Emissions Monitoring on Ships and an insight into the MARPOL Regulations

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Who is setting legislation?

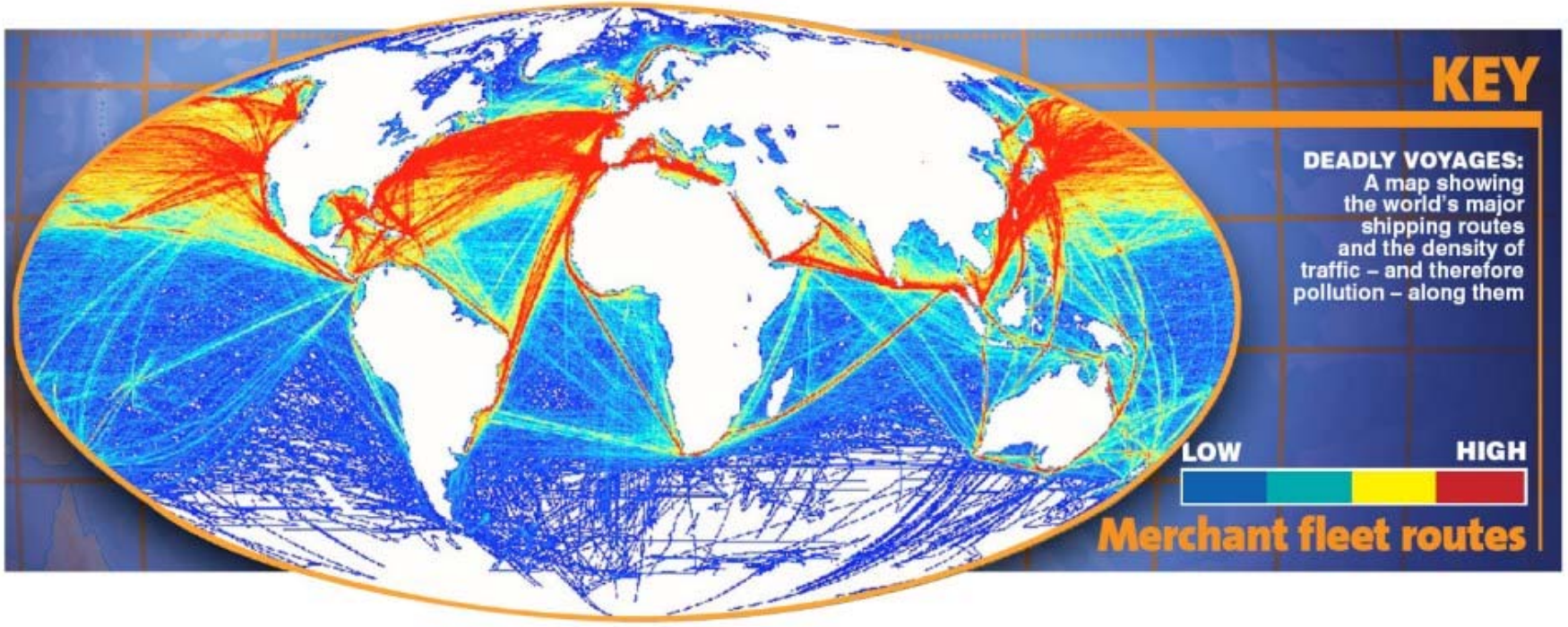
IMO International Maritime Organization
IMO is the United Nations agency responsible for the safety and security of shipping and preventing ships from polluting the environment.
MARPOL Marine Pollution
(International Convention for the Prevention of Pollution from Ships)

What is the legislation about?

IMO's adoption of MARPOL Annex VI, limits the main air pollutants contained in ships exhaust gas, including sulphur oxides (SOx) and nitrogen oxides (NOx),and prohibits deliberate emissions of green house gases (GHG), mainly CO_2.

Why is this legislation required?

Simultaneously with the growth of maritime transport, awareness of the influence of such maritime transport on the environment has increased, resulting in the creation of international regulatory framework to govern shipping's influence on the environment.



