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Assessment of diesel exhaust exposure in municipal fire halls in Ontario

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Towards a cancer-free workplace

Executive summary

This report summarizes the diesel exhaust exposure levels assessed in 12 fire halls from six fire services departments in Ontario and reviews how these exposures vary among the fire halls. This study was conducted following a request from the Prevention Office of the Ontario Ministry of Labour for evaluation of diesel exhaust in Municipal fire halls.

Fire departments from different cities within Ontario were recruited during a provincial health and safety meeting with the fire chiefs of Ontario where researchers presented and explained the purpose of the study. We requested two of the busiest fire halls from the departments that had different building designs and diesel exhaust controls, when possible. Stationary 24-hour air samples were collected in the vehicle bay, kitchen / common room area, and the sleeping quarters at each hall in the summer (July – October 2016) and in the winter (January – February 2017). The samples were analyzed for elemental carbon (a marker for diesel exhaust) at an accredited laboratory using NIOSH analytical method 5040. In addition to air monitoring, we also assessed the effectiveness of existing local exhaust ventilation controls (i.e. Nederman/Plymovent) that had been implemented in the different fire halls to minimize exposure.

A total of 69 samples were analyzed, where 11 samples (16%) had detectable elemental carbon concentrations, ranging from 0.6 to 2.7 μg/m^3. All but one of the samples with detectable elemental carbon concentrations were obtained from the vehicle bays. Higher maximum concentrations were observed in the summer (range: <0.7-2.7 μg/m^3) compared to the winter (range: <0.6-1.3 μg/m^3), which is most likely attributed to higher activity levels observed on the summer sampling days compared to the winter ones. Interestingly, higher elemental carbon concentrations were observed at the fire halls that had local exhaust ventilation (LEV) units compared to those that did not have. This is most likely explained by differences in activity levels as halls with LEV units also had more emergency calls, and potentially by alternative control measures which could have reduced exposures in halls that did not have LEV units. For the fire halls with LEV, the assessment revealed that the LEV units were operating at nearly half the expected recommended flowrate, an overall average of 54%. The observed concentrations in the vehicle bay and observed LEV flowrates suggest that fire halls should implement a consistent maintenance schedule if not already in place.

Because there is no occupational exposure limit that applies to diesel exposure levels in fire halls with which to compare the measured levels to, it is recommended that fire departments continue minimizing exposure within the fire halls using a combination of engineering and administrative controls. Exposure control strategies could include upgrading and maintaining ventilation and exhaust filtration systems, diesel exhaust monitoring systems, use of cleaner burning engines and/or fuel additives, and the development of policies such as prohibiting unnecessary idling.

Background

This study was initiated by the Prevention Office of the Ontario Ministry of Labour because of concerns regarding potential over-exposure to diesel engine exhaust among firefighters when they are in the fire halls. The International Agency for Research on Cancer (IARC) has classified diesel engine exhaust as carcinogenic to humans [1]. Diesel exhaust is a highly complex mixture of gases and particulates whose composition and ambient concentration is dependent on factors including diesel fuel and engine type, maintenance schedule, workload, and exhaust treatment [1]. Firefighters may be exposed to diesel exhaust while standing near idling apparatus, when performing training or maintenance duties near known diesel exhaust sources, or while in the fire hall where diesel exhaust may have been emitted.

Little is known about diesel exhaust exposure levels in Canadian fire halls; however, multiple exposure assessments have been conducted by the National Institute of Safety and Health (NIOSH) in the US over the last 30 years [2–10]. The most recent NIOSH diesel exhaust assessments measuring elemental carbon report ranges of 0.2-6.7 μg/m^3 in fire halls with just exhaust fans [11] and 0.43-13 μg/m^3 in fire halls with no mechanical ventilation or fans [12]. Studies have reported increasing concentrations in fire halls with more runs [13] while other studies reported reduction in fire fighters' exposure when ceramic filters were installed in the tail pipes of the fire trucks [14].

Currently there is no occupational exposure limit for diesel exhaust in Ontario that applies to fire halls and the American Conference of Governmental Industrial Hygienists does not currently have a threshold limit value. In a study conducted by Vermeulen and colleagues, a risk of 17 excess lung cancer deaths per 10,000 was estimated for a lifetime occupational exposure to 1 μg/m^3 of diesel exhaust (expressed as elemental carbon)[15]. The Dutch Expert Committee on Occupational Safety (DECOS) have recently, in a draft report sent out to the public for review, suggested a health based occupational exposure limit of about 1 μg/m^3 of diesel exhaust (elemental carbon) based on an excess occupational cancer risk of 4 per 1,000 [16]. Prevention of worker exposure is the only way to protect against developing diesel exhaust exposure related diseases.

