British Occupational Hygiene Society

FACULTY OF OCCUPATIONAL HYGIENE

Guidance for Occupational Hygienists on the Assessment and Control of the Health Risks from Diesel Engine Exhaust Emissions (DEEEs)

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Version 1

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Feedback

We welcome feedback on this guide.
Comments should be sent to BOHS at membership@bohs.org .

Version History

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Version 1	January 2026	Original version

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Contents

1. Purpose

The following information is made available to assist in the measurement and assessment of health risks from Diesel Engine Exhaust Emissions (DEEEs) and to ensure awareness of available control measures.

This guidance provides additional updated information to the existing HSE Guidance HSG187 'Control of Diesel Exhaust Emissions in the Workplace' (HSE HSG187, 2012).

2. What are DEEEs?

DEEEs consist of a complex mixture of particulate substances, liquid aerosols, gases, vapours, and dissolved components including:

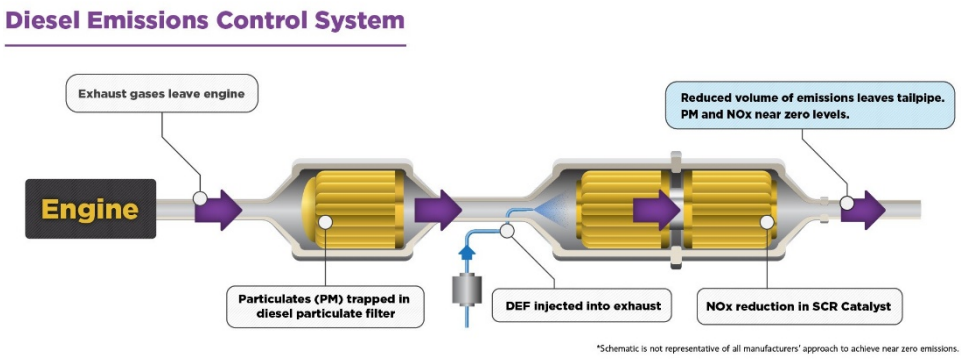
- Particulate matter - carbon particles of differing sizes. PM10 particles are those with a diameter smaller than 10µm and PM2.5 particles are those with a diameter smaller than 2.5µm.
- Gases – carbon monoxide, aldehydes, nitrogen oxides, sulphur oxides, nitrates.
- Vapours - polycyclic aromatic hydrocarbons (PAHs), water.

The composition of DEEEs will depend upon a number of factors including engine age, maintenance, temperature, and composition of the fuel in use.

Primarily driven by national air quality legislation and public health concerns, there have been significant advances in both diesel fuel and engine technology to reduce DEEEs; however, this has not eliminated the risk within industrial and transportation activities.

- Ultra low sulphur fuel has brought about a reduction in sulphur dioxide (SO2) emissions.
- Diesel particulate filters (DPF), which are designed to remove soot and particulates, are mandatory on new vehicles and plant.
- New Technology Diesel Engines (NTDE) now have diesel emissions control systems (see Figure 2.1) which have brought about reductions in Nitrogen oxide (NOx) emissions using selective catalytic (and also non-catalytic) reduction (SCR) through the addition of urea-based diesel exhaust fluid (DEF), commonly known as AdBlue®, into the exhaust stream. (Hesterberg et al., 2011).

Figure 2.1 Diesel Emissions Control System.



Source: Engine Technology Forum

3. What are the sources of DEEEs?

Major sources of DEEEs include ships, trains and trucks. These sources can be fixed or mobile. Fixed sources include diesel engines permanently mounted in workplaces or large diesel generators positioned near to workplaces. Mobile sources include vehicles and heavy equipment (e.g. used in construction and mining).

Table 3.1 details the types of workplaces where employees may be exposed to DEEEs, although the list is not exhaustive.

Table 3.1 Types of workplaces where employees may be exposed to DEEEs.

