Summary and comparison to legislative methods of UCL PLA pre- post- intervention exhaust emissions sampling

The measurement of engine exhaust gas composition pre- and post- an intervention, such as a switch to an alternative fuel or retrofit of an exhaust after-treatment system, can help indicate the success of these measures in reducing pollutants detrimental to air quality and Table 1 provides a summary of the UCL PLA sampling method in comparison to those used for engine certification and legislative compliance.

Table 1 - Test conditions and instrumentation utilised in exhaust emissions measurement for UCL PLA pre- and post- intervention emissions sampling and those commonly used for engine certification in accordance with emissions legislation

Engine sampling Method	**MARPOL**			**USA EPA**	**NRMM**		**UCL PLA**
	Tier 1	**Tier 2**	**Tier 3**	**Tier 4**	**Stage III**	**Stage V**	
Engine types applied	Installed on a ship constructed on or after 1 January 1990 but prior to 1 January 2000, NOx limit varies with engine speed, e.g. 12.1 g/Kwh at 720 rpm	Built on or after 1 January 2011, NOx varies with engine speed, e.g. 9.7 g/Kwh at 720 rpm	Built on or after 1 January 2016. NOx varies with engine speed, e.g. 2.4 g/Kwh at 720 rpm	Phased-in from 2008 through 2015. Based on the use of after treatment, applies to engines above 600 kW and enforces significantly lower NOx limits, e.g. 0.40 to 0.67 g/Kwh	Phased-in from 2006 to 2013: for engine of 19 to 560 Kw	Effective from 2019 for engines below 56 kW and above 130 kW, and from 2020 for engines of 56-130 kW	Can be applied to any engine with accessible exhaust e.g. Caterpillar 3306 DITA engines (235 bhp), D399, 1250HP and John Deere 200 horsepower marine diesel engines
Test standards, and Instruments used	ISO 8178 emission standards are used: Steady-state engine dynamometer test cycles.				Non-Road Transient Cycle (NRTC) , ISO 8178 C1,Non-Road Steady Cycle (NRSC)		Collection during matched condition, Horiba MEXA 9100 gaseous emissions analyser, volumetric particulate mass determination following desiccation.
Engine speed	Rated, intermediate and idle, Speed ranging from less than 130 rpm, 130 to 1999 rpm and above 2000 rpm				Rated speed, intermediate and low idle speed		Rated, intermediate and idle
Engine torque %	Various increment from 10% to 100 %						In-service: Variable but approximatly matched pre and post intervention engine conditions
Sampling procedure	Gaseous and particulate emissions on the test bed, at site measurement of exhaust gas smoke emissions using a filter-type smoke meter						Collection of gaseous and particulate samples during vessel operation for subsequent laboratory analysis.
Emissions units	Absolute amount of pollutant in the exhaust gas for a given amount of power deliver (Gram per Kilowatt-hour (g/kWh))						Gaseous: Volumetric proportion of exhaust composition (% volume and ppm)
							Particulate matter: mass per volume exhaust sampled
	Note: EIAPP certificate is issued to show engine compliance with applicable regulation 13 of Annex VI of MARPOL						

Purpose of UCL PLA exhaust emissions sampling

- Monitoring of exhaust gas composition before and after a vessel switches to the use of an alternative fuel, or an exhaust after-treatment system is retrofitted to a vessel engine, provides an indication as to how successful this intervention has been in reducing the emission of pollutants (for example NOx, particulate matter) to the atmosphere.
- The pre-intervention gas sampling and analysis takes place while the vessel is in operation on a route that can be repeated subsequently, following implementation of an alternative fuel or after-treatment retrofit. On both occasions, gas and particulate samples are taken at a range of engine speed and load conditions, for example low speed idling or high speed and power.
- The collected gas and particulate samples are then analysed in UCL's Engines and Fuels Laboratory to determine the level of pollutants present per volume of engine exhaust gas sampled (please see Table 1 for further methodological details).

Outcomes of pre- post- intervention exhaust emissions sampling

- Comparison of the measured pollutant levels at the same engine speed pre- and post- intervention will indicate in what way the pollutants that have a negative impact on local air quality have been impacted by the change in fuel or addition of after-treatment. For example, whether the switch to a renewable paraffinic fuel (such as HVO) has reduced the emission of particulate matter.
- Sampling at a range of conditions also allows for determination of whether certain interventions might be more or less beneficial for different types of vessel operation. For example, a larger difference in NOx emissions pre- and post- intervention at high engine load conditions versus engine idling.

Key differences between UCL PLA sampling and legislative methods

- Legislative methods (such as those described in Table 1) typically sample emissions from new engines outside of a vessel in order to determine compliance with regulated emissions limits. The UCL PLA pre- post- emissions sampling cannot be used for certification, or checking regulatory compliance, and is instead used to assess the effect of a specific intervention on an in-service vessel.
- Emissions measurements for certification take place at steady states conditions using an engine dynamometer laboratory, which facilitates the reporting of pollutant levels on a per power out basis to allow for comparison of different engines of varying specification. Where the UCL PLA method reports pollutant levels as a proportion of total exhaust gas volume, this can vary even where a vessel is operating at nominally similar conditions due to differences in weather and tides and also means that a direct comparison between different engines cannot be made.

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Further reading

https://server1.pla.co.uk/Environment/Alternative-Energy/Emissions-and-Performance-of-Alternative-Diesel-Fuels-on-PLA-Harbour-Service-Vessel-Kew

https://dieselnet.com/standards/cycles/iso8178.php

https://www.imo.org/en/About/Conventions/Pages/International-Convention-for-the-Prevention-of-Pollution-from-Ships (MARPOL).

https://www.london.gov.uk/sites/default/files/nrmm_practical_guide_v4_sept20.pdf

https://navsregs.wordpress.com/2017/01/03/engine-international-air-pollution-prevention-certificate-a-handy-guide/