5565	2011
6	Liberia	Sea Power	Bulk Carrier	225x32	74665	2001
7	Rusia	Kapitan Barmin	Oil Products Tanker	134x16	5742	2002
8	Rusia	Mekhanik Paramonov	Oil Products Tanker	141x16	5537	2011
9	Rusia	Kivach	General Cargo	105x16	3997	1985
10	Sierra Leone	Ranyus Sea	General Cargo	98x13	3732	1985
11	Panama	Tuna 1	RO-RO/ Vehicles Carrier	105x18	3297	1979
12	Malta	Sea Trader	General Cargo	127x16	6355	2007
13	Israel	Gb Pacific	General Cargo	102x15	582	1998
14	Liberia	Nordic Skagen	Bulk Carrier	185x30	33741	2010
15	Rusia	York	General Cargo	108x14	3201	1971
16	Panama	Lucky Spirit	Bulk Carrier	183x30	46570	1998
17	Hong Kong	Ocean Star	Bulk Carrier	177x28	32754	2007
18	Bahamas	Baker Spirit	Crude Oil Tanker	274x48	156929	2009
19	Marshall IS	Brentholmen	Chemical Tanker	144x22	16851	2010
20	Malta	Azov Mariner	Tanker	129x16	6623	1999
21	Moldova	UCF6	General Cargo	123x16	5185	2012
22	Bahamas	Ornak	Bulk Carrier	229x44	79677	2010
23	Malta	Seamagic	Crude Oil Tanker	249x44	116995	2007
24	Panama	Medi Segesta	Bulk Carrier	189x32	58730	2009
25	Azerbaijan	General Aslanov	General Cargo	108x16	5399	2005
26	Grecia	Aegean Horizon	Tanker	274x48	158738	2007
27	Rusia	Novopolye	General Cargo	115x13	3332	1992
28	St Vincent Grenadines	Barnet	General Cargo	139x16	6277	1989
29	Rusia	Sailqueen	General Cargo	113x15	3058	1991
30	Panama	Little Wind	General Cargo	107x13	3498	1976

Table 2. Ships operating in Black Sea, random chosen (15.06.2017) [6]

No.	Flag	Name	Type	L x B	Deadweight	Build
31	Rusia	Vityaz	Dredger	124x20	11602	1984
32	Togo	Adnan H	General Cargo	95x13	4226	1982
33	Malta	Sanar-7	Crude Oil Tanker	249x44	113424	2000
34	Togo	Blue Moon	General Cargo	97x17	7051	1983
35	Belize	Volgo-Balt-241	General Cargo	113x13	3171	1983
36	Rusia	Tigran Martirosyan	Tanker	99x15	4807	2006
37	Malta	Seref Kuru	General Cargo	125x20	13047	1987
38	Ucraina	Zvenigorod	General Cargo	185x44	2100	1963
39	Turcia	Muhammet Gumustas 2	General Cargo	77x13	3123	1982
40	Singapore	Knebworth	LPG Tanker	119x20	8584	2012
41	Panama	Petra II	Bulk Carrier	182x30	42284	1991
42	Moldova	Svyatoy Pyotr	Bulk Carrier	187x28	38110	1983
43	Rusia	Solidat	General Cargo	80x11	2155	1978
44	Marshall IS	Dem Five	General Cargo	176x29	31842	2002
45	Cook Is	Melissa	General Cargo	82x11	2267	1986
46	Grecia	Platium	Oil Products Tanker	183x33	45614	1996
47	Malta	Cassiopeia Star	General Cargo	172x29	32329	2005
48	Singapore	Maersk Bering	Oil/Chemical Tanker	175x29	29057	2005
49	Ucraina	Kilya	General Cargo	96x13	2157	1966
50	Cook Is	Bahar-K	General Cargo	120x17	8284	1993
51	Comoros	Streamline	General Cargo	108x15	3152	1978
52	Tanzania/Dr Congo	Fenix Oil/Natalie	Oil/Chemical Tanker	80x13	3212	1980
53	Belize	Donmaster Spirit	General Cargo	96x13	4294	2002
54	Sierra Leone	Day	General Cargo	114x13	3498	1976
55	St Vincent Grenadines	Great Arsenal	Bulk Carrier	169x25	26566	1997
56	Gibraltar	Vos Prince	Supply Vessel	80x18	3810	2016
57	Turcia	Tamrey S	Bulk Carrier	176x27	31025	1999
58	Ucraina	Deva Mariya	General Cargo	93x13	2072	1967
59	Liberia	NS LION	Crude Oil Tanker	248x43	115857	2007
60	Turcia	Metin Ka	Oil/Chemical Tanker	121x16	6308	2007
61	Liberia	Amphitrite	Oil/Chemical Tanker	182x27	39378	2006
62	Turcia	Ince Kastamonu	Bulk Carrier	189x32	56925	2010
63	Cipru	Orient Trader	Bulk Carrier	180x29	33757	2010
64	Tanzania	Ayatt	General Cargo	104x14	4244	1972
65	Grecia	Minerva Maya	Crude Oil Tanker	244x42	105709	2002
66	Turcia	Erdogan Senkaya	General Cargo	75x8	2429	1991
67	Panama	Magus	Crude Oil Tanker	269x46	149686	1993
68	Malta	M. Izmir	General Cargo	111x18	6624	1992
69	Palau	Atria	General Cargo	108x14	3177	1978

