Health Hazard Evaluation Program

Evaluation of Diesel Exhaust Control Methods at a Fire Station

HHE Report No. 2023-0099-3430

March 2026

CDC NIOSH

Authors: **Hannah Echt, MS**

Chaolong Qi, PhD, PE, CIH

Duane Hammond, MS, PE

Micah Niemeier-Walsh, PhD

Desktop Publisher: Shawna Watts

Industrial Hygiene Field Assistance: Karl Feldmann, Drew Thompson, and Alex Mayer

Logistics: Joseph Hartwell, Jessica Ramsey, and Colleen O'Connor

Keywords: North American Industry Classification System (NAICS) 922160 (Fire Protection), Diesel Exhaust, Elemental Carbon, Ventilation, Fire Station, Firefighters, Iowa

Program Description

The National Institute for Occupational Safety and Health (NIOSH) Health Hazard Evaluation Program investigates possible health hazards in the workplace under the authority of the Occupational Safety and Health Act of 1970 [29 USC 669a(6)]. The Health Hazard Evaluation Program also provides, upon request, technical assistance to federal, state, and local agencies to investigate occupational health hazards and to prevent occupational disease or injury. Regulations guiding the Program can be found in Title 42, Code of Federal Regulations, Part 85; Requests for Health Hazard Evaluations [42 CFR Part 85].

Disclaimer

This document is a NIOSH health hazard evaluation report prepared in response to a specific workplace or technical assistance request. The recommendations in this report are made on the basis of the findings at the workplace evaluated and may not be applicable to other workplaces. As such, this health hazard evaluation report is not intended as industrywide Centers for Disease Control and Prevention (CDC) or NIOSH guidelines or policy, and it does not establish new health standards, guidance, or regulatory requirements.

Mention of any company or product does not constitute endorsement by NIOSH/CDC. In addition, citations to websites, national guidelines, or recommendations external to NIOSH/CDC do not constitute NIOSH/CDC endorsement of the sponsoring organizations or their programs, products, or guidelines. Furthermore, NIOSH is not responsible for the content of these websites. All web addresses referenced in this document were accessible as of the publication date.

Availability of Report

Recommended Citation

NIOSH [2026]. Evaluation of diesel exhaust control methods at a fire station. By Echt H, Qi C, Hammond D, Niemeier-Walsh M. Cincinnati, OH: Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Health Hazard Evaluation Report 2023-0099-3430, https://www.cdc.gov/niosh/hhe/reports/pdfs/2023-0099-3430.pdf.

Table of Contents

Main Report

Supporting Technical Information

Introduction

Request

The Health Hazard Evaluation Program received a request from management at a city fire department. The request concerned firefighters' exposure to diesel exhaust when fire apparatuses were running in the apparatus bay.

Workplace

The single-story fire station had two pull-through apparatus bays with bay doors on the front and back walls. The station could hold up to four vehicles, and the adjoining living quarters included an emergency medical services (EMS) dormitory for the paramedics, a report room, a kitchen and dining area, a bunk room for firefighters, a gym, and a captain's office and bedroom. Turnout gear was stored in the apparatus bay. At the time of our evaluation, the station housed four diesel-powered emergency response vehicles: one fire engine (2015 Pierce), one fire truck (2001 Pierce), and two ambulances (2017 and 2022 Ford F-550s). None of the vehicles were equipped with engine exhaust filters.

The station's apparatus bay was equipped with a local exhaust extraction system consisting of four ceiling-mounted tailpipe exhaust hoses. Each hose attached to a vehicle tailpipe at one end and a metal exhaust duct at another end. All four ducts connected to a fan at the rooftop which discharged the vehicle exhaust to the outside. The system was designed to automatically activate from dispatch calls or when the exhaust flow at the tailpipe triggered the sensor. The fan serving the local exhaust extraction system could also be manually turned on and off from a control panel mounted on the bay wall. The hoses had an automatic disconnect feature which disconnected the hose from the tailpipe as the vehicle pulled out of the apparatus bay. In addition, a general ventilation exhaust system with a dedicated rooftop exhaust fan removed air from the apparatus bay through multiple grilles located on a duct suspended near the ceiling that ran parallel to the bay doors along the center of the space. It was designed to be activated when air concentrations of carbon monoxide reached a certain level in the bay or could be manually turned on with a timer control mounted on the wall.

To learn more about the workplace, go to Section A in the Supporting Technical Information

Our Approach

We conducted an initial walkthrough of the facility in August 2024 and returned in July 2025. During our return visit, we did the following activities:

- Observed work processes and practices.
- Collected area air samples of diesel particulate during one 12-hour period and one 8-hour period in the apparatus bay, report room, EMS dormitory, kitchen, and outdoors.

- Measured real-time concentrations of carbon monoxide, carbon dioxide, and particulates over an approximately 32-hour period in the apparatus bay, report room, EMS dormitory, kitchen, and outdoors.
- Conducted a ventilation assessment at the station.

To learn more about our methods, go to Section B in the Supporting Technical Information

Our Key Findings

Levels of diesel particulate and other components of diesel exhaust were low in the apparatus bay and living quarters

- Air concentrations of carbon monoxide, carbon dioxide, and particulates were well below occupational exposure limits. While these were not personal samples, the samples were collected near where employees typically worked.

We observed multiple operating issues for the local exhaust extraction system

- During our visit, one of the four hoses was under service.
- While the system did consistently activate when triggered by dispatch calls, it did not activate by vehicle start-up otherwise.
- The fire engine's tailpipe did not fit the hose for the local exhaust extraction system, leading to a large portion of the engine exhaust not being captured.
- When a vehicle returned to the station, firefighters manually reattached the hose to the vehicle's tailpipe while the engine was still running.
- When the fire truck left the apparatus bay, the system's hose forcefully disconnected from the vehicle's tailpipe and the hood attached to the hose came off.

Air flowed from the apparatus bay into the living quarters

- Unless all the bay doors were closed and the exhaust in the apparatus bay was on, air flowed from the apparatus bay into the living quarters. This could lead to vehicle exhaust getting into the living areas. The preferred situation would have air flowing from the living quarters into the apparatus bay.

To learn more about our results, go to Section B in the Supporting Technical Information

Our Recommendations

The potential benefits of improving workplace health and safety are:

- Improved worker health and well-being
- Better workplace morale
- Easier employee recruiting and retention
- Enhanced image and reputation
- Superior products, processes, and services
- Increased overall cost savings

The recommendations below are based on the findings of our evaluation. These recommendations are workplace-specific, based on the information available for the workplace evaluated, and are intended to improve this workplace's conditions. For each recommendation, we list a series of actions you can take to address the issue at your workplace. The actions at the beginning of each list are preferable to the ones listed later. The list order is based on a well-accepted approach called the "hierarchy of controls." The hierarchy of controls is a way of determining which actions will best control exposures. In most cases, the preferred approach is to eliminate hazards or to replace the hazard with something less hazardous (i.e., substitution). Installing engineering controls to isolate people from the hazard is the next step in the hierarchy. Until such controls are in place, or if they are not effective or practical, administrative measures and personal protective equipment might be needed. Read more about the hierarchy of controls on the NIOSH website.

