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Introduction: Air Pollution from Maritime Transport

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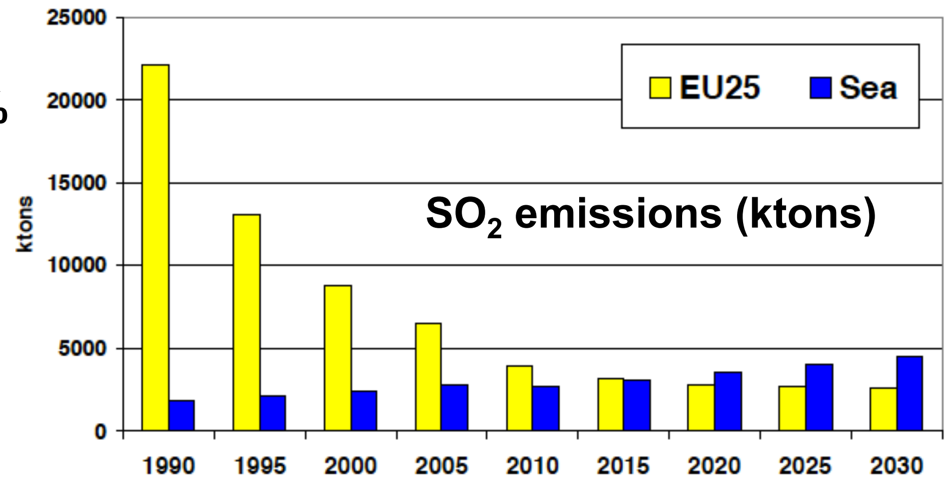
Bunker oil and air pollution emissions

- Almost all commercial ships use marine diesel engines
- These engines specially designed to burn “bunker oil”
  - High-sulfur product of gasoline, oil refinement process
  - International Maritime Organization (IMO) average for bunker oil is 2.7% sulfur (= 27,000 ppm); much bunker oil is over 3.0%
  - Much cheaper than the low-sulfur diesel fuel used in the much smaller engines of trucks (and cars)
  - Low-sulfur car fuels have about 50 ppm of sulfur
- Source of air pollutants
  - SOx, NOx (and CO_2)
  - Particulate matter



Source: Main baseline scenario (CP) developed by IIASA in autumn 2004 for the Commission’s CAFE programme. Data from: http://www.iiasa.ac.at/rains/cafe.html (October 2004).

UN regulation of maritime air pollution

- First major effort:
  "International Convention for the Prevention of Pollution From Ships, 1973" as modified by the Protocol of 1978.
- MARPOL (= Marine Pollution) Annex VI, adopted in 1997, came into force in 2005
  - Limits main air pollutants: SOx, NOx, particulate matter
  - Prohibits deliberate emission of ozone-depleting compounds
  - Regulates shipboard incineration
  - Regulates emission of volatile organic compounds by tankers
- MARPOL Annex VI revision from 2008: more stringent, progressive reduction of air pollutants through 2020
  - Some standards came into effect 2010
  - Other standards into effect 2012

MARPOL Annex VI, Regulation 14 (SOx)

Outside an Emission Control Area		Inside an Emission Control Area	
Before 1/01/2012	4.5 % m/m	Before 7/01/2010	1.5 % m/m
From 1/01/2012	3.5 %	From 7/01/2010	1.0 %
From 1/01/2020	0.5 %	From 1/01/2015	0.1 %

- **Emission control areas – where pollution is biggest problem: entire Baltic Sea, etc.**
- **Concern about availbility of high-quality oil: 2020 protocol may be delayed until 2025**
- **MARPOL Annex VI, Reg. 13, deals with NOx, but it is more complex and also includes provisions for new measurement & monitoring approaches**

Alternatives to solving the SOx problem

- Seawater scrubbing of emissions
- Use more expensive, higher quality fuel
  - What happens to the refinery output that used to go to bunker fuel? (It would have to be sequestered somewhere)
  - Energy and environmental cost of higher refinement
  - Desulfurization in refining creates other problems: typically use H_2, yielding H_2S (poisonous, although useful chemical), which can be further processed into sulfuric acid
- Other (onshore) desulfurization techniques mix SOx with limestone or chalk (mostly $CaCO_3$), yielding gypsum (calcium sulfate)
  - Would require transporting the raw materials
  - Energy cost of mining, etc.
  - In comparison, natural seawater is great source of $CaCO_3$

Sulfur in the air is a problem; sulfur in seawater less so

Sulfur in seawater	SOx
Most sulfur already naturally found in the oceans	SOx only naturally abundant near volcanic eruptions
Micro-organisms methylate sulfur, yielding dimethyl sulfide (DMS)	Burning sulfur in fossil fuels yields SOx (and NOx, etc.)
Some DMS evaporates; may help form seeds for clouds	SOx in the air forms sulfuric acid, other sulfates (inc. ammonium sulfate) = acid rain, haze
A lot of sulfur stays in living organism (hence its presence in fossil fuels)	SOx in seawater reacts with $CaCO_3$ to form calcium sulfate (gypsum) + CO_2
Sulfur from seawater scrubbing of SOx emissions barely increases total *local* sulfur already there (estimate from 928 ppm to 929 ppm)	