Fig. 14. Filter used in marinetraffic.com 15.06.2017

Using the same filters presented in Figures 13 and 14, a sample of 69 vessels was selected, representing 9.58% of the arithmetic mean of the two days. The 69 vessels were randomly chosen and Tables 1 and 2 were completed using the following information: flag, name, type, length and beam, deadweight and year of building. Table 1 contains information from June 13, 2017 (about 30 ships), while Table 2 contains information from June 15, 2017 (about 69 vessels).

In order to better visualize the situation of the fleet sailing in the Black Sea, it has plotted the chart in Fig. 15, using two defining components: the building year, to find out what the pollutant emissions norm was in force at that time and the length of the ship, to find out, according to the type of ship, which nominal power is installed on board the ship by means of Fig. 16.

Following an evaluation of the data in Fig. 15, it is found that: 14 vessels have a length of <100 m (20.28%), 30 ships have length 100 m <L <150 m (43.48%), 16 vessels have a length of 150 m <L <200 m (23.18%), 6 ships have length 200 m <L <250 (8.71%), 3 vessels have a length L> 250 m (4.35%), 5 ships are built after 2011 (7.24%), 10 ships are built after 2010 (14.48%), 31 vessels are built after 2000 (44.93%), the difference of 55.07% being older ships.

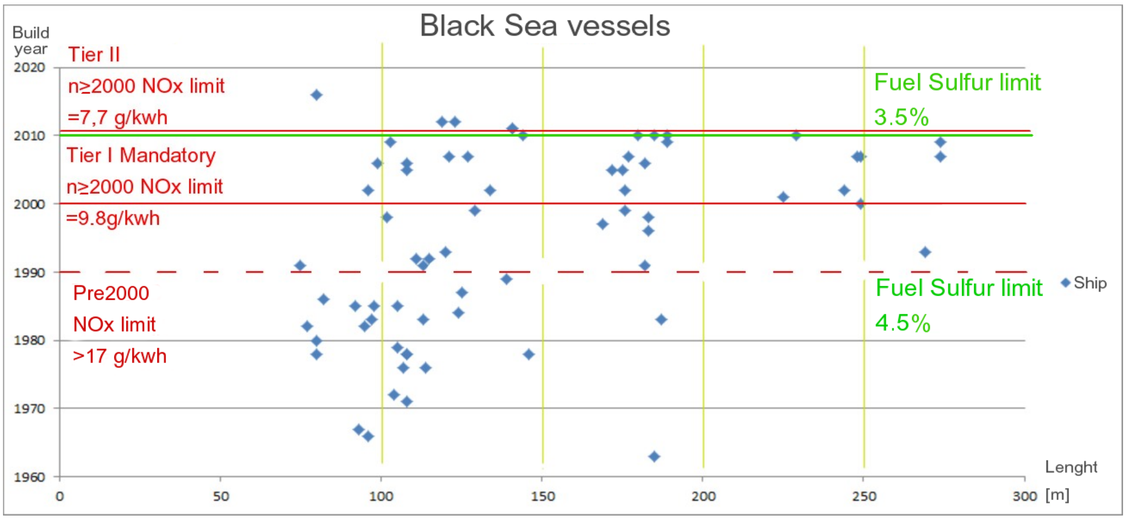

Fig. 15. Graphic of selected ships in table 1 and 2, depending of year build and length

4.2. Yearly Emission Generated by Vessels in Black Sea Areal

To calculate the amounts of NO_x and SO_x generated in one year by the maritime traffic in the Black Sea geographic area, the following hypothesis was worked out [4]:

- the sample of Tables 1 and 2, in which data were collected on a total of 69 vessels, representing 9.58% of the daily average of ships operating in the Black Sea, set as 720;
- it was considered as the operating mean of an engine installed on a ship, 8000 h, and equivalent to 21.9 operating hours per day, as compared to 365 days;
- emissions of 14 g/kwh SO_x were used in the calculation, for 3.5% sulfur in fuel;
- emissions of 18 g/kwh SO_x were used in the calculation for the percentage of 4.5% sulfur in fuel.

