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REVIEW OF MARPOL ANNEX VI AND THE NOx TECHNICAL CODE

Avoided Global Premature Mortality Resulting from Reduction of Sulphur in Marine Fuel

Submitted by the Friends of the Earth International (FOEI)

SUMMARY

Executive summary:	This document describes new scientific estimates of the human health benefits of several approaches to reducing sulphur in marine fuel, in terms of a reduction in premature mortality caused by particulate emissions from ocean-going ships. This document was produced by a coalition of environmental NGOs.[1]
Action to be taken:	Paragraph 7
Related documents:	BLG 11/5/5; BLG 11/5/6; BLG 11/INF.3; BLG-WGAP 1/2/11; BLG 10/14/13; MEPC 53/4/1; MEPC 53/4/8; BLG 12/6/9 and 12/6/16

Introduction

1 Document BLG 12/6/9 summarized the first scientific analysis estimating global premature deaths resulting from particulate matter ("PM") emissions from ocean-going ships. This peer-reviewed study was conducted by an international team of leading scientific researchers, and was published in the December 15, 2007 issue of the American Chemical Society journal *Environmental Science & Technology* (hereinafter the "Corbett and Winebrake Study").[2] The study estimated tens of thousands of premature deaths each year from PM air pollution emitted by oceangoing ships, estimated to increase with global trade by 40% by 2012.

[1] Clean Air Task Force, Friends of the Earth-US, European Federation for Transport and Environment, North Sea Foundation, Seas at Risk, Swedish NGO Secretariat on Acid Rain and Bellona.

[2] Corbett, J.J., Winebrake, J.J., Green, E.H., Kasibhatla, P., Eyring, V., and Lauer, A., "Mortality from Ship Emissions: A Global Assessment," *Environmental Sci. Technol*, American Chemical Society, 42(24), p. 8512–8518, Dec 15, 2007. It is available on the Internet at: http://pubs.acs.org/cgi-bin/sample.cgi/esthag/asap/pdf/es071686z.pdf .

2 The Corbett and Winebrake Study provided a base case for global shipping emissions mortality, but further work was needed to demonstrate quantitatively the beneficial impacts of reducing shipping emissions. That work has now begun, and this paper introduces and summarizes a report prepared by many of the original Corbett and Winebrake Study researchers that examined premature mortality under two potential control scenarios described below.

3 This present paper introduces and summarizes that report (hereinafter referred to as the "Corbett and Winebrake Benefits Study"). The full report, entitled "Mitigating Health Impacts of Ship Pollution through Low Sulfur Fuel Options: Initial Comparison of Scenarios," dated 23 January 2008, is attached hereto as an Annex.

Follow-up Shipping Emissions Reduction Benefits Study

Methodology

4 Employing the same methodology and inventory dataset used in the original scientific, peer-reviewed study and described in BLG 12/6/9 and documents referred to therein, the Corbett and Winebrake Benefits Study estimates global and regional premature cardiopulmonary and lung cancer mortality from shipping emissions in 2012 under three different scenarios—

a. a "no action" scenario, assuming no additional controls on particulate emissions and the use of HFO with an average sulphur content of 2.7%;
b. a "coastal _0.1" scenario, assuming no additional controls other than the use of marine distillate fuel with a sulfur content of 0.1%, but only within areas 200 nautical miles from coastlines worldwide; and
c. a "global _0.5" scenario, assuming no additional controls other than the use of marine distillate fuel with a sulfur content of 0.5% in all regions of the globe.

Results

5 The Corbett and Winebrake Benefits Study estimates mean global premature mortality from international shipping in 2012 as follows:

Scenario	**No Action**	**Coastal_0.1**	**Global_0.5**
Premature Mortality (mean, 2012)	83,700	42,200	33,700
Mortality Reduction from "No Action"	---	41,500	50,000
Per cent Reduction from "No Action"	---	~50%	~60%

6 Using cost methodology employed by US EPA in recent rulemakings to value the benefits of particulate emission reductions, [3] FOEI estimates that the 40,000 to 50,000 lives saved *annually* in the above coastal and global control scenarios produce *societal benefits of about $225 to $275 BILLION per year*. These benefits far outweigh the estimated costs of such reductions under either global or regional policy action by IMO consistent with the examined scenarios.

Action Requested of the Committee

7 The Committee is invited to consider the above information and to adopt stringent limitations for air emissions from ships.

