Air Quality and Shipping Emissions

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Maritime transport has been recognized as an essential driver for economic and social development, especially for coastal regions. However, shipping and in-port activities pose public health issues and environmental pressures, exposing coastal population to associated emissions (i.e., particulate matter and gaseous pollutants). In the last decades, several policies have been implemented at local/regional and international level, reducing the content of sulphur in marine fuels. This work provides a brief comment of some recent results regarding the impacts of maritime emissions on air quality, health effects and future projections, taking into account the current implementation of the IMO-2020 legislation. Finally, future perspectives and potential mitigation strategies are discussed.

maritime transport | shipping impacts | health impacts | harbour air quality | mitigation strategies | IMO legislation | low-sulphur fuel | ECA | particulate matter

1. Introduction

Shipping is a relevant atmospheric source of particulate matter (PM_{10}, $PM_{2.5}$) and gaseous pollutants (SO_2, NO_X, VOCs, CO_X), especially around harbour areas in coastal towns. Combination of increasing seaborne shipping demand, growing coastal population and foreseen decrease of the main land-based emissions in the next future (e.g. traffic, domestic heating), strengthens the weight of shipping emissions for urban air quality and health.

Being recognized as one of the first air pollution emission source, after road transport, heating and air conditioning [1], shipping poses an emerging health risk in port cities, reflected in increase in respiratory diseases (inflammation, asthmatic symptoms, lung cancer), as well as cardiovascular diseases, increase in hospital admissions and respiratory acute mortality.

In recent decades, many regulatory actions have been taken, both at global and local scales, to curb atmospheric pollutants emissions from maritime sector. The International Maritime Organization (IMO) introduced the Global Sulphur Cap 2020, enforced on 1/1/2020, setting the sulphur content of fuel oil used on board ships not exceeding 0.50% m/m (against the previous limit of 3.5% m/m) outside Emission Control Areas (ECAs) and 0.1% m/m remains the standard value (already established in 2015) inside the ECAs. In addition, a new Nitrogen Emission Control Areas (NECAs) will be enforced in the Baltic and North Sea, reducing both NO_X emissions from maritime transport by 80%, and $PM_{2.5}$ of 72% by 2040 [2].

Climate effects of maritime transport were quantified by a cooling net (-0.4 W/m^2) radiative forcing (RF) on short term [3], that could turn to a warming effect on long term because of the slow removal of CO_2 [4], amplified by the use of low-sulphur fuels [5].

This work briefly reviews the current knowledge on the impact of shipping to local air quality in harbour areas and on public health indicators. The effectiveness of the mitigation efforts such as the implementation of the recent IMO policy and of the new SECAs and NECAs, will be discussed in terms of health impact assessment, reporting the main evidences and future projections.

2. Discussion

2.1 Contribution of shipping to atmospheric pollutants

Although the contribution of shipping quickly decreases as the distance from the harbour increases [6], local air quality could be adversely affected by NO_X, PM and SO_2 emissions, exceeding, in some cases, those of road traffic [6][7].

Contribution of maritime activities to PM concentrations have been estimated by different methodologies consisting in source-oriented modelling [5][6][8] and receptor-oriented models [9][10][11][12], from large to local scale. In general terms, contribution to PM_{10} is lower (in relative terms) compared to those to $PM_{2.5}$, because ship emissions, being products of a combustion process, are dominated by smaller particles in the fine (diameter <0.3 µm) and ultrafine (diameter <0.1 µm) range. Because of this, contribution to Particle Number Concentration (PNC) in the fine and ultrafine range was found to be 3-4 times larger than those to PM mass concentrations in some Mediterranean harbours [13][14][15].

Harbours in East Asia, especially in China, showed maxima in $PM_{2.5}$ contributions, between 2.4% and 25%, being the largest ones and worldwide trafficked. In USA, relative contributions to $PM_{2.5}$ ranged between 3% and 9%, with the highest values on the Eastern coasts. The European Mediterranean harbours had larger impacts (from 0.2% to 14%), compared to ECAs in the Baltic and North Sea (1-5%). Future projections indicated a potential $PM_{2.5}$ reduction of 50% and 65% in 2030 and 2050, respectively, due to SECAs and NECAs designation in European seas [16]. Analogously, a descending trend (-35-37% of $PM_{2.5}$) was expected for the Baltic Sea, between 2012 and 2040 [17]. As opposed of studies on particulate matter, those on gaseous pollutants from ships are scarce. Estimated contribution to PM and CO was comparable [7], while SO_2 and NOx were generally more impacted compared to PM.