Objective

The purpose of this study was to assess diesel exhaust exposure levels (expressed as elemental carbon - a marker for diesel exhaust) in municipal fire halls in Ontario during regular operations in the summer and winter and evaluate how these exposures vary among the fire halls.

Methods

A field survey of 12 fire halls from six fire services departments in six cities across Ontario was conducted to assess diesel exhaust exposure. Fire departments from different regions were selected to assess any regional differences in exposures and work practices as well as differences in sizes of municipalities. Within each fire department, we selected two of the busiest fire halls for sampling, and when possible halls with different building designs (e.g. one vs. two story) and/or diesel exhaust controls were chosen. Sampling was conducted in the summer (July – October 2016) and winter (January – February 2017) to account for seasonal differences in exposures and work practices.

At each fire hall, we collected 24-hour stationary air samples for elemental carbon (i.e. diesel exhaust) in the vehicle bay, kitchen / common room area, and the sleeping quarters. Samples were collected using an

AC powered pump connected to an SKC aluminum cyclone and a 37mm quartz fibre filter cassette, following the NIOSH standard analytical method 5040. The samples were pre- and post-calibrated for quality control purposes. Field blanks were taken at each fire hall to check and correct for possible contamination of the samples during calibration, transportation, and storage. After sampling, samples were shipped to an accredited laboratory (i.e. Concord Analytical Laboratories) where they were analyzed for elemental carbon by thermal-optical analysis with flame ionization detector (limit of detection: 2µg for elemental carbon).

During the exposure assessment, we also assessed the efficiencies of existing local exhaust ventilation units (LEV) that remove vehicle exhaust (i.e. Nederman/Plymovent systems) by measuring the face velocities (m/s) of all available units using a TSI VelociCalc Multi-Function Ventilation Meter (Model 9565). A minimum of four measurements were taken at the face of each arm in both the summer and winter visits. All of these values were averaged for each arm and the average volumetric flowrate (m^3/s) and percentage of the manufacturer's recommended value (800 cubic feet per minute ≈ 0.39 m^3/s) were calculated. We collected additional supplementary information at each hall including the number and age of vehicles, vehicle bay design (i.e. back in or drive through), presence of man-holes in the living quarters (i.e. whether the manholes were open or closed), number of runs and the presence of LEV in the fire halls.

Results and Discussion

Sixty-nine samples from 12 fire halls in the summer (n=36) and 11 fire halls in the winter (n=33) were analyzed. One fire hall was excluded from the winter sampling campaign as it was converted into a volunteer fire hall and no longer met the study entry criteria. Only 11 samples (16%) had detectable elemental carbon concentrations (range: 0.6 - 2.7 µg/m^3) and all except one were from vehicle bays (*Table 1*).

Table 1. Summary of diesel exhaust exposure levels (elemental carbon) and LEV ventilation efficiency

City	Average number of runs / shift	Elemental carbon concentrations				LEV Units	
		Summer		Winter		Average flow rate (m^3/s)	Average Efficiency (%)
		N (% detect)[1]	Range (µg/m^3)	N (% detect)	Range (µg/m^3)		
City 1	11	6 (33%)	<0.5 – 2.7	6 (17%)	<0.5 – 0.6	0.16	40.5
City 2	17	6 (17%)	<0.6 – 1.0	6 (17%)	<0.5 – 0.9	0.21	54.2
City 3	8	6 (17%)	<0.6 – 1.0	6 (33%)	<0.6 – 0.9	0.26	66.5
City 4	2	6 (0)	<0.7	3 (0)	<0.6	-	-
City 5	4	6 (0)	<0.7	6 (0)	<0.6	0.21	53.0
City 6	4	6 (0)	<0.7	6 (50%)	<0.6 – 1.3	-	-

[1] N- Number of samples collected (% of samples with detectable elemental carbon);

No detectable elemental carbon was found in the samples obtained from Cities 4-6 in the summer and Cities 4 and 5 in the winter. Additionally, no detectable elemental carbon was found in any of the common areas and dormitories except for one fire hall from City 6, which had an elemental carbon concentration of 1.3 µg/m^3. Five samples exceeded the DECOS proposed 1 µg/m^3 limit; two in the winter, all from one fire hall, and three in the summer, all from different cities.