[3] *See, e g.*, US EPA (2004), Regulatory Impact Analysis, "Control of Emissions from Nonroad Diesel Engines," May 2004, EPA420-R-04-007, at pp. 9-21-22, 29-34, Table 9-7, available on the Internet at: http://epa.gov/nonroad-diesel/2004fr/420r04007.pdf .

Annex

Mitigating Health Impacts of Ship Pollution through Low Sulfur Fuel Options: Initial Comparison of Scenarios

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http://www.energyandenvironmental.com
23 January 2008

1 Purpose

The purpose of this document is to present initial results of continuing scientific research aimed at quantifying and comparing health benefits from reducing ship emissions. Upon request of the IMO industry expert group, we presented to them in November 2007 a summary of peer-reviewed, scientific work evaluating global-scale impacts of ship emissions to the environment, human health, and climate change (Eyring et al. 2007); as encouraged by that group, this ongoing scientific work is updated here with regard to potential IMO control policies to reduce emissions. In particular, this work focuses on PM emissions related to marine fuels. We quantify potential health benefits, measured as avoided premature mortality, building on scientifically peer-reviewed methodologies and datasets.

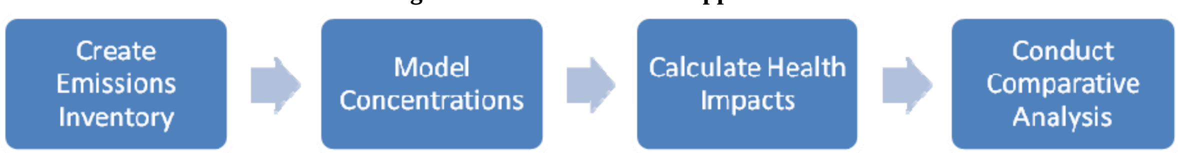
This analysis compares a 2012 "*No-Action*" scenario with two emissions control scenarios. The first scenario (*Coastal_0.1*) explores impacts associated with reduced ship PM emissions corresponding to a 0.1% sulfur concentration for marine fuels *within 200 nautical miles (nm) of coastlines*. The second scenario (*Global_0.5*) explores impacts associated with reduced ship PM emissions corresponding to a 0.5% sulfur concentration for marine fuels *globally*.

2 Analytical Approach

2.1 Overview

In conducting our analysis, we employ the approach depicted in Figure 1. This is a similar to the approach taken in scientifically peer-reviewed work (Corbett, Winebrake et al. 2007). Using a comparative analysis holding constant all parameters except those emissions mitigated by fuel switching, we isolate the percent change in premature mortality that can be expected from proposed action. We employ the same geospatial inventory (Wang, Corbett, and Firestone 2008), atmospheric model, uncertainty factors, and health risk functions as reported previously in peer-reviewed, scientific literature (Corbett, Winebrake et al. 2007). That work demonstrated mortality results that were consistent with previous scientific studies at both a global and regional scale (Cohen et al. 2004; California Air Resources Board 2006). This approach allows us to compare control scenarios with previous work assessing baseline impacts. We present our results for each mitigation case and show relative benefits compared to the *No-Action* case.

Figure 1. Schematic of Our Approach



2.2 Emissions Inventories

The first step of the analysis was to create shipping emissions inventories for our three scenarios (*No-Action*, *Coastal_0.1*, and *Global_0.5*). $PM_{2.5}$ emissions estimates were obtained based on global representation of ship emissions inventories of sulfur, black carbon, and organic carbon. We use the previously derived emissions inventory based on the International Comprehensive Ocean-Atmosphere Data Set (ICOADS) (Wang, Corbett, and Firestone 2008). This dataset combines detailed information about vessel characteristics with vessel traffic densities to determine emissions geospatially. All oceangoing commercial ship types are included in this dataset, with some oversampling of container ship traffic and refrigerated cargo ship (i.e., reefer) traffic. These emissions are overlaid on an inventory without ship traffic to obtain the increased PM pollution attributed to ships operations.

Ship emissions for 2012 values were estimated from current inventories using a uniform global annual compound growth rate of 4.1% to establish our *No-Action* scenario (Corbett, Wang et al. 2007). By estimating relative reductions across scenarios for the same year, different growth rate assumptions would produce similar relative benefits. To create inventories for our *Coastal_0.1* and *Global_0.5* cases we reduced emissions of sulfur and particulate organic matter to correspond with properties for different marine fuel types. The No Action case used the world average sulfur content of (2.7% S) assuming residual fuel properties typical for POM. Control scenarios used sulfur contents of 0.1% S (~4% of No Action within coastlines) and 0.5% S (~19% of No Action globally), respectively. We reduced POM emissions by ~68% for MDO at 0.5% S and by ~80% for MGO at 0.1% S, respectively in the control scenarios to correspond to typical differences among residual and distillate fuel PM measurements.