We encourage management to use a health and safety committee to discuss our recommendations and develop an action plan. Both employee representatives and management representatives should be included on the committee. Helpful guidance can be found in OSHA's Recommended Practices for Safety and Health Programs.

Recommendation 1: Reduce firefighters' exposures to diesel exhaust in the apparatus bay as much as possible.

Why? Reducing exposure to diesel exhaust would help keep eyes and respiratory systems from getting irritated, especially among workers who are sensitive to the presence of diesel exhaust, such as people with asthma. Breathing in diesel exhaust at work has been associated with eye, nose, throat, and lung irritation. Diesel exhaust is a carcinogen, and exposure is also associated with lung inflammation, can aggravate asthma and other chronic respiratory conditions, and make allergic responses worse. While air concentrations of components of diesel exhaust were lower than occupational exposure limits, the following recommendations could further reduce diesel exhaust exposure.

How? At your workplace, we recommend these specific actions:

Close apparatus bay doors when equipment is running outside of the bay

- This is especially important during morning equipment checks when all the equipment is running at once.

Improve maintenance and fix operating issues affecting the local exhaust extraction system

- Repair the exhaust hose that was out of service at the time of our visit.
- The local exhaust extraction system consistently activated when triggered by dispatch calls; however, the tailpipe exhaust pressure sensors did not consistently activate the system for all vehicles. Explore and implement other activation methods that engage the local exhaust extraction system in addition to pressure sensing and dispatch calls, e.g., when the engine is started or running.
- Consider switching the sides that the ambulances and fire trucks are parked in the bay or adjust the airflow in the four exhaust hoses to match each vehicle's exhaust flowrates. For example, increase the duct diameter for the fire truck side or add dampers at the ambulance side.
- Ensure that the hoods for the exhaust hoses properly fit onto each vehicle's tailpipe.
- When returning to the station, shut the vehicle engine off before attaching the local exhaust hose to reduce diesel exhaust exposure for the personnel assisting with that task.

Prevent contaminants from the apparatus bay entering the living quarters

- Run the apparatus bay general exhaust ventilation system whenever the local exhaust capture system fails to operate as designed. This provides backup protection when the primary source capture control is not functioning properly. Once the local exhaust capture system is repaired and confirmed to be operating reliably, the general exhaust ventilation may operate on an as-needed basis triggered by CO sensor activation.
- Adjust the energy recovery ventilator serving the living quarters to supply a greater volume of outdoor air than is exhausted, creating positive pressurization in the living quarters relative to the apparatus bay.
- Install door sweeps on the doors between the bay and living quarters, including the door to the EMS dormitory, to cover gaps between the door and floor reducing the ability for diesel exhaust to enter the living quarters.

Recommendation 2: Address other health and safety issues we identified during our evaluation

Why? A workplace can have multiple health hazards that cause worker illness or injury. Similar to the ones identified above, these hazards can potentially cause serious health symptoms, lower morale and quality of life for your employees, and possibly increased costs to your business. We saw the following potential issues at your workplace:

- We observed that when a vehicle is leaving the bay, the local exhaust extraction hose may swing quite violently after disconnecting, which may pose a hazard if anyone is standing in the vicinity.
- We observed mechanics using solvents while repairing a fire engine. During this time, the apparatus bay doors were closed, and the exhaust system was off.
- Firefighter turnout gear was stored directly across from apparatus exhaust pipes.

Although they were not the focus of our evaluation, these hazards could cause harm to your workers' health and safety and should be addressed.

How? At your workplace, we recommend these specific actions:

Reduce potential for injury from the local exhaust system hoses disconnecting as a vehicle leaves the station

- The local exhaust extraction hose occasionally failed to disconnect properly from the vehicle, causing it to either tear off or swing with enough force to strike nearby surfaces, creating a potential injury hazard near the personnel door. Adjust the disconnection tension and alignment of the hose and track system to ensure smooth release during vehicle departure. Relocating or shielding the nearby door could also be considered to prevent personnel from being struck.
- Ensure emergency personnel do not stand beside a vehicle or in the station entrance when it leaves the station to prevent injury when the exhaust system disconnects from the vehicle. Consider posting warning signs about this potential for injury.

Open bay doors and turn the exhaust system on when using solvents in the apparatus bay

- This will increase ventilation in the apparatus bay while solvents are being used.

Store turnout gear away from diesel engine exhaust pipes

Supporting Technical Information

Evaluation of Diesel Exhaust Control Methods at a Fire Station

HHE Report No. 2023-0099-3430

March 2026

Section A: Workplace Information

The single-story fire station was built in 1993 and was staffed daily by four firefighters and two paramedics. Firefighters worked three 24-hour alternating shifts, with 24 hours off between the first two shifts and 96 hours off after the third shift. All employees belonged to a union. During our initial walkthrough, this station was identified as the busiest of all the stations in the department. The apparatus bay's volume was approximately 64,000 cubic feet (ft^3).

In the apparatus bay, a local exhaust extraction system provided tailpipe source capture for up to four apparatuses. The system used a soft, inflatable nozzle that connected to the tailpipe and featured automatic activation either upon dispatch or when engine exhaust pressure was sensed, followed by a preset run time and automatic release as the vehicle exited the bay. It could also be manually activated from a control panel mounted on the wall of the bay. In addition, the bay was equipped with a ceiling-mounted general ventilation exhaust system that was designed to be activated when air concentrations of carbon monoxide reached a certain level in the bay or could be manually turned on. The ceiling-mounted general ventilation exhaust system has a capacity of 5,000 cubic feet per minute (cfm) and is located near the ceiling of the apparatus bay, which has a ceiling height of 19 feet. A timer control mounted on the wall in the corridor connecting the apparatus bay and living quarters provided manual control of this exhaust system. The living quarters of the fire station were served by residential-style air-handling units supplemented by an energy recovery ventilator (ERV) to provide dedicated outdoor air while recovering heating/cooling energy. The outdoor air intake for the living quarters ERV was located on the roof above the locker room area, away from where the two exhaust fans are located.

There were three doorways that separated the living quarters from the apparatus bay, referred to as D1, D2, and D3 in this report. D1 was in the bay and connected to the EMS dormitory. D2 and D3 were in the corridor connecting the apparatus bay and living quarters, with D2 connecting to the EMS dormitory and D3 connecting to the main living quarters.

Section B: Methods, Results, and Discussion

Methods: Observations of Work Processes, Practices, and Conditions

We evaluated or collected information on the following during our site visit:

- Number of runs made
- Work processes
- Workplace conditions

Results: Observations of Work Processes, Practices, and Conditions

Table C1 shows the number of runs per diesel apparatus during our site visit. This run list does not include those instances when a crew went out for reasons other than incident response, including training, hydrant testing, or grocery runs.

- We observed that when a vehicle is leaving the bay, the local exhaust extraction hose may swing quite violently after disconnecting, which may pose a hazard if anyone is standing in the vicinity. We noted marks left on the apparatus bay wall from the black rubber adaptor at the end of the hose hitting the wall after multiple disconnections from the vehicle.
- On the morning of the first sampling day, we observed firefighters performing their daily equipment checks outside of the apparatus bay while the doors were open. Equipment included two generators, a chainsaw, and a gas-powered fan.
- We observed mechanics using solvents while repairing a fire engine. During this time, the apparatus bay doors were closed, and the exhaust system was off.
- Firefighter turnout gear was stored directly across from the fire engine's tailpipe.

