Diesel Exhaust/Diesel Particulate Matter (DE/DPM)

Introduction
The diesel engine was patented in 1892 to provide improved fuel efficiency as compared to gasoline engines. The National Institute for Occupational Safety and Health (NIOSH) has estimated that more than 1.3 million workers are exposed to diesel exhaust in more than 80,000 workplaces\(^1\). These workers include, but are not limited to, mineworkers, bridge and tunnel workers, railroad workers, dock workers, vehicle/equipment maintenance garage workers, truck drivers, forklift operators, oil industry workers and farm workers.

The potential health effects that can occur as a result of overexposure to diesel exhaust warrant the need for stringent controls.

Background
The diesel engine injects fuel into compressed high temperature and pressure air, which then auto-ignites, releasing chemical energy. The gases then expand and move the pistons. The combustion of diesel fuel forms a complex mixture of organic and inorganic compounds in gas, liquid and solid phases. The chemical and physical properties of diesel exhaust cover a broad spectrum and are primarily dependent on the diesel fuel composition, the engine operating conditions, and the devices that are added to the engine to improve efficiency or reduce pollution.

Diesel exhaust contains thousands of chemical compounds that can fit into several categories, including:

**Gaseous components**
- Carbon dioxide
- Oxygen
- Nitrogen
- Carbon monoxide
- Nitrogen compounds
- Sulfur compounds
- Low-molecular-weight hydrocarbons

**Gaseous components of toxicological concern**
- Aldehydes (formaldehyde, acetaldehyde, acrolein)
- Benzene
- 1,3-butadiene
- Polycyclic aromatic hydrocarbons (PAHs)
- Nitro-PAHs
- Diesel particulate matter (DPM)
- Elemental carbon

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- Adsorbed organic compounds
- Small amounts of sulfate, nitrate, metals
- Other trace elements

**Compounds absorbed on DPM that are of toxicological concern**
(Note: PAHs and their derivatives are adsorbed on the surface of DPM)

- Polycyclic aromatic hydrocarbons
- Nitro-PAHs
- Oxidized PAH derivatives

**Potential health effects**

Short-term exposure to high concentrations of DE/DPM can cause headaches, dizziness, and irritation of the eye, nose and throat severe enough to distract or disable miners and other workers. Acute symptoms should go away after exposure to the diesel exhaust has stopped.

Prolonged DE/DPM exposure can increase the risk of cardiovascular, cardiopulmonary and respiratory disease and lung cancer.

In June 2012, the International Agency for Cancer Research (IARC) classified DE (including DPM) as a known human carcinogen (Group 1).

Recent animal studies confirm an association between exposure to diesel exhaust and cancer\(^2\). The lung is the primary site identified with carcinogenic or tumorigenic responses following inhalation exposures. The consistencies of these toxicological and epidemiologic findings suggest that a potential occupational carcinogenic hazard exists in human exposure to diesel exhaust.

Of the known compounds, the toxic effects of the gaseous compounds (carbon monoxide, carbon dioxide and the oxides of nitrogen and sulfur) of diesel exhaust have been well studied. Carbon monoxide, for example, interferes with the supply of oxygen to the blood. Overexposure to very high concentrations of carbon monoxide can result in death. Chronic exposure can lead to heart damage, loss of muscular strength and mental alertness, persistent headache and dizziness.

Nitrogen oxides are irritants that can cause pulmonary edema and damage the lung’s defense mechanisms, while sulfur oxides can create acid mists that also irritate the lungs and eyes.

The carbon particles contained in diesel exhaust emissions are of special concern, as the majority of the particles are less than 1.0 micron in diameter and small enough to be inhaled and deposited in the lungs. Gases and toxic hydrocarbons from the diesel exhaust easily stick onto the surface of the carbon particles and can be carried into the lungs.

The impact on health from exposure to diesel exhaust can be compounded by exposure to other hazardous materials in the workplace. The combination of diesel emissions with other workplace chemicals and pollutants (e.g., cigarette smoke, asbestos, solvents, etc.) may have a serious additive or potentially synergistic effect.

**Exposure limits**

**General industry, agriculture, construction and maritime operations**

The Occupational Safety and Health Administration (OSHA) does not have a permissible exposure limit (PEL) for DPM. However, OSHA has PELs for other components of diesel exhaust. Monitoring for these gases can provide an indication

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\(^2\) CDC Office of Mine Safety and Health Research: [http://www.cdc.gov/niosh/mining/topics/DieselExhaust.html](http://www.cdc.gov/niosh/mining/topics/DieselExhaust.html)
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of the presence of DE, and can be of help in evaluating the effectiveness of engineering and administrative controls implemented to minimize the potential for exposure to DE when working with or around diesel-powered equipment.

<table>
<thead>
<tr>
<th>Substance</th>
<th>PEL</th>
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<tbody>
<tr>
<td>Carbon monoxide (CO)</td>
<td>50 ppm</td>
</tr>
<tr>
<td>Nitric oxide (NO)</td>
<td>25 ppm</td>
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<tr>
<td>Nitrogen dioxide (NO₂)</td>
<td>5 ppm (ceiling)</td>
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</tbody>
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Miners are covered by the Mine Safety and Health Administration (MSHA). Workers in general industry, agriculture, construction and maritime industries are covered OSHA.

