Out of Sight, On the High Seas

THE BIGGEST PIECE OF LOW-HANGING FRUIT IN AIR POLLUTION HISTORY

Typically a discussion of how to reduce air pollution from vehicles would start with cars, continue with trucks, say a few words about buses and motorcycles, then various types of moving around off-road, then and move on to other subjects. But not so here.

The first subject here is the biggest piece of low-hanging fruit in air pollution history, a group of sources so large and easy to control that global air pollution could be sliced by 5 to 15 percent within a matter of two or three years, depending on the specific remedy.

Even better, eliminating the pollution is almost unbelievably easy: Simply switch from what is probably the dirtiest fuel on the planet, so-called bunker fuel, to one that's cleaner—kerosene, say, or natural gas.

Figure 1 International shipping burns only between 2 to 4 percent of the world's fossil fuels each year, but accounts for more than 5 percent of the global NO_X emissions and more than 14 percent of the global sulfur emissions from human activity.

Few would guess that the planet's largest aggregate source of air pollution -- emitting roughly as much as the entire continents of either North America or Europe—is cargo ships. According to one study, they emit as much sulfur dioxide as all the world's cars, trucks and buses combined. Sulfur dioxide is the principal cause of acid rain and sulfur-based fine particles that kill and injure humans. Cargo ships also emit immense amounts of oxides of nitrogen, a cause of both nitrogen-based fine particles and ozone, or smog. They undoubtedly emit immense amounts of black carbon, a cause of both global warming and human death and illness, but so little attention has been paid to ships that very few measurements have been taken. This is partially because of the difficulty of measuring pollutants that are rapidly mixed, but also because on-board measurements require the cooperation of ship owners, which they are not necessarily anxious to provide.[1]

Even though international shipping burns only from 2 to 4 percent of the world's fossil fuels each year, by some estimates it accounts for more than 14 percent of the global NO_X emissions and more than 16 percent of the global sulfur emissions from world petroleum use.[2] Ocean-going vessels transport 90 percent of all trade by volume to and from the European Union and nearly 80 percent by weight of all goods shipped in and out of the United States. As emissions from other sources are reduced, the contribution of shipping becomes increasingly important, not the least because of its rapid and constant growth.[3]

Compared to trucks, buses and cars, cargo and other ships are virtually unregulated. This is in large measure because ocean-going vessels are immune to national and most international laws. They are overseen by the International Maritime Organization (IMO), which is widely recognized as a bedfellow of the industry, not its regulator.

Diesel soot is so poisonous that it has been classified as a toxic air contaminant by California, and is known or believed to cause not only cancer, but premature death, diseases of the lungs and airways, heart and circulatory disease, and a variety of illnesses.[4]

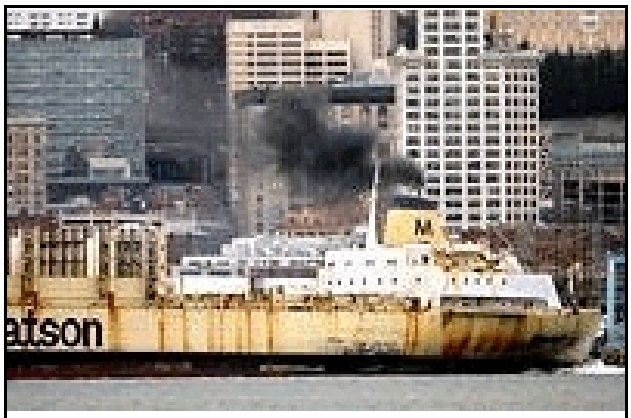

Figure 2 Ships like this one in Seattle overwhelm local efforts to curb emissions from cars and trucks.

