

DETERMINING THE KNOWLEDGE, ATTITUDES, AND BEHAVIOURS OF PEOPLE EXPOSED TO DIESEL
EXHAUST AT THE WORKPLACE

by

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ABSTRACT

Background:

Diesel exhaust (DE) is a common exposure in Canadian workplaces. The International Agency for Research on Cancer (IARC) classified DE as being *carcinogenic to humans* in 2012. Health and safety agencies provide information about DE and the mitigation strategies that can be used to reduce the exposure of individuals. However, there is little known about the extent to which those potentially exposed in the workplace understand the risks of DE or have recently changed behaviours to minimize workplace exposure to DE.

Objectives:

To identify exposure-related knowledge, attitudes and behaviours of individuals occupationally exposed to diesel exhaust; to reveal strengths, knowledge gaps and misperceptions therein.

Methods:

A Mental Models approach was used to gather information about current scientific understanding of DE exposure hazards and the ways in which exposure can be reduced. Thirty individuals in British Columbia who were regularly exposed to occupational DE were interviewed. The audio was recorded, transcribed, grouped together, and examined to draw out themes around DE awareness, hazard assessment and risk reduction behaviours. These themes were then compared and contrasted with existing grey and research literature in order to reveal strengths, gaps and misperceptions regarding exposure to DE.

Results:

Study participants were aware and concerned about DE but had incomplete and sometimes incorrect understanding of exposure pathways, health effects, and effective strategies to reduce their exposures. The perceived likelihood of exposure to diesel exhaust was significantly greater compared to that of other work

hazards ($p < 0.01$), whereas the difference for their perceived severity of consequences was not significant. There was no universally perceived main source of information regarding DE, and participants generally distrusted sources of information based on their past experience with the source. Most of the actions that were taken to address DE exposure fell into the area of administrative controls such as being aware of sources of DE and avoiding these sources.

Discussion:

This study of the knowledge, attitude, and behaviour of those occupationally exposed to diesel exhaust found, most notably, that more education and training and the creation of a health effects inventory regarding diesel exhaust exposure were desired.

PREFACE

This thesis is an original intellectual product of the author, M. Pui.

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TABLE OF CONTENTS

| | |
|--|------|
| ABSTRACT..... | ii |
| PREFACE..... | iv |
| TABLE OF CONTENTS..... | v |
| LIST OF TABLES..... | viii |
| LIST OF FIGURES..... | ix |
| LIST OF ABBREVIATIONS..... | x |
| ACKNOWLEDGEMENTS..... | xi |
| | |
| CHAPTER 1: INTRODUCTION..... | 1 |
| 1.1 What is Diesel Exhaust (DE)..... | 1 |
| 1.1.1 Fuel, Composition, and Source..... | 1 |
| 1.2 Occupational Exposure of DE..... | 1 |
| 1.2.1 Prevalence and Source of Occupational Exposure of DE..... | 1 |
| 1.2.2 Assessment of Occupational Exposure of DE..... | 2 |
| 1.2.3 Typical Occupational Levels of DE..... | 3 |
| 1.3 Effects of DE Exposure..... | 5 |
| 1.3.1 Carcinogenic Effects..... | 5 |
| 1.3.2 Impact of DE in Occupational Diseases..... | 5 |
| 1.3.3 Other Health Effects..... | 6 |
| 1.4 Regulations..... | 7 |
| 1.4.1 Basic Responsibilities and Rights for Workplace Health and Safety..... | 7 |
| 1.4.2 Hazard Control..... | 8 |
| 1.4.3 Exposure Limits..... | 10 |
| 1.4.4 Health and Safety Agencies..... | 11 |
| 1.4.5 Emission Standards and New Technologies..... | 12 |
| 1.5 Workplace Knowledge, Attitudes and Behaviours..... | 13 |
| 1.5.1 Relationship between Knowledge, Attitudes, and Behaviours..... | 13 |
| 1.5.2 Knowledge, Attitude, and Behaviour Studies..... | 14 |
| 1.5.3 Studies to Date..... | 14 |
| 1.6 Research Aim, Study Design and Specific Objectives..... | 15 |
| 1.6.1 Research Aim..... | 15 |
| 1.6.2 Study Design..... | 15 |
| 1.6.3 Specific Research Objectives..... | 17 |

| | |
|---|--------|
| CHAPTER 2: STUDY METHODS..... | 18 |
| 2.1 Overview | 18 |
| 2.2 Questionnaire Development..... | 18 |
| 2.3 Data Collection..... | 20 |
| 2.3.1 Recruiting Methods | 20 |
| 2.3.2 Participants | 21 |
| 2.3.3 Survey Implementation | 22 |
| 2.4 Data Analysis | 22 |
| CHAPTER 3: RESULTS | 24 |
| 3.1 Participants | 24 |
| 3.2 Job Titles and Descriptions | 25 |
| 3.3 Work Site Descriptions | 30 |
| 3.4 Safety Training | 31 |
| 3.5 Exposure of DE | 33 |
| 3.6 Thoughts and Concerns about DE..... | 35 |
| 3.7 DE Perceived as a Hazard | 40 |
| 3.8 Exposure of DE vs. Other Inhalational Hazards | 41 |
| 3.9 Health Effects of DE | 43 |
| 3.10 Trusted Sources of Information..... | 46 |
| 3.11 Talking to Others about Their Exposure of DE | 55 |
| 3.12 Information from Recent Media Sources Regarding DE | 60 |
| 3.13 Actions to Address Exposure of DE | 61 |
| 3.13.1 Personal Protective Equipment..... | 61 |
| 3.13.2 Administrative Controls | 62 |
| 3.13.3 Engineering Controls..... | 65 |
| 3.13.4 No Action | 67 |
| 3.14 Recommendations to Better Address Exposure of DE | 67 |
| 3.14.1 Personal Protective Equipment..... | 68 |
| 3.14.2 Administrative Controls | 69 |
| 3.14.3 Engineering Controls..... | 73 |
| 3.14.4 No Recommendations | 76 |
| CHAPTER 4: DISCUSSION..... | 77 |
| 4.1 Domain Experts' Beliefs | 77 |