MSHA currently enforces DPM standards at underground metal/nonmetal mines and at underground coal mines.

**Underground metal/nonmetal mines**
- A miner's personal exposure to DPM must not exceed 160 micrograms per cubic meter (μg/m³) of total carbon (TC) when measured as an 8-hour time-weighted average.
- Feasible engineering and administrative controls are required to reduce a miner's exposure to or below the permissible exposure limit (PEL).
- Respiratory protection must be used to supplement feasible engineering and administrative controls if such controls do not reduce a miner's exposure to the PEL, the engineering or administrative controls are infeasible, or the engineering and administrative controls fail to produce a significant reduction in DPM exposure.
- When respiratory protection is required, an air-purifying respirator equipped with a filter that meets one of the following: certified by NIOSH under 30 CFR Part 11 as a high-efficiency particulate air (HEPA) filter; under 42 CFR Part 84 as 99.97% efficient; or certified by NIOSH for DPM.
- Rotation of miners to comply with the PEL is prohibited.
- Evaluation of a miner's medical ability to wear a respirator and transfer rights for miners unable to wear respirators.
- Other requirements include:
  - Fueling practices, including sulfur content and fuel additives,
  - Maintenance of diesel-powered equipment,
  - Limits on engine emissions,
  - Annual training for miners,
  - Exposure monitoring,
  - Recordkeeping, and
  - Miners' and former miners' rights to access certain records related to their own exposures.
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**Exposure reduction**

Implementing effective control measures can significantly reduce occupational exposure to diesel exhaust.

- Whenever feasible, alternative sources of power or fuel with a lower potential health risk should be substituted for diesel.
- Use of diesel engines indoors should be avoided when there is a safer alternative.
- Adequate ventilation, both local exhaust and general/dilution, should be provided in areas where diesel engines must be operated indoors.
- Diesel-powered vehicles parked indoors or at loading docks should not be allowed to idle unnecessarily.
- Tailpipe or exhaust hoses should be provided for any vehicles running indoors.
- Bulkhead and auxiliary fans should be installed to help direct airflow in large or irregular areas such as mine caverns and maintenance shops.
- Low sulfur fuels should be used. MSHA requires 0.05% sulfur or less. OSHA recommends Fuel grade K-1 instead of Diesel 1. Higher grade fuels are more expensive, but burn cleaner.
- Truck and equipment cabs should be maintained to prevent diesel fumes from entering the cabs.
- Frequent tune-ups and regular maintenance should be provided for all diesel engines.
- Any diesel equipment that is producing visibly smoky exhaust should be removed from service until the condition has been corrected.
- Work practices should be modified to minimize operating diesel-powered equipment where workers may be exposed.
- Vehicles should be fitted with emission control such as collectors, scrubbers, and ceramic particle traps. Air cleaners should be checked regularly and replaced when dirty.
- Respirators can be used. However, usage should be considered only after engineering and administrative controls have been explored. For diesel exhaust, a combination air-purifying respirator that protects against acid gases, organic vapors and particulates should be used pursuant to the OSHA Respiratory Protection Standard 29 CFR 1910.134.
- Personnel involved with use of diesel machinery should thoroughly understand proper equipment operating procedures, maintenance and inspection procedures, and the potential hazards of the exposures.
- Prevent skin contact with diesel exhaust by wearing protective clothing (gloves, long pants, long sleeve shirts, and face and eye protection) if necessary.
- Exposure to diesel exhaust compounded with smoking tobacco may significantly increase risk. Smoking should be eliminated in the workplace if possible.
- Air monitoring using NIOSH Method 5040 for elemental carbon or methods for individual components should be conducted as needed to determine worker exposure.
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Conclusion

It is difficult to ascertain the nature of diesel exhaust and to measure exposures and potential health effects using the information available at this time. Improvements in engine design, fuel grade and emissions technology are being pursued, but this can also add to exposure assessment difficulties.

Diesel exhaust is only one source of particulate matter and gaseous air pollution in the atmosphere and workplace. Though the evidence is persuasive that diesel exhaust has the potential to cause adverse health effects, more definitive data and more research is needed. Based on available data, however, diesel exhaust exposures should be reduced to the lowest feasible limits.

References

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- osha.gov/SLTC/dieselexhaust/index.html
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- dieselnet.com/papers/9710nauss.html
- iarc.fr/
- oehha.ca.gov/public_info/facts/dieselfacts.html
- MSHA’s DPM Single Source Page msha.gov/01-995/dieselpart.htm
- OSHA’s partial list of chemicals found in diesel exhaust osha.gov/SLTC/dieselexhaust/chemical.html

The EPA recommends strategies for reducing diesel exhaust on their website: epa.gov/diesel

For more information, log in to the Risk Control Customer Portal at travelers.com/riskcontrol. (Need help? Read our Registration Quick Guide.) You also can contact your Risk Control consultant or email Ask-Risk-Control@travelers.com.