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REVIEW

Can Air Quality be Influenced in Coastal Areas by Shipping?

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ABSTRACT

The problem of pollution is a topical issue at global, regional but also at the local level. Starting from this idea, the question arises whether the coastal region in the North-East of the Black Sea is affected by the emissions resulting from the combustion of marine fuels in large ship engines, which manage to set in motion floating buildings intended for the transport of goods and passengers. This paper wants to evaluate the variation of the air quality indicators in the coastal area of Romania, taking into account the contribution that the ships by their number, size and destination can have on these qualitative factors. Such an approach is needed from the perspective of the more than 500,000 inhabitants possibly affected by the effects with which this industry is accompanied. As the Black Sea active fleet is already old, as its ages year by year, the premises for the need for this study can be set up. As in other regions, drastic measures are taken in order to reduce the effects of pollution due to such economic activity, the assessment of the effects that this industry produces in inhabited areas becomes necessary. In order to carry out this study, air quality data from the database provided by the National Air Quality Monitoring Network of the Workshop on the calitateaer.ro site were evaluated.

1. Introduction

At the European level, the issue of pollution is one of the priorities addressed and assumed by the European decision-making institutions.. In this regard, a series of measures are taken to mitigate the side effects that result from this harmful action to the environment. These measures are most often taken in force, based on strict monitoring periods, scientific, technical and economic evaluations aimed at determining the best solutions for limiting the side effects of pollution.

The effects of pollution act on the medium and short term by reducing the quality of life of living beings in the affected areas and in the long term through climate change. It is known that pollution in its various forms has direct effects on human health. The air quality is strictly influenced by air pollution, by changing the characteristics of the physio-chemical composition of the air. The most common process that influences air quality parameters is the combustion phenomenon. The combustion of fossil fuels is carried out for both industrial and domestic use. For industrial purposes, the combustion of fuels is used for the purpose of producing electricity, heating agent, freight transport by different means: road, rail, sea, air, passenger transport, etc.

According to the data provided by the International Maritime Organization (IMO) shipping (Shipping Indus-

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try) is a major producer of greenhouse gas emissions, with this economic sector being assigned 2.5% of the global greenhouse gas emissions.

In this context, the European Community has already implemented a number of European directives, with applicability, reducing greenhouse gas emissions by 20% by 2020 compared to the volume of emissions from the early 1990s [1]. In the field of maritime transport, the European Maritime Safety Agency (EMSA) represents the European entity with a role in the implementation of the above-mentioned decisions, the same agency aims to implement the monitoring, control and verification (MRV) process at the member country level [2].

However, the volume of emissions resulting from the transport of goods by sea will increase in the coming years, it is supposed till 2050 exist a potential of increasing from 50 to 250% depending of various scenarios, due to the trend of world trade. This will lead to an increase in the total volume of emissions from shipping, in the last IMO report is mentioned that the shipping is responsible for 2.5% annually from globally greenhouse gas emissions [3].

2. North-West Coast Area of the Black Sea

It is known that in general the shipping routes [4] are described, where it is possible, by the representation of the shores limit. In particular, even if the vessels did not have defined as navigation specification the coastal area, they often follow a direction parallel to the shore, but as close to the shore as possible. The Black Sea is characterized by the movement of goods by sea over short distances, according to Eurostat over 70% of voyages have this feature. According to the same Eurostat studies, we understand that the trend in the field of freight transport by water is increasing in the studied area. Constanta Port occupying the 18th position in a European top as importance, being taken into account the volume of cargo that transited this port. At the same time, the port of Constanța occupies the 5th position in the same top for the volume of bulk cargo that used the port services [5]. The trend of increasing the volume of goods, but also of the number of ships transiting the Black Sea region is also supported by the global direction which shows that in the period 1950-2001 the world fleet of active ships tripled its number [6].

Figure 1 shows the concentration of the navigable routes in the North-West area of the Black Sea. The bright red color represents critical points, where the route is intensely used. This map is created based on GPS location data, delivered by satellite for 2017 and processed by marinetraffic.com [7].