Immense amounts of extremely fine particles are created by the sulfur-rich "bunker" fuel burned by ships, killing as many as 60,000 people a year. Scientists who sampled southern California's coastal air found that up to 44 percent sulfur-based fine particle pollution was from ships.[5]

THE SOURCES OF SHIP AIR POLLUTION

Ships are immense polluters for three major reasons:

Bunker Fuel

Virtually all burn bunker fuel, which is laden with pollution because it is what's left when everything else of value has been removed from a barrel of crude oil. At room temperature it is so thick and dirty that it is solid. It must be heated before it can be moved from one place to another or burned. It has more in common with asphalt than it does with gasoline. It is called bunker fuel because it is stored in a bunker, a shipboard compartment or tank used for fuel storage. It is black or dark brown and contains anything that refining distills: heavy metals, such as sodium, potassium, calcium, vanadium, lead and nickel; immense amounts of sulfur and often nitrogen as well; and, of course carbon – lots of it. Ships burn bunker fuel because it is cheap.[6]

Diesel Engines

The quality of bunker fuel is so poor that almost the only engines that can burn it are massive diesel engines large enough to produce electricity for a city of 12,000 homes. What pours from the ships' stacks in a single day is a nearly unimaginable amount of pollution:

- 1.2 million pounds of carbon dioxide;
- 44,000 pounds of oxides of nitrogen;
- 18,000 pounds of sulfur dioxide;
- 3,600 pounds of particulate matter; and,
- 400 pounds of carbon monoxide.

Lubricants

Bunker fuel is immensely dense with pollution, especially sulfur. When burned, some of the sulfur combines with water to form sulphurous and sulphuric acids. These acids are extremely corrosive to engine components and must be neutralized to prevent corrosion and wear that would quickly ruin them. To neutralize and eliminate these acids and other deposits, the huge marine diesels require large quantities of specially formulated lubricants. A typical lubricant will contain detergents made from calcium, barium and magnesium.

Much of the lubricant—in one study, 64 percent—is burned and emitted as particulate matter.[7] The lube oil consumption can approach 5 percent, so it must be continually topped off, after which more is burned and emitted as air pollution.[8]

Figure 3 Beluga Shipping and SkySails have teamed to develop the use of giant kites as auxiliary power—a kind of hybrid wind/fossil-fuels system. The ship MV Beluga went from Germany to Venezuela in early 2008, a total of 11,952 nautical miles using this 160-square-meter kite to supply roughly 20 percent of the engine's power. The next step is to double the kite's size, which is predicted to save $2000/day in fuel costs. (Source: New Scientist)

SKYSAILS

There was a time when every ounce of cargo was moved from one place to another by the wind, and in Europe two companies are trying to tap into that tradition.

Beluga Shipping and SkySail have paired to develop and deploy huge kites—the first one is 160 meters square and the next will be twice that—to help cargo ships slice through the water using less fuel and making less air pollution.

The maiden voyage was in early 2008, from Germany to Venezuela, a total travel distance of 11,952 nautical miles. In even moderate winds the kite towing system worked well, substituting the wind for 20 percent of the engine's power.[9] The kite is controlled by computers. One computer helps it to fly in figures of eight in the sky, maximizing the power it produces. Another computer adjusts the kite's direction.[10]

1. Mellouki, A. et. al. Measurements of Ozone, Black Carbon and Particle Size Distributions Along a Mediterranean Cruise Track During the Period: October 2005-October 2006. NATO Science Series, Regional Climate Variability and its Impacts in The Mediterranean Area V. 79.
High levels of ozone as well as particles, including Black Carbon (BC), have been observed at sites around the Mediterranean Sea, and several studies have shown very high aerosol radiative forcing in the area, but systematical, long term observations are scarce. A collaboration between the JRC and the Italian company 'Costa Crociere' has allowed to install a monitoring station on board the cruise liner 'Costa Fortuna' that performs cruises on the Mediterranean, with regular weekly tracks in the Western Mediterranean during spring, summer and autumn, and in the Eastern Mediterranean during winter. Measurements of ozone, Black Carbon (aethalometer) and particle size distributions (optical particle sizer) have been performed, starting from the autumn of 2005; this activity will continue for several years. The measured ozone concentrations are compared to those obtained by simulations in a recent model intercomparison (ACCENT-PHOTOCOM); the initial measurements are in the higher end of the range of modeled values in the winter and in the lower end during the summer. Measured concentrations of ozone and BC in 2006 are compared to model simulations for previous years and the results are discussed.