| | |
|---|---------|
| 4.2 Study Participant Characteristics..... | 78 |
| 4.3 Safety Training..... | 79 |
| 4.4 Exposure of DE at the Workplace..... | 80 |
| 4.5 DE Perceived as a Hazard..... | 81 |
| 4.6 Exposure of DE vs. Other Inhalational Hazards..... | 82 |
| 4.7 Health Effects of DE..... | 83 |
| 4.8 Study Participants' Trusted Sources of Information..... | 85 |
| 4.9 Information from Recent Media Sources Regarding DE..... | 89 |
| 4.10 Study Participants' Behaviours to Address Exposure of DE..... | 89 |
| 4.10.1 Personal Protective Equipment..... | 89 |
| 4.10.2 Administrative Controls..... | 90 |
| 4.10.3 Engineering Controls..... | 94 |
| 4.10.4 No Actions or Recommendations..... | 95 |
| 4.11 Study Strengths and Limitations..... | 95 |
| 4.12 Conclusions..... | 97 |
| BIBLIOGRAPHY..... | 99 |
| Appendix A. Study Questionnaire..... | 105 |
| Appendix B. Study Advertisement..... | 108 |
| Appendix C. Unions and Workplaces Formally Invited to Participate in Study..... | 109 |
| Appendix D. Informed Consent Form..... | 110 |
| Appendix E. The first page of Google search results from the phrase “health effects of diesel” (assessed on August 13 th , 2014)..... | 114 |
| Appendix F. The first page of Google search results from the phrase “health effects of diesel fumes” (assessed on August 13 th , 2014)..... | 115 |
| Appendix G. The first page of Google search results from the phrase “health effects of driving a bus” (assessed on August 13 th , 2014)..... | 116 |

LIST OF TABLES

| | |
|--|----|
| Table 1: Typical Occupational Levels of DE | 3 |
| Table 2: Information from the Websites of Health and Safety Agencies | 11 |
| Table 3: Participant Characteristics | 24 |
| Table 4: Job Titles and Sectors | 25 |
| Table 5: Subjects' Perceived Top Five Occupational Hazards | 40 |
| Table 6: Subjects' Symptoms during Exposure to DE | 43 |
| Table 7: Subjects' Sources of Information | 47 |

LIST OF FIGURES

| | |
|--|----|
| Figure 1. Overall Study Flow | 18 |
| Figure 2. Subjects' Perceived Level of DE that they were Exposed to at Work | 34 |
| Figure 3. Subjects' Perceived Likelihood and Severity of Consequences due to DE vs. Other Inhalational Hazards | 42 |

LIST OF ABBREVIATIONS

CCOHS - Canadian Centre for Occupational Health and Safety

CO – carbon monoxide

DE – DE

EC – elemental carbon

IARC – International Agency for Research on Cancer

KAP – knowledge, attitudes, and practices

NIOSH - National Institute for Occupational Safety and Health

NO – nitrogen oxide

NO₂ . nitrogen dioxide

OSHA - Occupational Safety and Health Administration

PM_R – respirable particulate matter

PM_S . submicron particulate matter

PPE – personal protective equipment

WHMIS – Workplace Hazardous Materials Information System

WHO – World Health Organization

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CHAPTER 1: INTRODUCTION

1. What is Diesel Exhaust (DE)?

1.1.1 Fuel, Composition and Source

The two most commonly used transportation fuels in Canada are gasoline and diesel (1). The combustion of these fuels produces energy as well as pollutants that contribute to a myriad of health concerns. Diesel fuel contains 18-30% more energy per gallon compared to regular gasoline (2). In Canada, it accounts for approximately 30% of the fuel used for road motor vehicles (1).

Diesel Exhaust (DE), the end product of the combustion of diesel fuel, is a complex mix of gases and particles. Diesel fuel, which includes complex hydrocarbons, additives and impurities such as sulfur, mixes with air during combustion and results in carbon monoxide, carbon dioxide, nitrogen oxides, and volatile organic compounds such as benzene and sulfur (3). The particulate portion of DE consists of insoluble elemental carbon, and a soluble organic carbon surface coating. Almost all the particles emitted by diesel engines are very small and respirable (less than 10 micron), with the majority smaller than 1 micron (4).

DE is emitted from both “on-road” diesel engine vehicles such as diesel cars, buses, and trucks and “non-road” diesel engines such as locomotives, marine vessels, and some heavy-duty construction equipment.

1.2 Occupational Exposure of DE

1.2.1 Prevalence and Source of Occupational Exposure of DE

The majority of occupational exposures to DE emissions come from off-road vehicles such as trains, ferries, and mining and construction equipment (5). The highest reported occupational exposure levels were found in enclosed underground work sites where heavy equipment was used, such as in mines and

construction sites; the exposure levels from underground mines were more than 100 times the ambient level of DE, and 10 times the level of DE in other workplaces (6, 7).

DE is a very common workplace hazard because of the widespread use of diesel fuel and engines. CAREX Canada (CARcinogen EXposure, a multi-institution research project that is generating an evidence-based carcinogen surveillance program for Canada) estimates that approximately 897,000 people in Canada are exposed to some level of DE at the workplace (8). Specifically, approximately 108,000 people are exposed in British Columbia, making it the second most common workplace carcinogen (after solar radiation) (8). Those at particular risk for high exposures include miners, loggers, heavy equipment operators, trucking company drivers, and forklift operators in the mining, forestry and construction industries which are very prominent in British Columbia (4).

1.2.2 Assessment of Occupational Exposure to DE

If a worker is occupationally exposed to a hazardous substance, according to the Workers' Compensation Act – Occupational Health and Safety Regulation from the Workers' Compensation Board in British Columbia, the employer must ensure that a walkthrough survey is conducted to assess the potential for overexposure, taking into account all routes of exposure, and the potential of additive effects with other substances at the workplace (9). If the walkthrough survey reveals a risk of overexposure, then workplace exposure monitoring and assessment must be conducted.

Measuring and monitoring personal DE exposure is difficult because there is disagreement among experts as to the optimal metric for measurement; no single constituent of DE is considered a unique marker of exposure (10). Several non-specific components of DE are used as surrogates, such as respirable particulate matter (PM_R) (including PM_{2.5} and PM₁₀), submicron particulate matter (PM_S), gases such as carbon monoxide (CO), nitrogen oxide (NO), or nitrogen dioxide (NO₂), and elemental carbon (EC) (11). Most of these

surrogates are not suitable as they can be generated from non-DE sources such as oil mist (12). Out of these surrogates, EC is used more often since it is relatively simple to measure, has few non-DE sources and is the major component of diesel particulate matter, though it is still not unique to DE (13, 14). There is still no consensus from the occupational health and safety community on which surrogate is the best metric for measuring DE; therefore, exposure data is not consistently collected and catalogued.

Occupational exposure to DE can be measured by either personal measurement devices or area samples. Because both type of measurements may be measuring gases or particles other than DE, the presence of a diesel engine is a minimal requirement for attribution of gases or particles to DE (5). Personal sampling, where a portable sampler is attached to a worker to measure the particle concentration in the vicinity of the worker, is considered a more accurate measure as it measures what the worker is actually exposed to rather than what is in the general area (15). However, measurements are not consistently obtained by either one of these measurement types, and there is no generally preferred method and therefore it is more difficult to make comparisons between measurements.