Methods: Exposure Assessment

Particulates

Diesel Particulate Matter (as Elemental Carbon)

We used elemental carbon as a surrogate for diesel exhaust exposure because diesel exhaust is a complex mixture of gases and particles comprised of more than 80% carbon. Due to the emergency response nature of their jobs and the importance of quickly putting on firefighter turnout gear to leave the station, personal samples were determined to be impractical and could have potentially impeded their ability to perform their emergency response duties. Although we did not collect personal samples, we placed the area samples in locations where firefighters typically worked or resided within the station. We collected air samples for diesel particulate matter (as elemental carbon) from the apparatus bay, report room, EMS dormitory, kitchen, and outdoors. We collected the air samples at a flow rate of 2 liters per minute on a three-piece, 37-milimeter diameter open-faced cassette with a heat-treated quartz-fiber filter supported on a cellulose pad.

- We analyzed each sample for elemental carbon using NIOSH Method 5040, using thermal-optical analysis [NIOSH 2025].
- We calculated area air concentrations of elemental carbon at each of the sampling locations.

DustTrak Monitors

We measured particulates using DustTrak™ DRX 8533 aerosol monitors (TSI, Inc.) in the apparatus bay, report room, EMS dormitory, kitchen, and outdoors. All monitors were set to log particle mass concentrations every 30 seconds in different size groups: particulate matter (PM) smaller than 1 micron (µm) (PM_1); PM smaller than 2.5 µm ($PM_{2.5}$); respirable (less than 4 µm); PM smaller than 10 µm (PM_{10}); and total PM (less than 100 µm). The data output was expressed as the mass concentration, in milligrams, of particles per cubic meter (mg/m^3) of the sampled air. The lower instrument range was less than 0.001 mg/m^3.

Condensation Particle Counters

We also measured particulates using TSI® Model 3007 handheld condensation particle counters (CPCs) in the apparatus bay, report room, EMS dormitory, kitchen, and outdoors. All CPCs were set to log particle number concentrations every second in the size range of 0.01 to >1 µm, including ultrafine particles (smaller than 0.1 µm). The data output was expressed as the total number of particles per cubic centimeter (p/cm^3) of the sampled air. The detectable concentration for the CPC ranged from 0 to 100,000 p/cm^3.

Carbon Monoxide and Carbon Dioxide

We used TSI Q-Trak™ indoor air quality monitors to measure carbon dioxide, carbon monoxide, temperature, and relative humidity in the apparatus bay, report room, EMS dormitory, kitchen, and outdoors. Carbon dioxide is released by occupants and its levels in air can be used to assess the effectiveness of ventilation systems. Carbon monoxide is a component of most combustion processes. The monitors were set to log data every 30 seconds. While we were able to observe near real-time carbon monoxide air concentrations in the sampling locations, not all of the carbon monoxide data from the Q-Traks were appropriately saved and thus summary data for the kitchen, report room, and outdoors cannot be reported.

Results: Exposure Assessment

Particulates

We collected area air samples for approximately 12 hours on the first sampling day and eight hours on the second day. Elemental carbon was not detected in any of the samples. Tables C2 through C4 summarize particle concentrations, reported as mg/m^3 in different size groups during the sampling period. Respirable particle concentrations ranged from less than 0.001–0.034 mg/m^3 in the apparatus bay, less than 0.001–0.014 mg/m^3 in the EMS dormitory, 0.007–0.051 mg/m^3 in the report room, 0.012–0.256 mg/m^3 in the kitchen, and 0.004–0.053 mg/m^3 outdoors. The Occupational Safety and Health Administration (OSHA) has a permissible exposure limit (PEL) for respirable dust of 5 mg/m^3 time-weighted average (TWA). This limit is intended for nuisance dust that is known to not contain harmful components. Additionally, area samples cannot be compared to occupational exposure limits since these limits are based on personal exposure levels.

Concentrations of airborne ultrafine particles (less than 0.1 μm in diameter) increased in the bay while diesel engines were running. Figure B1 shows the concentrations of ultrafine particles in the sampling locations during the second sampling day. At around 10:20 a.m., the concentration of ultrafine particles in the apparatus bay increased after the reserve truck's engine was started despite the exhaust capture hose being attached. We observed visible exhaust exiting the tailpipe around the hose attachment. The reserve truck pulled outside of the bay and high-idled in the driveway while we measured the flow rate of the exhaust. After the truck returned to the bay and the engine was turned off, the concentration of ultrafine particles decreased, followed by another smaller spike when the fire engine was dispatched to a call. The exhaust system in the bay is normally activated by dispatch calls, but in this case had to be manually turned on. After the exhaust system turned on, the concentration of ultrafine particles decreased and took approximately 20 minutes to reach background levels. Later in the day, around 12:25 p.m., the fire engine returned from a call, but the exhaust system in the bay did not turn on. It took around 40 minutes for the concentration of ultrafine particles to return to background levels. When levels spiked in the apparatus bay, smaller peaks could be seen in the EMS dormitory, but not in the report room or kitchen. The peaks in the kitchen and report room around 11:50 a.m. coincide with emissions from the firefighters cooking lunch on a gas stove.