Industry	Workplaces
Shipping	Dock/cargo/passenger ship workers
Airports	Airport ground crew (e.g. cargo and luggage handlers)
Railways	Railway operations in stations, railway repairs and rail tunnels
Road transport	Custom officer/border/toll control booth Road tunnels Police and traffic officers Road maintenance workers
Vehicle repair	Mechanics performing vehicle maintenance and repairs
Logistics	Garages or vehicle depots Distribution centres Warehouses
Construction	Building sites – activities and vehicles Temporary generators Tunnelling
Mineral Extraction	Mining and quarrying

4. What are the health effects of DEEEs?

Short term (acute) effects of exposure to DEEEs can cause irritation to the eyes or respiratory tract. Other symptoms may include feeling lightheaded, headache, or nausea.

Long term exposure may lead to chronic health effects. Some components of DEEEs, such as Polycyclic Aromatic Hydrocarbons (PAHs), are carcinogenic and there is evidence that repeated exposure to diesel fumes increases the risk of lung cancer. In 2012 the International Agency for Research into Cancer (IARC) classified exhaust emissions arising from the combustion of diesel fuel in compression ignition engines (DEEEs) as a Group 1 Carcinogen — carcinogenic to humans.

5. How to initially assess DEEEs in the workplace?

The quantity and composition of DEEEs depends on:

- Type of engine/equipment
- Composition of the fuel(s) used
- Number of sources in the workplace
- Maintenance and tuning
- Engine temperature
- Workload

Table 5.1 summarises conditions that are indicators of poor control of DEEEs in the workplace on older engines and those that are poorly maintained.

Table 5.1 Indicators of poor control of DEEEs in the workplace.

Indicator	Further detail
White smoke	In the form of water droplets and unburnt fuel which is produced when the engine is started from cold. White smoke from diesel engines produces an acrid smell.
Blue smoke	Mainly oil and unburnt fuel from badly worn engines requiring servicing and tuning.
Black smoke	Contains oil and unburnt fuel together with soot. This suggests a mechanical fault or defect in the fuel delivery system, or if the engine is working near its maximum speed.
Visible soot deposits	Particularly if these are heavy and collect around emission points or locations where workers are located.
Complaints of irritancy	Particularly if several workers complain about the air quality and respiratory ill effects.

Refer to Table 8.1 Hierarchy of control measures and the DEEEs Exposure Tool in Appendix 1 to review and risk assess potential exposure to DEEEs. Air sampling may be required if exposure is considered to be a significant risk or to confirm the evaluated risk rating.

6. Personal or static sampling?

DEEEs are a complex mixture including both particulate and gaseous components. The recognised approach for air sampling is to measure specific DEEEs components and compare against available exposure limits.

As always, the exposure profile will need to be considered by the occupational hygienist when deciding whether to carry out personal and/or static sampling. In cases where the exposure to DEEEs is expected to be due only to background levels, static monitoring may be preferred for the majority of samples, particularly if taken towards the source to reflect a worst-case scenario. Some personal sampling may be advisable to provide confirmation of compliance with exposure limits.

Particulate components - Elemental Carbon

Soot, which could include both elemental and organic carbon, may include particulates larger than respirable size. For this reason, the collection of the respirable fraction appears a better option as the presence of organic carbon can interfere with the analysis for elemental carbon.

The particulate content of DEEEs is typically between 60 – 80% elemental carbon (EC) (HSE HSG187, 2012). Adopting EC as a surrogate, when it has such a variable % content, is subject to limitations; however, EC is considered the best marker for assessing airborne risks from the particulate components.

The recognised air sampling method for elemental carbon is HSE MDHS 14/4 ‘General methods for sampling and gravimetric analysis of respirable, thoracic and inhalable aerosols’ (HSE MDHS 14/4, 2014). Pumped aerosol samples would be captured using a cyclone sampler loaded with a pre-conditioned quartz or similar suitable filter as required by the ISO 17025 accredited analytical laboratory. If it is anticipated that there will be other significant aerosol sources in the monitored areas e.g. welding fume, mining dust, it is advisable to use a cyclone with an impactor to separate out particles < 1 micron for the EC analysis. Both organic and elemental carbon results should be requested on the analysis request form when the samples are submitted to the laboratory for analysis.