1.2.3 Typical Occupational Levels of DE

Typical levels of DE found in different occupations as reported in scientific journals worldwide are shown in Table 1.

Table 1. Typical Occupational Levels of DE (EC=elemental carbon; PM_S=submicron particulate matter; PM_R= respirable particulate matter; CO=carbon monoxide; NO=nitrogen oxide, NO₂=nitrogen dioxide; ND= not detectable; nm= not measured)

| Occupation | EC ($\mu\text{g}/\text{m}^3$) | PM _S ($\mu\text{g}/\text{m}^3$) | PM _R ($\mu\text{g}/\text{m}^3$) | CO (ppm) | NO (ppm) | NO ₂ (ppm) | References |
|-------------------------|------------------------------------|---|---|-------------|-------------|--------------------------|------------|
| Truck, bus, taxi driver | 1-20 | 12-15 | 30-600 | Nm | 0.2-0.3 | 0.03-0.04 | (16-24) |

| Occupation | EC ($\mu\text{g}/\text{m}^3$) | PM_s ($\mu\text{g}/\text{m}^3$) | PM_R ($\mu\text{g}/\text{m}^3$) | CO (ppm) | NO (ppm) | NO₂ (ppm) | References |
|-------------------------------------|---|---|---|---------------------|---------------------|---------------------------------|----------------------|
| Mechanic | 20-40 | 28 | 120-1100 | Nm | Nm | Nm | (13, 16, 18, 21, 23) |
| Firefighter | ND-40 | nm | Nm | Nm | Nm | Nm | (25, 26) |
| Vehicle tester | 11 | nm | 160 | Nm | Nm | Nm | (13) |
| Parking booth attendant | 1.1 | nm | Nm | Nm | Nm | Nm | (22) |
| Miner (Surface) | 13-23 | nm | 880 | Nm | 0.3 | 0.04 | (14, 20, 21, 27-34) |
| Miner (Underground) | 30-640 | 150-1600 | 560-2100 | 2-9 | 0.7-15 | 0.2-5.5 | (14, 20, 21, 27-34) |
| Train crew | 4-20 | nm | 120-860 | 4 | 0.2-1.2 | 0.05-0.3 | (13, 21, 35-37) |
| Train maintenance crew | 5-39 | nm | 70-250 | Nm | 0.3 | 0.1 | (13, 21, 35-37) |
| Construction crew (above ground) | 4-13 | 23 | 766 | 1 | 0.2 | 0.02-0.3 | (23, 38-41) |
| Construction crew (tunnels) | 132-314 | 120 | 1100-1700 | 5-9 | 2.6 | 0.2-0.9 | (23, 38-41) |
| Dock and distribution personnel | 4-122 | nm | 359-442 | Nm | Nm | Nm | (13, 18, 20) |
| Airline personnel | 11 | nm | Nm | 2.4-5 | 0.13 | 0.12 | (42) |
| Ferry personnel | 6-49 | nm | 295 | 2.5 | Nm | Nm | (13, 42) |

Table 1 indicates DE exposure levels from a number of occupations. Exposures are the highest among underground miners and construction crews in tunnels. Table 1 demonstrates that in some cases, large variations in exposure levels are reported for the same occupation by different studies. For example, one study found that the occupational exposure levels for firefighters were non-detectable, while another study determined up to 40 $\mu\text{g}/\text{m}^3$ EC (25, 26). Table 1 also demonstrates the inconsistency in the surrogate used for measuring DE. For example, PMs and CO were used to measure exposure of underground miners, but not surface miners in the same studies.

1.3 Effects of DE Exposure

1.3.1 Carcinogenic Effects

The International Agency for Research on Cancer (IARC), part of the World Health Organization, reclassified DE as Group 1 (*carcinogenic to humans*) in June of 2012 (43). This was attributed to a few studies. One of the most important studies was known as the DE in Miners Study (DEMS) and was conducted by the National Cancer Institute (NCI) and the National Institute for Occupational Safety and Health (NIOSH) (6, 7). They completed a 20-year retrospective cohort mortality and nested case-control in 2012 with more than twelve thousand workers in non-metal mining facilities to determine the risk of lung cancer related to current and historical exposures of occupational DE. They found that there was an increased risk of mortality from lung cancer in exposed people compared to those in the general population. At higher exposures of DE, the mortality rates were three to five times greater compared to workers who had the lowest exposures. The relationship between DE exposure and lung cancer risk remained after controlling for smoking and other lung cancer risk factors.

Beyond IARC and NIOSH, many advisory and regulatory authorities in North America and Europe, including the Mine Safety and Health Administration, and the US Environmental Protection Agency, have also concluded that sufficient evidence existed that chronic exposure to DE caused an increased risk of cancer (44).

1.3.2 Impact of DE in Occupational Diseases

The Occupational Cancer Research Centre in Ontario conducted a study to estimate the burden of cancer attributable to occupational DE exposure in Canada from 1961 to 2001 and found that 1.4 million people were occupationally exposed to DE during the 40-year period, and the attributable fraction of lung cancers due to occupational DE exposure was 2.7% (45). This is the only study to date on the impact of DE in occupational

diseases in Canada. To put it into perspective, with 26,600 Canadians diagnosed with lung cancer annually, 718 cases of those are attributable to occupational DE exposure (46).

To date, surveillance of occupational DE-related health is poor. There is no Canadian organization that collects data and does national surveillance on DE-related health outcomes from workplaces. However, the Occupational Cancer Research Centre and Cancer Care Ontario are currently conducting a study to determine whether occupational DE exposure increases the risk of developing colorectal and bladder cancer (47).

A few studies have been conducted to date on the impact of DE in occupational disease in other countries. For example, the DEMS study from NIOSH in the United States contributed to the subsequent IARC declaration (6, 7). Another study was conducted in Great Britain; Rushton *et al.* investigated all the cancer registrations in 2004, and determined that occupational DE exposure was the third most important contributor to lung cancer after asbestos and silica exposure (48). Vermeulen *et al.* estimated in another study in the United States in 2014 that 6% of annual lung cancer deaths were due to DE exposure which translated to about 9,000 lung cancer deaths per year (49).

1.3.3 Other Health Effects

DE exposure was associated with cardiovascular disease, neurophysiological symptoms, and consequent premature death in several studies (50-55). In the airway, DE has been shown to be associated with increased resistance, inflammation and oxidative stress, as well as exacerbate asthma and asthma-like symptoms such as airway hyper-responsiveness, reduced lung function, and wheezing (56-60). Furthermore, DE exposure was linked to symptoms such as eye, throat and bronchial irritation, cough, and phlegm (61, 62). With most of the health effects described above, DE exposure was associated with a higher incidence of hospital admission, as well as increased mortality (63).