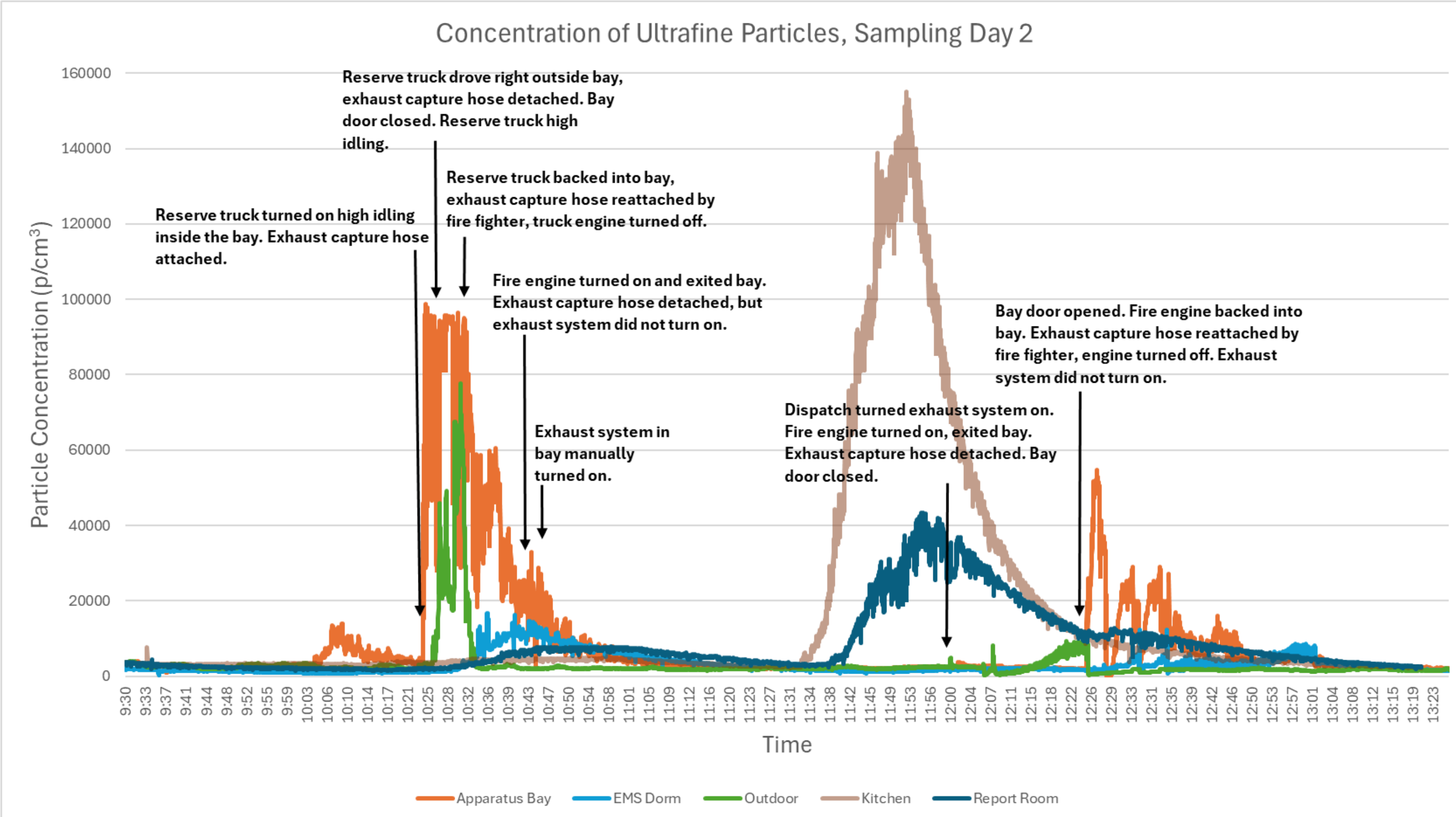

Figure B1. Concentration of ultrafine particles during the second sampling day. Figure by NIOSH.

Carbon Monoxide and Carbon Dioxide

Table C5 summarizes carbon monoxide concentrations in parts per million (ppm) in the apparatus bay and EMS dormitory during the sampling period. The average carbon monoxide concentration in the apparatus bay was 0.1 ppm (range: <0.1 ppm to 11.6 ppm). The average carbon monoxide concentration in the EMS dormitory was 0.9 ppm (range: 0.5 ppm to 4.7 ppm). For perspective, the OSHA permissible exposure limit for carbon monoxide of 50 ppm TWA, and the NIOSH recommended exposure limit is 35 ppm, TWA [NIOSH 2019; OSHA 2025].

Figure B2 shows the concentration of carbon monoxide in the apparatus bay and EMS dormitory during morning equipment checks on the first sampling day. When the fire engine was turned on at 7 a.m., increases in carbon monoxide concentrations were observed in the bay and EMS dormitory. Later in the morning, the generators, chainsaw, and fan were turned on outside of the bay while the bay doors were open, and carbon monoxide concentrations increased in both sampling locations.

Carbon dioxide concentrations ranged from 336–894 ppm in the apparatus bay, 488–918 in the EMS dormitory, 533–983 ppm in the report room, 538–1388 ppm in the kitchen, and 351–639 ppm outdoors. The carbon dioxide OSHA PEL and NIOSH REL are both 5,000 ppm TWA [NIOSH 2019; OSHA 2025].

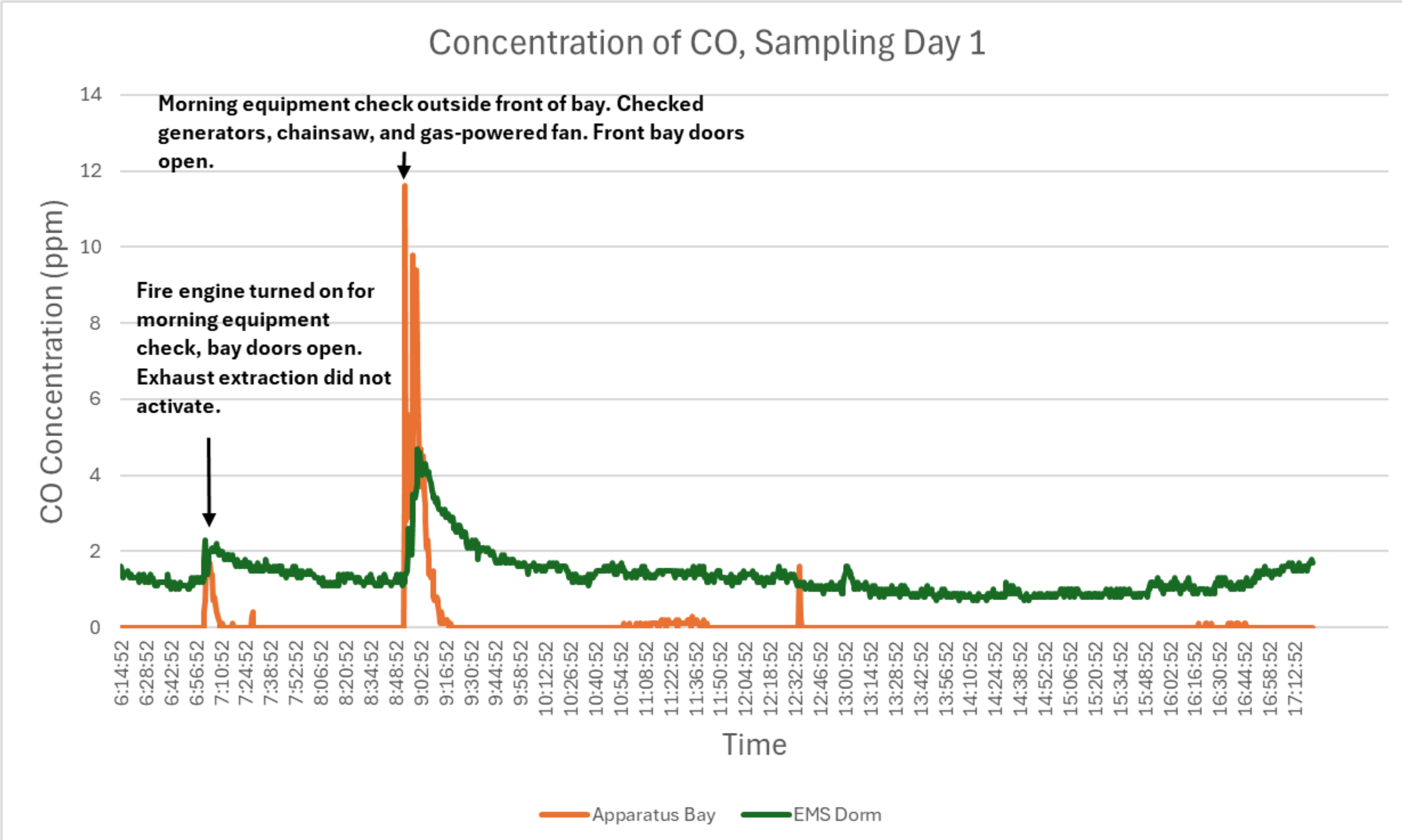

Figure B2. Concentration of carbon monoxide in the apparatus bay and EMS dorm during the first sampling day. Figure by NIOSH.

