LONDON LOW EMISSION
CONSTRUCTION PARTNERSHIP

‘Best in Class’ Guidance on Dust and Emissions ~~from~~ Construction

SUPPORTED BY

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Member Boroughs:

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Greater London Authority

Transport for London

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Introduction

This document summarises the work from the London Low Emission Construction Partnership (LLECP) project. This was a Mayor's Air Quality Fund Project which comprised central London boroughs, the construction industry and their supply chain, low emission solution providers and King's College London; more information on the project can be found at www.llecp.org.uk. The LLECP aimed to highlight the impact that the construction industry has on local air quality through dedicated outreach activities as well as encourage the uptake and test 'best in class' pollution reduction approaches. This document therefore provides an information resource for local authority staff working with the construction industry and should be considered alongside other guidance documents when considering how best to minimise emissions from this sector.

"Best in Class" emission reduction encourages uptake of low emission approaches that will further reduce the impacts on worker exposure, local air quality and the environment.

Current guidance for the construction industry sets out minimum requirements for dust management and emission standards for all developments across London. As well as the individual borough's own construction guidance, these include:

GLA's supplementary planning guidance

The control of dust and emissions during construction and demolition (2014)

IAQM guidance

Guidance on monitoring in the vicinity of demolition and construction sites

Guidance on the assessment of dust from demolition and construction

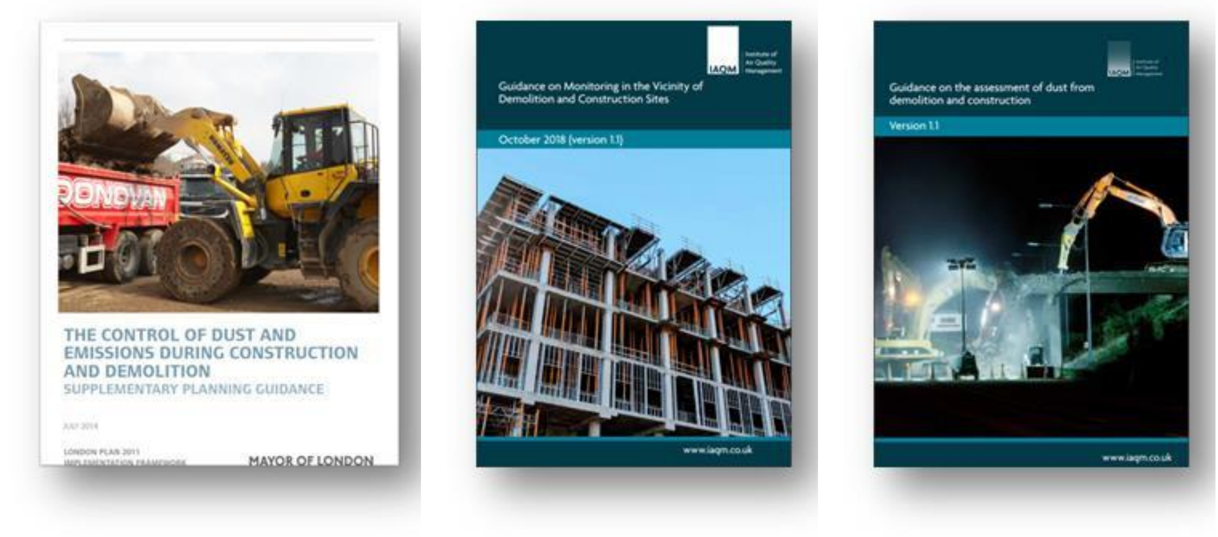


Figure 1: Current guidance for construction

Impact of construction industry on local air quality

The Greater London Authority have estimated that there were 9,500 premature deaths in London that were attributable to long term exposure to particulate matter (PM) and nitrogen dioxide (NO_2) emitted into the air during 2010. This pollution comes from many different sources, with approximately half of it coming from road transport.

There has been a great deal of focus on reducing the emissions from commercial road transport in recent years through the introduction of the London Low Emission Zone requiring cleaner engine technology or retrofit after-exhaust treatments systems in HGV’s, buses and taxis. We have also had hydrogen, hybrid and full electric buses added to the London fleet. The Ultra-Low Emission Zone (ULEZ), started in April 2019, and includes private vehicles. The emissions from this sector are expected to reduce further, therefore pollution from other sources will increase in significance.

According to the 2016 London Atmospheric Emissions Inventory (LAEI); the machinery used by the construction industry contributes 7% of the total nitrogen oxides (NOx), 34% of the PM_{10} and 15% of the $PM_{2.5}$ emissions in London.

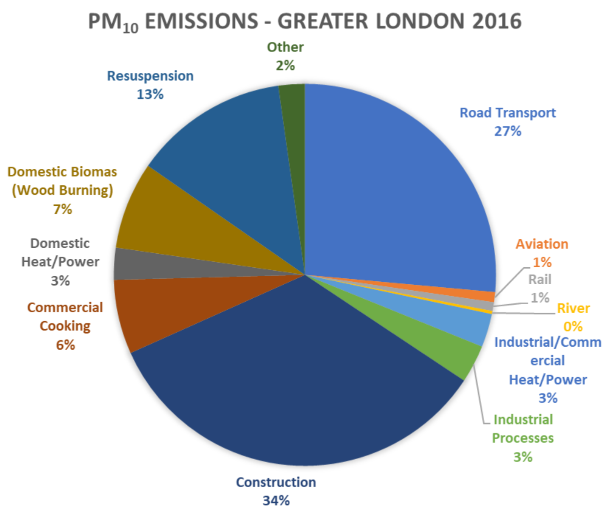


Figure 2 PM_{10} Emissions, source: LAEI 2016

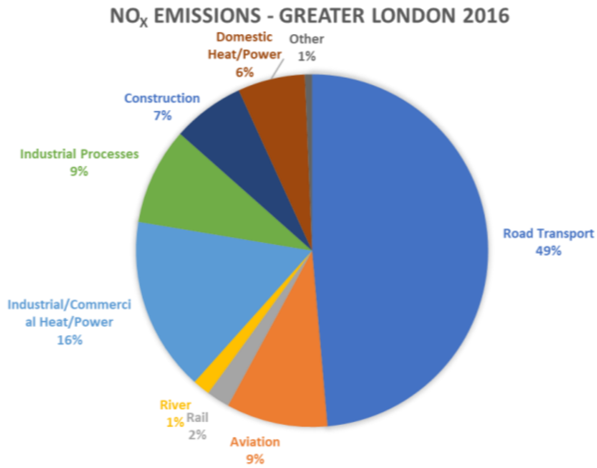


Figure 3 NOx Emissions, source: LAEI 2016

London is currently in breach of the European limit values for nitrogen dioxide (NO_2). Fugitive or nuisance dust, mainly from demolition and earth works activities, also leads to increased particulate concentrations around developments.

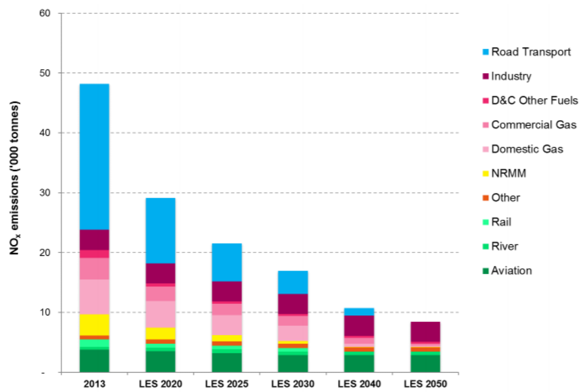


Figure 4 Emission trend and main source categories for London’s NOx 2013-2050

The Mayor’s London Environment Strategy (2018) outlines the vision, and challenges, for London as it moves towards becoming a zero-carbon city by 2050. This target can only be achieved by the construction sector using less polluting machinery and the adoption of zero and ultra-low emission technologies such as hydrogen fuel cell, hybrid and electric.

The Mayor introduced the world’s first low emission zone for non-road mobile machinery in 2015 with minimum emission standards required that are progressively tightened from 2020 to support the London Ultra Low Emission Zone. These are described in further detail later in this document.

What are the main pollutants of concern?

Construction sites can generate and emit many different types of pollution but the main concerns for human health is the 'dust' or particulate matter measured as PM_{10} (particles less than 10 µm in diameter) or $PM_{2.5}$ (particles less than 2.5 µm in diameter) and NO_2.

On construction sites these pollutants are produced by the diesel engines in off-road machinery and static engines such as power generators (collectively known as non-road mobile machinery' or NRMM). Dust is also generated from activities such as demolition and earthworks. This harmful dust is often 'tracked out' onto public roads on the wheels of vehicles leaving the sites and is then resuspended back into the air by subsequent vehicle movements and can remain in suspension for many days or even weeks.

The long-term health impacts of these pollutants include:

- Respiratory illness, cardiovascular disease and mortality as well as lung cancer
- Reduced lung function (especially in children)
- Strong links to early onset dementia and autism

The fine particulate matter in diesel engine exhaust is also classed as being carcinogenic to humans and in 2004 the World Health Organisation (WHO) advised that there is no evidence of a safe level of PM exposure or a threshold below which no adverse health effects could occur.

The Greater London Authority (GLA) estimated that 9,500 premature deaths in London during 2010 were attributable to long-term exposure to nitrogen dioxide and particulate matter in the air.

Occupational exposure

Construction workers are exposed to the greatest levels of risk when working on sites near machines and activities that produce pollution. The CITB reported that during the 2016/17 period around 3000 construction workers were suffering with breathing and lung problems they believed were caused or made worse by their work.

Occupational cancer burden research indicates past occupational exposure to known and probable carcinogens is estimated to account for about 5% of cancer deaths and 4% of cancer registrations currently occurring across sectors each year in Great Britain. This equates to about 8,000 cancer deaths and 13,500 new cancer registrations annually.

Of the estimated 8,000 occupational cancer deaths, the construction industry had the largest number (3,500). Most of these cases were caused by past exposure to asbestos (2,600) and silica (450) as well as diesel emissions.

Of the estimated 13,500 occupational cancer registrations during this period, the construction industry had the largest number (5,500).

New EU workplace exposure limits for diesel exhaust were proposed 2017 and are being adopted. COSSH regulations require that every employer ensures that the exposure of his employees to substances hazardous to health is either prevented or, where this is not reasonably practicable, adequately controlled.

In 2012, the International Agency for Research on Cancer (IARC) classified diesel engine exhaust as carcinogenic to humans (Group 1). This classification is based on sufficient evidence that exposure to diesel engine exhaust is associated with increased lung cancer risk.

There are resources and guidance that specifically address the risks of diesel emissions from IARC:

https://www.iarc.fr/wp-content/uploads/2018/07/pr213_E.pdf

and IOSH’ No Time to Lose campaign:

https://www.iosh.co.uk/NTTL/Home/About-NTTL/About-IOSH.aspx

Fugitive Dust Monitoring

Construction activity without effective mitigation can have a temporary impact on particulate concentrations near development works. This is particularly noticeable during demolition and ground work phases of a project; therefore, boundary monitoring should form part of dust management plan for all major developments. Visible dust emissions are also the cause of most site complaints relating to local air quality even if they do not pose the greatest health risks.

It is normal to require a baseline measurement period of at least three months, but this is rarely possible if the contractor carrying out enabling works is required to start work soon after planning permissions have been granted.

All sites should carry out a daily inspection for visual dust emissions, both inside and outside the site boundary. The results from this should be recorded and kept onsite and made available if requested. There is an increased risk of fugitive dust emissions during prolonged dry periods or during stronger wind conditions as well as during certain types of activity and therefore the frequency of checks should also be increased.

There are often planning conditions that require major developments to install continuous boundary dust monitoring to give an early alert if anything goes wrong and there is a rapid increase in local particulate concentrations that may be related to site activity. However, this is only an effective measure in reducing fugitive dust emissions from a site if the monitoring equipment is correctly installed and maintained with a high level of quality control.

Purpose of monitoring

Although monitoring is increasingly included as a requirement of the planning conditions, developers are often not aware of what is required or what actions should follow if an exceedance of the agreed site boundary threshold is recorded.

Construction monitoring at the site boundary is carried out to:

- ensure that construction activities do not cause any exceedances of the air quality objectives for PM_{10}. This is of importance where there are long-term works and/or multiple developments operating within a confined area;
- ensure that the site mitigation measures outlined in the dust management plan are being applied and are effective;
- provide a rapid "alert" system to notify key personnel on site of any exceedance of the agreed threshold concentrations in order that appropriate action may be taken;
- provide a body of evidence on the likely contribution of the site works for reporting back to the local planning authority, other stakeholders and at public meetings

It is often the case that the site is carrying out monitoring to provide evidence that the dust management plan has been instigated and is effective and therefore it is not creating a nuisance, however in the event that something has gone wrong rapid action can be taken to control emissions.

PM Exceedances are routinely recorded outside of site operational hours and may be caused by windblown resuspension of dust from spoil heaps, other uncontained materials or surfaces where they have been deposited as well as the resuspension of dust 'tracked out' onto the public highway by passing vehicles.

What to do when alerts are received?

If alerts are received during operational hours the cause needs to be investigated as soon as possible. If the exceedance has been caused by an obvious activity such as dry cutting materials, then work should stop until supplementary abatement can be applied.

In the case of all exceedances a report should be submitted to the local planning authority, normally within 48 hours, outlining the date and time, concentrations recorded, activities that were being carried out within the vicinity of the dust monitor at the time and further actions taken to prevent recurrence.

Alerts often occur during regional episodes when background particulate concentrations are elevated due to a polluted air mass being imported into London and the south east and although the local contribution from the construction activity may not have changed it still causes an exceedance. As such it is useful to raise awareness of the air pollution forecasting services available such as LondonAir (www.londonair.org.uk) and the Canairy air pollution exposure app for outdoor workers (https://www.britsafe.org/campaigns-policy/time-to-breathe-air-pollution-campaign/canairy-the-mobile-app-for-outdoor-workers/) so the developer or contractors are aware of ambient conditions and can apply additional mitigation when required.

An exceedance report template is given in appendix 1.

Figure 5: Chain of action when pollution alerts are received

It is also a requirement of the GLA's SPG that the local planning authority are given access to download the data from the monitors in real time. This is normally made possible through sharing access details to an online portal such as the LLECP website.