1.4 Regulations

1.4.1 Basic Responsibilities and Rights for Workplace Health and Safety

The Occupational Health and Safety Legislation in Canada states that the parties responsible for an employee's health and safety at the workplace include the government, the employer, the manager or supervisor, health and safety committee if applicable, and the employee themselves (64). The responsibilities for an employee's health and safety at the workplace are similar across Canada.

The government is responsible for enforcing occupational health and safety legislation, inspecting the workplace, disseminating information, promoting training and education, as well as resolving any disputes regarding occupational health and safety (64).

The employer is responsible for ensuring that the workplace is safe for the employee and taking "every reasonable precaution" to do so (64). The employer is also responsible for training the employees on handling hazardous substances, advising employees of potential and actual hazards, supplying any necessary personal protective equipment (PPE) to the employee and ensuring that the employee uses the prescribed PPE. The manager or supervisor acts on behalf of the employer, and hence is responsible for meeting the duties of the employer.

More variable is the role of the health and safety committee (64). Not all workplaces are able to provide health and safety committees, depending on the size of workforce, industry, accident record, or some combination of these factors. Where they are created, they act as an advisory body for the employees, and are usually composed of 50% management, and 50% labor representatives. The health and safety committee is responsible for identifying hazards and providing information about them, making recommendations to the

employer regarding health and safety concerns, participating in accident investigations and workplace inspections, as well as assisting in resolving work disputes.

The employee has both responsibilities and rights specific to workplace health and safety (64). In terms of responsibility, they must work safely in a manner stipulated by the employer, reporting any potential and actual hazards and dangers at the workplace, and using PPE as directed by the employer. In terms of rights, the employees have three basic rights while at work. First, the employee has a right to refuse unsafe work. Second, the employee has the right to participate in the workplace health and safety activities through a health and safety committee or as a worker health and safety representative. Lastly, the employee has the right to be informed about potential and actual dangers in the workplace.

Even though other parties and the employee share responsibilities for the employee's health and safety at the workplace, as stated above, there are a few reasons that it is important for the employees to be aware of the health effects of DE exposure, and measures to prevent or minimize DE exposure at the workplace (64). First, it is the employees' right to be informed about and to know about actual and potential dangers at the workplace. Second, if they are informed about actual and potential dangers in the workplace, then they have a responsibility to use PPE and other measures to prevent and minimize exposure as directed by the employer. Furthermore, they are able to recognize when work is unsafe and proceed to report workplace hazards and dangers as it is their responsibility to do so, or to refuse unsafe work when necessary, as it is their right to do so.

1.4.2 Hazard Control

A hazard control program, for a hazard such as DE, consists of all steps necessary from all the different parties responsible for the employees' health and safety at the workplace, and includes temporary and

permanent controls; this is tailored to suit the needs of each workplace (65). In order to implement a program for DE, the environmental and occupational exposures and conditions that are likely to cause diseases are determined well in advance of the occurrence of health outcomes. Traditionally, it is expected that industrial hygienists and employers fulfill the role of anticipating, recognizing, evaluating, and controlling the health hazards in the workplace (15). However as mentioned previously, employees can benefit by being aware of how they can protect themselves from DE exposure and participating in the process of exposure remediation, especially in the control category.

Four methods of hazard control are described below. They are presented together as a “hierarchy of control” as they are considered in the order that they are presented; those items earlier in the order presented are considered more effective and desirable, as they are less likely to burden the employee, and less likely to require understanding, cooperation or motivation from the employee to provide protection. Conversely, in the order that they are presented, they are also thought to be harder to implement.

Controls are implemented anywhere along the exposure route, namely at the source, along the transmission path, or at the employee’s location. The four methods of hazard control are elimination (substitution), engineering controls, administrative controls, and personal protective equipment (65). Elimination (substitution) involves removing DE from the workplace. Engineering controls include designs or modifications to the workplace that reduce the source of exposure; this can be achieved by isolation, or ventilation. Administrative controls include changing work practices such as job rotations, or employee education about the exposure and health effects of DE. Personal protective equipment refers to equipment that is worn by individuals that reduce exposure for the individual, such as masks. It is important to note that while personal protective equipment may provide a high degree of protection, wearing it can be uncomfortable and stressful. Also, in order for the personal protective equipment to be effective, it needs to be complemented with proper selection, fitting, and maintenance as well as sufficient workplace knowledge and cooperation that

is seldom achieved in practice (66).

1.4.3 Exposure Limits

In the field of industrial hygiene, workplace health and safety is usually controlled based on the assumption that there exists a safe or at least tolerable level of exposure below which no significantly adverse effect occurs for nearly all people who may be repeatedly exposed day after day (67). These levels are called threshold limit values. It is recognized that, because of the wide variation in individual susceptibility, a small number of individuals may experience discomfort at concentrations at or below the threshold, as well as some individuals who may be affected more seriously because of a pre-existing condition.

Threshold limits are frequently updated and are based on the most up-to-date information from experimental human and animal studies and industrial experience. The latest documentation is utilized in order to assess the most current information regarding threshold limits and recommendations.

A time-weighted average (TWA) permits durations of exposure that exceed the limit provided that they are compensated by equivalent exposures that are below the limit. These may be provided from health and safety agencies. The TWA provided in British Columbia, Canada are discussed in the next section.

It is important to note that the threshold limit values and the time-weighted average for DE were established before 2012 (68). Carcinogens are an exception to the rule of threshold limits as it is thought that there are no acceptable risk limits and therefore there are no thresholds (69). Since the reclassification of DE as *carcinogenic* (Group 1) in 2012, the ALARA “as low as reasonably achievable” principle is to be used instead.

1.4.4 Health and safety agencies

Health and safety agencies such as WorkSafeBC, the Canadian Centre for Occupational Health and Safety (CCOHS), the National Institute for Occupational Safety and Health (NIOSH), and the Occupational Safety and Health Administration (OSHA) provide information about DE, its health effects, and possible mitigation strategies. Given the limitations of the study budget and for the purposes of direct comparison, the information readily available on the websites of the health and safety agencies are shown in Table 2.