Elemental Carbon can be measured and analysed using thermal or thermo-optical measurement techniques (Folesani et al., 2024). Analysis involves heating the filter at different temperatures to determine both Organic Carbon (OC) and Elemental Carbon (EC). It should be noted that different monitoring standards may produce different EC results (Folesani et al., 2024) so in order to obtain comparable measurements the same standard should be used each time. The technique recommended in the UK for environmental monitoring of EC is BS EN 16909.

It should be recognised that exposures to DEEEs may occur from the general environment rather than the activities being undertaken. There are a number of sources which could present interferences with airborne elemental carbon (EC) concentrations including:

- Inner city areas
- Biomass burning e.g. wood or agricultural waste
- Proximity to major transportation routes
- Carbon black manufacturing

Consideration should be given to any potential environmental interferences when the operations being assessed are close to such sources. It is advised to take one or more static samples outside the building to allow an estimation of the "environmental contribution" to the results.

Gaseous components

The most significant gaseous components are oxides of nitrogen and carbon dioxide. Due to the often transient nature of DEEEs, these gases are best measured using handheld and/or personal real-time data logging monitoring devices, particularly if carried out simultaneously. If detected, peaks from these gases would be shown on the data log of the measurements.

It should be noted that when CO_2 gaseous measurements are taken within an individual's breathing zone, the measured concentrations may be affected by the exhaled breath.

7. What exposure limits should be used to assess DEEEs?

Particulate components

There is no formal Workplace Exposure Limit (WEL) in the UK for DEEEs or EC. However, EU Directive 2019/130 amended Directive 2004/37/EC on the protection of workers from the risks related to exposure to carcinogens or mutagens at work (the Carcinogens Directive). The amendments introduced a new exposure limit for DEEEs of 0.05 mg/m^3 (8-hour TWA) as elemental carbon. This limit was adopted in the EU as from 21 February 2023, with the underground mining and tunnel construction section having until 21 February 2026 to adopt the limit. The EU limits make no reference to the respirable fraction and hence the limits apply to inhalable dust; however, the elemental carbon arising from DEEEs is highly likely to be of respirable particle size.

BOHS recommends that for assessment purposes the EU exposure limit for DEEEs of 0.05 mg/m3 (8-hour TWA) as elemental carbon is applied.

Gaseous components

The UK WEL for nitrogen monoxide is 2 ppm (8-hour TWA). Nitrogen monoxide will oxidise relatively rapidly in air to produce nitrogen dioxide, with WELs of 0.5 ppm (8-hour TWA) and 1 ppm (15-minute STEL).

The UK WELs for carbon dioxide are 5000 ppm (8-hour TWA) and 15000 ppm (15-minute STEL). However, HSE Guidance (HSE HSG187, 2012) indicates that levels of 1000 ppm or higher are indicative of inadequate control of exposures to DEEEs.

8. What control methods should be used?

DEEEs are generated as a by-product from diesel engines and do not exist in any other form. As such, within the UK they are not assigned the hazard statements H340 (may cause genetic defects), H350 (may cause cancer) or H350i (may cause cancer by inhalation) and are not listed in Schedule 1 of COSHH. Therefore, from a legal perspective exposure does not need to be controlled to as low as reasonably practicable (ALARP).

The IARC classification of DEEEs is a Group 1 Carcinogen. Therefore, given that DEEEs are substances arising from combustion and contain carcinogenic components such as PAHs, it would be prudent to consider ALARP during an exposure assessment in addition to the controls listed below.

When selecting and implementing controls to mitigate DEEEs exposure, the following factors need to be considered:

- Indoor vs. outdoor work environment
- Effectiveness of ventilation (natural, dilution and local)
- Size of an enclosed or partially enclosed workspace
- Number/type of DEEEs sources and their location
- Mobile vs. fixed source(s)

Follow the hierarchy of control when mitigating DEEEs exposure; Table 8.1 outlines controls that are known to reduce the risk of exposure. Although engineering controls are more effective, there are safe work practices which can also be effective at eliminating or reducing exposure. However, work practices are prone to human error which can reduce their overall effectiveness.