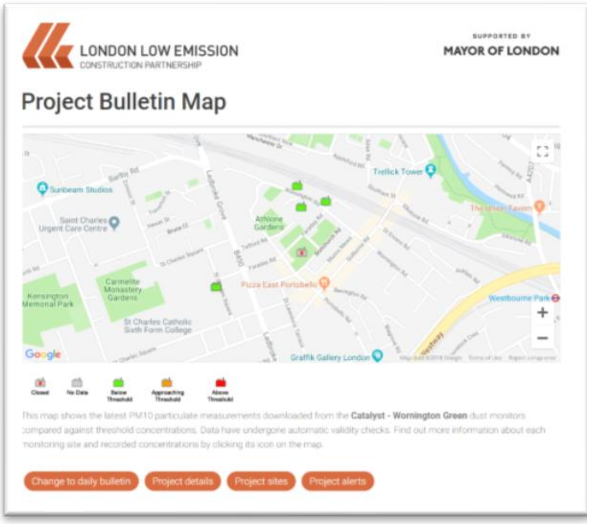


Figure 6 'Real time' monitoring data displayed on the LLECP website

There is evidence that additional local PM_{10} during the construction periods can also arise from the roadways in addition to that from within the construction site boundary. This is normally in the form of resuspension of material from the road surface that has been 'tracked out' of the site along the haulage route. Therefore, site haulage routes need to be considered within a developments dust management plan.

Monitoring would normally continue until a site is completed, even if the later phases of development are considered to be of a lower risk, to provide evidence that emissions are being controlled.

Types of dust monitors

There are several different monitoring techniques available ranging from continuous (powered) monitors that give real time measurements and can raise an alarm if local concentrations increase to allow immediate mitigation, hand held monitors for taking 'spot' readings and passive (unpowered) directional dust gauges and sticky discs to measure deposition rates.

Where there is a planning requirement it will normally be for continuous dust monitoring at the site boundary or next to sensitive receptors such as schools or hospitals. These monitors collect data in 'real time' and can rapidly raise an alarm if anything goes wrong on site allowing for corrective measures to be put in place. The local planning authority should also be able to access the data from these monitors in real-time, normally via a web portal.

There are two main types of continuous monitors, referred to as either reference or indicative.

Reference monitors

Reference monitors are very accurate instruments that measure particles using gravimetric, beta-attenuation or optical light-scattering methods and are most commonly used on the national networks (e.g. AURN) to produce high quality datasets that can be used for direct comparison against DEFRA's daily air quality index (DAQI). However, these instruments are expensive to buy and maintain and require regular intervention by highly trained operators. Often particles are size selected in PM_{10} or $PM_{2.5}$ before being measured so only one size fraction is reported. Time resolution varies, it is typically daily for gravimetric samples but automatic instruments report measurements at resolutions between 5 minutes and 1 hour. Where the time resolution is low, short term exceedances may not be detectable.

Unless a development is likely to run for an extended duration or is considered to be particularly high risk to a sensitive receptor there is rarely a requirement for reference monitoring to be carried out around construction sites.

Current examples of reference monitors include can be found at https://uk-air.defra.gov.uk/networks/monitoring-methods?view=mcerts-scheme.

Indicative monitors

Indicative monitors normally use a light scattering methodology to calculate particle concentrations based on known characteristics. They can measure several size factions simultaneously which is useful for source identification. As the name suggests these are less accurate than reference monitors but they are also significantly cheaper. A minimum of two monitors are required to assess impacts across a site but larger sites will often require several more to be representative of exposure around the boundary.

Indicative monitors are smaller and therefore are easier to locate around the site at the points they are required, often being attached just above the site hoarding or to street lighting columns where a power supply can be obtained. This also allows them to be quickly relocated during different phases of a project if the centre of activity moves or parts of a residential development are occupied. Local authorities should be notified prior to relocation or removal of any monitors ahead of project completion.

Indicative monitors used for dust monitoring are required to meet the Environments Agency's MCERTS standard meaning that they are suitable for this type of application. Details can be found here:

https://www.gov.uk/government/publications/mcerts-performance-standard-for-indicative-ambient-particulate-monitors

Indicative monitors used around construction typically require a heated inlet to remove or reduce the water content in the air sample as this can significantly interfere with the accuracy of measurement in light-scattering monitors. Water is routinely used as an abatement method on construction sites either through direct application or mist canons and this should be a consideration when installing the units.

Figure 7: Typical Indicative Monitors `

Urban developments are affected by air movements that are not necessarily the same as the regional wind direction on any day, particularly when there are tall buildings or structures in the local vicinity. Local meteorological measurements are therefore of great value when it comes to assessing the source of any dust emissions and a measurement station should be recommended in the site monitoring requirements.

Hand held monitors

Hand held samplers may be useful at low-risk sites, and at other sites to supplement data gathered from permanent monitoring.

They are easily deployed for walk-over surveys to check effectiveness of mitigation measures and may be used as supplementary monitoring during any high-risk activities possibly located at a sensitive receptor such as in a school to demonstrate that the applied mitigation is effective. They are of limited use in a larger construction environment as they are unlikely to be deployed in the right location during any potential period of dust emissions.

Figure 8: Typical Hand Held Monitors

Passive monitors and sticky gauges

Passive monitors can be used as additional low-cost measurement tool to increase coverage around a site. They use directional and depositional sticky pads that are easy to install and do not require a power supply however they are limited as they require laboratory analysis and therefore the data obtained is historical, so it is not possible to be reactive to any dust generating activities onsite. The sample collected on the pads can undergo particle characterisation through a number of different techniques to give an indication of the mineralogy and therefore the likely source.

Passive dust gauges and analysis can be supplied by Dustscan.

Figure 9: Directional dust gauge

Data quality and traceability

With indicative monitors being used around construction sites it is important to go beyond simply installing them to meet a planning requirement and to check them regularly to make sure that they are operating correctly and that the data produced is of the highest possible standard.

Any measurement device requires intermittent calibration to assess how it is performing over time and to make sure that the data is as accurate as possible. This is even more critical with indicative monitors due to the larger error margin allowed within the MCERTS certification scheme than reference equipment.

All diagnostics need to be recorded to provide traceability, this is essential if a fault develops and there is the potential to scale the data to adjust for any drift within the sensor. This should include records of field checks, pre and post service calibrations and the results from in-service cross checks. Although annual calibration is normally carried out within a workshop environment it is important to routinely check the flow rate and make adjustment as required using a calibrated flowmeter or rotameter.

Inter-comparison with ambient measurement data collected on regional networks gives a good indication on whether the monitor is performing within an acceptable range as is comparisons between periods when there are low concentrations due to no construction activity such as overnight and weekends.

Monitors should be periodically co-located to see how they perform in comparison with each other, this is a more beneficial assessment if they can also be co-located with a local reference monitor.

Basic steps to maximise data quality and improve site alert systems and any subsequent data analysis should therefore include:

Good quality siting with a free movement of air around the inlet and clear lines of sight to expected sources

Correct configuration of instruments; paying attention to ensure that the sample system is heated to reduce interference from water and secondary PM. The operation of the heater needs to be verified by continuous measurement of sample temperature or by manual verification of heater operation using a hand-held pyrometer.

Regular visits to change filters and adjust flows as necessary, using a calibrated flowmeter, and to assess site environs to ensure that the monitor and location remain fit for purpose.

HEPA filters should be fitted to the sample system and the measured concentrations should quickly fall to within the signal noise of limit detection for the equipment.

Regular servicing, either on-site or back to base for cleaning and recalibration

Regular data download and checking to ensure that equipment remains operational, to assess for consistency over time and make between instrument comparisons to identify outlier performance.

Equipment should be investigated for faults and remedial action taken if any are found.

Site boundary threshold

The site boundary threshold or 'trigger limit' is used to indicate when particulates from construction related activities may be affecting local air quality. It can provide near real-time feedback for operators enabling them to take rapid and responsive measures to control emissions.

The trigger limit value is not based on any health standard and does not indicate a breach of the EU Limit Value concentrations or occupational limits, merely the presence of a local PM source that may be related to unmitigated activity.

Historically the recommended site boundary threshold has been set at 250 µg/m^3, measured as a 15-minute mean PM_{10} concentration (Fuller & Green 2004) based on London Air Quality Network measurements made near construction sites. This value was adopted by the GLA and IAQM and incorporated into the current guidance.

This research was revised during 2015 by researchers at KCL, funded through HS2 work packages. It involved the analysis of a far larger construction dataset than the original study, with over 1.8 million data points used collected from 9 different construction sites.

As a result, a revised site action level of **190 μg/m^3, measured as a 1-hour mean** has been recommended. An hourly mean has the advantage of avoiding repeated trigger alerts from very short duration exceedances.

This trigger will not be a perfect detector of construction emissions, but false detections should be around 0.5% of construction days. This new value has been adopted by the Institute of Air Quality Management in their latest construction guidance (October 2018).

As the understanding of fugitive dust and emissions from construction and demolition activities has increased so has the requirement for monitoring around the sites to reduce the risk of human exposure. The actual locations for the monitoring equipment will always be site specific but should be representative of potential exposure to residents and people working in the surrounding area as well as any 'sensitive receptors', such as schools and hospitals.

Where to site monitors

Monitors are normally located both upwind and downwind to form a transect across a site in line with the predominant wind direction, this is south westerly in the UK. As mentioned above developments in an urban area may be affected by tall buildings and structures and it may be more sensible to locate monitors where they are representative of receptor groups.

The monitors need to be installed in a location where they have a clear unobstructed air flow around the sample inlet. The area should allow for safe operator access with level hard standing if a ladder is required in line with working at height regulations. The monitors are normally installed between 2.7-3m high to be representative of human exposure but also to reduce the risk of interference or vandalism.

When considering where to locate monitors the long-term plan for the site needs to be considered so that they are not installed somewhere that is subsequently shielded by new structures that reduce or interfere with the air flow.

It is common for construction sites to have a minimum of two monitors located at the site boundary to form a transect across the site in line with the predominant wind direction, with the UK having a prevailing south-westerly wind through the year. Larger developments may have a requirement for many more monitors to give representative coverage across the life of the project. The monitoring locations should be approved by the local planning authority prior to installation and once agreed they should not be moved without consultation.

There are a few basic guidelines as to where the monitors should be installed which fall in line with the microscale siting criteria according to European Directive 2008/50/EC, these include:

- the flow around the inlet sampling probe shall be unrestricted (free in an arc of at least 270°)
- without any obstructions affecting the airflow near the sampler (normally some metres away from buildings, balconies, trees and other obstacles and at least 0,5 m from the nearest building in the case of sampling points representing air quality at the building line),
- in general, the inlet sampling point shall be between 1.5 m (the breathing zone) and 4 m above the ground.

The inlet probe shall not be positioned in the immediate vicinity of sources to avoid the direct intake of emissions unmixed with ambient air.

The following factors should also be considered:

- interfering sources (including site access gates, mist canons and water suppression)
- security

- safe operator access
- availability of a permanent electrical power supply

There are many interpretations of the advice given above; below is a gallery of the good, the bad and the ugly! The images used have been taken across several construction projects in London and are not representative of any one developer, contractor or supplier of monitoring equipment and services.

Deciding on the locations for monitoring should be integral to the larger site plan.

This monitor was already installed in a 'well' with significantly restricted airflow, but it was then further boxed in when the subcontractor placed a shipping container directly in front of it.

You should avoid installing monitors near trees.

This monitor formed part of a long-term measurement campaign around a major area of redevelopment. It may have been installed during the winter months when there was little or no foliage on the trees. After being in place for several years it was shielded from the construction activity by the surrounding tree canopy.

Air flow should open unimpeded around the sample inlet.

This monitor was installed inside Heras security fencing along the site boundary. The contractor had built an enclosure to shield the monitor from the road but this also significantly restricted airflow around the sample head. In this case moving the monitor up within the enclosure or extending the length of the sample inlet would improve the airflow around the inlet.

Monitors should be located in clear unobstructed positions away from walls or buildings.

This monitor has been installed very low on the lea side of a building, shielded from all construction related dust.

This monitor is correctly installed with the sample head extending above the hoarding to give 360-degree unrestricted airflow.

If there are no suitable options for installing a monitor at the location where it is required it is possible to create your own using a cage, which also provides a safe working area for the operator.

Another correctly installed monitor alongside a busy construction access road. This monitor is mounted at approx. 2.7m to prevent any interference from the public or site workers and has a level area of hard standing for safe ladder access.

Further information can be found in

MCERTS
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/642895/LIT_7070.pdf

IAQM Guidance on Monitoring in the Vicinity of Demolition and Construction Sites https://iaqm.co.uk/text/guidance/guidance_monitoring_dust_2018.pdf

GLA SPG - The Control of Dust and Emissions from Construction and Demolition (2014)

https://www.london.gov.uk/what-we-do/planning/implementing-london-plan/planning-guidance-and-practice-notes/control-dust-and

European Directive 2008/50/EC
Microscale siting criteria

https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32008L0050&from=EN

London boroughs own guidance

Emission Reduction Approaches – Fugitive Dust

Dust Suppression

Construction and demolition activity are a major source of fugitive dust and a common cause of complaint. Dust can be mechanically generated through on-site activity, resuspended by machinery moving around the site as well as tracked-out on the wheels of construction related vehicles onto the public highway. Dust can also be resuspended from unmade surfaces and stockpiled materials by wind and these emissions will often occur outside of a site’s operational hours if there is insufficient mitigation in place. As existing structures are demolished large areas will often be exposed that allow for increased wind speeds to generate across the site and therefore increase the potential for further resuspension and longer transport of PM.

Traditionally the construction industry has used water as its primary source of dust suppression. This may either be directly applied to the ground using a sprinkler system attached to a water bowser, hose pipe for more targeted application or sprayed into the air as a fine mist from a canon. The efficacy of these techniques has not been tested by the LLECP and there is not much guidance as to how and when it should be applied. Water is expensive and is used sparingly on sites, even during the dryer months when dust is a greater problem and it will evaporate rapidly. There is also a limitation on the quantity that can be used on many sites due to subterranean infrastructure that may be impacted.

Using a more targeted approach may have an increased impact, either using direct application by hose with hand held spray attachments to allow water to be targeted to where it is most needed or the use of water or mist cannons. Automated systems allow for continued application and damping down of stored materials outside of the sites operational hours. If loose materials are to be stored on site for any length of time, full containment using a suitable material or seeding of the area should be considered.