Table 2. Information from the Websites of Health and Safety Agencies.

| Health and Safety Agency | Acronym for DE | Education | Recommendations | Exposure Limits | Refs |
|--------------------------|---|---|--|--|------|
| WorkSafeBC | “diesel fuel, as total hydrocarbons, inhalable” | <ul style="list-style-type: none"> Smoke colour indicators Exposure route | <ul style="list-style-type: none"> Servicing engines according to manufacturer Using more than CO as exposure indicator | <ul style="list-style-type: none"> 8-hour time weighted average limit = 100mg/m³ | (70) |
| CCOHS | DE | <ul style="list-style-type: none"> Health effects and mitigation strategies IARC re-classification Types of occupations at high risk | <ul style="list-style-type: none"> Use reformulated diesel or biodiesel Low-emission engines Exhaust extractor hoses for idling vehicles Respirator if other methods not effective or suitable | N/A | (71) |
| NIOSH | DE | <ul style="list-style-type: none"> DE Miners Study results Underground miners 10x exposure as in other workplaces Health effects | N/A | N/A | (72) |
| OSHA | Diesel particulate matter | <ul style="list-style-type: none"> Health effects and mitigation strategies IARC re-classification Types of occupations at high risk | <ul style="list-style-type: none"> Use filters, oxidation catalysts Cleaner-burning engines Restrict amount of diesel-powered equipment in an area to not exceed ventilation capacity | <ul style="list-style-type: none"> Underground miner 8-hour time weighted average limit = 160µg/m³ | (73) |

Table 2 indicates some similarities and differences in the information provided by the health and safety agencies. There are several deviations and areas of missing information that are worth noting. Even though DE is referred as such in the website of WorkSafeBC, the closest substance to DE that is listed in their Table of Exposure Limits for Chemical and Biological Substances is “diesel fuel, as total hydrocarbons, inhalable” (70). It also says that the substance can contribute significantly to the overall exposure by the skin route and does not mention about the inhalation route. It is also worth noting that DE is not listed as one of the Hazardous Materials on their Exposures page (74). Meanwhile, on the NIOSH website, DE is addressed in an exclusively “Mining Topic” on their website and lacked information about mitigation strategies (72).

Lastly, it is worth noting that none of the agencies mentions about the ALARA principle. Two of the four health and safety agencies provide information about exposure limits in the way of TWA’s. OSHA’s information about TWA is only relevant for underground miners.

1.4.5 Emission Standards and New Technologies

The government and the market are involved with minimizing exposure for people exposed to DE, in the way of introducing and enforcing emission standards, and offering new technologies for diesel fuel as well as for energy consumption in general.

Fortunately, increasingly stringent on-road emission standards for diesel engines were introduced in Canada, the United States, and the European Union in 2012, with other countries (*e.g.* China, India, Brazil) following with a delay of about five to 10 years (75). These regulations resulted in the recent introduction of new diesel technologies such as lower sulfur content in the fuel, diesel particulate filters and oxidation catalysts, which altogether achieved a >95% reduction of particulate mass and nitrogen oxides emissions.

Emission standards for off-road vehicles and industrial applications are usually less stringent and generally introduced after those for on-road vehicles (76). For example, a sulfur limit of 15 mg/kg was made effective for diesel fuel in motor vehicles since 2006, whereas a sulfur limit of 1000 mg/kg for large stationary engines for production, import or sales was not made effective until June of 2014 (77). Specifically in British Columbia, Canada, a non-road diesel engine emission regulation bylaw was instated as of 2012 which included a fee for operating diesel non-road equipment (78).

Furthermore, new and renewable energy sources such as ethanol and bio-diesel are being explored and capitalized, which may contribute to cleaner air and has potential to reduce greenhouse gas emissions compared to diesel (79).

It is worth noting that although technological advances as described above are available, it may take many years before they have a significant penetration into the diesel engine fleet, especially in less developed countries. Also, off-road vehicle turnover is lower; older engines are generally used longer in off-road applications compared to those on-road. Therefore, it is predicted that the working population will continue to be exposed to DE.

1.5 Workplace Knowledge, Attitudes and Behaviours

1.5.1 Relationship between Knowledge, Attitudes, and Behaviours

As mentioned above, it is important that the person occupationally exposed to DE is informed of their exposure. The purpose of this study is to understand what the individual knows regarding their occupational exposure. Furthermore, we are interested in understanding their attitudes and behaviours, along with just their awareness of DE exposure. This additional information is sought because an individual having knowledge of a health risk does not mean that they necessarily believe themselves to be at risk or that they are likely to do

anything to prevent themselves from being in harm's way or apply their rights. Factors in risk reduction have been well studied in public health, demonstrating for example the knowledge of the health risk of smoking, driving under the influence and over-eating are not enough to drive individuals to believe they are at risk or to take actions to reduce these exposures (80-82). It was through the inquiry of factors alongside knowledge that researchers in risk analysis, health promotion and allied fields have learned the importance of factors such as trust, social norms and perceived vulnerability in the context of behaviour change (83, 84).

1.5.2 Knowledge, Attitude and Behaviour Studies

A knowledge, attitude, and behaviour (KAB) study collects data from a specific population on what they know, believe, or are doing in regards to a specific topic (85). The study is usually conducted orally using a semi-structured questionnaire and the data can be qualitative or quantitative. KAB studies 'identify knowledge gaps, cultural beliefs, or behavioural patterns that may facilitate understanding and action', and also collect evidence for 'planning, refining, and evaluating advocacy, communication and social mobilization work'.

1.5.3 Studies to Date

In the workplace setting, the relationship between knowledge, attitudes and behaviours is even more important, given that employees play a legally mandated role in managing their exposures, as described above. Exposed individuals have the right to know what they are exposed to and the right to actions that reduce their exposure and, as such, the concept of knowledge, attitudes and behaviours is even more significant than in the general public health settings. To date, little data from knowledge, attitude and behaviour studies in occupational settings has emerged. Most studies regarding occupational and inhalational hazards are related to the measured levels of the hazards or the health effects, and lack any information on the employees' awareness or perception of the risk (16, 86-90).

Even fewer studies have determined workplace knowledge, attitudes and behaviours regarding occupational exposure to DE. The Workplace Awareness and Knowledge Study from the University of British Columbia aimed to explore individuals' knowledge and understanding of their exposure to various occupational carcinogens including DE (91). Preliminary findings identified knowledge gaps of potentially harmful workplace exposures and that awareness differed substantially across different exposures. However, the study was not focused on DE and no data specific to DE was disclosed. Preliminary interpretations of the Workplace Awareness and Knowledge Study included that study participants were aware of their right to know and right to refuse their job, however they would not act on these rights. No other studies relevant to workplace knowledge, attitude and behaviour regarding occupational exposure to DE have been found.

1.6 Research Aim, Study Design and Specific Objectives

1.6.1 Research Aim

While the understanding of occupational exposure is important for all exposed individuals, the recent acknowledgment of DE as being *carcinogenic to humans* (IARC Group 1) has increased the urgency for improved health and safety around DE. Recognizing that simply providing information is not sufficient for behaviour change, this study set out to gather information on the knowledge, attitudes and behaviours of individuals in occupations where DE exposure was occurring. This information was analyzed to examine strengths, gaps, and misconceptions, along with the societal and organizational factors that could influence how new information about DE could be better translated in an occupational context.