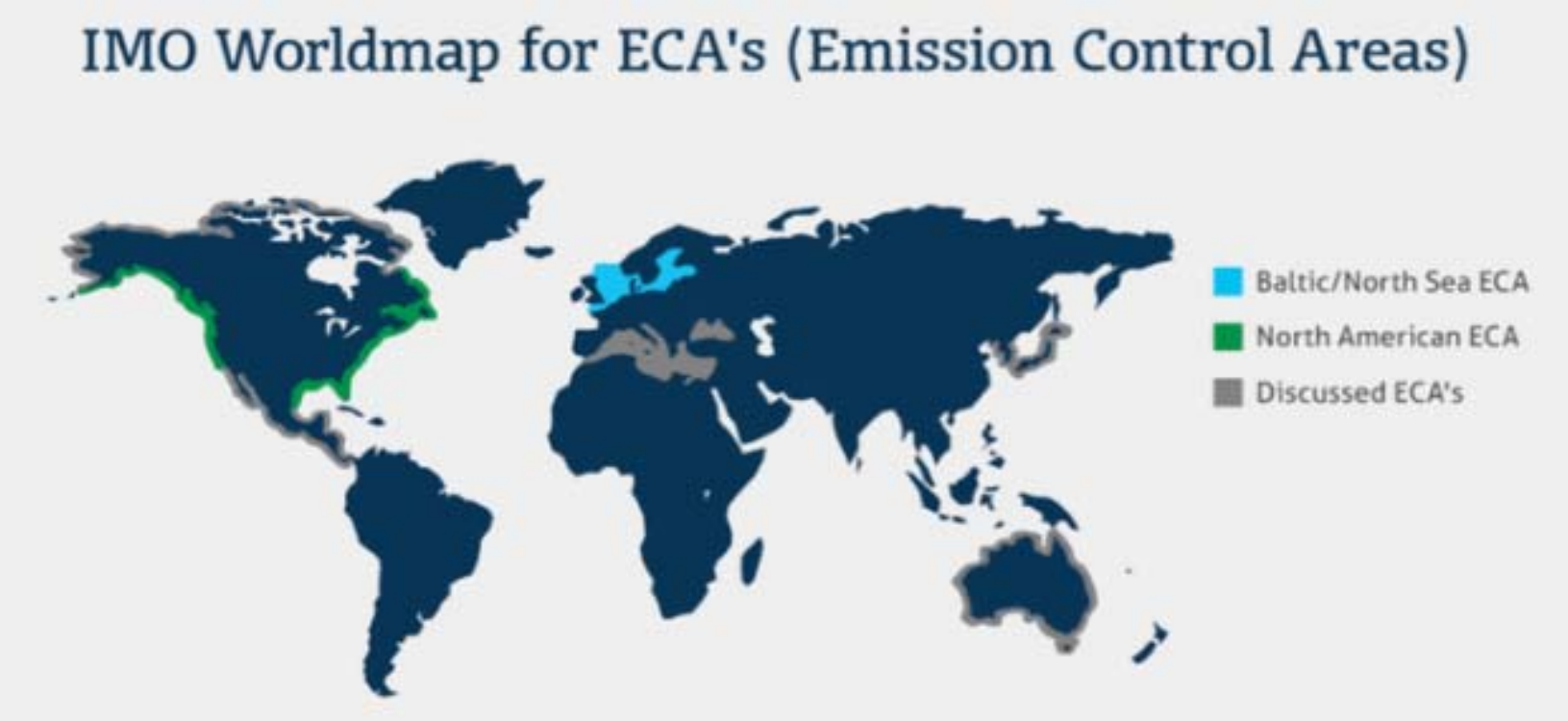
MARPOL Annex VI
Regulates emissions SOx, NOx and GHG

A progressive reduction in emissions of SOx, NOx and particulate matter is introduced and so are emission control areas (ECAs) where the emission of NOx as well as SOx and particulate matter is further restricted.
The main drivers of emission monitoring in marine industry are:

- Setting limits on the emissions of nitrogen oxides (NOx) from new ship engines
- Setting limits on the sulfur content of marine fuel oils
- Focus on CO2 emission reduction as predominant GHG emission from ships
- Defined emission control areas (ECA)