Figure 10: Dust suppression examplesConsideration should be given to the

task being undertaken when selecting the best method for dust suppression at different phases of a development. Whichever method is used it should be capable of reaching the area where the dust is being generated. A hose or mist canon may not be as suitable for mitigation on a tall building that is being demolished top down as a spray attachment mounted on the excavator boom arm would.

Chemical dust suppressants

There are several alternative chemical dust suppressants that may be more effective and reduce water use, and therefore cost on sites. These range from moisture absorbing (hydroscopic) liquids that help to prevent resuspension of particles effectively trapping them on the ground through to solutions that dry to leave a thin flexible seal that may be more suitable to stabilise surfaces that won’t be disturbed for a longer time.

When a chemical dust suppressant, such as Calcium Magnesium Acetate (CMA), is sprayed onto a surface it forms a hygroscopic coating, keeping the surface damp. When particulate matter encounters a treated surface, it is less likely to become resuspended, thus reducing the amount of PM in the air. The CMA will only affect PM that meets the treated surface, therefore the greater the area treated the larger the potential benefits will be.

Previous trials of CMA on paved roads in London found that there was an observable level of improvement in 24-hour PM_{10} concentrations during low intensity application periods, with a potential reduction of about 10% at kerbside locations. Analysis of results from a more intense period of treatment suggest that there was a greater level of improvement, with approximately 14% reduction achieved (Deakin, 2011).

Further trials carried out by TfL (Barratt et al, 2012) found limited measurable impact when CMA was applied to the public road, however there was a greater impact around industrial areas such as waste transfer stations, cement batching plants and construction sites where there was a clear reduction in local PM_{10} concentrations in the hour following on-site CMA application of between 31% and 59% relative to the control.

Consequently, the GLA recommended that there may be emission reduction benefits using dust suppressant along heavily trafficked roads and also roads close to, and within, construction and industrial waste sites with high levels of local PM pollution.

For construction sites it was recommended that CMA should be considered on haulage routes on and off site during the demolition and construction phases of large developments. In these cases, where CMA is applied to unpaved roads and haulage routes on construction sites there must be consideration made to dust being carried from the unpaved areas to the paved roads due to the strong dust binding effects of the CMA. To avoid trackout occurring onto the public highway constructions sites where CMA in being used should ideally also be equipped with wheel washing facilities.

Dust mitigation trials conducted by King’s College London through the LLECP on a haulage route crossing the construction site at the Heygate Estate in Southwark identified a slight reduction in PM resuspension when CMA was applied in comparison to applying water, however the greatest reduction (up to 153%) was measured when there was an accumulative effect of multiple CMA applications during the working day.

A further study carried out on Freight Lane in Camden was inconclusive as a significant reduction in PM was not measured during periods of CMA application at all measurement locations. This may have been due to variations in vehicle flow, inadequate application of CMA to last for the 9-hour analysis period and possible interference from other local sources.

Measurements were made over a year period at this location and the results clearly indicate that the resuspension was a result of the industrial activity occurring during operational hours Monday to Friday and half day working on a Saturday. This also indicated that if dust suppressants are used then application between March and September would have the biggest impact due to natural dust suppression outside this period.

Application of CMA on the public highway over a 5-day week cost £800 and therefore it cannot be recommended as a cost-effective way of mitigating resuspension of fine particles.

CMA has low toxicity, is biodegradable and has low corrosive properties so is safe for use in the environment. If other products are used for chemical dust suppression, they will need to be thoroughly assessed to make sure that they do not pose risk to human health or the environment.

Street Sweeping efficacy

Road dust is generated from mechanical breakdown of the road surface, vehicle tyre and brake wear as well as tailpipe emissions.

Non-exhaust emissions in urban environments, comprising brake wear, tyre wear and resuspended road dust, currently represent a PM source comparable to, or even greater than exhaust emissions.

The Greater London Authority estimates that 13% of the PM_{10} particles emitted into the air in London are attributable to resuspension (London Atmospheric Emissions Inventory, 2016). Furthermore, whereas continuing advances in cleaner fuels, tailpipe emission abatement technology and urban traffic controls are acting to decrease exhaust emissions, no such tendency exists for non-exhaust emissions which are often uncontrolled and represent a major air quality management challenge in some areas.

There is a substantial contribution to road dust in the form of ‘track out’ near industrial processes, such as waste transfer and construction sites. If the road dust is not removed by sweeping or rain it is resuspended back into the air by the mechanical actions and turbulence generated by subsequent vehicle movements over the surface. The turbulent wake behind the vehicle continues to act on the road surface even after it has passed, and this effect is greater at increased traffic volumes and speeds.

Reducing the road dust available for resuspension is an obvious way to reduce the resulting ambient concentration. There is an additional benefit of efficient street sweeping as it reduces the load being washed into the sewer system with improves the water quality of run-off and reduces treatment costs.

Street Sweeping methods

There are three mains types of sweeping technology used by the street cleaning industry, these are:

- Mechanical broom sweepers
- Vacuum sweepers
- Regenerative air sweepers

Most sweepers use gutter brooms to loosen material and direct it into the path of the sweepers’ pick-up mechanism. Many also utilise mist sprays to reduce fugitive dust emissions both around the brooms and within the sweeper hopper.

Mechanical sweepers are the oldest type in use and are good at picking up heavy materials such as coarse sand and gravel but are limited in their ability to remove material from cracks and potholes in the road surface.

Vacuum sweepers use an engine powered fan to create suction, mechanical brooms are engaged to move material into the path of a vacuum nozzle where it is sucked into the hopper. Once in the hopper the air loses velocity and the collected material is separated by weight with lighter materials being trapped on a screen before the air is exhausted. Vacuum sweepers are more efficient at picking up finer materials than mechanical sweepers but again have limited ability to remove material from cracks and potholes, the suction nozzle typically only covers 1/3 of the width of the sweeping path. The vacuum exhaust can also emit significant amounts of fine dust back into the air.

Regenerative air sweepers use an engine powered blower to push air through a blast orifice that covers the entire width of the pick-up head which rides on, and seals to, the road surface. The high-pressure air blast removes material from imperfections with the road surface such as cracks and potholes before being sucked into the sweeper's hopper. The material is separated in a similar fashion to the vacuum sweeper, but the air is not emitted but instead is cleaned by a centrifugal dust separator, passing through a fabric filter before being returned to the blast orifice in a closed loop cycle. Regenerative air sweepers are therefore more effective at removing fine particles and the pickup head covers the entire width of the vehicle including areas not accessible to cylindrical brooms.

Some sweepers are referred to as 'high efficiency sweepers' and use membrane filters for dust suppression. These are also referred to as 'dustless' or 'waterless' sweepers as they generate very little dust and therefore use little or no water for dust suppression. These sweepers are generally used where water cannot be applied due to freezing weather conditions, where materials harden or become caustic when wet.

There has been an increased demand for low emission alternative fuel vehicles and currently there are liquified petroleum gas (LPG) and compressed natural gas (CNG) sweepers available on the market. Full electric road sweepers are now being manufactured, with zero emissions and low noise levels, however they are only available in the smallest size category due to the size and weight of the batteries required and no full electric regenerative road sweepers are currently available. Johnston Sweepers CityCat 2020ev uses a lithium ion battery supplying 56 kWh which is enough to power 8 hours use in drive mode. Recharging takes 2-3 hours and can use any of the on-street charging stations.

Effectiveness of road surface cleaning

Studies into the effectiveness of street cleaning activities found that mechanical sweeping combined with water flushing achieved reductions of >90% in deposited dust loads on the road. The results also indicate that street washing is an effective mitigation technique of reducing ambient kerbside concentrations PM_{10} particulate matter concentrations with a measured reduction of 7-10%.

Mechanical broom sweepers are more effective at picking up the larger particles (>1000-125 um) whilst regenerative air sweepers are recommended for finer particles (< 100um). Several factors influence the effectiveness of these street sweepers for the removal of dust sediments; these include environmental factors (climate, season) type of vehicle (sweeping mechanism), particle size and loadings, sweeping frequency and timing, surface type and moisture.

A combination of sweeping followed by washing is a reliable practice to mitigate PM emission from resuspension on a paved road.

Where there is a higher loading, such as in the proximity of demolition and construction activities it may be best to use a tandem operation, where the streets are first cleaned with a mechanical street cleaner to remove the larger particles, followed by a regenerative-air street cleaner to remove finer particles.

One area where there seems to be no research is the effectiveness of street cleaning activities and the condition of the street surface. In areas where there is a high volume of heavy vehicles passing over the public highway there is often visible signs of wear, fracturing and damage to the road surface which would almost certainly reduce the ability of mechanical street cleaners to clean efficiently. Consideration should therefore also be given to the condition of the road surface outside the site boundary when assessing the potential impacts of street cleaning and re-surfacing may be required to allow the cleaning process to be effective.

Many on-site roads and haulage routes across demolition and construction sites are temporary and therefore have an unmade road surface. Studies on the effect of vehicle characteristics on unpaved roads have found that the magnitude of emissions was controlled primarily by vehicle speed and vehicle weight, both of which had a linear effect on the emissions, this suggest that the emissions are linearly dependant on a vehicle’s momentum. Other physical characteristics of the vehicles (e.g. the number of wheels, undercarriage, area, height) did not appear to heavily influence the emissions.

Controlling vehicle speed on unmade roads may therefore be a simple method of reducing emissions

Evaluating the effectiveness of any single emission abatement strategy, such as street cleaning, on ambient concentrations is extremely challenging due to the diverse sources of PM_{10} and the variability induced by changes in meteorology and seasonality. Consequently, the scientific evidence describing the efficacy of these approaches is somewhat limited.

Evidence suggests that the use of water alongside street sweeping is the most effective approach in the abatement of road dust. However, this evidence is from warmer, drier climates and the direct transferability to the UK is questionable. The abatement achieved in Barcelona from their intense sweeping and washing programme was 4–5 $\mu g\ m^{-3}$ (7–10%).

There is some clear evidence that regenerative sweepers are more effective than mechanical and vacuum cleaners. Therefore, if an improved street cleaning programme is required then, based on the evidence available, regenerative sweepers appear to provide an improved approach.

Wherever possible a preventative approach should be adopted with thorough wheel washing being carried out to prevent material being tracked out onto the road.

Figure 11 Wheel washing to reduce material tracked out of the site

A feasibility study for introducing regenerative street cleaners into the street cleansing fleet was produced for the LB Lambeth and some of the included information has been reproduced with permission above.

Emission Reduction Approaches – Non-road mobile machinery

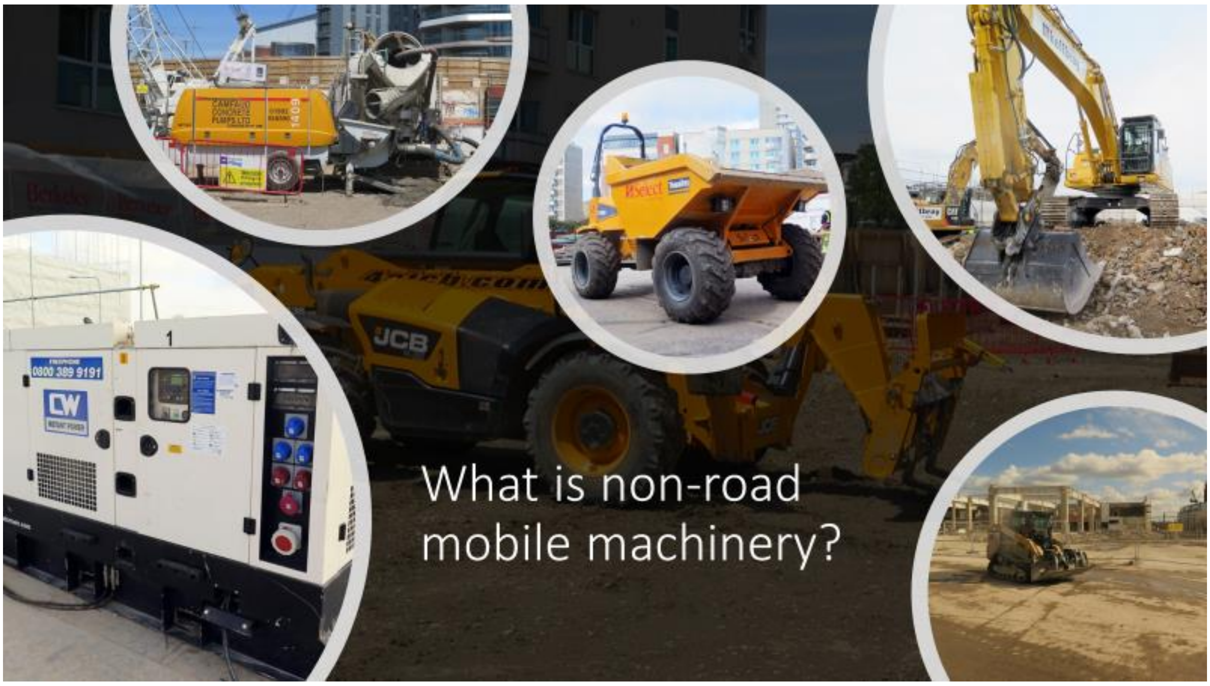
Non-road mobile machinery, or NRMM, is defined as any mobile machine, item of transportable industrial equipment, or vehicle - with or without bodywork - that is:

not intended for carrying passengers or goods on the road

installed with a combustion engine - either an internal spark ignition (SI) petrol engine, or a compression ignition diesel engine

Examples of NRMM used in construction include, but are not limited to, excavators, telehandlers, cranes, dumpers (including those with road-going markings) and also include mobile plant that is not self-propelled such as generators, pumps and compressors.

Where there are machines with multiple engines, such as truck mounted cranes, it is the secondary engine that powers the crane that will be considered as the primary truck engine will already be required to meet the tighter on-road emission standards.



In the UK, the legislation governing emissions from off-road engines is the The Non-Road Mobile Machinery (Type-Approval and Emission of Gaseous and Particulate Pollutants) Regulations 2018. This sets emission standards for carbon monoxide, hydrocarbons, oxides of nitrogen and - for diesel engines - particulate matter.

Engines installed in NRMM are split into categories for spark ignition (SI) and compression ignition (CI), and then further classified according to the engine power rating. These categories are then given limits for specified gaseous output, more commonly known as the engine's 'stage'.

SI engines of up to 19kW net power that are used in land-based portable or mobile machinery are covered by the NRMM regulations.