Although a greater proportion of the winter samples had detectable levels compared to the summer, the maximum concentrations were higher in the summer. Higher elemental carbon concentrations were also observed in the fire halls with more runs, and interestingly, in fire halls that have LEV units. These findings are most likely attributed to two major details: 1) lower activity levels were observed during sampling in the fire halls without LEV units compared to those with LEV units, and (2) the fire halls without LEV rely on alternative control measures (e.g. exhaust filtration systems) which could have reduced their exposures. The maximum elemental carbon concentrations observed in this assessment were generally lower than levels reported in the most recent NIOSH evaluations of fire halls with lower number of runs and minimal controls present to minimize exposure e.g. fire halls where only exhaust fans were used to minimize exposure (Maximum concentration = 6.7 μg/m^3)[12], and fire halls with no mechanical ventilation where only source capture on board systems (Ward diesel reduction system) were used (Maximum concentration = 13 μg/m^3)[11].

A total of 24-LEV units were assessed in the summer and winter sampling campaigns from eight of the 12 fire halls with LEVs. The ventilation units performed on average at half of the manufacturer's recommended flow rate (mean = 54%, range 41-67%) (Table 1). Despite the lower than ideal LEV flowrate and the measureable concentrations observed in the vehicle bays, exposures were still much lower (or non-detectable) in other areas of the hall. This finding, where measured elemental carbon exposures were consistently higher in the vehicle bays compared to the living quarters and dormitories, is comparable to what other studies have reported [8–12]. During our walkthrough, we observed that the fire departments had several measures in place in the fire halls (engineering and administrative controls) to assist in minimizing fire fighters' exposure to diesel exhaust. These findings suggests that the control practices in place to minimize diesel exhaust exposure in the fire halls are reducing /preventing the amount of elemental carbon in the vehicle bay from entering the common areas. A summary of the different control measures we observed during our walkthrough and discussions with the fire departments included:

Engineering control measures:

1) The fire halls from four out of six fire departments had LEV units installed to remove emissions in the vehicle bays. Although the LEV units at the fire halls with LEVs were not operating at the manufacturer's recommended flowrate at the time of the assessment, routine inspection and maintenance of these ventilation systems was conducted.
2) One fire department had installed new general exhaust ventilation (filtration systems) in their fire halls at the time of the assessment to minimize exposure.
3) Some fire departments utilized newer apparatus with cleaner burning fuel additives and some fire departments had plans to add fire trucks with cleaner-burning diesel engines (as well as special fuel additives).
4) Some fire halls utilize natural ventilation (i.e. keep bay doors open most of the time), depending on the weather, to minimize exposure.
5) All the fire halls had doors separating the vehicle bay from the common areas of the fire hall and had a closed door policy.

Administrative control measures:

1) Some fire departments have developed several policies to help reduce exposures including:

a. Anti-idling policies or procedures restricting unnecessary idling within the vehicle bay.

b. Policies outlining the frequency and/or procedure of LEV use in the halls.

c. Policies stating safe driving rules to limit wear/damage to LEV units.

d. Policies stating vehicle bay doors must be open to ventilate the space prior to starting apparatus, idling in the bay, operating equipment in the bay, or upon return to the bay.

e. Policies stating vehicle bay doors should be closed when performing equipment checks or when apparatus is idling on tarmac in front of the hall.

f. Policies requiring all doors and fire pole hatches to be closed to the vehicle bay at all times.

g. Policies requiring all apparatus and equipment checks to be performed outdoors, not in the vehicle bay.

2) Several fire departments have monitors within the vehicle bay to measure contaminants (carbon monoxide and nitrogen oxide) from vehicle exhaust, which will alarm at set levels.

Limitations

During this assessment, we were not able to collect an outdoor comparison sample. In addition, we were limited to one sampling day per hall for each season so we were not able capture a range of exposures the halls may experience. We were also not present in the hall during the sampling and do not have information on the adherence to use of controls or activities that may have influenced exposures. We were able to obtain the number of emergency calls during the measurement period, however, there may have been multiple times the apparatus may have been started or left/returned to the hall for other tasks, such as training that we do not have information on. Despite the small sampling size, we believe the halls that were assessed in the different regions are reflective of the career firefighting population within Ontario.

Recommendations and conclusions

In summary, we found detectable levels of diesel exhaust (elemental carbon) in 16% of the samples collected. A greater proportion of the detectable diesel exhaust levels obtained was from the vehicle bays. All the fire halls had some controls in place to minimize diesel exhaust exposure although we do not have information on adherence. Because there is no occupational exposure limit for diesel exhaust in Ontario that applies to fire halls we recommend that fire departments implement / maintain a consistent maintenance schedule and continue to use a combination of both engineering and administrative controls to minimize exposure within the fire halls and keep exposure levels as low as reasonably achievable.

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