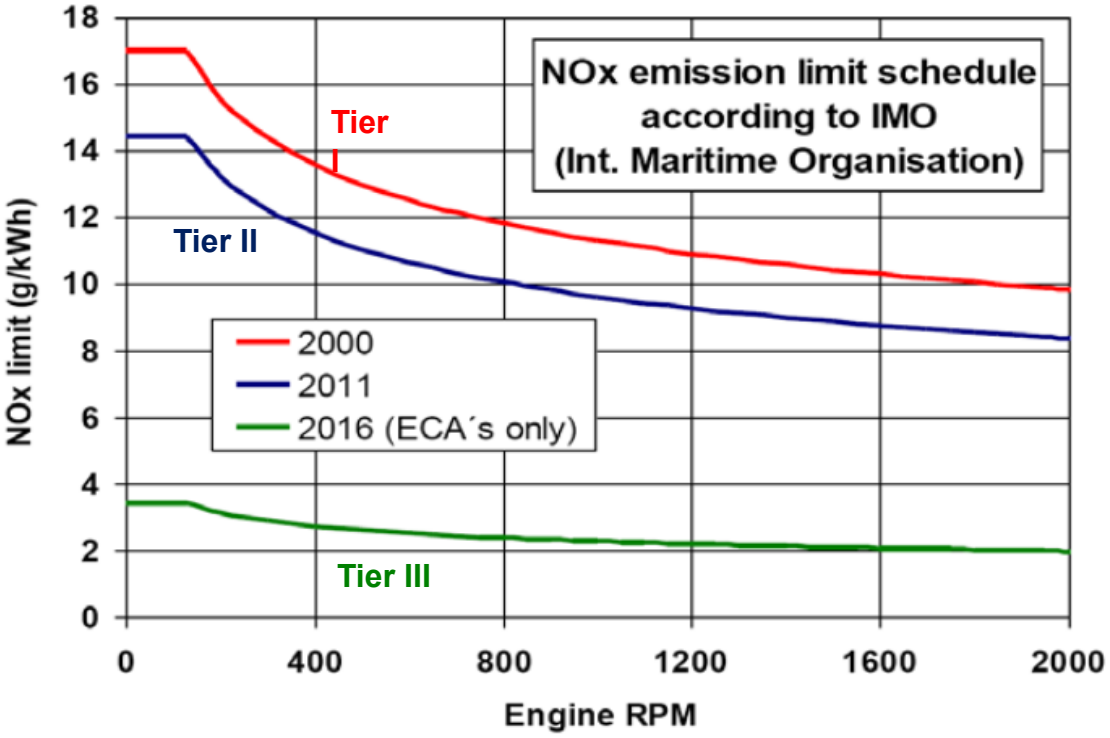
MARPOL ECA's - Emission Control Areas

Baltic/North Sea ECA established from 2006
North American ECA established from 2012
Discussions continue on new ECA's



NOx emission standard
Current legal situation with pollutant NOx

Global reduction of NOx emissions according to a “tiered approach". Tier I, II and III are given as specific emissions (g/kWh) based on the maximum operating speed of the engine



Tier I	Up to Dec. 2010
Tier II	After 1st Jan. 2011
Tier III	After 1st Jan. 2016 NECA only

Regulation 13 of IMO Annex VI applies to marine diesel engines with an output of more than 130 kW

Tier III standards which came into force in 2016 for NECA (North American ECA) are expected to increase focus on after-treatment unit for emission control.