2.2 Health effects of shipping emissions

Negative health effects from shipping like asthma, cardiovascular diseases, lung cancer, premature mortality and morbidity have been documented by epidemiological evidences [18][19][20][21][22][23]. The most common exposure estimates are calculated using population-weighted concentrations of ship-related pollutants and specific concentration (or exposure) - response (C/E-R) functions [23][24][25][26][27][28][29]. Grid resolution, population density and C/E-R functions used can significantly affect estimates, producing important differences among health assessment studies.

About 60,000 and 90,000 premature deaths in 2010 and 2012, respectively, due to cardiopulmonary diseases and lung cancer were attributed to exposure to PM emissions in coastal regions of Europe and Asia [21]. From 14,500 to 37,500 premature deaths were estimated worldwide as due to $PM_{2.5}$ emitted from shipping with the highest values of 24,000 in East Asia for year 2013 [18]. A health assessment study conducted in eight European Mediterranean coastal cities [30] reported 430 premature deaths per year attributable to ships-related $PM_{2.5}$ exposure. Recent modelling results demonstrated the effectiveness of SECA in the Baltic and North Sea regions, estimating a decrease in total YOLLs (Years Of Life Lost), from 17,000-38,000 in 2014 to 11,000-25,000 in 2016 [31]. For the same area, 0.1-0.2 YOLLs per person were estimated considering 2010 emissions, along the southern coastlines, with a 24% average reduction in 2030 for stricter sulphur standards [22].

Exposure to NO_2 and $PM_{2.5}$ due to ships was found responsible of 2.6 premature deaths per year and 0.015 YOLLs per person, respectively, while an opposite trend was recorded for ozone exposure with -0.4 premature deaths per year estimated in 2012 [32].

Recent studies evaluated the effectiveness of the stricter SECA regulations implemented since 2015 in the Baltic area, with a decrease in mortality, morbidity and YOLLs by at least one third from 2014 to 2016 [31]. Predictions revealed that a NECA would reduce total premature deaths in the North Sea countries by nearly 1% by 2030, doubling after 2040 [33], while the implementation of a Mediterranean ECA could reduce of 1730 premature deaths per year [34].

In addition, the application of the IMO 2020 policy could reduce $PM_{2.5}$-attributable premature deaths by 15% (considering both primary and secondary $PM_{2.5}$) in the Mediterranean area [30] and by 34% at global level [5].

From an economic point of view, reduction of emissions obtained using higher quality fuels could lead to an increase of operational costs with economic feedbacks consisting in slower fleet replacement rate due to increased ship costs, and modal shift to other transportation routes (roads, railways, and aviation) [35][36].

3. Concluding remarks

The present work reviews available literature about impact of maritime activities on PM and gaseous pollutants levels and on related health effects of coastal communities. Results evidenced that ship traffic contribution to PM was lower than those to NO_X, CO and SO_2. In particular, $PM_{2.5}$ impact ranges typically between 0.2% and 14% in Europe, with lower values in northern Europe compared to Mediterranean area; between 3% and 9% in North America and from 2.4% to 25% in Asia. Recent policy actions at international level (IMO regulation, ECAs, NECAs) are expected to cause a reduction of shipping emissions of SO_2 and primary PM, with limited effects on emissions of NO_X, metals, and PAHs in PM.

Projections indicated that the IMO-2020 policy will lead to a global decrease of premature deaths due to shipping of about 34%. In addition, the implementation of the new NECA in northern Europe would reduce total premature deaths by 1% by 2030, doubling after 2040. Nevertheless, the estimated ships-related premature deaths will be 250,000 after 2020 and, even with the actual reduction efforts, ships could be responsible for about 6.4 million cases of childhood asthma annually in the future [5].

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