Methods: Ventilation Assessment

Ventilation measurements for the apparatus bay local exhaust extraction system were taken using a TSI Velocicalc® with an attached rotating vane anemometer. Velocity readings were taken at the exhaust capture hose inlet while it was disconnected from the tailpipe, and the measured average velocity was multiplied by the free area of the opening to calculate volumetric airflow. Total exhaust flow for the local exhaust extraction system was also measured at the fan discharge outlet located on the roof. Similarly, ventilation measurements for the general exhaust ventilation system serving the apparatus bay were taken at the fan discharge outlet located on the roof. Velocity readings were also taken at the tailpipes of each apparatus, and measured average velocity was multiplied by the free area of the tailpipe to calculate vehicle exhaust flowrates.

A micromanometer was used to measure differential pressure across the three doorways separating the living quarters from the apparatus bay. To supplement the quantitative pressure readings, smoke tracer tests were conducted at each doorway to observe airflow direction and confirm pressurization relationships. This method provided a visual verification of the micromanometer results.

Operation of the local exhaust extraction system in the apparatus bay was observed throughout the site visit to qualitatively assess system performance under typical use conditions. Observations focused on system activation, connection and disconnection from vehicles, capture effectiveness at the tailpipe, and any operational or safety issues encountered during normal fire station activities.

Results: Ventilation Assessment

The total airflow for the local exhaust extraction system was measured at ~2,000 cfm. Measured airflow rates ranged from 236 cfm on the fire truck side to 471 cfm on the ambulance side. When operating, the general exhaust fan in the apparatus bay provided nearly 5,000 cfm airflow, contributing 4.6 air changes per hour.

The apparatus bay was generally observed to be under positive pressure relative to the living quarters, except when all bay doors were closed and the bay general ventilation exhaust system was operating. Table C6 lists the measured differential pressure under four conditions.

Multiple operating issues were observed for the local exhaust extraction system:

- The fire engine's tailpipe (a double-walled sleeve) did not fit onto the local exhaust extraction system's hose, leading to a decrease in backpressure and a large portion of the engine exhaust not being captured by the local exhaust extraction.
- The local exhaust extraction system was only activated by dispatch calls for the fire engine and both ambulances. The reserve fire truck was the only apparatus in the bay with exhaust that created enough air pressure to activate the local exhaust extraction system without a dispatch call. The reserve truck (manufactured in 2001) was older than the fire engine, which was manufactured in 2015.
- One of the exhaust hoses failed to disconnect properly from the reserve fire truck's tailpipe after the truck left the station. The hood of the exhaust hose remained on the tailpipe for a short period of time while the hose disconnected.

- During our visit, one of the four exhaust hoses was out of service.
- We observed that firefighters needed to manually connect the local exhaust extraction hose to the vehicle's tailpipe when the vehicle returned, which is not desirable especially when the engine is on. As a result, firefighters may experience peak (short-term) exposures to diesel exhaust when reattaching the hose to the running vehicle.

Discussion

There are a variety of different strategies fire departments use to control diesel exhaust emissions into fire stations. These include exhaust filtration systems, dilution ventilation, and tailpipe exhaust ventilation. Engine exhaust filtration systems work by removing particulates from the diesel exhaust. The filters are installed in the vehicle's exhaust system or at the tailpipe. These systems are typically on a timer and operate for a preset amount of time (from a few seconds to a couple of minutes) to allow for the vehicle to exit the station. Dilution ventilation relies on a fan to exhaust contaminated air to the outside while outside makeup air flows into the bay through open doors or supply-air openings. Unlike the other two strategies, dilution ventilation does not capture emissions at the source. Tailpipe exhaust ventilation involves attaching an exhaust hose to the vehicle tailpipe with the exhaust hose connected to a fan that discharges diesel exhaust to the outside. An advantage of using an exhaust hose is that it removes both gaseous and particulate emissions in the diesel exhaust. The disadvantage of using tailpipe exhaust ventilation is that it requires the firefighter to remember to attach the hose to the apparatus when the vehicle returns to the station [Baldwin et al. 2011; Roegner et al. 2002]. The station we evaluated utilized tailpipe exhaust ventilation to control indoor diesel exhaust emissions.

Tables C2 through C4 summarize particle concentrations, reported as mg/m^3 in different size groups during the sampling period. Most of the particles were smaller than 1 µm in diameter. In general, average particle concentrations were highest in the kitchen, followed by the outdoors, report room, apparatus bay, and EMS dormitory. When the exhaust system did not turn on in the bay, we observed corresponding increases in particle concentrations in both the apparatus bay and EMS dormitory. We also observed increases (more than twice the background level) in the EMS dormitory and bay during apparatus run times. Similarly, when the generators, chainsaw, and fan were turned on outside of the bay while the bay doors were open, carbon monoxide concentrations increased in both sampling locations. This is likely due to the positive pressure differential in the bay relative to the living quarters under certain conditions (i.e., the bay doors are open, or all the bay doors are closed and the exhaust systems are not on). To minimize this risk, the bay exhaust system could be operated whenever the local exhaust capture system (tailpipe extraction) fails to operate as designed, and door sweeps could be installed on all three doors to reduce the potential for contaminant transfer. Also, consider adjusting the energy recovery ventilator serving the living quarters to supply a greater volume of outdoor air than is exhausted, creating positive pressurization in the living quarters relative to the apparatus bay.

Particles larger than 100 µm in diameter may be too big to enter the deepest areas of the lungs but can enter the nose, mouth, and upper airways during breathing. Particles smaller than 4 µm in diameter are respirable and can penetrate deeply into the lower respiratory system [ACGIH 2025]. Fine particles (less than 2.5 µm in diameter) and ultrafine particles (less than 100 nanometers (nm) in diameter) are primarily deposited in the small airways and alveoli [EPA 2025]. Ultrafine particles are small enough to pass through the alveoli into the bloodstream [American Lung Association 2025]. Acute and chronic exposure to respirable particles have been linked with adverse health effects, including cardiovascular disease, respiratory disease, developmental and reproductive effects, and lung cancer [EPA 2025]. Most diesel exhaust particles are within the respirable size fraction and most are ultrafine, in terms of particle counts [Debia et al. 2016].

OSHA has a permissible exposure limit of 5 mg/m^3 for respirable dust over an 8-hour TWA [OSHA 2025]. This PEL is for particulates not otherwise regulated, including nuisance dust or inert dust. For dust containing diesel particulate this PEL may not be applicable. The American Conference of Governmental Industrial Hygienists (ACGIH®) recommends that airborne concentrations of respirable dust be kept below 3 mg/m^3 [ACGIH 2025]. Currently, neither OSHA nor NIOSH have occupational exposure limits for exposure to diesel particulate matter (as elemental carbon) or ultrafine particles of nuisance dust. We did not detect elemental carbon in any of the samples.