Measurement of NH_3 as Slip Control after denox technologies - selective catalytic reduction (SCR) and selective non-catalytic reduction (SNCR)

- The tight requirements set by IMO Tier III can be met by utilizing SCR (Selective Catalytic Reduction) or SNCR (Selective Non Catalytic Reduction) technology.
- Ammonia or Urea is used to reduce NOx produced by the combustion process:

$$4\ NO + 4\ NH_3 + O_2 \rightarrow 4\ N_2 + 6\ H_2O$$

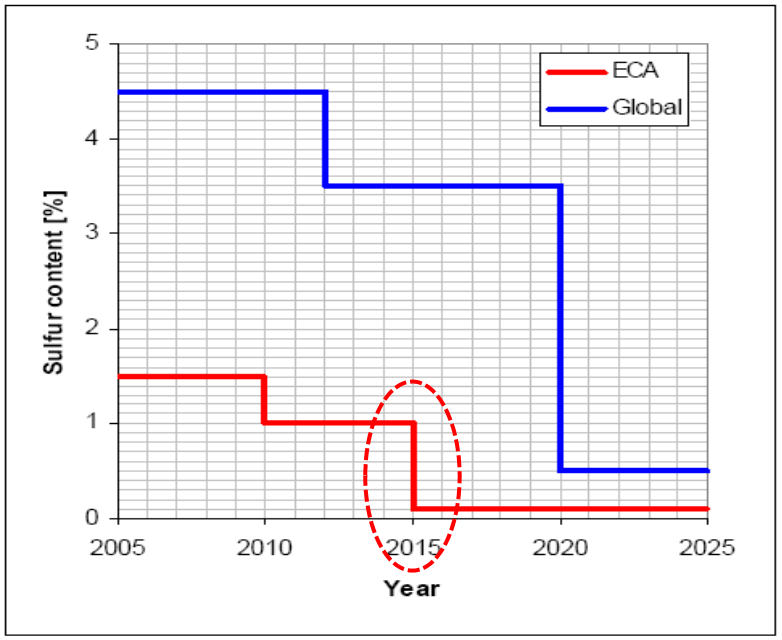
- Emission of ammonia is not a result of the combustion of fossil fuels, but of incomplete reaction of ammonia in the denox process (excess ammonia).
- Ammonia slip at SCR and SNCR installations rises with an increasing NH3/NOx ratio, but also with decreasing catalyst activity.
- Ammonia concentration is usually kept below 5 mg/m³

NH3 slip measurement enables:

- Cost-saving and rapid setting of urea/ammonia injection
- Diagnosis of catalyst deactivation
- On-line monitoring of all results
- Reaction conditions in SCR/SNCR

SOx regulation
Current legal situation regarding SOx

Starting in 2015, all vessels entering an ECA (Emission Controlled Area) have to use a fuel with less then 0.1% sulfur - or alternatively need to have exhaust gas cleaning systems (scrubbers) that scrub the flow of exhaust gas prior to being discharged to the atmosphere. Emission monitoring is required when employing such an arrangement.



Fuel regulation out of ECA
4.5% S m/m up to 2011
3.5% S m/m Jan. 2012
0.5% S m/m Jan. 2020

Fuel regulation in ECA
1.5% S m/m up to Jun 2010
1.0% S m/m Jul. 2010
0.1% S m/m Jan. 2015

How to comply with challenging SOx emission regulations?