1.6.2 Study Design

One effective way of eliciting knowledge, attitudes and behaviours around risks is by using the Mental Models approach (92). The Mental Models methodology, developed by Morgan *et al.*, postulated that an individual's mental model was their simplified cognitive representation of the actual complex system that

existed in the world (92, 93). The mental model consists of relevant knowledge and beliefs, including perceptions of interconnectedness, which may be called upon over time for making inferences and affecting how subsequent information is processed (94). For example, information that is consistent with existing beliefs is more easily integrated, strengthening those beliefs over time, whether accurate or not. The Mental Models methodology is also exceptional at identifying relevant knowledge gaps and misperceptions; communication materials developed after Mental Models methodology versus other methodologies were better equipped to correct knowledge gaps and misperceptions while reinforcing appropriate beliefs (84). The rationale behind employing the Mental Models methodology is that individuals' decisions and behaviours play a critical role in determining their probability and severity of injury from risk, such as DE occupational exposure. Therefore, the Mental Models methodology allowed us to gather information about the study participants' relevant knowledge and beliefs that might affect their decisions and behaviours, which in turn affected their probability and severity of injury from DE occupational exposure.

In the Mental Models methodology, in order to identify knowledge gaps and misperceptions, the beliefs from domain experts and from the relevant homogenous population are elicited and then compared. The domain experts' beliefs are established in some studies by interviewing experts in the domain with questions similar to those asked from the relevant population (95). For example, Wood *et al.* interviewed US Army Corps of Engineers with similar questions asked of laypersons for a study on flood preparedness (96). In other studies, the domain experts' beliefs are established with a review of relevant literature to identify important factors as well as relationships among them in the system (84). For example, in order to identify information needs about wildland fires, Zaksek *et al.* established experts' beliefs by performing an extensive literature review on existing processes of wildland fires (97). In this current study, the Mental Models approach was applied to a group of individuals exposed to DE on the job in BC. Given the recent attention paid to the review of DE and its health effects and the limitations of the study budget, expert elicitation was not undertaken with interviewing experts. Instead, the latter method to elicit experts' beliefs was used and a

review of relevant grey and research literature was used as the basis to compare the participants' relevant decisions and behaviours around DE exposure.

1.6.3 Specific Research Objectives

The overall aim of this study was to determine individuals' knowledge, attitudes and behaviours regarding DE, characterize information gaps or misconceptions about occupational DE risk and identify channels that could be used to help individuals reduce their exposure. In order to achieve this aim, a set of specific objectives was developed:

1. To design and conduct a questionnaire that would measure individuals' workplace knowledge, attitudes and behaviours around DE exposure.
2. To compare and contrast individuals' responses regarding occupational DE exposure and the list of best practices using the Mental Models approach to identifying strengths, gaps, and misperceptions.
3. To propose a set of recommendations that could be used by employees, workplaces, unions, and the government agencies to promote better health and safety around DE.

CHAPTER 2: STUDY METHODS

2.1 Overview

The following section outlines the specific steps that were undertaken in this Mental Models research study.

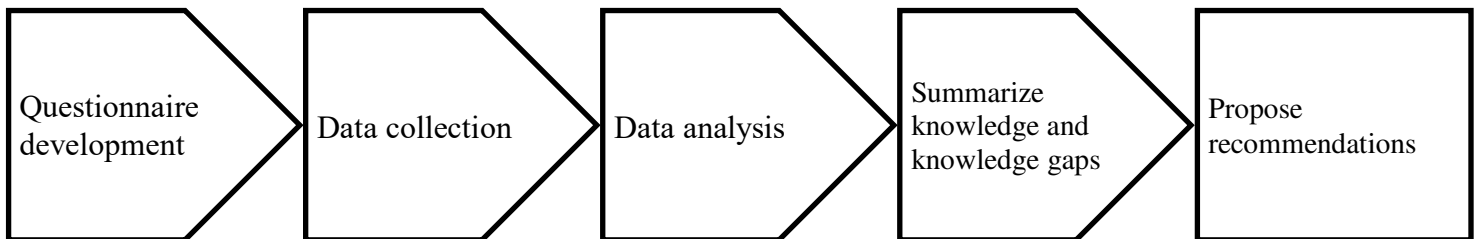


Figure 1. Overall Study Flow.

2.2 Questionnaire Development

The questionnaire was designed in such a way that the data was collected using the Mental Models methodology. As mentioned, given the recent attention paid to DE and the limitations of the study budget, expert elicitation was not undertaken with interviewing experts. Instead, the questionnaire was developed by a collaboration between the author and three domain experts (supervisory committee members). Dr. Christopher Carlsten is an expert in the respiratory and immunological health effects of environmental and occupational exposures. Dr. Michael Brauer leads monitoring and epidemiological studies on the global health effects of air pollution, and serves on advisory committees to the World Health Organization. Dr. Anne-Marie Nicol is a professor with expertise in risk communication and knowledge translation. These three experts also provided suggestions on relevant grey and research literature to review and reference for the questionnaire. Examples of grey literature included the websites of WorkSafeBC, CCOHS, NIOSH, and OSHA as well as web links of ongoing studies. Research literature included ones found through the PubMed search engine that were related to occupational exposure, occupational DE exposure, or DE health effects. All literature reviewed are cited in this thesis.

The questionnaire underwent iterative evaluation with the three domain experts (supervisory committee members), as well as a librarian with expertise in qualitative research. This questionnaire formed the basis for gathering information from the employees. See Appendix A for the study questionnaire.

The study questionnaire contained basic questions to establish demographics. The study subjects were asked to report their age and the number of years that they have worked at a work site where they were occupationally exposed to DE in integers. The study subjects were asked if they had relevant health conditions such as allergies, asthma, other lung conditions, and occupational injuries and diseases, since that might increase their knowledge level when they were personally affected. They were also asked about the highest level of education that they obtained to gain an understanding of their general level of knowledge.

The study participants were asked if they currently or previously smoked, as well as to provide information on how much they exercised per week to gain an understanding of how concerned they were about their health. If the subject only walked, or only exercised once per week, the subject was categorized as doing a “low level” of exercise. If the subject exercised two to five times per week, he was categorized as doing a “moderate level” of exercise. If the subject exercised six times or more per week, he was categorized as doing a “high level” of exercise.

