RESEARCH ARTICLE

An evaluation of diesel particulate matter in fire station vehicle garages and living quarters

Diesel particulate matter (DPM) has recently been classified as a human carcinogen by the International Agency for Research on Cancer. As a component of diesel exhaust, DPM is created from the combustion of diesel fuel. Diesel engines are commonly used in heavy duty trucks and equipment, including fire engines and ambulances. The potential for DPM migration in a fire station from an attached vehicle garage to the fire station living quarters was studied in Salt Lake County, Utah. The difference in air pressures between the living quarters and vehicle garage was measured in 24 fire stations. Of the 24 fire stations sampled, three test stations were selected based on negative air pressure test results and evidence of poor sealing doors between the living quarters and vehicle garages. These stations were the most likely to represent stations with measurable DPM within the living quarters. A control station was also sampled based on balanced air pressure test results. These selected stations were then measured for carbon concentrations in the living quarters, vehicle garages, and outdoors on two separate days. Results indicate that DPM, measured as elemental carbon, was below the limit of detection (<1.8 $\mu g/m^3$) for all samples with the exception of one vehicle garage sample (2.3 $\mu g/m^3$), which was found to be within acceptable exposure concentrations. Average total carbon concentrations for the three test stations were 44 $\mu g/m^3$ for the living area, 26 $\mu g/m^3$ for the garage and 14 $\mu g/m^3$ for the outside sample. These results suggest diesel particulate exposures are low, both within the vehicle garages and the attached living quarters.

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INTRODUCTION

Approximately 304,080 individuals worked as firefighters within the United States in 2011.[1] A firefighter's work often involves a variety of chemicals and chemical emissions, as well as physical hazards.[2] A meta-analysis of 32 studies found an elevated relative risk of multiple myeloma in addition to an association with some other cancers among firefighters.[3] Another potential hazard is exposure to the emission by-products from the combustion of diesel fuel, as diesel engines typically power fire engines and ambulances.

Diesel engines produce a variety of by-products from both complete and incomplete fuel combustion.[4] Diesel exhaust (DE) has both gaseous and solid components.[4,5] Gaseous components include aldehydes, carbon monoxide, benzene, and sulfur dioxide.[2,4] Solid components of DE, commonly

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1871-5532
http://dx.doi.org/10.1016/j.jchas.2015.10.020

known as diesel particulate matter (DPM), include elemental carbon, organic carbon, and trace amounts of various metals.[4] DE is known to cause irritation of the eyes and nose, changes in lung function, airway inflammation, headaches, fatigue and nausea.[6,7]

Diesel particulate matter, the solid component of diesel exhaust, was recently classified by the International Agency for Research on Cancer (IARC) as a Group 1 carcinogen.[8] One study from 1987 showed that firefighter exposure to DPM, after responding to 7–15 calls, was between 170 and 480 micrograms per cubic meter ($\mu g/m^3$).[9] However, newer engine emission standards have reduced diesel exhaust emissions.[10] The only U.S. agency occupational exposure limit for DPM is that of the Mine Safety and Health Administration (MSHA), which has an exposure limit of 160 $\mu g/m^3$ measured as total carbon.[11] In 2001, the American Conference of Governmental Industrial Hygienists (ACGIH) proposed a limit for DPM as elemental carbon of 20 $\mu g/m^3$; however, this proposed limit was never adopted.[12]

Typically, firefighters are equipped with a self-contained breathing apparatus (SCBA) that limits their exposures to DPM during firefighting activities. Most other activities are typically not performed with SCBA. As the Occupational Safety and Health Administration (OSHA) has not established a permissible exposure limit (PEL) for DPM, it is particularly unclear what concentration should be acceptable for firefighters who typically work an extended shift schedule of two days on and four days off.

A recent indoor air quality study conducted by the Salt Lake County Health Department identified higher concentrations of total carbon within the living quarters of a fire station than in its attached vehicle garage.[13] Additionally, the fire station's living quarters were found to be at negative air pressure relative to the vehicle garage. However, this was subsequently attributed to lack of an active pressure relief fan to balance the garage's summertime evaporative cooler usage. The lower pressure was thought to be a possible contributor to the higher concentrations of total carbon within the living quarters of the station.[13]

The purpose of this study was to determine if negative air pressures in the living quarters of a fire station, in relation to the vehicle garage, are a DPM exposure concern.

METHODS

A total of 24 fire stations in Salt Lake County, Utah were tested for air pressure differences between living quarters and vehicle garages to determine optimal sites for this study. Selection of stations to be sampled for airborne DPM concentrations was made on two criteria: (i) at least 0.02 mmHg (0.01 inches H_2O) decrease in air pressure between the living quarters and the garage and (ii) the ability of the door to seal tightly to the door jamb between these two areas (see Table 1). These criteria were expected to efficiently screen all 24 stations for DPM in the living quarters, by selecting stations most likely to expose firefighters to DPM.

Pressure tests were conducted with a differential pressure manometer (EXTECH Instruments HD700 (Waltham, Massachusetts, USA)). This manometer has two inlet ports where small tubing was attached. The instrument was placed on the living quarter sides of the doorways between the living areas and garages at all 24 stations. One tube was placed through the doorway, either near the door handle, or at the base of the door through the weather stripping. The inlet for the other tube, which was attached to the second port, was left in the same area of the living quarters as the instrument. Air pressure measurements were collected for a 30–60 s time interval. The average value resulting from this 30–60 s time interval was recorded.

Several types of ventilation systems within the living quarters of the station

Table 1. Summary Results of Air Pressure Tests and Door Fit Information Collected for 24 Screened Fire Stations.

Station #	Air Pressure Range (mmHg)	Weather Stripping Present	Latchable Door
101	0.00	Yes	Yes
102	0.00	No	–
103	−0.02 to 0.00	No	Yes
104[a]	−0.02 to 0.00	–	–
105	−0.02 to 0.00	Y/N[b]	–
106	0.00	Yes	Yes
107	−0.02 to 0.00	No	No
108	−0.02 to 0.00	Yes	Yes
109	0.00	Y/N[b]	Yes
110	0.00	Y/N[b]	Yes
111	−0.04–0.00	Yes	Yes
112	0.00 to +0.02	No	No
113[c]	−0.06 to +0.04	Partial	Yes
114[c]	−0.02 to +0.04	No	Yes
116	−0.02 to 0.00	–	Yes
117	0.00 to +0.02	No	–
118	−0.02 to 0.00	Yes	Yes
119	−0.02 to 0.00	Yes	Yes
120[c]	−0.02 to 0.00	Yes	Yes
121	−0.04 to +0.02	Y/N[b]	Yes
122	−0.02 to 0.00	–	Yes
123	−0.02 to 0.00	Yes	Yes
125[c]	−0.04 to 0.00	No	No
126	−0.02 to 0.00	–	Yes

[a] Station structure was condemned.
[b] One door with and one without.
[c] Station included in DPM sampling.