For the quantity of NO_x, the following values were identified in the Marpol Annex VI [4]:

- emissions of 7.7 g/kwh NO_x were used, the maximum limit for fast Tier II engines;
- emissions of 9.8 g/kwh NO_x were used, the maximum limit for Tier I fast engines;
- emissions of 17 g/kwh Pre2000 (ships built before 2000) were used, the maximum limit for slow Tier I engines.

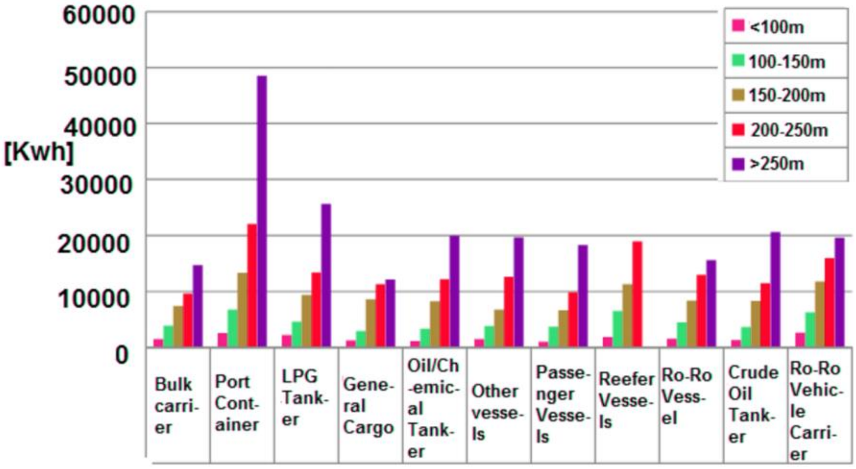

Fig. 16. Power installed on board (kWh) by ship type and size [1]

In Table 3, it has been selected vessels in the first place in ~~the~~ length and type, then according to these two parameters, power has been deducted, using the graph of Fig. 16. Then, taking into account the year of construction, the annual emissions of NO_x and SO_x were calculated for the 69 ships considered as the sample.

Table 3. Annually calculation table of SOx and NOx emission for all ships that are operanting in Black Sea

Ship<100m	**Type**	**No Ships**	**Power per ship [kwh]**	**Build year**	**Nox [g/h]**	**Sox [g/h]**
	General Cargo	11	1600	1>2000	287680	316800
	Tanker	1	1600	1>2000	15680	28800
	Supply Vessel	1	1800	1>2011	13860	25200
	Oil/Chemical Tanker	1	1500		25500	27000
100< Ship<150						
	General Cargo	20	3000	3>2000,1>2011	927300	1068000
	Oil/Chemical Tanker	3	3700	2>2000,1>2010	108780	185000
	Oil Products Tanker	2	3700	1>2000,1>2011	64750	118400
	Tanker	2	4200	1>2011	103740	134400
	Dredger	1	4700		79900	84600
	LPG Tanker	1	5000	1>2011	38500	70000
	Ro-Ro Vehicles Carrier	1	6000		102000	108000
150< Ship<200						
	Bulk Carrier	10	7500	2>2000,3>2010	1005000	1260000
	General Cargo	3	8800	2>2000	471680	475200
	Oil/Chemical Tanker	2	8000	2>2000	156800	288000
	Oil Products Tanker	1	8000		136000	144000
200m< Ship<250m						
	Crude Oil Tanker	4	11000	4>2000	431200	792000
	Bulk Carrier	2	9800	1>2000,1>2010	192080	313600
Ship>250m						
	Crude Oil Tanker	2	20300	1>2000	544040	730800
	Tanker	1	20300	1>2000	198940	365400
				Total NOx(year)	39227,44	tons
				Total SOx(year)	52281,6	tons

This leads to the calculation for the entire fleet:

- 39.22*100/9.58=409.39 kilotons NO_x, for an operating regime of 8000 h per year in the Black Sea,
- 52.28*100/9.58=545.72 kilotons SOx, for an operating regime of 8000 h per year in the Black Sea.