2.3 Atmospheric Modeling

Next, emissions inventory values were translated into $PM_{2.5}$ concentration data (in $\mu g/m^3$ dry weight) from atmospheric modeling using ECHAM5/MESSy1-MADE (referred to as E5/M1-MADE), an aerosol microphysics module (MADE) coupled to a general circulation model (ECHAM5), within the framework of the Modular Earth Submodel System MESSy (Lauer et al. 2007). Along with global $PM_{2.5}$ concentrations attributed to non-ship sources, the E5/M1-MADE model provides ambient concentrations of BC, POM, sulfates (SO_4), nitrates (NO_3), and ammonium ion (NH_4) aerosols. This model was run under similar input assumptions as previously published in peer-reviewed scientific publications (Corbett, Winebrake et al. 2007). Model output at 2.8^o x 2.8^o was interpolated to a 1^o x 1^o global resolution; therefore, we report our results at the global and continental scales.

Because health-risk studies have concentrated on long-term mortality impacts, we aggregated monthly $PM_{2.5}$ data into annual averages. Monthly variations are quite small and can be neglected, given that we are primarily interested in the *change* across scenarios (Wang, Corbett, and Firestone 2008). In addition, although some variation does exist over open oceans (due to seasonal shifts in shipping routes), concentration variation on land is much smaller because nearly 70% of global ship emissions are within 400 km of land, and because ship activity and emissions near shore remains relatively constant throughout the year. We don't expect these modest seasonal variations within the ICOADS global shipping pattern to affect long-term mortality results.

Comparing results of each model with and without ship inventories of $PM_{2.5}$ components, we quantify changes in ambient concentrations of $PM_{2.5}$ due to marine shipping. From these data, we produced "air quality graphs" that depict concentrations on a 1^ox1^o global grid.

2.4 Health Impacts

In addition to concentration data, we use 2012 population estimates by 1^ox1^o grid cells for all three cases. Our population estimates were obtained in a 1^ox1^o format from the Socioeconomic Data and Applications Center at Columbia University (SEDAC 2007). Values for 2010 and 2015 were acquired, and a linear interpolation was used to estimate values for 2012. We used U.S. Census Bureau International Database numbers to derive, by continent, the percent of population between 30 and 99 years of age (the age group of concern for the examined mortality impacts).

We examine cardiopulmonary mortality and lung cancer mortality. For calculating these impacts, we used concentration-response (C-R) functions derived from the literature (Pope et al. 2002; Ostro 2004). Functional coefficient values were obtained for cardiopulmonary and lung cancer mortality from Ostro (2004). The incidence rates of these health impacts (necessary for calculating the increased risk due to ship emissions) were estimated using World Health Organization (WHO) data. We used 2002 WHO estimates for causes of death by age to derive the incidence rates by WHO region for each type of mortality examined. United States cardiopulmonary incidence values obtained from BenMAP technical documentation (Abt, 2005) were used for North American incidence estimates.

We analyzed mortality impacts using C-R functions from Pope, et al (2002), the same epidemiological study used to estimate mortality impacts in EPA's regulatory analysis of controlling emissions from non-road diesel engines. Here, we assume that the global PM concentration-mortality association is equivalent to that of the United States. As noted in other work (Davis et al. 1997), epidemiological studies have found a relatively consistent association between short-term PM exposure and mortality across several countries—from South America to Western Europe. Therefore, long-term PM exposures will be similarly consistent—an assumption made by other experts in air pollution health-risk assessments (Ostro 2004).

We employed log-linear C-R functions to estimate changes in relative risk of mortality, as recommended in Ostro (2004). The relative risk is calculated considering the C-R function and change in PM concentration, and is given by:

$$RR = \left[\frac{(C' + 1)}{(C_0 + 1)} \right]^{\beta}$$

where β = 0.1551 (95% CI = 0.05624, 0.2541) for cardiopulmonary mortality, and β = 0.232179 (95% CI = 0.08563, 0.37873) for lung cancer related mortality (Ostro 2004).

