Environmental Stewardship Discussion Group
April 23rd 2012
“Exploring current regulations and mitigation options for black carbon emissions”

Black carbon (BC) Definition: a climate forcing agent formed through the incomplete combustion of fossil fuels, biofuel, and biomass; emitted in both anthropogenic and naturally occurring soot.

- Consists of pure carbon in several linked forms.
- Warms the Earth by absorbing heat in the atmosphere and by reducing albedo (reflectance) when deposited on snow and ice.

Importance for Arctic:

- Snow/Ice Darkens & Warms with BC deposition = 3X Warming rate
- Sea ice extent declines; Arctic shipping traffic increases
- Resource exploration/extraction and full Arctic ship transits become possible
    - Significant increase in shipping activity and related emissions
- BC emissions from ships as far South as 40°N (Brooklyn, NY) may impact the Arctic

Human Health Concerns:

- Secondary ozone (formed from NOx 15 emissions),
- Secondary particulate sulfate (formed from gaseous sulfur dioxide emissions)
- Directly emitted particulate sulfate, organic matter and black carbon (BC)

BC Emissions Reduction Methods

1. Ship speed reductions (or “slow steaming”)
2. Fuel quality improvements
3. Exhaust scrubbers.

1. Ship Speed Reduction:

- Maintaining ship speed reductions as industry practice or regulation has been discussed within industry and regulatory circles as an emissions reduction strategy.
- Some coastal regions have mandatory or voluntary ship speed reduction programs

- When engines operate outside of the tuned engine load without retuning, fuel efficiency often decreases and emissions (including BC) increase
- Some advanced engines with electronically controlled fuel meters may be able to modify combustion settings, per cylinder, essentially tuning during operational changes to better approximate best-performance conditions

- If fleets were required to operate at lower maximum engine loads, presumably associated with reduced speeds, then engines could be re-tuned, which would reduce BC emissions.

However, variable load conditions make it difficult to assess the likely emissions rate of BC.

Case Study:

In 2007 the AP Moller-Maersk2 shipping company implemented a systematic management system for reducing ship speed in an effort to reduce fuel consumption, vessel idle time, and emissions

- To assess potential BC changes we define two scenarios:
  1. No engines were re-tuned across the time period.
     - Using the average BC mass change emissions could have increased by up to 7% for the load changes reported.

  2. The alternative scenario is where all engines are re-tuned to the lower load.
     - BC emissions are linearly correlated to fuel consumption and could have decreased by over 20%

- Not all engines were re-tuned. However, if the operators retuned even some of the engines, BC emissions likely declined as a result of the Maersk speed reduction program.

2. **Fuel Quality Improvements:** is there a co-benefit reduction in BC, or an unintended increase?

- These studies provide converging evidence that improved fuel quality is linked to reductions in BC for marine diesel engines.
- This is consistent with the well understood relationship between fuel quality and EFBC for on-road diesel engines

Case Study:

- Buffaloe et al. (2012) measuredBC for 41 ships in compliance with the Californian *F*S regulations (*F*S = 0.4±0.3 %, average load=10±5 %).
- Lack et al. (2008b) measured BC in the Gulf of Mexico and Houston where no *F*S regulations exist

  - California BC data are 57% lower than the BC measured in the Gulf of Mexico

3. **Exhaust Scrubbers**

- Scrubbers can use wet or dry physical scrubbing or chemical adsorption to remove combustion products.
- Current studies show scrubbers to be efficient at reducing the mass of PM emissions from anywhere from 25 to 98%

De-rating or investment in automatic tuning to achieve these BC reductions are likely to be motivated by regulations on ship speed. If ship speed regulations were a permanent part of the regulatory environment, new ship designs could innovate to use smaller engines with maximum-load ratings appropriate for the required speed.

Up to 80% reductions in BC have been observed for such fuel quality shifts within several studies. From the data presented, an average EFBC reduction of 30% at 100% engine load is observed. It is likely that *F*S regulations will reduce BC emissions.

Switching to high quality fuels will lead to a 24%--- 38% reduction in total warming potential of Arctic ship emissions by 2030

Above information distilled from:
Lack, D. A. and Corbett, J. J. (2012). Black carbon from ships: a review of the effects of ship speed, fuel quality and exhaust gas scrubbing, Atmos. Chem. Phys. Discuss., 12, 3509–3554
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