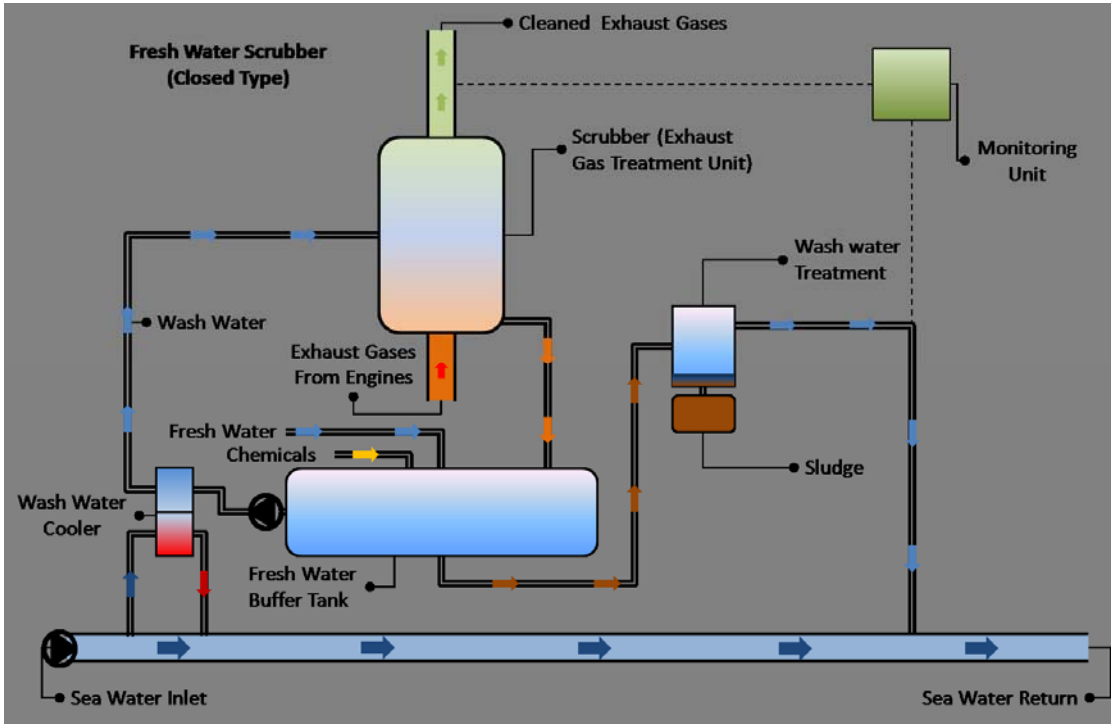
Option 1 - 'Dual-fuel' or diesel only **No Exhaust Emission Monitoring Required**	Option 2 - 'Modification' **No Exhaust Emission Monitoring Required**	Option 3 - 'Scrubber' **Emission Monitoring is Required**
Heavy oil (high sulfur) **+ / or** **Diesel-oil (low sulfur fuel)**	**Switch to LNG (ultra low sulfur)**	**Heavy oil (high sulfur)** **+** **EGCS* for SOx Removal**

Main advantages of EGCS are as follows:

- Lower operating costs through access to less costly fuel
- Avoiding fuel switching, storage and availability issues
- Reducing your operational impact on the environment

***EGCS – exhaust gas cleaning system**

How does exhaust gas scrubbing work?



Wet scrubber principle:

As a result from the chemical absorption process sulphur oxides from the exhaust gas are neutralized to sulphates in the scrubbing water.

Marine Environment Protection Committee (MEPC) 184(59) – Guideline for exhaust gas cleaning systems

Compliance demonstration by use of the SO2 (ppm)/CO2 (Vol-%) ratio method.

This method is independent of the engine load, moisture content and does not require flue gas flow monitoring.

Fuel Oil Sulfur Content (% m/m)	Emission Ratio SO2 (vpm) / CO2 (Vol-%)
4,5	195,0
3,5	151,7
1,5	65,0
1,0	43,3
0,5	21,7
0,1	4,3

Example for Emission ratio 4,3:
SO2: 43 vpm
CO2: 10 Vol-%

EGCS must meet SO2 / CO2 ratio

Examining MEPC 184(59) in more detail

There are 2 compliance plans:

a.) Scheme A *(unit approval)* Certification of the unit with parameter and emission value test

b.) Scheme B *(continuous monitoring)* SO2 range: 0 - 100/750 ppm, CO2 range: 0 - 10 Vol-%

but even with Scheme A

- In the case that continuous measurement is not installed, a daily analysis on the quality of the system in view to the SO2 (ppm) / CO2 (%) ratio is required. Getting type approval is also very difficult where unit has to be compliant across the whole range.