We employed the change in relative risk, population, and existing incidence rates to calculate the change in mortality due to excess pollution for each grid cell. Ship pollution incrementally increases ambient pollution conditions due to non-ship sources. Where concentrations over populated regions are already high, there would be no expectation of a threshold effect; moreover, the literature discussion on thresholds shows little support for threshold effects and instead demonstrates non-zero slopes at low concentrations (Zanobetti and Schwartz 2005; Samet et al. 2000; Schwartz 2000). The total effect (E) of additional PM concentrations is then given by:

$$E = AF \times B \times P$$

where B represents the incidence of the given health effect (e.g., deaths/1000 people); P represents the relevant exposed population; and, AF is the relative risk due to the increase in pollution, and is given by:

$$AF = \frac{RR - 1}{RR}$$

As in the previous work, we compared multiple CR functions from the literature. A direct comparison across different parametric inputs and functional forms produced nearly identical best estimates and ranges. We report the log-linear results here, consistent with results reported in peer-reviewed, published work (Corbett, Winebrake et al. 2007).

3 Results

Table 1 shows aggregated global mortality results for all three scenarios. This table identifies mortality type in the first column, followed by the mean (β at 50th percentile) estimate of mortality for each case examined, and the range of values representing the 95% confidence interval based on confidence intervals for β from the literature as described above (Ostro 2004). All values are rounded to the nearest hundred. Note that the mortality estimates for the two control scenarios span similar ranges.

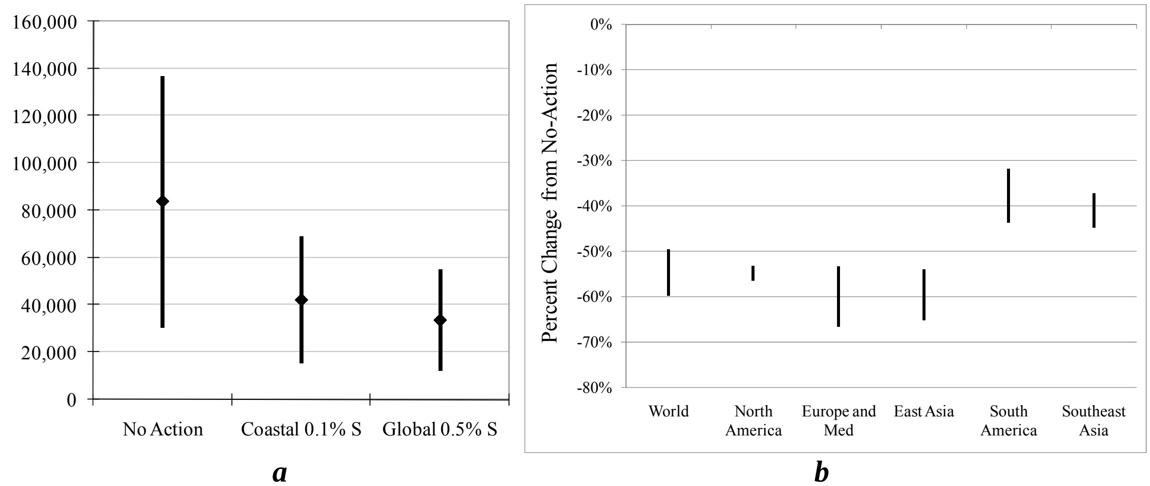
Table 1: Global Mortality Impact Results for Three Scenarios

Mortality Impact	No-Action	Coastal_0.1	Global_0.5
Cardiopulmonary Mortality			
• Mean	76,700	38,800	31,000
• Range of estimates	27,800 – 125,400	14,100 – 63,500	11,300 – 50,800
• Percent reduction from No-Action	--	49%	60%
Lung Cancer Mortality			
• Mean	7,000	3,400	2,700
• Range of estimates	2,600 – 11,400	1,300 – 5,500	1,000 – 4,300
• Percent reduction from No-Action	--	52%	62%

Our results show that fuel switching can reduce premature mortalities by 50-60% from the *No-Action* case (Figure 2a). These results confirm that meaningful benefits are achieved from either action.

Our regional results (Figure 2b) show the benefits of emissions reduction by region relative to *No-Action* without distinguishing among control scenarios. We are conducting statistical tests to confirm whether one scenario consistently produces higher benefits across all regions.

Figure 2. a) Mortality Estimates with Confidence Intervals for *No-Action*, *Coastal_0.1* and *Global_0.5*; and b) Relative Changes in Reduced Mortality from the *No-Action* Case by Region.



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