Variable-speed and fixed-speed CI engines are covered where their rated power is between 18kW and 560kW (equivalent to 24hp to 760hp).

EU Engine emission plate

All engines manufactured in compliance with the EU engine emissions Directive 97/68/EC must be marked with certain information. These markings are commonly located on an emissions label or emissions plate. They may be marked by any durable method such as printed, stamped, engraved, etc, and should include the name of the engine manufacturer and type approval number.

Machinery owners and operators should familiarise themselves with the location of engine plates on their plant as this will make it easier and quicker when checking in to site or being inspected.

Why would you read engine plates?

The engine plate is marked with a code detailing the EU Engine Emission Stage, which tells us how much pollution an engine generates. The NRMM LEZ sets the minimum stage allowable and should be recorded as part of an entry to the nrmm.london register.

Why would you not read engine plates?

Engine plates can be difficult to locate. The reader should take care NOT to put any part of the body in a dangerous situation whilst seeking the necessary information. Please take extra care to turn-off and isolate equipment, and to ensure that it has properly cooled. Any parking brake or safety interlocks should be applied, and operating keys removed. You may want to consult health and safety advice.

How do you find an engine plate?

The markings should be locatable with the engine installed in the machine with any necessary access covers to the engine bay open. Where the engine plate is not visible on the engine there should be a duplicate plate in an alternative visible location, such as in the driver's cab, or inside the engine hood, so it may be helpful to check here first

How do you read an engine plate?

There is one key digit in the type approval number that provides explicit evidence of the emission level to which the engine was manufactured. This is the method by which surveillance authorities check the engine. There is a second digit that can be used as an indication as to whether the engine is typed approved for variable speed or constant speed operation. This second digit is of importance because constant speed engine regulation in the EU is currently limited to stage IIIA (stage IIIB and IV constant speed engines do not exist).

Note also that stage IV does not exist for any NRMM engines < 56 kW. In this case emission regulation in the EU is limited to stage IIIB.

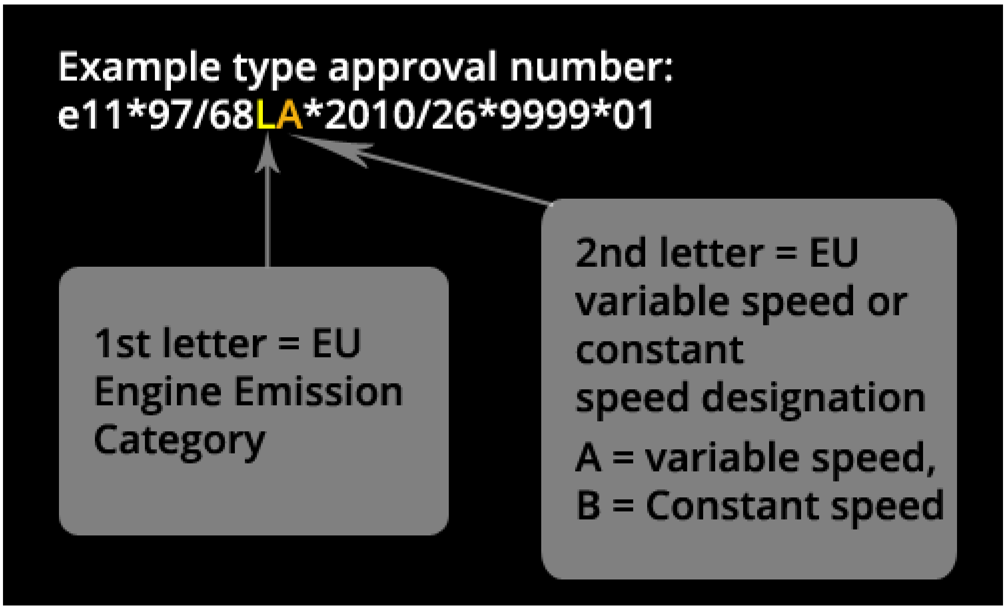


Figure: How to interpret an engine plate number

In this example the letters LA mean it is a variable speed stage IIIB 130 560 kW engine. This complies with 01 Sept 2015 GLA NRMM requirements for all zones and complies with 01 Sept 2020 GLA NRMM requirement for all zones EXCEPT Central Activity Zone and Canary Wharf.

You can then use the first letter to find the EU Emissions Stage of the engine as follows:

Engine Category Letter	EU Emissions Stage
A-C	EU Stage I
D-G	EU Stage II
H-K	EU Stage IIIA
L-P	EU Stage IIIB
Q-R	EU Stage IV

Further information for identifying the emission stage, the engine category stage by power and country of manufacture can be found in appendix 1-3.

A Low Emission Zone for Non-Road Mobile Machinery

Since 2008, heavy duty diesel road vehicles have had to meet emissions standards for PM to avoid being charged for travelling within the London Low Emission Zone (LEZ). The mayor has introduced an ultra-low emission zone in central London from April 2019. This will require all vehicles to be either zero or ultra-low emission.

It is also important to act to reduce emissions from non-road mobile machinery (NRMM) to protect and improve Londoners health. The latest version of the London Atmospheric Emissions Inventory estimates that in 2016 the NRMM used on construction sites was responsible for 7% of NO_x emissions and 15% for $PM_{2.5}$ emissions in Greater London.

To address this significant contribution by NRMM to London's poor air quality the GLA has put in place policies to control the emissions from this equipment by establishing emissions standards for London.

The world’s first low emission zone for NRMM started in 2015 and sets a minimum emission standard for plant used on major developments within Greater London and all developments within central London and other indicated opportunity areas.

GLA - Emission Standards

From 1 September 2015 NRMM of net power between 37kW and 560kW used in London will be required to meet the standards set out below. This will apply to both variable and constant speed engines for both NOx and PM. These standards will be based upon engine emissions standards set in EU Directive 97/68/EC and its subsequent amendments. NRMM used on the site of any major development within Greater London will be required to meet Stage IIIA of the Directive as a minimum; and NRMM used on any site within the Central Activity Zone or Canary Wharf will be required to meet Stage IIIB of the Directive as a minimum.

From 1 September 2020 the following will apply: NRMM used on any site within Greater London will be required to meet Stage IIIB of the Directive as a minimum. NRMM used on any site within the Central Activity Zone or Canary Wharf will be required to meet Stage IV of the Directive as a minimum.

From 1st January 2020 the block exemption for constant speed engines meeting Stage IIIB in the CAZ/CW will be lifted and generators will be required to meet Stage V standards either by technology or by retrofit for both NOx and PM reduction.

These requirements may be met using the following techniques;

- Reorganisation of NRMM fleet
- Replacing equipment (with new or second-hand equipment which meets the policy)
- Retrofit abatement technologies
- Re-engining

All eligible NRMM should meet the standards above unless it can be demonstrated that the machinery is not available or that a comprehensive retrofit to meet both PM and NOx emission standards is not feasible. In this situation every effort should be made to use the least polluting equipment available including retrofitting technologies to reduce particulate matter emissions.

It is recognised that some NRMM plant is not yet widely available in the numbers required to meet the above standards and that some options for retrofitting or re-engining are not currently available or are cost prohibitive. The GLA retrofit policy includes a list of NRMM that is exempt from this policy and what criteria individual machines will need to meet to obtain an exemption.

The London Environment Strategy

The Mayor has laid out the future vision for London in his first integrated environment strategy. This document addresses many of the environmental issues that we currently face, including NRMM and construction emissions.

The NRMM Low Emission Zone will include progressively tightening standards, with the current proposals as follows:

- Currently: Stage IIIB in the Central Activities Zone (CAZ) plus Canary Wharf (CW) area, Stage IIIA everywhere else
- **2020**: Stage IV in CAZ/CW plus Opportunity Areas, Stage IIIB everywhere else.
- **2025**: Stage IV throughout London
- **2030**: Stage V throughout London
- **2040**: zero emissions throughout London

NB: Stage IV emission standards only apply to variable speed engines with a power range between 56 and 560 kW.

The Mayor will continue to review the NRMM Low Emission Zone standards to ensure that they deliver the largest possible improvements.

The LLECP worked with the GLA and London Boroughs to produce template wording to be used as a standard planning condition for NRMM. This has now been updated, with the following text:

'All Non-Road Mobile Machinery (NRMM) of net power of 37kW and up to and including 560kW used during the demolition, site preparation and construction phases of the development shall comply with the emission standards set out in chapter 7 of the GLA's supplementary planning guidance 'Control of Dust and Emissions During Construction and

Demolition' dated July 2014 (SPG) or any subsequent guidance.

All major development sites in Greater London shall keep an inventory on site and on the online register at: https://nrmm.london/ of all NRMM between 37kW and 560kW. All NRMM shall meet Stage IIIA of EU Directive 97/68/EC (as amended) as a minimum within Greater London (Stage IIIB from 1st September 2020) and Stage IIIB of EU Directive 97/68/EC as a minimum within the Central Activity Zone and Canary Wharf (the Central Activity Zone, Canary Wharf and the GLA defined Opportunity Areas shall meet Stage IV from 1st September 2020). Constant speed engines such as those found in generators shall meet Stage V standards either by technology or by retrofit for both NOx and PM reduction from 1st January 2020.'

Emission Compliance Validation

The Construction Equipment Association ***(CEA)*** is the trade association that is recognised by the Government as representing the UK construction equipment sector.

In 2007, ahead of the UK Olympic Park construction, the CEA initiated the Construction Equipment Security and Registration ***(CESAR)*** scheme with the support of the Home Office and the Police to tackle an estimated £400 million annual plant and agricultural machinery theft problem in the UK.

The CESAR scheme uses Datatag as its independent third party, secure service provider. Datatag fix tamper-proof identification plates to machines in highly visible positions that contain both a unique RFID data chip (transponder) to allow the machine to be verified using a scanner, as well as a QR code that can be interrogated using the Datatag smartphone app.

Figure 12 Datatag system for reading machines emission data

In June 2019 Datatag extended the ID plate information to include a colour coded emissions banner that is linked to the machines EU emission stage.

The new banner is factory fitted by the OEM for new machines or retrofitted by an approved dealer network during service for older machines.

Figure 13 - JCB have already adopted the new emissions banner for all new machines

The new emissions banner system has been adopted by JCB for all new machines and it will also become a requirement for machines used across the whole HS2 project. It is likely that it will become an industry standard soon allowing for rapid and safe NRMM compliance checks on developments across London.

Diesel Use in Construction

The construction industry is still highly diesel dependant for off-grid power generation and on-site machinery fuel. This is partly due to the relatively low cost of subsidised 'red diesel' and lack of a viable alternative particularly in the larger machine types.

In theoretically perfect combustion, carbon dioxide, water and nitrogen are the end products. The incomplete combustion of diesel fuels results in emissions that include oxides of nitrogen (NOx), carbon monoxide (CO), carbon dioxide (CO2), water (H2O) and unburned hydrocarbons (HC). There are also un-burnt carbon particles, as well as engine oils, debris, soot and ash particulates, known as particulate matter (PM).

The 2016 London Atmospheric Emissions Inventory currently estimates that non-road mobile machinery exhaust contributes 7% of nitrogen dioxide, 8% of PM_{10} and 14.5% of $PM_{2.5}$ of the total emitted into the air in London. Diesel exhaust is also classified as carcinogenic and there are strong links between exposure and an increased risk of lung cancer, so it therefore poses a health risk to construction workers.

It is recognised within the industry that there needs to be a move away from diesel, but often economic factors become the deciding factor when procuring plant. 'Red diesel' makes up about 15% of the total used in the UK and the government believes that most of this is used in NRMM. Defra put out a 'call for evidence' of use in construction following the treasury's spring statement in 2018 and have stated in the 2019 Clean Air Strategy that there will be further announcements this year.

The GLA's SPG states that all NRMM shall use ultra-low sulphur diesel which is a refined, cleaner fuel with a sulphur content of 15ppm or less that can be used in any diesel engine. It reduces the fine PM emissions between 5-9%, depending on the baseline sulphur content, but when combined with a diesel particulate filter (DPF) it can lead to emission reductions of 60 - 90%.

Alternatives to diesel are often seen as a quick solution to reducing exhaust emissions as they are relatively low cost, often do not require any engine modification before use and can be blended with existing diesel in the engine. Many also contain engine lubricants and detergents that may offer improvements to engine efficiency. There have been some big claims made about the emission reduction potential of alternative fuels but there is still a real lack in the scientific evidence, emission testing using recognised test cycles, and therefore the real-world benefits are still largely unknown.

Alternatives fuels should not take precedence over certified retrofit with proven emission reduction properties. It may be that there could be benefits for using alternative fuels in conjunction with retrofit to achieve a higher level of reduction.

Diesel Fuel alternatives

With the search for future 'clean' energy provision that delivers both air quality impact and GHG emission reductions there are many alternative fuels currently available including biodiesel (BD), blends of biodiesel with petroleum diesel and emulsified diesel, hydrogenated vegetable oils (HVO), Gas-to-liquid (GTL) and synthetic diesel. A brief guide to the main fuels is given below:

Biodiesel is produced from new and used vegetable oils and animal fats. Biodiesel is safe, biodegradable and leads to a reduction in particulate matter (PM) , carbon monoxide (CO) and hydrocarbons (HC) but it can lead to an increase in the nitrogen oxides (NOx) emissions from the engine. It can be used in its pure form (B100) if engine modifications are made but is more usually blended as 20% biodiesel with 80% regular diesel (B20) which leads to a 10% PM reduction but increases NOx emissions by 2%. Biodiesel can also reduce lifecycle CO2 emissions since its production employs a closed carbon cycle that grows and processes plants to produce new fuel. Biodiesel may also have a cleaning effect on the engine, resulting in an engine that produces less smoke, runs more smoothly and produces less noise.

Emulsified diesel is a blended mixture of diesel, water and other additives and leads to a reduction in both PM and NOx emissions. Emulsified diesel can be used in any diesel engine but the addition of water reduces the energy content of the fuel which in turn reduces engine power and fuel economy. Emulsified diesel can reduce NOx emissions between 10 - 20% and ultra-fine PM between 50 - 60%.

Studies have indicated that compared to ULSD both biodiesel (BD) and butanol diesel (DBu) blends can effectively reduce the PM and elemental carbon emissions with butanol being more effective than bio-diesel. Compared with biodiesel fuels, butanol blended fuels have a lower gas exhaust temperature and emit lower PM and NOx levels although they also exhibited a higher level of CO and unburned HC emissions.