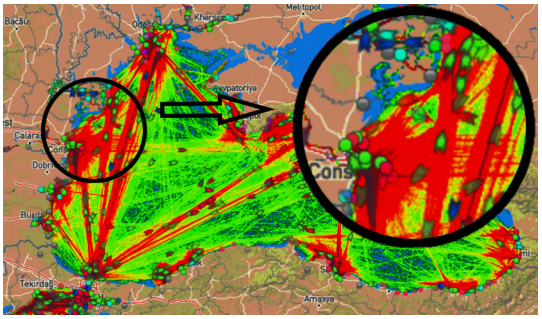

Figure 1. North-West shipping routes in the Black Sea [8]

Every day, the region is transited by over 300 ships, due to a considerable number of ports on the Romanian shoreline, from which can be mention: Constanta Port, Mangalia, Agigea, Midia-Năvodari, Sulina. Ships that voyage destination the Ukrainian region of Odessa and come from Bulgaria or the Bosphorus Strait, also transit the round perimeter shown in Figure 1. This number represents approximately 40% of the total volume of naval traffic carried out throughout the Black Sea area.

The Black Sea active fleet can be characterized as aging, poorly technized criteria resulting from a series of randomly selected batches of vessels [7]. An important number of these ships (36%) were built before 1990, when the rule was imposed that the composition of Sulfur in fuel should not exceed 4.5%. 55% of the ships were built before 2000, when the TIER I regulation on NOx emissions was imposed. Over 85% of the identified vessels were built before 2010, the year in which the TIER II regulations regarding NOx emissions and the rule that refers to the percentage of Sulfur in fuel that should not exceed more than 3.5% were imposed.

The North-West of the Black Sea is represented by the coast of Romania, shown in Figure 2, where we find a series of urban settlements and numerous rural settlements. The area considered the purpose of the study being delimited by the 245km long Romanian shoreline, with a depth of 30km inside the terrestrial area. According to the latest maps, the marked area is totaling around 5500 square km, except for the lake areas.

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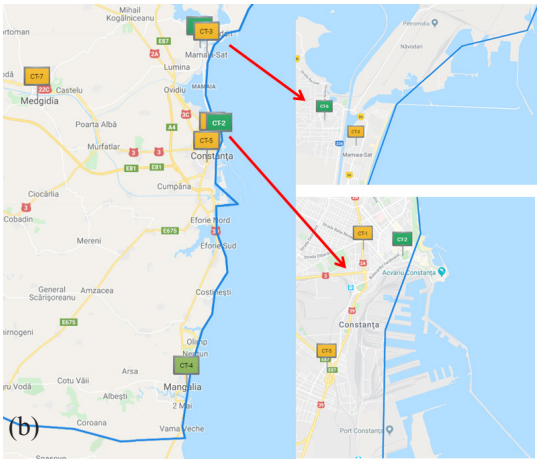

Figure 2. (a) The Romanian coastal area affected by shipping emission from Black Sea [9], (b) the position of the monitoring station located in Constanta County [10]

According to the data in table 1, on the Black Sea shore in Romania there are over 412,000 people living in the urban area, about half a million summing up the rural area.

Table 1. The number of inhabitants possibly affected by shipping emissions in Black Sea, Romanian shore

County	City	No. of inhabitants
Constanța	Constanța	306332
	Mangalia	40740
	Năvodari	34337
	Ovidiu	13490
	Eforie	9555
	Techirghiol	7034
Tulcea	Sulina	3663

3. Air Pollutant Compounds

National Air Quality Monitoring Network webpage [10] provides information about the air quality, showing in real-time the specific indicators (specific index) of air quality for the following pollutants: sulfur dioxide (SO2), nitrogen dioxide (NO2), particulate (PM10) and carbon monoxide (CO). Some limits are there indicated for each pollutant, starting with which the bad quality of the air is considered. These limits are: for SO2 is 350 μg/m^3, for NO2 is 200 μg/m^3, for PM10 is 50 μg/m^3, while for CO is 10 mg/m^3.