Important details in chapter 6:

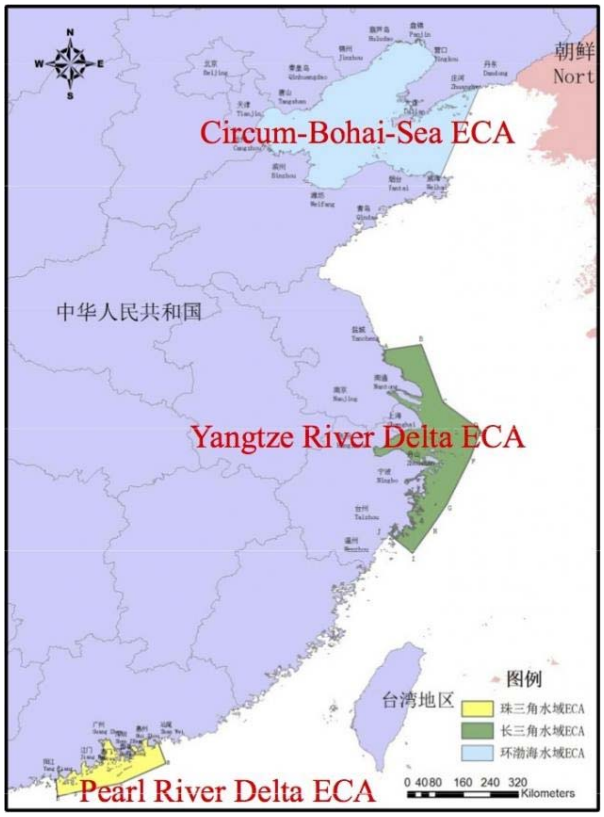
6.2 CO2 should be measured on a dry basis using an analyser operating on non-dispersive infra-red (NDIR) principle. SO2 should be measured on a dry or wet basis using analyzers operating on non-dispersive infra-red (NDIR) ….

6.5 SO2 and CO2 should be monitored using either in situ or extractive sample systems.

6.8 Where SO2 is measured by an in-situ system, the water content in the exhaust gas stream at that point is also to be determined …

Emission Control Areas - China

- In December 2015, China announced the creation of three ECA's
- This is domestic legislation and not part of MARPOL
- Starting in 2016, phased introduction of a maximum fuel sulphur content of 0.5% or the use of alternative emission controls eg. exhaust gas scrubber
- Possible reduction to 0.1% maximum fuel sulphur content after 2019



Green House Gases Reduction

- On 1 July 2015. EU Regulation 2015/757 came onto force to regulate the CO2 emissions in the marine industry as apart of EU targets to reduce GHG (Green House Gases) emissions by 2030 to levels 40% lower than of the emissions in 1990.
- This regulation establishes a European MRV (Monitor-Report-Verify) system for shipping.
- The regulation applies to ships above 5000 GT which represents 55% of ships using EU ports but 90% of the total emissions
- MRV system can either be based on the calculation of fuel consumption or stack monitoring.
- A monitoring plan shall be submitted by shipping companies to authorised verifiers by August 2017.
- Start of monitoring: 1 January 2018

Instrumentation to be used and gases required

Component	Measuring principle	Gases Required
Nitrogen oxides (NOx)	Chemiluminescence Detector (CLD)	Environmental calibration gas mixtures, HiQ Synthetic Air 5.0, HiQ Hydrogen 5.0, HiQ Argon 5.0, HiQ Nitrogen 5.0
Sulphur oxides (SOx)	Non Dispersive Infrared Spectroscopy (NDIR)	Environmental calibration gas mixtures, HiQ Synthetic Air 5.0 Zero, HiQ Argon 5.0, HiQ Nitrogen 5.0 Zero, BASELINE equipment
Carbon dioxide (CO2)	Non Dispersive Infrared Spectroscopy (NDIR)	Environmental calibration gas mixtures, HiQ Synthetic Air 5.0 Zero, HiQ Argon 5.0, HiQ Nitrogen 5.0 Zero, BASELINE equipment
Carbon monoxide (CO)	Non Dispersive Infrared Spectroscopy (NDIR)	Environmental calibration gas mixtures, HiQ Synthetic Air 5.0 Zero, HiQ Argon 5.0, HiQ Nitrogen 5.0 Zero, BASELINE equipment
Hydrocarbons (HC)	Heated Flame Ionisation Detector (FID)	HiQ Synthetic Air 5.0, HiQ Hydrogen 5.0, HiQ Helium 5.0, HiQ Nitrogen 5.0 , 40% H2 in He
Oxygen (O2)	Paramagnetic or Zirconium dioxide	Calibration gas mixtures