The questionnaire contained questions about the nature of their work. The study subjects were asked for their job titles, and to describe how their jobs were day-to-day and their work sites. The questionnaire also included questions about the study participants’ knowledge, attitudes and behaviours regarding the occupational exposure of DE. Some of these questions were open-ended; examples included “Can you describe in as much detail as possible a situation at your workplace when you feel like you are being exposed to DE?”, “What are your thoughts about being exposed to DE at your workplace?” and “What do you think would happen to a person as a result of DE exposure?” Some questions were asked for the study subjects to

provide a list of responses, such as to list the top five perceived hazards at work, or to list as many actions to address DE exposure as they could think of, or to list any recommendations that they could think of to better address DE exposure. Additionally, some more-structured questions were asked to obtain quantitative answers, such as “On a scale of one to five, one being minimal, two being tolerable, three being irritating, four being unhealthy, and five being life-threatening, how much DE do you think you are exposed to at work?” and “What is the actual level of DE that you are exposed to at work?” Some of the questions were followed up by probes designed to elicit more information on a particular subject matter, such as “Can you give me an example?” or “When might this occur?”

Throughout the study, one interview question was changed. After the first subject did not have an answer for the question, “*How much DE are you exposed to at work?*” the question was changed to “*On a scale of one to five, how much DE do you think you are exposed to at work, one being minimal, two being tolerable, three being irritating, four being unhealthy and five being life-threatening?*” After the first 15 subjects were interviewed, the supervisory committee suggested that it would be helpful to ask the subjects, in addition to their perceived level of occupational DE exposure, if they knew the actual level of DE that they were exposed to at work. Thereafter, the remaining 15 subjects were asked “*how much DE do you think you are exposed to at work...*”, as well as “*what is the actual level of DE at your workplace?*”

2.3 Data Collection

2.3.1 Recruiting Methods

Subjects were recruited by local advertising (by posting flyers in several locations thought to be likely to be frequented by those exposed to DE, such as a Starbucks coffee café next to a construction site, as well as posting advertisements on the local Craigslist website). Subjects were also recruited by word of mouth, and through contacting unions and workplaces that were believed to have members who were regularly exposed to

DE. See Appendix B for an example of an advertisement for the study and Appendix C for a list of those formally contacted.

If the subject was interested and contacted us on their own accord, they were sent an informed consent form. It was required that the subject has read and understood the study details, and consented to participating in the study. See Appendix D for the informed consent form. The key information that were given to the potential study participants were the purpose of the study, that their participation was entirely voluntary, that the study involved one session with them that would take about 30-45 minutes with no other individuals present, that their identity and location would be anonymous and the data collected would not be individually linked to any participants.

The subjects were recruited on a first-come, first-recruited basis; as long as they fulfilled the eligibility criteria, they were interviewed as soon as they submitted the informed consent form, and the subject's and the interviewer's schedules coincided. It was decided that participation was limited to four subjects per workplace and six per occupation, to prevent narrowing the occupational focus.

2.3.2 Participants

To be eligible for the study, the study participant needed to be working in a position where they were regularly exposed to DE at their workplace. Whether the subjects were regularly exposed to DE was determined by the presence of at least one source of DE at their workplace, and by their job description. They also needed to be older than 19 years old, and have worked for at least one year at their current workplace. People who were not exposed to DE at their workplace on a regular basis, or who were not willing to participate in an interview, were excluded from participating in the study.

According to Mental Models theory, a representative sampling of 20 individuals within a homogenous population would provide approximately 50% chance of observing each belief held by at least 5% of a population (84). Therefore, a study using the Mental Models methodology typically includes 20-30 respondents, which would reveal most of the beliefs that are at least somewhat common. Accordingly, this study included interviews with 30 participants. No subject who submitted the informed consent form dropped out of the study.

2.3.3 Survey Implementation

The study involved one-on-one interviews conducted by the same interviewer (Mandy Pui) to maintain consistency in the style of the questioning. Individual interviews were preferred to focus group interviews; because the behaviours in question were generally at the individual level, this was presumed to avoid people influencing others' thoughts as it could happen at focus group interviews. The interviews were conducted between the interviewer and the study participant with no other individuals present, at a private and quiet location, which were usually in-person at the interviewer's worksite, or over the phone. The average time for these interviews was 30 minutes. The interviews were audio-taped, and the interviewer took notes.

2.4 Data Analysis

The audio recording of the interviews was transcribed using the NVivo software. The initial coding schema for data analysis, like the development of the questionnaire, was informed by a review of grey literature as well as research literature to develop model categories. An example of the development of the coding schema is as follows: Nicol and Hurrell conducted a similar study to determine the knowledge, attitude and behaviour of individuals who were occupationally exposed to metal working fluids, a dermal and respiratory irritant (95). Informed by this research literature, the categories of "sources of information for a work hazard" and "trusted sources of information" were added to the initial coding schema. The nouns and

verbs of importance are used to identify categories, and the adjectives and adverbs make up the properties of these categories. In this sense, the initial coding schema acted as the template for the expert understanding of DE, its health effects and the strategies that could be used to reduce exposure. Then the respondents' responses were read, re-read and examined to identify additional categories and properties, to infer interrelationships, and to generate a theory. An example question would be "*Can you tell me what you think would happen to a person as a result of DE exposure?*" The known health effects that result from DE exposure (e.g. lung cancer, asthma) were taken from the literature. However, if an individual's responses did not fit into the initial coding schema, then additional codes were created (e.g. if the response was "problems with lungs"). This allowed for both well-known answers along with participants' less specific or incomplete understanding of exposure. If survey responses deviated completely (e.g. an impossible health effect), the result was included to ensure completeness of respondents' perceptions of exposure.

Responses for each code were grouped together and counted. A representative quote for each group of responses was shown to illustrate themes, while making a concerted effort to include anything that was relevant to DE. In the quotes shown, some sections were edited for the purpose of maintaining the subjects' anonymity, or to make the quotes more concise, or to correct the grammar. The categories and themes elicited from the study participants were compared and contrasted to those established from the expert beliefs from the research literature, and illustrated and discussed in the Discussion section.

In the case of quantitative answers from the more structured questions, such as those regarding demographics, and ranking responses from "On a scale of one to five..." questions, results were counted up, put in categories if possible, compared by Wilcoxon rank test if applicable, and shown in tables and figures. If applicable, quotes were collected, and a representative quote for each group of responses was shown.

CHAPTER 3: RESULTS

3.1 Participants

Thirty eligible participants were successfully recruited into the project over a one-year period. The characteristics of the 30 study participants are outlined in Table 3. The participants were recruited on a first-come, first-served basis.

Table 3: Participant Characteristics.

| Characteristic | Average (SD) |
|----------------------------------|--------------|
| Age | 46.3 (13.6) |
| Years Exposed to Occupational DE | 20.0 (12.8) |
| Characteristic | N |
| Male | 25 (83%) |
| Smoker | 2 (7%)* |
| Previous Smoker | 7 (25%)* |
| Known Asthma | 6 (21%)* |
| Known Allergies | 10 (36%)* |
| Other Lung Conditions | 1 (3%)* |
| Occupational Disease or Injury | 3 (11%)* |

* Data for this variable was only obtained for 28 subjects

The subjects' ages ranged from 22 to 69. The duration that the subjects were occupationally exposed to DE ranged from one year to 50 years. The cohort of study subjects consisted mostly of male non-smokers. Some of the data was only obtained for 28 subjects because two subjects refused to provide the data. One subject reported to have a lung condition (chronic obstructive pulmonary disease). Three subjects reported to have an occupational disease or injury (chronic pain from a car accident, disc problems and chronic obstructive pulmonary disease).