On the territory of Constanta County there are 7 locations where the air quality is evaluated from the perspective of various parameters. All 7 locations are located in the perimeter bounded by the grid in Figure 2(a). Only 6 locations are near to the coastline and also in the proximity of the Romanian ports. These 6 locations are shown in Table 2. In Tulcea County there are not stations located near to the coast.

Table 2. Monitoring fix station situated on the Romanian coastal area (see also Figure 2b)

No.	ID sample station	Location
1	CT1	Constanța
2	CT2	Constanța
3	CT3	Năvodari
4	CT4	Mangalia
5	CT5	Constanța
6	CT6	Năvodari

3.1 COx Emissions

Carbon monoxides result from the burning of fossil fuels like: oil products and LNG. CO emissions are directly proportional to fuel consumption. Consumption can be reduced by modifying ship shapes that involve the reducing ship's resistance, the ship's resistance can be also improved by optimizing the appendix, using active solution like bubble air lubricant systems, propulsion system efficiency, and operational factors such as sea state knowledge which involve the route planning, speed regime of ship/fleet, etc.

From the perspective of CO emissions levels are not alarming, but it is worrying that there is a trend to increase the values and the recurrence number of the maximums recorded by the stations mentioned in Table 2. This statement is based on the evolution of the values recorded in the last 3 years [10].

3.2 NOx Emissions

Nitrogen oxides are a result of the reaction between two common chemical compounds, oxygen and nitrogen, in a medium with high temperature. The most common way of producing is by combustion of fuels, like the burning of fuel inside the engines. Massive marine engines represent a significant source of emissions. The amount of NOx resulting from combustion varies depending on the type of fuel (diesel, gas, etc.), the mechanical and operating conditions of the engine. There are systems for cleaning the resulting exhaust gases, used in practice even in the naval field and are called SCRs based on Catalyst-based. Tehse emissions can cause acid rains that are T contributing to the acidity of seas and oceans, because this gas is easily soluble in water.

3.3 SOx Emissions

Sulfur oxides are formed during the burning process in ma-

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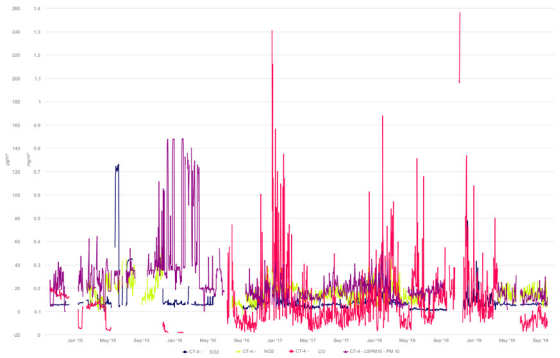
rine engines, but not only, it appears because of presence of sulphur in the fuel. It is recognised as an emission that contributes to pollution and which is harmful to humans.

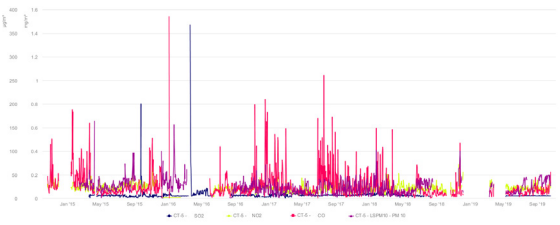
3.4 Particle Matter Emissions

PM emissions are associated with gas emission processes due to burning of fossil fuels and lubricating oils. These residual products of combustion are an international issue that threatens human health. These emissions are sometimes visible due to smoke and soot dimensions. On the other hand, the most dangerous of this kind of emissions are those that can be seen only with microscopic devices. These emissions cannot be detected without special measurement devices or detectors.

After the analysis of the data available data in each location presented in Table 2, for the last six years (from October 2014 until October 2019), only two locations (CT4 and CT5) were chosen for a graphical representation (Figure 3) because more data are available for all pollutants. Also, these stations are located near to the maritime ports where the ship's traffic is more intense. The station CT4 is located near to the Mangalia port, while the station CT5 is situated close to the Constanta port, the most important Romanian port. It can be also mentioned that in the other stations no worrying values were observed.