The local exhaust extraction system consistently activated when triggered by dispatch calls. However, the tailpipe exhaust pressure sensors did not consistently activate the system for all vehicles, likely due to exhaust on some of the vehicles not reaching sufficient pressure for activation. Evaluating whether the pressure activation threshold for the local exhaust system can be adjusted to improve sensitivity and reliability could help decrease diesel exhaust concentrations. The addition of engine-start detection or engine-running sensors as supplemental activation methods would ensure the system engages reliably in concert with the existing pressure and dispatch call triggers. Airflow distribution among the four hoses of the system was uneven and not well matched to vehicle exhaust flowrates. This imbalance was suboptimal given that fire trucks produce substantially higher exhaust flowrates than ambulances (approximately 405 cfm for the reserve truck versus 170 cfm for the ambulance). To address this, consider reconfiguring the hose placement so that the higher-flow fire trucks are paired with higher-capacity connections, or rebalance the system by adjusting duct diameters and/or installing dampers to redistribute airflow more appropriately.

Firefighter turnout gear can become contaminated with various compounds after use in firefighting and other operations. Volatile organic compounds will continue to off-gas from the gear after a response [Fent et al. 2015; Fent et al. 2017]. In addition, when turnout gear is stored in the apparatus bay, combustion products from gas and diesel engines in the bay may transfer to and further contaminate the gear. Firefighters can be exposed to these contaminants from contact with the skin. Some of these contaminants are carcinogens or potentially carcinogenic as defined by the International Agency for Research on Cancer (IARC) [IARC 2010]. During our evaluation, we observed that firefighter turnout gear was stored directly across from the tailpipe of the fire engine. To reduce firefighters' exposures to contaminated gear, we recommend gear be stored in a dedicated storage area, ideally with an exhaust fan that exhausts to the outdoors. NIOSH and the Firefighter Cancer Support Network have put together a factsheet that may provide some additional information on gear decontamination and storage procedures.

Limitations

This evaluation is subject to several limitations. Industrial hygiene sampling can only document exposures and conditions in the locations evaluated on the days that the evaluation occurred. These results may not be representative of conditions during other days due to the nature of the work or change in season. It is important to note that we only collected area samples where employees typically worked. We did not collect any personal exposure measurements and so cannot directly compare our results with occupational exposure limits, which are for personal exposures.

Conclusions

Levels of diesel exhaust particulate (as elemental carbon) and other components of vehicle exhaust were low in the apparatus bay and living quarters. Our results showed that most of the particulate in the apparatus bay was smaller than 1 μm in diameter. We observed peaks in particle concentrations in the EMS dorm when apparatuses were running in the bay. Our ventilation measurements indicated that both the local and general exhaust systems provided measurable airflow, but the local exhaust extraction system did not always successfully capture vehicle emissions due to design and operational issues. System activation relied heavily on dispatch signals and in some cases the exhaust extraction system failed to consistently respond to engine exhaust pressure, particularly for newer vehicles. Observations showed poor compatibility between the local exhaust extraction system and modern diffuser style tailpipes, uneven airflow distribution, and mechanical problems such as hose disconnections. These issues increase the risk of diesel exhaust exposure and potential safety hazards during normal operations. Overall, the fire department could consider functional adjustments, equipment repairs, and reconfiguration to ensure effective exhaust capture and safe operation to further reduce potential exposures.

Section C: Tables

Table C1. Daily diesel engine apparatus runs

Diesel apparatus	Sampling day 1	Overnight	Sampling day 2
Ambulance	3	0	0
Fire engine	1	1	4
Total	4	1	4

Table C2. Average particle concentrations (mg/m^3) during the first sampling day

	Bay Average (range)	EMS dorm Average (range)	Kitchen Average (range)	Report room Average (range)	Outdoors Average (range)
PM_1	0.006 (0.002–0.033)	0.005 (0.003–0.012)	0.037 (0.012–0.253)	0.012 (0.001–0.050)	0.025 (0.007–0.045)
$PM_{2.5}$	0.006 (0.002–0.033)	0.005 (0.003–0.013)	0.037 (0.012–0.254)	0.012 (0.008–0.050)	0.025 (0.008–0.047)
Respirable	0.007 (0.002–0.033)	0.005 (0.003–0.013)	0.037 (0.013–0.256)	0.012 (0.008–0.051)	0.026 (0.010–0.053)
PM_{10}	0.008 (0.002–0.035)	0.006 (0.003–0.016)	0.038 (0.013–0.263)	0.014 (0.008–0.052)	0.028 (0.012–0.089)
Total	0.009 (0.003–0.036)	0.007 (0.003–0.035)	0.040 (0.016–0.294)	0.015 (0.008–0.053)	0.029 (0.013–0.143)

Table C3. Average particle concentrations (mg/m^3) overnight, between the first and second sampling day

	Bay Average (range)	EMS dorm Average (range)	Kitchen Average (range)	Report room Average (range)
PM_1	0.002 (ND–0.013)	0.002 (ND–0.013)	0.024 (0.023–0.033)	0.008 (0.005–0.024)
$PM_{2.5}$	0.002 (ND–0.014)	0.002 (ND–0.013)	0.024 (0.023–0.034)	0.008 (0.006–0.024)
Respirable	0.002 (ND–0.014)	0.002 (ND–0.014)	0.024 (0.023–0.035)	0.008 (0.007–0.025)
PM_{10}	0.002 (ND–0.017)	0.002 (ND–0.014)	0.025 (0.023–0.041)	0.009 (0.007–0.033)
Total	0.002 (ND–0.019)	0.002 (ND–0.021)	0.025 (0.023–0.062)	0.010 (0.007–0.085)

* ND = non-detect, less than the instrument's limit of detection, 0.001 mg/m^3

Range = minimum - maximum

Table C4. Average particle concentrations (mg/m³) during the second sampling day

	Bay Average (range)	EMS dorm Average (range)	Kitchen Average (range)	Report room Average (range)	Outdoors Average (range)
PM_1	0.008 (0.005–0.032)	0.005 (0.003–0.009)	0.027 (0.026–0.037)	0.012 (0.009–0.039)	0.022 (0.004–0.034)
$PM_{2.5}$	0.008 (0.006–0.033)	0.005 (0.003–0.009)	0.027 (0.026–0.037)	0.012 (0.009–0.039)	0.023 (0.004–0.034)
Respirable	0.008 (0.006–0.034)	0.005 (0.003–0.009)	0.028 (0.026–0.037)	0.012 (0.009–0.041)	0.023 (0.004–0.035)
PM_{10}	0.009 (0.006–0.037)	0.005 (0.004–0.010)	0.028 (0.026–0.054)	0.014 (0.010–0.062)	0.024 (0.005–0.038)
Total	0.010 (0.006–0.045)	0.007 (0.004–0.024)	0.031 (0.026–0.078)	0.017 (0.010–0.133)	0.025 (0.005–0.051)

Range = minimum - maximum

Table C5. Average carbon monoxide concentrations (ppm)

Sampling Day	Bay Average (range)	EMS dorm Average (range)
Day 1	0.1 (ND*–11.6)	1.4 (0.7–4.7)
Overnight	ND (ND–1.5)	0.7 (0.5–1.1)
Day 2	ND (ND–1.5)	0.7 (0.5–1.0)

* ND = non-detect, less than the instrument's limit of detection, 0.1 ppm

Range = minimum - maximum

Table C6. Measured differential pressure in the apparatus bay relative to the living quarters (inches of water gauge, in. w.g.)