In petroleum-diesel and biodiesel blended fuels the emissions of PM and particulate organic carbon (OC) decrease significantly as the percentage of waste-edible-oil-biodiesel is increased. Addition of acetone and isopropyl alcohol to produce biodieselhols leads to further the concentration reductions of PM and particulate OC emissions.

Hydrogenated vegetable oils (HVO) is a fuel produced from vegetable fats and oils. This differs from regular biodiesel through its production process where hydrogen is used instead of methanol as a catalyst in esterification. This process prevents oxidation of the fuel, leading to contamination, whilst storage so it is considered a more sustainable longer lasting fuel.

Paraffinic fuels, such as Shell GTL (gas to liquid), are manufactured using the Fischer-Tropsch process which breaks down gas molecules and reassembles into larger uniform molecules. As gas is cleaner fuel than crude oil GTL does not contain sulphur, metals and aromatics

Fuel cell technology is in the early stages of being developed for use within the construction sector, but it is currently being used to power tower lighting, security cameras, welfare cabin and forklifts. It is likely that there will be an increase in fuel cell use over the next few years as the costs reduce and the industry looks to zero emission alternatives.

Fuel cells use an electrochemical device that generates power from reaction of the fuel with oxygen from the air and produces zero emissions at the point of use. Fuels can include hydrogen, methanol, propane, biogas or natural gas. There have been concerns over the use of hydrogen on construction sites due to its hazardous nature, however it is safe to store with other gases (other than LPG) and does not require any special permits and in the event of an accidental leak it doesn’t cause any ground contamination.

This technology has the added benefits of having very few moving parts therefore it quiet and has a long operational life with minimal intervention being required.

As alternative fuels become more widely used in the construction industry better understanding of their potential for reducing PM and NO_x emissions will become even more important and further studies should be carried out.

Diesel Fuel Testing

The LLECP did not conduct independent assessment of the efficacy of the different fuel types currently available as this didn’t fit within the project remit and this testing should be funded by the fuel manufacturer or supplier and this was raised on several occasions through regular interaction with the Environmental Industries Commission (EIC) and this should lead to a programme of testing due to start in 2019.

The LLECP conducted real world measurement trials comparing the emission profiles of an ISO grade diesel fuel against standard red diesel using an EU approved test cycle for constant speed engines in a diesel power generator.

The standard red diesel contains many contaminants including water, inorganic and organic material. Due to the hydroscopic nature of the fuel it absorbs condensation from within the fuel tanks which in turn allows for rapid growth of microbial bacteria, fungi and algae known commonly as diesel bug. This contamination leads to the fuel filters become clogged and is therefore a major cause of engine failure on construction sites.

The trial found that the emissions produced using both fuels were very similar. Improvements in emissions were only observed at low loads for CO (10-50%), however, at these low loads the generator remained above the Stage III-A emission standard for CO. A small deterioration in emissions was observed only at low loads for NO (10-50%) and PM (10%). NO2 emission increased at all loads, although the concentrations measured were very low; making up only 10% of total NO_x emissions. Therefore, although the ISO fuel may offer substantial benefits in terms of generator operation and maintenance, there is no reason to promote its use from an emissions reduction perspective. These tests did provide a perspective on generator emissions characteristics at different loads which is useful when specifying the generator capacity required. They demonstrated that generators should be operated at 50% load and above, to be compliant with the present (Stage III-A) and future (Stage III-B) emission standards for CO_2, NO_X, and PM.

The company that have produced the ISO grade fuel have reported that they are seeing fewer mechanical issues with machines using it and therefore there is less downtime within the projects due to machine failure and therefore have increased production across the UK.

A full copy of this case study can be found at: http://www.llecp.org.uk/sites/default/files/Generator%20Fuel%20Analysis%20Final%20Report.pdf

Diesel fuel additives

Studies carried out by the LLECP have indicated that elevated concentrations of black carbon particles occur in and around construction sites due to the machinery that is used and that there is a risk to the machinery operators and other workers due to the long exposure periods as well as to those living and working near these sites.

Diesel fuel additives (DFA) are a chemical treatment using nanoparticle technology to increase the efficiency of the combustion process by allowing the black carbon, or soot, to burn off at a lower temperature. This can lead to an increased fuel economy as well as a reduction in PM emissions.

DFA's can be used in all diesel NRMM engines. Where there is an existing diesel particulate filter fitted they will reduce soot formation during the combustion cycle as well as actively assist in regenerating the filter, this in turn will increase the time required between routine maintenance and vehicle downtime.

DFA's are simple to apply as they can be added to the fuel barrels or direct to the NRMM fuel tanks following manufacturers dosing guidelines.

The LLECP ran several trials to assess the efficacy of diesel fuel additives used in NRMM. Direct measurement was made from the engine exhaust stream using small black carbon aerosol monitors for a period before and after the DFA application with a known dose to see if an emission reduction could be identified. Telematic data from the engine was also collected and assessed to make sure that there were similar activity and load profiles during both phases of the assessment period.

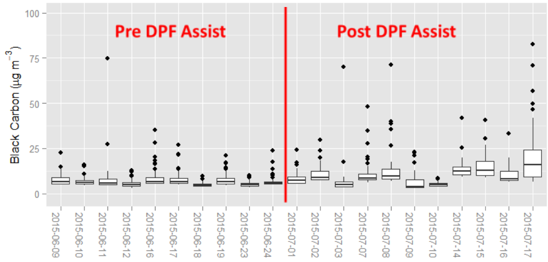


Figure 14 BC measurement made during the DFA trials

Analysis on the black carbon data pre and post application of the diesel fuel additive did not indicate any significant reduction. Regular fuel samples were taken for laboratory analysis to make sure that DFA dose was within the guidelines and that settling had not taken place within the fuel tank.

There appeared to be an increase in BC concentrations following the addition of fuel additive but on further investigation it is likely that this was due to an increased number of large plant being present on the site and increased activity compared with the pre-application measurement period.

This is an area for further research.

Figure 15 Taking fuel samples during DFA field trials

Retrofit

Retrofitting of older and lower emission stage engines with pollution control technology will significantly reduce emissions and allow the engine to meet the next stage limit values i.e. a stage IIIA engine with retrofit could be used in the low emission zone where the minimum requirement is stage IIIB.

There are two main types of retrofit available for NRMM, diesel particulate filters (DPF) and selective catalyst reduction (SCR) systems. The DPF's have the potential to remove more than 95% of the PM depending on the type used and the SCR will reduce the NOx by 75-90%. All diesel engines are potentially suitable for retrofit to mitigate particulate emissions but space within the engine compartment and cost may both be limiting factors.

There are several main exhaust treatment technologies used in retrofit and selection will normally be based on scale of reduction required and available budget.

Technology	**Emission Reduction Potential**		
	Particle Mass	**Particle Number**	**Nitrogen oxides**
Wall-Flow Filter	> 95%	> 99%	< 5%
Partial Flow Filter	30 - 60%	No data	< 5%
Diesel Oxidation Catalyst	< 25%	No impact	< 5%
Selective Catalytic Reduction	< 10%		>70% (up to 95%)

Combined DPF+SCR	> 95%	> 99%	>70% (up to 95%)

Figure 16 Typical PM and NOx reduction potential for various retrofit devices.

Only retrofit technology that has been registered and endorsed by the Energy Saving Trust NRMM certification scheme should be fitted to machinery to ensure the retrofit is correctly specified and fitted in order to prevent engine damage or any risk to the operator. A list of suppliers and endorsed products can be found here.

Diesel Particulate Filters

Diesel oxidation catalysts (DOC's) are like a catalytic convertor as used in on road vehicles and can lead to a reduction on PM emissions of between 20 - 40%, HC by 50% and CO by 40%. Catalytic convertors use catalytic chemical conversion to transform CO and unburned HC's into non-toxic carbon dioxide and water. This conversion is carried out through a metallic honeycomb substrate coated with platinum, palladium and rhodium (GenCat 2008).

Flow-Through Filters (FTF's) or through-wall filters can be used a wide variety of construction equipment and provide greater emission benefits than a DOC. A FTF can reduce VOC and CO emissions by 50 to 89% and PM emissions by approximately 50%. A FTF includes a flow-through catalyst core and is very similar to a DOC, but it uses a different type of core material to hold the catalyst. Different manufacturers use wire mesh, wire fleece, or sintered metal cores, all coated with a precious metal catalyst and packaged into a metal container. As in the DOC the catalyst promotes the oxidation of unburned PM, VOCs and CO in the exhaust stream passing through the device. Due to the core configuration individual PM particles have greater opportunity for contact with the catalyst site than in a standard DOC. FTF's require a minimum exhaust gas temperature and this limits their use compared with DOC's and DPF's.

Diesel particulate filters (DPF's) are ceramic devices that collect PM in the exhaust stream by means of physical filtration; the high temperature of the exhaust heats the ceramic structure and causes the particulates to oxidise into less harmful components, once captured the accumulated deposits must be dealt with is a safe and secure manner. When DPF's are used with ULSD reductions in particulate matter of up to 90% can be achieved, with a reduction in both HC and CO emissions of 60-90%.

Retrofit technologies must fit the equipment application. Some technologies have exhaust temperature requirements to allow them to achieve the greatest emission reductions. Passive diesel particulate filters need to operate above a certain temperature to ensure regeneration, prevent the filter from becoming blocked and potentially cause engine damage due to increased backpressure. This should be a consideration when fitting to equipment that has long periods of low-load operating or idling as the required temperatures will not be achieved.

There are two types of DPF, **non-regenerative** where the filter is removed and replaced with a fresh one at the end of its working life and **regenerative** where the filter is reused.

Non-regenerative filters are generally constructed from fibre matting in which materials such as steel wool and fibre glass are used. Housed in a steel canister the particulate matter is trapped within the fibre matting. When full the filter must be replaced with a clean one. These types of filter have a life of around 300 working hours and are therefore best suited for low usage applications or on equipment that is only used for short periods.

Regenerative filters are commonly produced from ceramic materials such as cordierite or silicon carbide. Constructed as a honeycomb monolith, channels are blocked at alternate ends forcing the exhaust stream to flow through the walls between the channels, known as 'wall flow'. The PM cannot pass through the walls so is deposited within the channels and these deposits are then burnt away. Due to the high temperatures involved in regeneration these filters are best suited to high-use applications where the exhaust gas temperature (EGT) is high.

Diesel particulate filters can be fitted to almost any piece of machinery or vehicle, for on-road or off-road use, which uses a diesel engine.

Selective Catalyst Reduction

Selective catalyst reduction is advanced emission control technology that injects a liquid agent, normally urea, through the exhaust stream of a diesel engine and absorbed onto a catalyst. This starts a chemical reaction that converts nitrogen oxides into nitrogen, water and carbon dioxide. It also produces ammonia, so the system also has a slip agent at the end to prevent this being released into the environment. The quantity of urea being injected needs to precisely match to the ammonia demand correlating to the NO_x concentrations entering the catalyst, if the dose is too low it will not efficiently convert the NO_x and too high and there is a risk of ammonia slip.

SCR systems can reduce NO_x emissions over 90 percent while reducing HC and CO emissions by 50-90 percent, and PM emissions by 30-50 percent. When SCR systems are combined with a DPF even greater emission reductions for PM can be achieved.

Although SCR technology is now being installed on many machines to achieve the stage V engine limit values there are limitations to its use as a retrofit on NRMM. The system requires liquid urea to be injected therefore there needs to be capacity for a storage tank within the existing machine canopy. Additionally, the SCR reaction requires exhaust gases and the SCR catalyst to be at temperatures typically greater than 200 degrees, this is readily achieved in variable speed engines however constant speed engines, such as those used in diesel generators, only reach these temperatures when the load demand increases sufficiently.

SCR dosing is normally cut off below a pre-set operating temperature to prevent deposits of ammonia nitrate and ammonia sulphate accumulating within the system

Generators are often oversized for a sites actual power requirement and therefore run at very low loads making an SCR DFF solution very challenging.

Using engine telematics for emission control

At present there is relatively little knowledge on emissions whether NRMM engines meet the EU regulatory 'engine limit values' for key pollutants whilst used under normal operation in a construction or demolition environment.

Telematics is a combination of telecommunications and the transfer of data from sensors measuring a variety of machine diagnostics back to the machine owner or manufacturer and has become increasingly common on modern NRMM. These systems were originally developed to extract data from the engines control module (ECM) as a means of tracking a machines location as an anti-theft measure, checking the engine performance and allowing remote diagnosis of faults and as a fleet management tool for routine maintenance. Remote access allows the performance across a whole fleet to be tracked and managed which is particularly useful within the construction sector in London where the machines may be on long-term hire for large scale projects and therefore rarely returned to their base.

As the systems have become more sophisticated and record more parameters they are now being routinely installed on plant across the whole size and power range. They are becoming a useful tool producing an insight into, and managing, operator behaviour. For many machine owners their primary interest will still be in maintenance and reducing fuel costs, but these have the potential added benefit of reducing emissions of CO_2, NOx and PM.

Rapid acceleration, speeding an idling will all cause excessive fuel consumption and produce unnecessary emissions, and this will be captured through the machines ECM. It may be that identifying where a machine is being misused and introducing tool-box talks raising awareness of the issue that behavioural changes can be monitored and may lead to a reduction in emissions. If an operator knows that data is being collected and monitored are more likely to change their behaviour.

For the new EU Stage V engine regulations, it will be necessary to carry out in-service monitoring on engines for real-world emissions.

Off grid power

One of the biggest issues causing delays on construction sites is infrastructure and supply of utilities. The supplier having disconnected the power ahead of enabling works can then take months to reconnect the site leading to the requirement for long-term dependency on off-grid power, often in the form of diesel generators.

Delays can result from the developer as well as the supplier and steps can be taken to avoid these through:

- Early identification of utility providers and all stakeholders
- Planning and communication with the supplier, even prior to planning consent, and preferably with a single point of contact.
- Timely submission of plans and requirements
- Providing dates, site access procedures and site-specific information
- Providing utilities routing with obstacles

The current OFGEM guidance does not specify timescales for high voltage works as these should be agreed with the developer with clear milestones highlighted.