The results may have a correction margin of ± 20%.

Below you can see the grounding of the two SOx and NOx chemical compounds, extracted from a 2005 study.

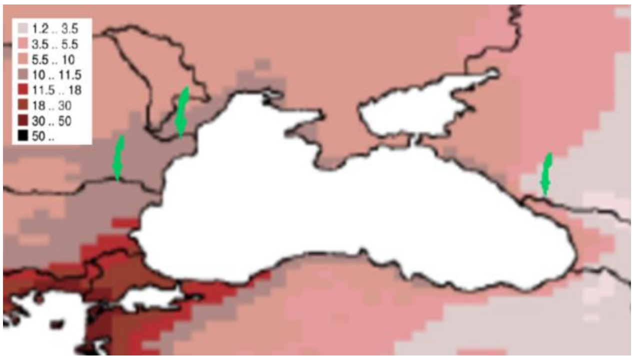

Fig. 17 Deposition of nitrogen from shipping sources 2005, eq/ha/year [1]

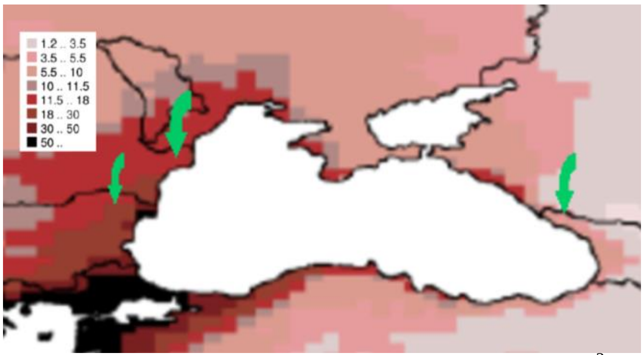

Fig. 18 Sulfur deposition from shipping sources 2005, $mg/m^2/year$ [1]

It can be seen that the three protected areas as UNESCO heritage, marked with green arrows in Fig.17 and Fig.18, are quite affected by the arrangement of the Sulfur and Nitrogen densities, resulting from the maritime transport at the ground level.

CONCLUSIONS

Pollution in the Black Sea basin plays a rather important role, having as its main factor the maritime transport done in this geographical area, with a fleet of ships comparable to the proposed and randomly selected sampling. The atmospheric emissions from the action of vessels in the Black Sea are chemical compounds of the NO_x type, amounting to 39.22 kilotons. This result represents only 69 vessels out of the total set as reference of 720 vessels operating daily in the Black Sea and 409.39 kilotons NO_x for the entire fleet operating 8000 hours per year. We can opt for a correction factor of ± 20%, since 8000 h per year is an almost ideal operating mode. For NO_x: Tier II standards give a maximum of 14.4 g/kWh in 2011, for new ships; in calculation the authors used 7.7g/kWh.

The atmospheric emissions from the Black Sea vessels of SO_x-like chemicals amount to 52.28 kilotons, only the sampled vessels represent 9.58% of the total 545.72 kilotons of SO_x for the entire active fleet in the Black Sea, for an almost ideal operating regime, which is why we can have a correction of ± 20%.

Considering the enormous volume of emissions resulting from shipping operations, correlated with the air currents discussed in Fig. 11, the regime of water transport operations in the Black Sea region should be reconsidered, as much of these residues end up in sea waters, another part reaches the ground level in coastal areas (Fig.17, Fig.18), areas that include natural areas, hosting rare biodiversity in the world, but also three UNESCO protected areas (see Fig.3). Due to this cumulus of factors, they can be affected in the short, medium but especially long term, so much that they could change the biotope structure that would lead immediately and irremediably to influence the biogenesis in a negative way.

According to the data presented in this study, the Danube Delta has the most to suffer, due to a poor geographic positioning, as compared to the other two protected areas. The proximity to the navigable area is a decisive factor, the Danube Delta is affected both by the Danube river traffic and by the coastal and maritime shipping in Sectors I and II, as highlighted in Fig. 3.

Finally, the authors make several recommendations in order to limit shipping pollution in the coastal areas are:

- to implement stricter fuel quality standards to reduce SO_x pollution,
- to mount scrubbers and EGR type systems for NO_x reduction,
- to reduce the ships speed in the coastal areas, especially closer than 200 km from the coast.

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