(a)



(b)

Figure 3. The pollutant emissions in Romanian coastal area measured at the stations CT4 (a) and CT5 (b), time period 1st October 2014 – 20th October 2019

From Figure 3 it can be observed that only PM10 emission values reached many times the worst index. It can be noticed that in 2016 at CT4 location for several times the PM10 emission was about three times higher than the limit value. In the case of CT5 location, there are some peaks in 2015 and 2016, but also there are various periods when the PM10 emission reaches the limit.

On October 4, 2019, a critical limit can be observed in Figure 4, namely the air quality index 5 which is related to the quantity of 50 µg / µg/m^3.

Name	Hourly index	Today index	Yesterday index
CO	1 0.08mg/m³ 2019/10/04 08:00:00	1 0.13mg/m³	1 0.14mg/m³
PM 10	5 52.50µg/m³ 2019/10/04 08:00:00	5 53.13µg/m³	4 47.08µg/m³
SO2	1 5.27µg/m³ 2019/10/04 08:00:00	1 5.47µg/m³	1 5.92µg/m³
O3	1 15.65µg/m³ 2019/10/04 08:00:00	2 47.92µg/m³	2 79.95µg/m³
NO2	1 18.78µg/m³ 2019/10/04 08:00:00	1 18.78µg/m³	1 28.28µg/m³

Figure 4. PM10 level alarm CT-5 site, time frame 04.10.2019

Following the wind rose (Figure 5) we can see that the predominant direction of the wind is from S and SSE, which indicates that the wind is blowing from the Constanta port and from sea. Taking into consideration that onshore there are no factories or other pollution sources than the usual car traffic, it reasonable to suppose that air pollution is coming from the sea, due to the maritime traffic and harbor operations.

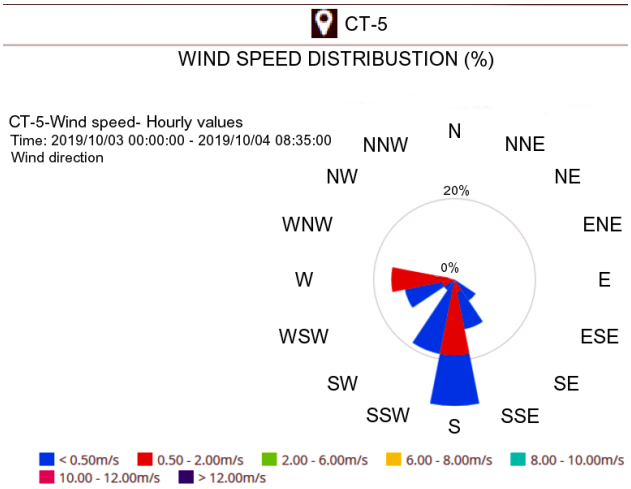


Figure 5. Wind speed and direction in CT-5 site

Numerous studies conducted for the Black Sea region show that a significant volume of pollutants is emitted into the air and has the origin of industries operating various types of ships [11-13]. They are of various categories as commercial ships, navy ships, special ships, etc.

According to a recent study [11] that evaluated total SOx and NOx emissions from shipping activities in the Black Sea region over a year, considerable values have resulted: 409.39

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kilo tonnes NOx compared to an active fleet of 720 vessels operating 8000 hours a year in the Black Sea region. The same operating conditions were imposed for SOx emissions, which resulted in 545.72 kilo tonnes that are dispersed in the atmosphere annually according to this estimate [11].

These high values are also due to the way in which the vessels operating in the Black Sea are maintained, many of them being very old even with the operating period resulting from the design exceeded 2 times.

Other European studies [14,15] claim that emissions from ships in 2009 represent 19% of total NOx emissions, 12% of total SO2 emissions and 5.2% of PM10 total. These percentages vary, however, depending on the geographical situation and the proximity of the waterways and ports. The Romanian coastal area is in an unfavorable case due to the numerous ports that are in the region and the navigable routes to the Ukrainian ports that are 50-60 miles away from the Romanian shore, this specification characterizing the European navigable area where 89% of the emissions are produced at less than 50 miles from shore and 97% of cases at less than 100 miles from shore [14]. According to the study above mentioned (see Table 1 from [14]), in the area of the Mediterranean and the Black Sea the following values are assigned in 2009, at the same time an estimate was made for the year 2030 (see Table 3).