Evaluating the Air Quality Impacts of Hybrid Generators used on Construction Sites in London

The London Atmospheric Emissions Inventory (LAEI 2016) attributes 7%, 15%, and 1% to NO_X, $PM_{2.5}$, and CO_2, respectively, in non-road mobile machinery (NRMM) in London. Generators are one of the most commonly used types of NRMM on construction sites, and the register of construction machinery for London[2] quantifies generators as the 4th most common NRMM type, 6% of the fleet. They therefore contribute significantly to NO_2 and $PM_{2.5}$ pollution problems in London, which is a major concern for public health. The use of diesel-battery hybrid generators is being promoted as a way of reducing the impact of air pollution, as well as saving fuel. This study aimed to compare the emissions from diesel generators and diesel-battery hybrid systems, during operation.

Figure 17 Diesel generator being tested using a load bank to increase power demand during PEMS testing

Figure 18 Generators being PEMS tested to characterise diesel emissions in the hire depot

NO_X, $PM_{2.5}$, and CO_2 emission factors of seven generators with different capacities were measured using a portable emissions measurement system (PEMS). A resistive load bank was used to load the generators to 10%, 25%, 50%, 75%, and 100% electrical power output capacity. The ISO 8178 standard D2 cycle was used to test the generators, which were all Stage III-A (Tier 3), since older stage constant speed engines are no longer approved for use in Greater London[3]. The measured emission factors (Fig. 2) were coupled with the register of construction machinery and activity data, to quantify the emissions from generators in London.

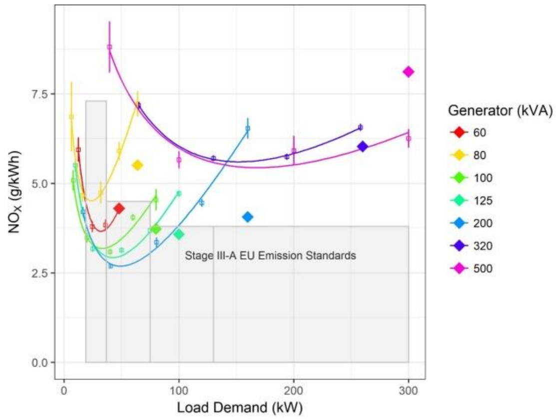


Figure 19 Measured NO_X (g/kWh) emissions v/s load demand (kW). Estimated standard error bars are plotted for each measured point. 2nd order polynomial curves are applied between the points. ISO D2 weighted average NO_X emission factor points are plotted for each generator

Hybrid Generator Evaluation

To assess the impact of hybridization of the generator fleet, activity data was acquired from a generator hire company, which detailed hourly site load demand, as well as hybrid and diesel generator operation. The measured emission factors were coupled with this activity data to assess whether adopting hybrid technology reduces emissions of NO_X, $PM_{2.5}$, and CO_2, compared to standard diesel generator use (Table 1).

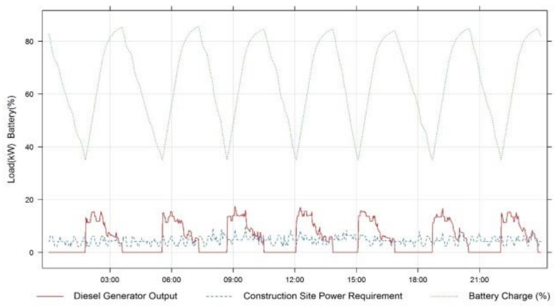


Figure 20 Load-demand activity data for a hybrid generator, for a single-day, chosen at random.

Generator (kVA)	NO_x			$PM_{2.5}$			CO_2		
	Diesel	Hybrid	Change	Diesel	Hybrid	Change	Diesel	Hybrid	Change
60	2760(±4)	2264(±4)	-18%	0.11(±0.09)	0.09(±0.09)	-10%	1781(±0.02)	1668(±0.02)	-6%
80	2239(±3)	2043(±4)	-9%	0.26(±0.01)	0.21(±0.01)	-21%	2970(±0.01)	2637(±0.01)	-11%
100	1677(±2)	1590(±2)	-5%	0.15(±<0.01)	0.12(±<0.01)	-19%	1516(±0.00)	1499(±0.00)	-1%
200	1448(±1)	1553(±2)	7%	0.12(±<0.01)	0.13(±<0.01)	4%	1486(±0.00)	1690(±0.00)	14%

Figure 21 Comparison between diesel and hybrid, NOX, PM2.5 & CO2 emissions (grams/day), for load-demand operation, for the period from 1st January 2015 to 17th September 2015

Measured load dependant emission factors showed that minimum NO_X emissions were recorded at 25-50% engine load, while minimum PM emissions were recorded at 50-100% engine load.

Emissions of 118.5t NO_X, 1.16t $PM_{2.5}$, and 19,258t CO_2 were calculated, on coupling the measured emission factors with activity data from the register of construction machinery; this corresponds to 5%, <1%, and 1.8% of the NRMM current emissions inventory, respectively.

Hybrid generator activity data were only available for generators less than 100kVA. However, both load-demand & timer-based hybrid generator activity showed that hybridization decreased the emissions of NO_X by 9%, $PM_{2.5}$ by 11%, and CO_2 by 10%.

Along with a reduction in noise and fuel consumption, hybrid generators could provide the health benefit of reduced emissions, if specified correctly.

Smaller-capacity, conventional diesel generators emit more NO_X & CO_2 than hybrid generators.

Larger-capacity diesel generators do not benefit as much from hybridization, however, they demonstrate lower overall NO_X & CO_2 emissions when compared with the smaller-capacity generators.

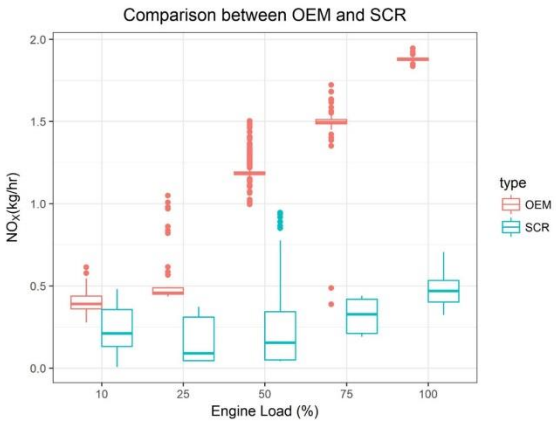
If hybridization were rolled out to the <100kVA generator fleet in London, it would decrease emissions by 2.9% for NO_X, 3.6% for $PM_{2.5}$, and 3.3% for CO_2

The efficacy of other off-grid power generation equipment was not tested during the LLECP project however it is worth noting that there are other new innovations that are becoming available and there include variable speed diesel generators, gas generators and fuel cell technology.

Retrofit SCR DPF for constant speed engines
Firstly Catalysed Diesel Particulate Filter (DPF) combusts the Diesel Particulate Matter as well as oxidising the Carbon Mon-Oxides (CO) and Hydrocarbons (HC) into harmless CO2 and water.

This is followed by an advanced SCR system where AdBlue (a combination of 32% urea in a water solution) is injected into the exhaust to convert the remaining NOx (NO+NO2) into harmless emissions of nitrogen and water.

When the Adblue is injected into the exhaust the water content is evaporated and the urea which is left decomposes into a gaseous ammonia gas which reacts across the SCR Catalysts to reduce the NOx back to harmless Nitrogen (N2) and water vapour



The SCR is more efficient at higher loads, due to the increased engine temps and delivers ~ 73% NO_x reduction at full load compared to the OEM.

Construction Logistics Plans (CLP's)

A construction logistics plans (CLP) is an effective way of reducing the environmental impact of construction. It is a management tool for planners, developers and construction contractors and will often include a combination of agreed planning requirements and best practice. The CLP adopts an integrated approach to managing construction supply chains and how their impact on the road network can be reduced. The construction supply chain covers all movements of goods, waste and servicing activity to and from site.

A well-designed CLP will reduce the environmental impacts from noise and emissions, increased road user safety, reduced road congestion – particularly during peak periods and they also lead to reduced costs for developers due to more efficient working practices and reduced number of deliveries. The CLP document needs to be easy to understand, remain a ‘live’ working document and should include key activities likely to take place throughout the development.

Construction site working time will be regulated to reduce the impacts on residents and these constraints will also affect vehicle movements including routes to and from the site. To reduce the number of site deliveries being made during peak hours consideration should be given to ‘early doors’ agreements where vehicles can enter a site during quiet hours. Unloading arrangements should be made on an individual site basis in consultation with the local authority.

A CLP’s is most effective when it is adopted across several sites working in the same area to reduce the cumulative impacts as well removing the ability to ‘blame the site next door’ for any issues. This is becoming increasingly common with large areas of central London currently undergoing urban regeneration.

To overcome the challenge of the CLP just being a paper document rather than being used as an accountable tool by the construction sector there needs to be active engagement with developers and contractors working within the included area with proactive site visits, and potential enforcement when required.

Delivery management systems

A delivery management system (DMS) is an effective way to book, track and manage vehicle movements to and from the site. The systems are flexible so can be adapted to different projects and individual phases and when integrated effectively into a project they can help reduce local congestion, vehicles queuing, idling outside sites or even worse HGV’s endlessly circling the area. For on-site management they allow for materials to be delivered as they are required rather than piling them on already overcrowded sites and subsequently moving them around to accommodate other activity.

Where truck holding areas or construction consolidation centres can also be utilised the sites have even greater control over delivery logistics. ‘Just-in-time’ deliveries can be scheduled effectively, and a site can adopt a ‘pull’ rather ‘push’ approach to making sure that materials are on site only when required.

A DMS allows logs of daily activity to be produced, by zone, gate or contractor so it is possible to monitor site performance against the CLP requirements and identify any problem areas that require improvement or enhanced compliance. Reports can be supplied to local authorities covering various construction logistics activity including HGV emissions and operator performance.

Future opportunities to include real-time routing information will lead to improvements in delivery logistics as well as compliance monitoring.

The CLP should also demonstrate that the overall number of deliveries required has been reduced through use of construction consolidation centres and off-site fabrication of materials.

Waste management plans should include recycling and reuse of materials on-site where possible.

Construction Consolidation Centres

London traffic speeds are slowing, and population is rapidly increasing but road capacity hasn't really increased, further to this the existing road capacity is being reduced due to the introduction of bus lanes and the new super cycle highways and cycle lanes.

One of the hardest issues for contractors working in London is managing the supply chain and making sure that materials and equipment are delivered to the site exactly when they are needed. Not many inner-city sites have the luxury of on-site storage and most try to work on a just-in-time (JIT) basis for deliveries but this can be difficult to manage if items are being transported over a long distance or there are any delays due to local congestion.

Site deliveries are normally uncoordinated with many part-loaded vehicles travelling to site each day and returning to their start point empty. This impacts on the local air quality, traffic congestion and safety for other road users.

If vehicles arrive early at the gates they will normally be turned away and unless there is a designated holding area, either on or off road, they are often sat idling outside the site or potentially circling the local area until they can make their delivery.

Construction consolidation centres offer a potential solution by supplying a storage and distribution facility where materials can be held until required for their JIT delivery. Deliveries to the CCC are not restricted to site operation hours, many run a 24-hour operation, so materials can arrive during the night so that they are ready for the next day. TfL have reported that CCC can lead to reductions of urban freight transport by up to 70%.

Another advantage is the ability to select a suitable vehicle for the last leg of the journey into central London, this may be a smaller van for single item deliveries or a larger vehicle with mixed loads for different clients and it can also utilise vehicles that meet the highest available emission standards, either electric or euro VI.

Working with a dedicated logistics facility team can really help to improve the safety and productivity on a complex project as well as reducing the impacts on air quality.

Deciding to use CCC's early in the planning stage can allow their inclusion as a contractual requirement in the procurement process and therefore introduce behavioural change to the industry.

Alternative modes of freight transport

Whenever possible consideration should be given to removing freight from the road completely through the use of the river or rail. This reduces congestion and direct exposure to emissions whilst increasing road safety. if best practice guidance is followed and river vessel operators have membership of the PLA Green Tariff Scheme.

https://www.pla.co.uk/assets/finalguidanceforinlandoperators.pdf

Large infrastructure projects are leading by example, Thames Tideway have invested heavily to improve the wharf facilities and inshore fleet to promote river use both during and after the project.

There is some guidance on producing CLP's on the Transport for London (TfL) website:

Construction Logistics Plan (CLP) guidance

https://tfl.gov.uk/info-for/deliveries-in-london/delivering-efficiently/consolidating-deliveries

Consolidation Centres

https://tfl.gov.uk/info-for/deliveries-in-london/delivering-efficiently/consolidating-deliveries

Additional guidance on drafting CLP's and codes of practice can be found on the London Borough of Croydon’s website:

Construction Logistics in Croydon

https://www.croydon.gov.uk/planningandregeneration/regeneration/construction-logistics-in-croydon

ICE - Engineering Cleaner Air

https://www.ice.org.uk/getattachment/about-ice/near-you/uk/london/publications/engineering-cleaner-air/ICE-Engineering-Cleaner-Air-Report.pdf.aspx

TfL – Rethinking deliveries report

http://content.tfl.gov.uk/rethinking-deliveries--summary-report.pdf

TfL – Directory of London Construction Consolidation Centres

https://constructionlogistics.org.uk/wp-content/uploads/2017/07/The-Directory-of-London-Construction-Consolidation-Centres-1.pdf

WRAP – Using construction Consolidation Centres to reduce waste and Carbon Emissions

http://www.wrap.org.uk/sites/files/wrap/CCC%20combined.pdf

Case Study: Thames Tideway Air Quality

Millions of tonnes of raw sewage spill into the River Thames every year. The Victorian sewer network, though in good condition, lacks the capacity to cope with the demands of the modern-day city. That’s where the Thames Tideway Tunnel comes in. This giant tunnel – 25km long and 7.2m wide – will ‘intercept’ those spillages (which happen once per week, on average) and clean up the Thames.

This is a huge project, one in which more than half a million HGVs would be needed to move material to and from site. But air quality is already a major issue for London, and that many extra lorries on the city’s busy roads would increase the risk to vulnerable road users.

So, Tideway’s river strategy was developed to move at least 4.2 million tonnes of material on the river itself – a reduction of an anticipated 72% (down to 140,000). Keeping lorries off the roads will help keep cyclists and pedestrians safer and will reduce the impact of our work on the local community. It will also drive down air emissions. But more than that, Tideway’s river strategy will serve to boost the river economy, increase jobs and leave a lasting economic legacy for the River Thames.

On average one large barge (1,500 tonne capacity) can carry more than 50 HGV-loads of material, so it was clear that it would reduce congestion. But there was concern that any significant modal shift could result in increased in air pollution, as the marine sector currently is not subject to as many restrictions as the road and the vessels are often older.