Doorway	Bay doors open	Bay doors closed; exhaust fan on; local exhaust off	Bay doors closed; exhaust fan on; local exhaust on	Bay doors closed; exhaust fan off; local exhaust off
D1	0.006	-0.007	-0.011	0.006
D2	0.005	-0.007	-0.011	0.005
D3	0.008	-0.012	-0.022	0.006

Section D: Occupational Exposure Limits

NIOSH investigators refer to mandatory (legally enforceable) and recommended occupational exposure limits (OELs) for chemical, physical, and biological agents when evaluating workplace hazards. OELs have been developed by federal agencies and safety and health organizations to decrease the risk of adverse health effects from workplace exposures. Generally, OELs suggest levels of exposure that most employees may be exposed to for up to 10 hours per day, 40 hours per week, for a working lifetime, without experiencing adverse health effects.

However, not all employees will be protected if their exposures are maintained below these levels. Some may have adverse health effects because of individual susceptibility, a preexisting medical condition, or a hypersensitivity (allergy). In addition, some hazardous substances act in combination with other exposures, with the general environment, or with medications or personal habits of the employee to produce adverse health effects. Most OELs address airborne exposures, but some substances can be absorbed directly through the skin and mucous membranes.

Most OELs are expressed as a time-weighted average (TWA) exposure. A TWA refers to the average exposure during a normal 8- to 10-hour workday. Some chemical substances and physical agents have recommended short-term exposure limits (STEL) or ceiling values. Unless otherwise noted, the STEL is a 15-minute TWA exposure. It should not be exceeded at any time during a workday. The ceiling limit should not be exceeded at any time.

In the United States, OELs have been established by federal agencies, professional organizations, state and local governments, and other entities. Some OELs are legally enforceable limits; others are recommendations.

- OSHA, an agency of the U.S. Department of Labor, publishes permissible exposure limits [29 CFR 1910 for general industry; 29 CFR 1926 for construction industry; and 29 CFR 1917 for maritime industry] called PELs. These legal limits are enforceable in workplaces covered under the Occupational Safety and Health Act of 1970. The Occupational Safety and Health Act requires employers to provide a safe workplace.

- NIOSH recommended exposure limits (RELs) are recommendations based on a critical review of the scientific and technical information and the adequacy of methods to identify and control the hazard. NIOSH RELs are published in the NIOSH Pocket Guide to Chemical Hazards [NIOSH 2007]. NIOSH also recommends risk management practices (e.g., engineering controls, safe work practices, employee education/training, personal protective equipment, and exposure and medical monitoring) to minimize the risk of exposure and adverse health effects.

- Another set of OELs commonly used and cited in the United States includes the threshold limit values or TLVs, which are recommended by the American Conference of Governmental Industrial Hygienists (ACGIH). The ACGIH TLVs are developed by committee members of this professional organization from a review of the published, peer-reviewed literature. TLVs are not consensus standards. They are considered voluntary exposure guidelines for use by industrial hygienists and others trained in this discipline "to assist in the control of health hazards" [ACGIH 2025].

Outside the United States, OELs have been established by various agencies and organizations and include legal and recommended limits. The Institut für Arbeitsschutz der Deutschen Gesetzlichen Unfallversicherung (Institute for Occupational Safety and Health of the German Social Accident Insurance) maintains a database of international OELs from European Union member states, Canada (Québec), Japan, Switzerland, and the United States. The database contains international limits for more than 2,000 hazardous substances and is updated periodically.

OSHA (Public Law 91-596) requires an employer to furnish employees a place of employment free from recognized hazards that cause or are likely to cause death or serious physical harm. This is true in the absence of a specific OEL. It also is important to keep in mind that OELs may not reflect current health-based information.

When multiple OELs exist for a substance or agent, NIOSH investigators generally encourage employers to use the lowest OEL when making risk assessment and risk management decisions.

Diesel Exhaust

Diesel exhaust is a complex mixture of various gases and fine particles. Diesel exhaust is typically black in color with a low odor threshold (odors easily detected at low concentrations) and contains more than 40 toxic compounds [EPA 2002]. The gases in diesel exhaust include hydrocarbons and oxides of carbon, sulfur, and nitrogen [NIOSH 1988; OSHA 1988]. The particles mainly consist of organic carbon compounds adsorbed onto cores of microscopic elemental carbon. More than 95% of these particles are less than 1 micrometer in size and are respirable [NIOSH 2016]. Because of their small size, diesel exhaust particles can be inhaled deeply into the lungs and even into the bloodstream.

Diesel exhaust exposure is associated with acute health effects, such as eye, nose, throat, and lung irritation; cough; headache; lightheadedness; and nausea [Gamble et al. 1987; Pronk et al. 2009; Reger and Hancock 1980; Sydbom et al. 2001]. Diesel exhaust exposure is also associated with lung inflammation, can aggravate asthma and other chronic respiratory conditions, and make allergenic responses worse [Sydbom et al. 2001; Ulfvarson and Alexandersson 1990]. Whether a person experiences these acute or chronic health effects depends on the duration and magnitude of the exposures and on individual susceptibility.

Research from NIOSH has shown an increased risk of death from lung cancer in underground miners [Attfield et al. 2012]. The International Agency for Research on Cancer has concluded, with sufficient evidence, that diesel exhaust is a Group 1 human carcinogen that causes lung cancer, and is positively associated, with limited evidence, with an increased risk of bladder cancer [IARC 2012]. NIOSH considers diesel exhaust emissions a potential occupational carcinogen and recommends exposure be kept at the lowest feasible concentration. NIOSH is currently considering developing quantitative recommended exposure limits based on human and/or animal data, with consideration to the availability of workplace exposure controls. The Occupational Safety and Health Administration does not have a permissible exposure limit for diesel exhaust.

Carbon Monoxide

CO is a colorless, odorless, tasteless gas produced by incomplete burning of carbon-containing materials, e.g., gasoline. The initial symptoms of CO poisoning may include headache, dizziness, drowsiness, and nausea. These initial symptoms may advance to vomiting, loss of consciousness, and collapse if prolonged or high exposures are encountered. Coma or death may occur if high exposures continue. Exposure to CO limits the ability of the blood to carry oxygen to the tissues by binding with the hemoglobin to form carboxyhemoglobin (COHb) [ACGIH 2025; NIOSH 1972, 1977, 1979, 2007; Proctor et al. 1988]. The NIOSH REL for CO is 35 ppm for an 8-hour TWA exposure, with a ceiling limit of 200 ppm that should not be exceeded [NIOSH 2007]. The NIOSH REL is designed to protect workers from health effects associated with COHb levels in excess of 5% [NIOSH 1972]. The ACGIH recommends a TLV of 25 ppm as an 8-hour TWA. This is designed to protect workers from health effects associated with COHb levels in excess of 3.5% [ACGIH 2025]. The OSHA PEL for CO is 50 ppm for an 8-hour TWA exposure [29 CFR 1910.1000].

Section E: References

Methods

NIOSH [2025]. NIOSH manual of analytical methods (NMAM). 5th ed. O'Connor PF, Ashley K, eds. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2014-151, https://www.cdc.gov/niosh/nmam/default.html.

Results

NIOSH [2019]. NIOSH pocket guide to chemical hazards. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2005-149, https://www.cdc.gov/niosh/npg/npgd0105.html.