Table 8.1 Hierarchy of control measures to mitigate the risk of DEEEs exposure

Control Method	Examples of Control Measures
Elimination	• Use electric powered equipment (e.g. buses, forklifts, trucks). • Whenever possible, schedule and perform tasks where there are no DEEEs sources (also a work practice control). • Connect to alternative auxiliary power sources. For example, in rail depots, lighting and heating could be run from electrical supplies allowing servicing activity with the train engine switched off and therefore DEEEs stopped.
Substitution	• Use alternative fuels (e.g. dimethyl ether, low sulphur diesel). • Implement a vehicle/equipment replacement program with engines that will produce less combustion-related emissions (e.g. propane, natural gas, biofuels). • Replace old diesel-powered equipment with newer, more efficient diesel-powered equipment.
Engineering controls (at source)	• Engine modification (e.g. implement a retrofit program to rebuild diesel engines that produce less emissions). • Install catalytic converters (e.g. forklifts, trucks, buses). • Install selective non-catalytic reduction (a method that can be used to reduce nitrogen oxides emissions). • Implement exhaust gas recirculation (another nitrogen oxides emissions reduction technique). • Install diesel particulate filters (DPF). • Routine exhaust emission testing.
Engineering controls (ventilation)	**Dilution Ventilation** • Increase building general ventilation rate . • Provide sufficient fresh air from an uncontaminated source. • Use mechanical ventilation to draw fresh air into the workplace. **Filtration** • Air filtration inside vehicle cabs, keep under positive pressure. • Keep offices or toll booths under positive pressure. **Local Exhaust Ventilation** • Install local exhaust or extraction ventilation (e.g. in enclosed spaces such as maintenance and repair shops). • Isolate equipment (in an enclosure if practicable) and ventilate the exhaust away from the workplace.
Work practices (administrative controls)	• Perform training on DEEEs hazards and the control measures. • Reduce use of diesel engines inside buildings or structures. • Run engines outdoors (if possible), especially during warm up. • Allow cold engines to warm up in well ventilated areas. • Open garage doors before starting vehicles, keep doors open (where practical and weather permitting) for at least 10 minutes following vehicle operation. • Turn engines off when not needed – no engine idling policies. • Proper maintenance of the engine and exhaust system, perform regular maintenance on vehicles or equipment (follow the manufacturer instructions and guidance). • Minimise tasks and their duration (if possible) that are performed in close proximity to DEEEs sources. • Maximise distance between workers and DEEEs sources, segregation if possible. • Rotate jobs between different employees to reduce exposure.
Personal protective equipment	• Until alternative control can be implemented use suitable respiratory equipment (RPE) with their selection and associated control measures covered by a full risk assessment. Protection from both particulate and gaseous components should be considered.

9. Assess, monitor and review

There have been many advances in new diesel engine and low sulphur fuel technologies; however, DEEEs still present a significant health risk in many industries, particularly in confined areas and unventilated environments.

The control of exposure to DEEEs requires effective management of a range of measures to ensure the risk is reduced to as low as reasonably practicable (ALARP), therefore it is recommended that regular reviews are carried out to ensure that exposures are, and continue to be, adequately controlled.

Suggestions for conducting a DEEEs risk assessment to monitor and review the management of DEEEs are given in Appendix 1.

10. References

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Appendix 1 DEEEs Exposure Tool

A1.1 Example tool for the assessment and control of DEEEs exposure

This tool aims to provide a framework for assessing the risk of exposure, by inhalation, to DEEEs to inform a suitable and sufficient risk assessment.

The tool has been completed only with examples of High Risk factors.