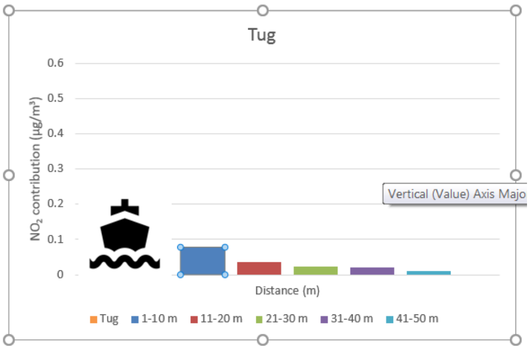
Tideway is the first major infrastructure project to develop a comprehensive set of monitoring data to demonstrate the reduced impact of moving material by river – rather than by road. *Emission Analytics* carried out monitoring on one of the tugs (Felix) owned by *Livetts* using a PEMS system. The results concluded that river transport produces far fewer emissions per tonne km than the road equivalent even when compared with modern standard Euro VI HGVs. Compared with its HGV equivalent, a 75% engine load 1,000 tonne barge will on average produce:

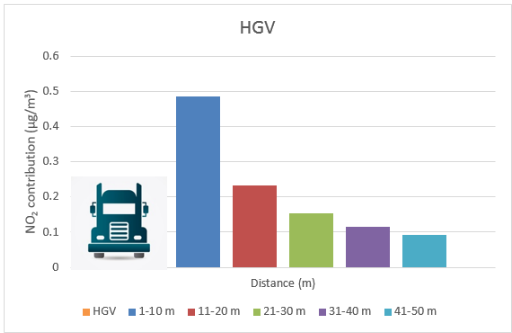
- 54% less NOx
- 52% less NO
- 86% less NO2
- 95% less CO
- 90% less CO2

These benefits are increased when larger barges are used.

To assess the dispersion of the emissions from the tugs, the PEMS data was used by *Air Quality Consultants* to model the extent of its impact. A comparison of the average tug emission rate to the emission rate from 50 HGVs travelling at 20kph shows that emissions from 50 HGVs are 2.3 times higher than from Felix.

The study found that average emissions from Felix contribute less than 0.13 µg/m3 to concentrations of nitrogen dioxide, even at locations very close to the tug. Compared to the nitrogen dioxide objective of 40 µg/m3, this is a negligible amount. The tug will generally travel at distances greater than 50m from bank of the Thames, and therefore from the closest residential properties; at this distance, the contribution to nitrogen dioxide concentrations from tug emissions is just 0.01 µg/m3.

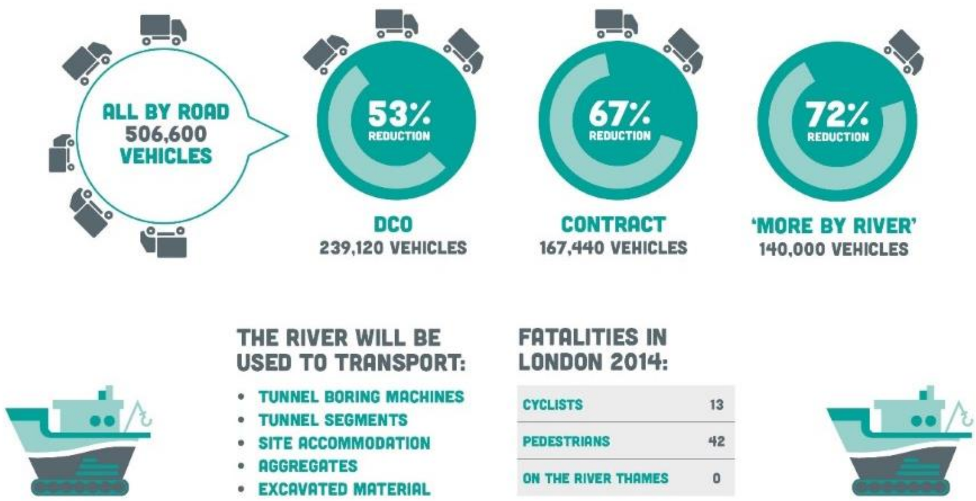




It also concluded that HGVs travel on roads significantly closer to residential properties; in congested conditions, speeds are lower and emissions higher. Contributions from 50 slow-moving HGVs can potentially contribute around 0.3 µg/m3 to nitrogen dioxide concentrations at approximately 10m from the HGV, at which distance residential properties exist adjacent to some roads (for comparison, the contribution of tug emissions at 10m is less than 0.05 µg/m3). Additionally, due to the presence of buildings alongside roads, emissions get trapped between buildings, increasing the potential for adverse impacts.

The study that Tideway has carried out demonstrates the social and environmental benefits associated with the use of the river as a means of mass haul of construction material, which produces less harmful emissions and congestion, and reduces the likelihood of impact with vulnerable road users. The increased use of the river also rejuvenates the river economy, which could be utilised for future construction projects that have river access or to service riverside developments.

Tideway is currently working with a number of organisations to trial various new technologies to the marine sector which will hopefully reduce its impact even further.



Local Authority Funding Models

Partner Local Authorities provided information on the models they utilise for funding and compliance work associated with NRMM. The range of funding measures varied and included funding via Section 106/CIL agreements, use of funding from within existing team budgets and the use of a self-funding model. Compliance processes were equally as varied and included requiring compliance with planning conditions, section 106 agreements and contractual agreements between the developer/contractor and the Local Authority. Case studies on the range of measures employed by Local Authorities are detailed below.

Funding Through Section 106/CIL

London Borough of Wandsworth

The Vauxhall Nine Elms Battersea (VNEB) opportunity area (OA) comprises over 50 construction sites spanning Wandsworth and Lambeth. An air quality monitor was installed within the Wandsworth Council borough boundary, then the first construction works began at Battersea Power Station. Developer contributions through Section 106 planning agreements from developments within the Wandsworth borough VNEB OA funded the installation of an air quality monitoring station in 2016. Section 106 agreements have been phased out and replaced by CIL; the rates are given in table 1 below.

Table 1: CIL rates

Within the area designated as ‘Nine Elms Residential Area A’ on the “Community Infrastructure Levy Charge Zones” Map: Residential Development	£575 per square metre
Office (All B1a) or Retail (All A use classes) Development	£100 per square metre
All other Development	£0 per square metre

Within the area designated as ‘Nine Elms residential Area B’ on the “Community Infrastructure Levy Charge Zones” Map: Residential Development	£265 per square metre
Office (All B1a) or Retail (All A use classes) Development	£100 per square metre
All other Development	£0 per square metre

Within all other areas of the London Borough of Wandsworth; Residential Development	£250 per square metre
Office (All B1a) or Retail (All A use classes) Development	£0 per square metre
All other Development	£0 per square metre

In 2017 developer contributions from CIL funded two air quality officer posts, one of whom worked as a compliance officer for the construction sites following an exceedance of the 24-hour mean objective for PM10. For the years 2018/19 and 2019/2020 further funding from CIL was sought for two air quality officers, air quality monitoring and management fees. This is specifically, £200,000 for two officers, £50,000 for monitoring (this includes diffusion tubes) and £10,000 for management fees. Developers are required to submit a construction environmental management plan which includes an NRMM condition. Responsibility for formal (or enforcement) action regarding non-compliance of CEMPs, etc. lies with planning department, however in practice many of the actions taken are informal and require the co-operation of construction site managers and developers. This is partly due to the planning obligations agreed at some sites before NRMM legislation and the Mayor’s Control of Dust and Emissions during Construction and Demolition SPG came into force. Wandsworth Council outsource their NRMM audits to Merton Council; this is funded by LIP funding.

London Borough of Islington

The London Borough of Islington has in place construction impact monitoring posts, funded by the S106 standard obligation for Code of Construction Practice monitoring for all major sites. This model commenced when the planning policy was adopted to use the S106 planning obligation to fund the inevitable cost of managing impacts and enforcing at construction sites in 2006. Presently 3 officers are funded through money gained from this model. Officers are allocated sites and deal with noise & vibration, dust, air quality and contaminated land complaints or issues with the site. As part of their visits to site they undertake NRMM audits where possible. The team have audited 20 sites of which 4 have remaining compliance issues. This equates to approximately 50 % of the current ongoing major sites.

This funding model was selected to finance the auditing of NRMM as this model was historically in place and therefore the most straightforward way of incorporating NRMM audits as Officers already had links in place with site.

- The fee structure formula is calculated for major sites (i.e. 10 residential units or greater or 1000sq m of commercial space) at:
- £100 per residential unit and per 100 sq m commercial floor space (additional and/or replacement)
- £50 per student housing, hotel and hostel bedroom

This model is dependent on the level of development within the borough bringing in sufficient funding for the team, this has been enough thus far for the team to be sustainable and grow but these circumstances can change dependent on the state of the economy and the London property market. Officers already have a workload dealing with other environmental issues so NRMM compliance work is undertaken alongside those other issues which inevitably take up the majority of officer’s time.

Construction Management Plans are required by a planning condition and therefore any potential breach of the requirement of the CMP, including NRMM is investigated as a breach of planning condition.

London Borough of Camden

Camden Council requires compliance with NRMM via Section 106 planning obligations. Audits are undertaken through a desk top assessment of NRMM equipment registered via the NRMM website. A fee is charged for sites which are required to submit construction management plans which requires details of NRMM compliance amongst other matters including transport planning, environmental health and air quality control mechanisms.

The benefit of this model is that NRMM is part of the regular planning obligations structure. The dis-benefit is that there currently aren't enough resources to conduct on site audits independently – however with the introduction of the pan London NRMM audit model proposed by the GLA this will change. LB Camden have also included a new construction and NRMM officer role within their borough action plan.

In 2019, Camden Council will be joining the pan-London NRMM project led by LB Merton which requires a contribution of £4,000 annually for the duration of the project. From this project, an officer will visit sites to conduct audits and ensure compliance with NRMM.

Funding through existing budgets

City of London Corporation

The City of London Corporation currently outsource NRMM audits to the London Borough of Merton who undertake audits on behalf of a number of London Local Authorities. This scheme is part funded by the Mayor of London, with a small financial contribution from the City of London Corporation. This programme will continue into 2019 as the City will join the pan London NRMM scheme proposed by the GLA. This work is currently funded through the Corporation's low risk budget however this could be subject to change. Enforcement of NRMM requirements is through a planning condition.

London Borough of Lewisham

The London Borough of Lewisham outsource NRMM audits to the London Borough of Merton. The fees for this service are currently funded through the Environmental Protection Team budget however Lewisham is exploring options for a charging structure as part of its Good Practice Guide linking this to the CMP planning condition discharge.

The benefits of the primary borough type compliance project is the ability to provide uniform compliance standards and should allow borough officers to focus on other aspects of environmental protection.

Funding through Code of Construction Practice

Westminster City Council

Westminster City Council adopted a new Code of Construction Practice in 2016 to monitor, control and manage impacts on construction sites in Westminster. The code classifies developments according to their size and the obligations and fees payable are dependent upon the size of the project. This approach aims to provide an effective and responsive service to the community who may be affected by construction site impacts, whilst simultaneously proactively monitor the construction sites and providing a high-quality advice service to the construction industry as a chargeable service. Officers undertake NRMM audits on sites and recharge the time taken to undertake the visit and associated administrative work to the developer via the COCP recharging scheme. The COCP is applied through the following process.

Planning application submitted which indicates the development would be either a basement or a level 1 or Level 2 project.

Should consent be granted, a planning condition is attached to the consent. Prior to the commencement of any demolition or construction on site the applicant shall submit an approval of details application to the City Council as local planning authority comprising evidence that any implementation of the scheme hereby approved, by the applicant or any other party, will be bound by the council's Code of Construction Practice. Such evidence must take the form of a completed Appendix A of the Code of Construction Practice, signed by the applicant and approved by the Council's Environmental Inspectorate, which constitutes an agreement to comply with the Code of Construction Practice and requirements contained therein. Commencement of any demolition or construction cannot take place until the City Council as local planning authority has issued its written approval of such an application.

Prior to the commencement of the development, the applicant must submit a signed ‘Appendix A’ and provide the required documents, e.g. a Site Environmental Management Plan (for Level 1 and Level 2 developments) or a Construction Management Plan (for Basement developments) to the City Management & Communities Department for review. For level 1 and level 2 developments there is also the requirement to apply for a Section 61 prior consent for noisy works.

Once the documents are agreed, the City Council raises an invoice for the required amount based on the fees table in appendix F of the COCP. Once this is paid, the Public Protection and Licensing Officer countersigns the Appendix A which the developer then submits to the planning department to discharge the relevant planning condition.

Once the COCP planning condition is discharged, the site may commence works.

The signed Appendix A forms a contract between the signatory and the City Council. The COCP requires compliance with NRMM requirements and should any non-compliance be found, action would be taken in line with the City Council’s enforcement policy. Ultimately, if necessary, this would involve commencing proceedings for breach of contract, enforced by the Civil Courts. The City Council has not taken any action for breach of NRMM requirements at the time of writing.

The fee structure in place is broadly based on an hourly fee for Officers, the duration of the project, with the expected amount of time spent on each site dependant on the classification of the site. Average fees along with the expected levels of services provided for each site classification are provided with the Code of Construction Practice. The overall fees depend on the quality of the submitted documents and on the number of complaints received during the course of the works, for example.

There are multiple benefits to the COCP model. It provides assurance to the community that adequate controls are in place to manage and control environmental impacts from construction sites whilst the City Council can ensure that adequate steps are taken to monitor the sites without pressurising Council budgets - based on the polluter pays principle. The Construction site are provided with named contacts for an environmental health officer and a highway licensing inspector who will take personal responsibility for managing the site and liaising with them.

South London Air Quality Cluster Group Inspection Model

London Borough of Merton

The London Borough of Merton on behalf of the South London Air Quality Cluster Group applied for funding from the Mayors Air Quality Action Fund (MAQF) to deliver the ambition to enforce cleaner plant equipment on construction sites. Within 3-4 months a number of other boroughs requested to join the initiative and eventually the service represented around 12 Local Authorities. The project was funded through the MAQF and was allocated £96,000 per year with £2,000 per borough a year match funding. Additional funding of around £30,000 was secured from the MAQF to accommodate the additional boroughs.