OSHA [2025]. CFR 1910.100 Table Z-1 Limits for air contaminants. Washington, DC: U.S. Department of Labor, Occupational Safety and Health Administration, https://www.osha.gov/laws-regs/regulations/standardnumber/1910/1910.1000TABLEZ1.

Discussion

ACGIH [2025]. TLV®s and BEI®s: threshold limit values for chemical substances and physical agents and biological exposure indices. Cincinnati, OH: American Conference of Governmental Industrial Hygienists, https://www.acgih.org/tlv-bei-guidelines/policies-procedures-presentations/.

American Lung Association [2025]. Particle pollution. Washington, DC: American Lung Association, https://www.lung.org/clean-air/outdoors/what-makes-air-unhealthy/particle-pollution.

Baldwin TN, Hales TR, Niemeier MT [2011]. Controlling diesel exhaust exposure inside firehouses. Fire Eng *164*(2):63–74, https://www.fireengineering.com/fire-apparatus/controlling-diesel-exhaust-exposure-inside-firehouses/.

Debia M, Trachy-Bourget MC, Beaudry C, Neesham-Grenon E, Perron S, Lapointe C [2016]. Characterization of indoor diesel exhaust emissions from the parking garage of a school. Environ Sci Pollut Res *24*:4655–4665, https://doi.org/10.1007/s11356-016-8129-4.

EPA [2025]. Particle pollution exposure. Washington, DC: U.S. Environmental Protection Agency, https://www.epa.gov/pmcourse/particle-pollution-exposure.

Fent K, Evans DE, Booher D, Pleil JD, Stiegel MA, Horn GP, Dalton J [2015]. Volatile organic compounds off-gassing from firefighters' personal protective equipment ensembles after use. J Occup Environ Hyg *12*(6):404–414, https://doi.org/10.1080/15459624.2015.1025135.

Fent K, Alexander B, Roberts J, Robertson S, Toennis C, Sammons D, Bertke S, Kerber S, Smith D, Horn G [2017]. Contamination of firefighter personal protective equipment and skin and the effectiveness of decontamination procedures. J Occup Environ Hyg *14*(10):801–814, https://doi.org/10.1080/15459624.2017.1334904.

IARC [2010]. IARC monographs on the evaluation of carcinogenic risks to humans. Painting, firefighting, and shiftwork. Vol. 98. Lyon, France: World Health Organization, International Agency for Research on Cancer, https://publications.iarc.who.int/_publications/media/download/2945/mono98.pdf.

Roegner K, Sieber KW, Echt A [2002]. Evaluation of diesel exhaust controls. J Occup Environ Hyg *17*(1):1–7, https://doi.org/10.1080/104732202753306050.

Occupational Exposure Limits

ACGIH [2025]. TLVs and BEIs: threshold limit values for chemical substances and physical agents and biological exposure indices. Cincinnati, OH: American Conference of Governmental Industrial Hygienists, https://www.acgih.org/tlv-bei-guidelines/policies-procedures-presentations/.

Attfield MD, Schleiff PL, Lubin JH, Blair A, Stewart PA, Vermeulen R, Coble JB, Silverman DT [2012]. The diesel exhaust in miners study: a cohort mortality study with emphasis on lung cancer. J Natl Cancer Inst *104*(11):869–883, http://dx.doi.org/10.1093/jnci/djs035.

CFR [2025]. Code of Federal Regulations. Washington, DC: U.S. Government Printing Office, Office of the Federal Register, https://www.ecfr.gov/.

EPA [2002]. Health assessment document for diesel engine exhaust. Washington, DC: National Center for Environmental Assessment, Office of Transportation and Air Quality, U.S. Environmental Protection Agency (EPA) Publication No. EPA/600/8-90/057F, https://ordspub.epa.gov/ords/eims/eimscomm.getfile?p_download_id=36319.

Gamble J, Jones W, Mishall S [1987]. Epidemiological-environmental study of diesel bus garage workers: acute effects of NO_2 and respirable particulate on the respiratory system. Environ Res *42*(1):201–214, https://doi.org/10.1016/s0013-9351(87)80022-1.

IARC [2012]. IARC: diesel engine exhaust carcinogenic. Lyon, France: World Health Organization, International Agency for Research on Cancer, http://www.iarc.fr/en/media-centre/pr/2012/pdfs/pr213_E.pdf.

NIOSH [1972]. Criteria for a recommended standard: occupational exposure to carbon monoxide. Cincinnati, OH: U.S. Department of Health, Education, and Welfare, Health Services and Mental Health Administration, National Institute for Occupational Safety and Health, DHEW (NIOSH) Publication No. 73-11000, https://stacks.cdc.gov/view/cdc/19324/cdc_19324_DS1.pdf.

NIOSH [1977]. Occupational diseases: a guide to their recognition. Rev. ed. Cincinnati, OH: U.S. Department of Health, Education, and Welfare, Center for Disease Control, National Institute for Occupational Safety and Health, DHEW (NIOSH) Publication No. 77-181, https://www.cdc.gov/niosh/docs/77-181/default.html.

NIOSH [1979]. A guide to work-relatedness of disease. Rev. ed. Cincinnati, OH: U.S. Department of Health, Education, and Welfare, Center for Disease Control, National Institute for Occupational Safety and Health, DHEW (NIOSH) Publication No. 79-116, https://www.cdc.gov/niosh/docs/79-116/default.html.

NIOSH [1988]. Current intelligence bulletin 50: carcinogenic effects of exposure to diesel exhaust. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 88-116, https://www.cdc.gov/niosh/docs/88-116/.

NIOSH [2007]. NIOSH pocket guide to chemical hazards. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2005-149, http://www.cdc.gov/niosh/npg/.

NIOSH [2016]. NIOSH manual of analytical methods (NMAM). 5th ed. O'Connor PF, Ashley K, eds. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2014-151, http://www.cdc.gov/niosh/nmam.

OSHA [1988]. Hazard information bulletin on potential carcinogenicity of diesel exhaust. Washington, DC: U.S. Department of Labor, Occupational Safety and Health Administration. OSHA Bulletin 19881130.

Proctor NH, Hughes JP, Fischman ML [1988]. Carbon monoxide. In: Chemical hazards of the workplace. 2nd ed. New York, NY: Van Nostrand Reinhold, New York.

Pronk A, Coble J, Stewart PA [2009]. Occupational exposure to diesel engine exhaust: a literature review. J Expo Sci Environ Epidemiol *19*(5):443–457, http://dx.doi.org/10.1038/jes.2009.21.

Reger R, Hancock J [1980]. Coal miners exposed to diesel exhaust emissions. In: Rom W, Archer V, eds. Health implications of new energy technologies. Ann Arbor, MI: Ann Arbor Science Publishers, Inc., pp. 212–231.

Sydbom A, Blomberg A, Parnia S, Stenfors N, Sandström T, Dahlén SE [2001]. Health effects of diesel exhaust emissions. Eur Respir J *17*(4):733–746, https://doi.org/10.1183/09031936.01.17407330.

Ulfvarson U, Alexandersson R [1990]. Reduction in adverse effect on pulmonary function after exposure to filtered diesel exhaust. Am J Ind Med *17*(3):341–347, http://dx.doi.org/10.1002/ajim.4700170306.

Promoting productive workplaces through safety and health research

HHE Report No. 2023-0099-3430