2. Corbett, J. & Fischbeck, P. Emissions from Ships. Science 31 October 1997: Vol. 278. no. 5339, pp. 823 - 824 DOI: 10.1126/science.278.5339.823.
Air emissions from ships have not been adequately evaluated for their scientific or policy importance. Current international policy initiatives by the International Maritime Organization (IMO) to reduce emissions from ship propulsion systems (NOx and SOx, primarily) mark the first efforts to define a framework to address this issue. Corbett and Fischbeck estimate ship emissions on a global scale, updating current emission inventories. Global annual nitrogen and sulfur emissions from ships are estimated to be 10.12 Tg (1012 grams) and 8.48 Tg, respectively, showing that ship emissions represent more than 14 percent of nitrogen emissions from global fuel combustion sources and more than 16 percent of sulfur emissions from world petroleum use. The policy implications of ship emissions are discussed.

3. International Council on Clean Transportation, "Air Pollution and Greenhouse Gas Emissions from Ocean-going Ships: Impacts, Mitigation Options and Opportunities for Managing Growth," March 2007.

4. California Air Resources Board, "2nd Public Workshop to Discuss Development of Regulations for Ocean-going Ship Main Engines" June 13, June 13, 2007 Sacramento, California, http://64.233.169.104/search?q=cache:QSSrtiIef9oJ:www.arb.ca.gov/ports/marinevess/presentations/061307/061307ogvpres.pdf+ship+emissions+from+lubricants&hl=en&ct=clnk&cd=3&gl=us

5. Dominguez, G. et. al. Discovery and measurement of an isotopically distinct source of sulfate in Earth's atmosphere. PNAS September 2, 2008 vol. 105 no. 35 12769-12773.
Sulfate (SO4) and its precursors are significant components of the atmosphere, with both natural and anthropogenic sources. Recently, our triple-isotope (16O, 17O, 18O) measurements of atmospheric sulfate have provided specific insights into the oxidation pathways leading to sulfate, with important implications for models of the sulfur cycle and global climate change. Using similar isotopic measurements of aerosol sulfate in a polluted marine boundary layer (MBL) and primary sulfate (p-SO4) sampled directly from a ship stack, we quantify the amount of p-SO4 found in the atmosphere from ships. We find that ships contribute between 10% and 44% of the non-sea-salt sulfate found in fine [diameter (D) < 1.5 ?m) particulate matter in coastal Southern California. These fractions are surprising, given that p-SO4 constitutes ?2–7% of total sulfur emissions from combustion sources [Seinfed JH, Pandis SN (2006) Atmospheric Chemistry and Physics (Wiley–Interscience, New York)]. Our findings also suggest that the interaction of SO2 from ship emissions with coarse hydrated sea salt particles may lead to the rapid removal of SO2 in the MBL. When combined with the longer residence time of p-SO4 emissions in the MBL, these findings suggest that the importance of p-SO4 emissions in marine environments may be underappreciated in global chemical models. Given the expected increase of international shipping in the years to come, these findings have clear implications for public health, air quality, international maritime law, and atmospheric chemistry.

6. Liquid Minerals Group, Inc., "Bunker Fuels," http://www.liquidminerals.com/fuels.htm

7. Thomas C. Miller, T.C., Jackson M.A., Brown, A. J.& Wong, V.W., " Prevention of Air Pollution from Ships: Diesel Engine Particulate Emission Reduction via Lube-Oil-Consumption Control," supported by the U.S. Maritime Administration, the U. S. Coast Guard and the Massachusetts Institute of Technology. http://64.233.169.104/search?q=cache:SxXWv5iuTCgJ:www.aoe.vt.edu/~brown/Papers/2c2ppr.pdf+ship+emissions+from+lubricants&hl=en&ct=clnk&cd=4&gl=us

8. Federation of American Scientists, Military Analysis Network, “Diesel Engines,” http://www.fas.org/man/dod-101/sys/ship/eng/diesel.htm

9. Environmental Network News, “Kite-Driven Beluga Skysail Completes 12,000 Mile Journey and Proves Concept,” March 17, 2008.

10. Steve Rosenberg, “Gone with the wind on 'kite ship'” BBC News, Jan. 23, 2008.