The delivery team created a new process of auditing sites, including the provision of documentation and promotion of the project. To date we have audited around 1,400 individual pieces of equipment across approximately 500 sites in South London. Audits were prioritised around areas of poor air quality and density of construction. The project is currently raising compliance levels from a general standard of 27% to around 70%. An emission saving tool was developed and currently suggests the project has delivered savings of around PM’s = 17 Tonnes and NOx = 300 Tonnes (caveats apply). The project will now be extended London-wide, based upon the foundation of the work in South & Central London.

Challenges to the project include lack of enforcement powers, covering a large geographical area, the new agenda and finessing how this is delivered on the ground, staffing the structure, standardising the agenda throughout the boroughs and health and safety issues within the audit process. Positives include the desire from the construction industry to comply and the success of the South London project.

Appendix 1 – Exceedance Report Template

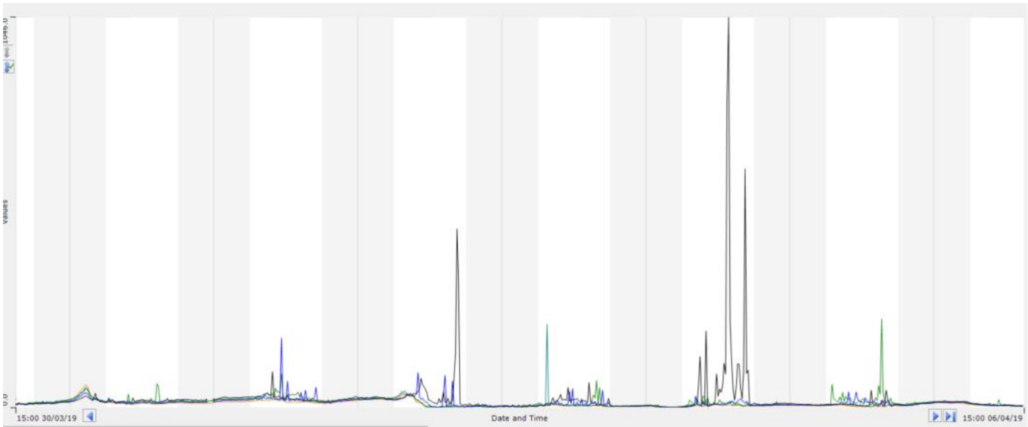
Company name/logo	Head office address Demolition Contractors Street, Town, Postcode

PM10 Exceedance Report

Site Address: The New Builds, New Road, London **Contact Person:** Project site manager, mobile phone number	Report Date:

Site map/plan with monitoring locations and activity centres marked

Graph of exceedance period showing all monitor data



Exceedance date and concentrations recorded:

Location	Date Time	Concentration (ug/m3)
Site 1	02/04/2019 16:30	478.9
Site 1	02/04/2019 16:45	335

Metrological condition at the time of the exceedance:

Dry conditions with moderate north-easterly winds

Activity being carried out at the time of the exceedance including any photos:

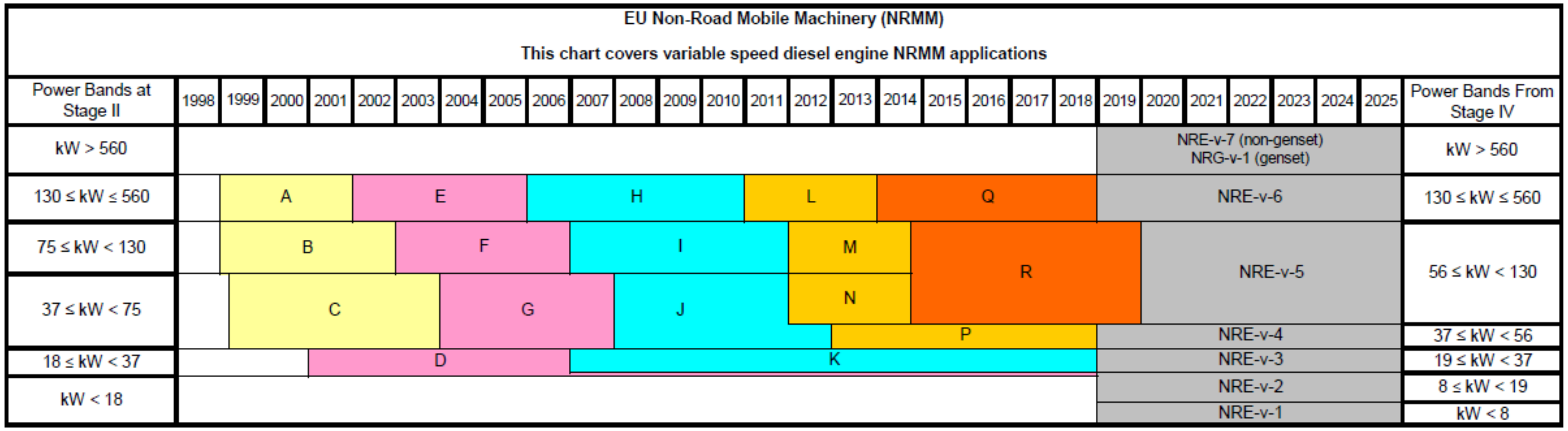
Breaking concrete slab and dry cutting with angle grinder near monitoring location 1

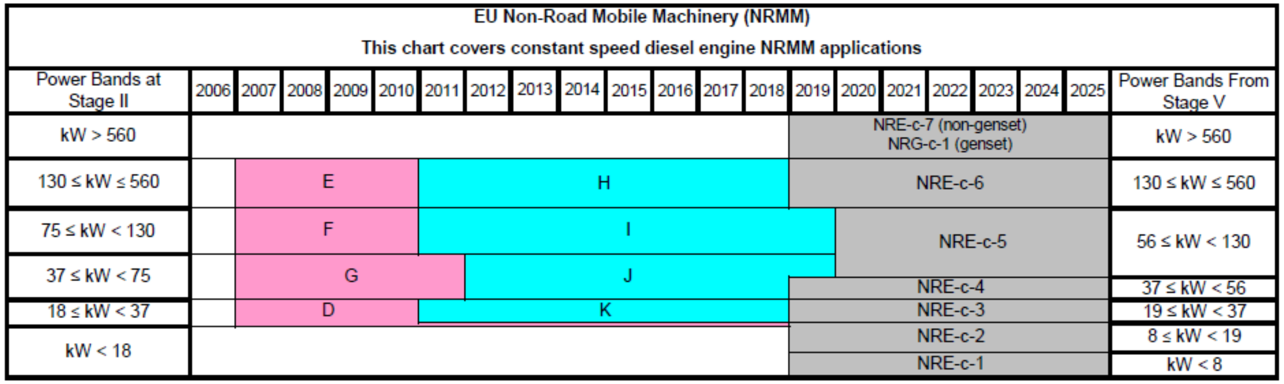
Remedial action taken:

Stopped work, spoke to machine operator and put second person on the job to apply water. No more exceedance alerts received.

Added to topics to cover in toolbox talks this week

Appendix 2 – NRMM Emission Stage Tables





Appendix 3 – NRMM Engine Limit Values

EU Non-Road Mobile Machinery (NRMM)

This chart covers variable speed diesel engine NRMM applications

Power Bands at Stage II	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	Power Bands From Stage IV
kW > 560																						**3.5 / 0.19 / 3.5 / 0.045 (non-genset) **0.67 / 0.19 / 3.5 / 0.035 (genset)							kW > 560
130 ≤ kW ≤ 560		**9.2 / 1.3 / 5.0 / 0.54			**6.0 / 1.0 / 3.5 / 0.2				*4.0 / 3.5 / 0.2					** 2.0 / 0.19 / 3.5 / 0.025			**0.4 / 0.19 / 3.5 / 0.025					**0.4 / 0.19 / 3.5 / 0.015 + 1E12							130 ≤ kW ≤ 560
75 ≤ kW < 130		**9.2 / 1.3 / 5.0 / 0.70				**6.0 / 1.0 / 5.0 / 0.3				*4.0 / 5.0 / 0.3					**3.3 / 0.19 / 5.0 / 0.025		**0.4 / 0.19 / 5.0 / 0.025						**0.4 / 0.19 / 5.0 / 0.015 + 1E12						56 ≤ kW < 130
37 ≤ kW < 75		**9.2 / 1.3 / 6.5 / 0.85					**7.0 / 1.3 / 5.0 / 0.4				*4.7 / 5.0 / 0.4				**3.3 / 0.19 / 5.0 / 0.025														
																*4.7 / 5.0 / 0.025						*4.7 / 5.0 / 0.015 + 1E12							37 ≤ kW < 56
18 ≤ kW < 37				**8.0 / 1.5 / 5.5 / 0.8						*7.5 / 5.5 / 0.6												*4.7 / 5.5 / 0.015 + 1E12							19 ≤ kW < 37
kW < 18																						*7.5 / 6.6 / 0.4							8 ≤ kW < 19
																						*7.5 / 8.0 / 0.4 (1)							kW < 8

(1) 0.6 for air-cooled hand-startable direct-injection engines

EU Non-Road Mobile Machinery (NRMM)

This chart covers constant speed diesel engine NRMM applications

Power Bands at Stage II	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	Power Bands From Stage V
kW > 560														**3.5 / 0.19 / 3.5 / 0.045 (non-genset) **0.67 / 0.19 / 3.5 / 0.035 (genset)							kW > 560
130 ≤ kW ≤ 560		**6.0 / 1.0 / 3.5 / 0.2				*4.0 / 3.5 / 0.2								**0.4 / 0.19 / 3.5 / 0.015 + 1E12							130 ≤ kW ≤ 560
75 ≤ kW < 130		**6.0 / 1.0 / 5.0 / 0.3				*4.0 / 5.0 / 0.3									**0.4 / 0.19 / 5.0 / 0.015 + 1E12						56 ≤ kW < 130
37 ≤ kW < 75		**7.0 / 1.3 / 5.0 / 0.4					*4.7 / 5.0 / 0.4														
														*4.7 / 5.0 / 0.015 + 1E12							37 ≤ kW < 56
18 ≤ kW < 37		**8.0 / 1.5 / 5.5 / 0.8				*7.5 / 5.5 / 0.6								*4.7 / 5.5 / 0.015 + 1E12							19 ≤ kW < 37
kW < 18														*7.5 / 6.6 / 0.4							8 ≤ kW < 19
														*7.5 / 8.0 / 0.4 (1)							kW < 8

(1) 0.6 for air-cooled hand-startable direct-injection engines

EU Emission Stages	(yellow)	Stage I
	(pink)	Stage II
	(cyan)	Stage IIIA
	(gold)	Stage IIIB
	(orange)	Stage IV
	(grey)	Stage V
Limit Values	*	NOx+HC / CO / PM (g/kWh) + PN (#/kWh)
	**	NOx / HC /CO / PM (g/kWh) + PN (#/kWh)

Appendix 4 – NRMM Emission Stages and Country Codes

Engine category code	Machinery standard	Power =>	Power <
A	EU Stage I	130	560
B	EU Stage I	75	130
C	EU Stage I	37	75
D	EU Stage II	18	37
E	EU Stage II	130	560
F	EU Stage II	75	130
G	EU Stage II	37	75
H	EU Stage IIIA	130	560
I	EU Stage IIIA	75	130
J	EU Stage IIIA	37	75
K	EU Stage IIIA	19	37
L	EU Stage IIIB	130	560
M	EU Stage IIIB	75	130
N	EU Stage IIIB	56	75
P	EU Stage IIIB	37	56
Q	EU Stage IV	130	560
R	EU Stage IV	56	130

Country code	Country name	Country code	Country name
e1	Germany	e3	Italy
e11	United Kingdom	e32	Latvia
e12	Austria	e34	Bulgaria
e13	Luxembourg	e36	Lithuania
e17	Finland	e4	Netherlands
e18	Denmark	e49	Cyprus
e19	Romania	e5	Sweden
e2	France	e50	Malta
e20	Poland	e6	Belgium
e21	Portugal	e7	Hungary
e23	Greece	e8	Czech Republic
e24	Ireland	e9	Spain
e25	Croatia	eCY	Cyprus
e26	Slovenia	eIRL	Greece
e27	Slovakia	eMT	Malta

Appendix 5 - Glossary of Terms

AQMA	Air Quality Management Area
AQS	Air Quality Strategy
BC	Black Carbon
CAZ	Central Activity Zone
CIL	Community Infrastructure Levy
CMA	Calcium Magnesium Acetate
DFA	Diesel Fuel Additive
DMP	Dust Management Plan
DMS	Delivery Management System
DOC	Diesel Oxidative Catalyst
DPF	Diesel Particulate Filter
Dust	All airborne particulate matter (see also TSP)
GLA	Greater London Authority
HC	Hydrocarbon
HSE	Health and Safety Executive
KCL	King's College London
LAEI	London Atmospheric Emissions Inventory
LEZ	Low Emission Zone
NO_2	Nitrogen Dioxide
NO_X	Oxides of Nitrogen
NRMM	Non-road mobile machinery
OC	Organic Carbon
PEMS	Portable Emission Measurement System
PM	Particulate Matter
PM_{10}	Particles with a diameter less than 10 micro-metres
$PM_{2.5}$	Fine particles with a diameter less than 2.5 micro-metres
PN	Particle Number
S106	Section 106 of the Town and Country Planning Act 1990
SCR	Selective Catalyst Reduction
SPG	Supplementary Planning Guidance
TEOM	Tapered Element Oscillating Monitor
TfL	Transport for London
Track out	Transportation of dust and materials on the wheels of vehicles
TSP	Total Suspended Particulate matter
ULEZ	Ultra Low Emission Zone
ULSD	Ultra Low Sulphur Diesel (present UK specification is EN590:2004)
WHO	World Health Organisation

Useful resources
Reports
DEFRA – Clean Air Strategy
GLA - SPG: The control of Dust and Emissions during construction and Demolition
GLA - London Environment Strategy
LB Merton - NRMM – A Practical Guide
IAQM - Guidance on Air Quality Monitoring in the Vicinity of Demolition and Construction Sites
IAQM - Guidance on the Assessment of Dust from Construction and Demolition
ICE - Engineering Cleaner Air
IOSH - No Time to Lose – Diesel Exhaust Emissions
PLA - Air Quality Strategy-Best Practice Guidance for Inland Fleet Operators. August 2018
Supply Chain School Air Quality: Toolbox Talk

https://www.youtube.com/watch?v=yK9UmMlvJCA