Table 3. Mediterranean and Black Sea emission 2009 and 2030

Mediterranean and Black Sea					
Year\Emissions (Ktonnes)	**Nox**	**SO2**	**CO**	**PM2.5**	**PM10**
2009	1701	1194	188	137	144
2030	1735	264	188	31	33

Referring to Table 3 and taking into account the trend of expansion of the global fleet, which brings with it a greater fuel consumption is supported only by the worldwide approach of strict regulations and in force to regulate the shipping activity for the purpose of shipping. reducing emissions as a result of fuel consumption. This expansion was met during the years 1950-2001, where we meet the following considerations [15]:

A considerable source of pollution in the coastal area is the fact that it is near numerous ports. For example, in Constanta port one of the largest ports in the Black Sea and in the top 20 in Europe [5] are issued in the atmosphere every hour according to a recent average estimate: between 2 and 2.5 tons of SOx, 1- 1.5 tons NOx and about 12 kg of PM10 [12].

All the above information, which results largely from calculations, following the application of a series of mathematical models and technical constraints, is confirmed by evaluations of the data collected with the help of satellite images, statuettes that have been equipped with equipment capable of performing tropospheric spectroscopy [16].

4. Conclusions

The present study is focused on the Black Sea basin and discusses the pollution-induced by the ships in this area. Commercial vessels use as fuel for diesel engines, few are LPG / LNG. Ships equipped with full electric transmission cannot be found in the Black Sea basin, because in general they are intended for relatively short distances such as access to islands, in case of ferries. Gasoline is used only for dealerships, which most often have a removable engine. The fact that freight activities by water have an influence on changing the concentrations that form atmospheric air is a reality. The air quality is based on an allowable concentration of substances, which must be found in a certain percentage of the general composition, and the way in which this economic activity influences the concentrations of component gaseous elements of the atmospheric air results that the activity itself influences the quality of the air in the areas bordering her area.

However, environmental factors do not yet favour the accumulation in the atmosphere of considerable quantities of polluting agents due to the active air currents in the coastal area that have a dispersing role. Also, the phenomenon of rain has the role of cleaning the air, a phenomenon quite common on the Romanian coast.

The coastal area is an area of interest for such studies due to the risk potential it presents both because of its proximity to sea routes to other locations (less than 60 miles) and the fact that ships arriving in ports reduce considerable speed, which is materialized by the increase of emissions such as NOx, and PM. The difference for PM can be more than 6 times higher, in case of reduced speeds compared to the cruise speed navigation situation [17,18].

A series of measures to combat these effects exist and can be taken into account:

(1) Use in ports of solutions such as those of shore-connection completed by LNG plant facilities in ports [13]. The SOx emissions would tend towards 0, and the CO2 and NOx emissions would decrease considerably in these conditions.

(2) Slow steaming

In the period of economic crisis 2009-2012 shipping as an industry sought to reduce its costs) the cost of fuel representing up to 50% [19]) was deliberately chosen to reduce the speed of the fleets, which led to a decrease and up to 30% of the emissions that this industry is responsible for. This fact is confirmed by the evaluation of the satellite data [15].

(3) Use of quality fuels (with a low percentage of Sulfur) / fuel switch.

This solution is beneficial for reducing the percentage

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of SOx emissions but it is very costly, many shipowners avoid increasing their operating prices since so far, the cost of fuel represents up to 50% of the total. The second option is only a compromise solution, because the emissions of pollutants would be as far as 150-200 miles away, which in the long term still affects the environment, reducing only the short-term effects locally.

(4) Technical solutions to reduce emissions by filtration (Scrubber).

This approach presents several types of technologies, which seem to be a viable solution. In the long term, since it is a new solution, they are unknown in terms of long-term operation and maintenance costs.

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