Diesel Engine Exhaust Emissions (DEEEs) Exposure Tool	
Section A1: DEEEs Risk Factors	
Type of plant/vehicles in operation	**High risk:** Diesel generator power plant and forklift trucks (FLT).
Age of DEEEs sources	**High risk:** 20+ year old machinery. Predated any emission control equipment.
Static or mobile sources	**High risk:** Static sources continually exhausting into working areas where workers are present.
Indoors or outdoors	**High risk:** Indoor environment.
Visible emissions (smoke/soot/irritancy)	**High risk:** Visible black smoke indicating oil and unburnt fuel together with soot deposits. Highly irritant to workers in the area who complain of respiratory issues.
Overall Risk Rating	**High risk**
Section A2: DEEEs Controls Review	
Elimination control feasibility	**High risk:** No replacement power source or FLTs will be considered.
Substitution controls	**High risk:** No alternative fuels can be used on the equipment due to their age and design.
Engineering control – at source	**High risk:** No diesel particulate filters (DPF) to trap particulate or selective catalytic / non-catalytic reduction (SCR) to reduce NOx concentrations.
Engineering control – ventilation	**High risk:** No dilution ventilation present. No enclosed cabs on FLT so no filtration option. No LEV to exhaust to external atmosphere.
Working practices	**High risk:** Engines being left idling when not in use.
Maintenance regime	**High risk:** Little or no maintenance regime on diesel plant. Run to failure then maintained.
PPE	**High risk:** FFP1 respirator issued without any face fit testing. All personnel have facial hair. Respirator will provide little protection to particulates and negligible protection from DEEEs gases and vapours.
Training	**High risk:** No information, instruction or training on the hazards of DEEEs, the risks the working environment presents or adequate controls that could protect the individuals from exposure.
Overall Risk Rating	**High risk**

Section A3: DEEEs Exposure Assessment	
Number of DEEEs sources operating in area	**High risk:** 1 x generator; 10 diesel powered FLTs.
Duration of plant/vehicle operation	**High risk:** Continuous operation.
Interaction frequency/duration	**High risk:** Continuous interaction offering no relief of exposure to workers during the shift.
Number of workers exposed	**High risk:** 50+ personnel per shift being exposed to DEEEs.
Air monitoring results	**High risk:** Elemental Carbon concentrations = 0.5 mg/m^3 (8-hour TWA) Nitrogen Dioxide concentrations = 2.0 ppm (8-hour TWA) Carbon Dioxide concentrations = 9000ppm All measured parameters exceed the relevant occupational exposure limits.
Qualitative assessment	**High risk:** Visible black particulate hanging in the air indicating little air movement and increasing DEEEs concentrations within the working environment.
Overall Risk Rating	**High risk**

A1.2 Blank template tool for the assessment and control of DEEEs exposure

This tool aims to provide a framework for assessing the risk of exposure, by inhalation, to DEEEs to inform a suitable and sufficient risk assessment.

Diesel Engine Exhaust Emissions (DEEEs) Exposure Tool	
Section A1: DEEEs Risk Factors	
Type of plant/vehicles in operation	
Age of DEEEs sources	
Static or mobile sources	
Indoors or outdoors	
Visible emissions (smoke/soot/irritancy)	
Overall Risk Rating	
Section A2: DEEEs Controls Review	
Elimination control feasibility	
Substitution controls	
Engineering control – at source	
Engineering control – ventilation	
Working practices	
Maintenance regime	
PPE	
Training	
Overall Risk Rating	
Section A3: DEEEs Exposure Assessment	
Number of DEEEs sources operating in area	
Duration of plant/vehicle operation	
Interaction frequency/duration	
Number of workers exposed	
Air monitoring results	
Qualitative assessment	

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BOHS was founded in 1953: it is a learned society, publishing the world-renowned, scientific, peer-reviewed journal, Annals of Work Exposures and Health, and the only professional society representing qualified occupational hygienists in the UK. The Society supports, develops and connects its members with resources, guidance, events and training.

Its Faculty of Occupational Hygiene sets professional standards, promotes professional development and maintains the UK's only accredited Register of Occupational Hygiene Professionals.

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