The subjects were asked how much exercise they did per week outside of work, and their replies were categorized as described in the Methods section. Out of 28 subjects who responded to this question, two did not exercise, 10 subjects did a low level of exercise, 12 subjects did a moderate level of exercise, and four subjects did a high level of exercise.

The subjects were asked, “*What was the highest level of education that they have obtained?*” Out of 28 subjects who responded to this question, two have done some high school, five have finished high school, five have done some university or college, 12 have finished university or college, and four have done some diploma or trade school.

3.2 Job Titles and Descriptions

The study subjects were asked to give their job titles as Table 4 shows.

Table 4: Job Titles and Sectors.

| Job Title | Job Sector (Subsector) | # Subjects with Job Titles |
|----------------------|-------------------------------|-----------------------------------|
| Transit Operator | Transportation (Buses) | 5 |
| Bus Service Clerk | Transportation (Buses) | 2 |
| Vehicle Inspector | Transportation (Cars) | 1 |
| Locomotive Engineers | Transportation (Railway) | 3 |
| Heavy Duty Mechanic | Transportation (Railway) | 1 |
| Airport Crew Member | Transportation (Airplanes) | 1 |
| Marine Oiler | Transportation (Ferries) | 1 |
| Ferry Engineer | Transportation (Ferries) | 6 |
| Fuel Dock Supervisor | Transportation (Boats) | 1 |
| Firefighter | Rescue Service | 3 |
| Fire Battalion Chief | Rescue Service | 1 |

| Job Title | Job Sector (Subsector) | # Subjects with Job Titles |
|--------------------------|------------------------|----------------------------|
| Commercial Fisherman | Fishing | 1 |
| Heavy Equipment Operator | Construction | 2 |
| Welder | Construction | 1 |
| Lab Technician | Health Sciences | 1 |

While the job titles were given by the study participants, the corresponding job sectors were determined with guidance from a list of job sectors from the Government of Canada Job Bank (98). Out of 30 subjects, 21 subjects worked in the Transportation sector, while four subjects worked in Rescue Service. One subject worked in the Fishing sector. Three subjects worked in the Construction sector, and one subject worked in Health Sciences.

When asked “What is the job like day-to-day?” the participants gave varying answers; shown here are a few that are representative of each of the job titles. These explanations help to illustrate the ways in which employees understood and conceptualized their exposure to DE.

From a transit operator: *“In the morning, we go outside where there are a large number of buses parked in the yard areas, we start them up and they sit there idling for 10-15 minutes, while you do what's called a pre-trip check, and at that time, you are breathing generally a lot of fumes from the exhaust unless there's a good wind blowing. In each yard, there is a total, with conventional buses and shuttle buses, of over a 100. Maybe 200. Then we drive out onto the streets, and we go to our bus stations, and drive out onto the different routes from there. A full shift is [on] average seven and a half hours. There are intermittent scheduled breaks, which can range between 60 seconds to 20 minutes, and it can vary every day. We take the bus back to the yard, and at that point, there is a shut-down procedure, what they call a post-trip, in which case you do a quick inspection of the bus, but we're talking less than five minutes if anything at all that the bus is running but usually it's not. It's more to*

check if there are dents or scrapes. Having said that, if a bus comes up next to you, there are fumes coming your way. And then we walk into the building, where we take our paddle which is our little timetable back inside, then out the building to our vehicle and drive away.”

From a bus service clerk: *“It's generally re-fueling buses, making sure that [they're] ready for the next day, cleaning [them], [doing] general maintenance.”*

From a vehicle inspector: *“Essentially, different cars drive into the garage, and they are left idling. At that time, I would check that they're not emitting too many emissions into the atmosphere. [To know whether it's too many emissions is to] hook up the tube to the exhaust pipe, and the computer does the rest. The computer tells me pass or fail.”*

From a locomotive engineer: *“I drive freight trains from [one location] to [another location] and also the return. It's up to 10 hours each direction. The trains are diesel-electric meaning that diesel generates electricity to run the traction motors. The trains carry mostly freight like grain and coal, though on [some routes] I would have passengers.”*

From a heavy-duty mechanic: *“Basically, I deal with locomotives, they bring in running locomotives into the shop with poor ventilation. And we do work with engines running. All the time, all day long”*

From an airport crew member: *“I work at the airport, and I spend my time marshalling planes, off-loading luggage, and putting [them onto] the belt. [There are DE vehicles everywhere], and when I inhale the DE, it would sting my throat, and it doesn't smell good.”*

From a marine oiler: *“We are responsible for all main engines and auxiliary equipment on the vessel, so checking continuously the motors, fluid treatment plants, hydraulic systems, just anything on board of the vessel. Any boilers, oil changes, and of course one of the main things was diesel fuel, there was a 500-gallon diesel tank in the engine room, which had to be filled up at the end of each shift.”*

From a ferry engineer: *“I work in and around engines, make sure that they're running as they should. I check leaks, check other machinery. I do rounds and fix things. I work all of morning, afternoon, and graveyard shifts. On graveyard shifts is when we fix things, and we're more hands-on then.”*

From a fuel dock supervisor: *“I dispense fuel, outdoors to vessels on a dock. I untie and tie vessels to the dock. I also work at the cash register at a retail store on the dock. In the winter, there might be 3-5 vessels on the dock. In the summer, the busy months from May-September, I would see 50-100 vessels, and about 75% of them run on diesel.”*

From a firefighter: *“How much time do we have? Haha. Basically there's obviously training and emergency calls. And aside from that, we have hall duty, that includes truck maintenance, I can go on and on, and each one of those branches goes into five or 10 branches. On average, I'd say in a 10-hour shift, five to six hours are spent in the fire hall, and four to five hours are spent on the field.”*

From a commercial fisherman: *“The main thing is catching and processing fish, though I'm also a jack of all trades on the fishing boat, responsible for the quality of the product, and be a plumber, an electrician, a cook. The boat has two engines, one main and one auxiliary engine for freezer systems, though some have more than two, and don't forget the diesel stove; it can be pretty bad when they're smoking, it's gross!”*

From a heavy equipment operator: *“I pick things up and drop them back down. Do pre-trip inspection of boom trucks, check fluids, mechanical stuff and hydraulics. Either drive the truck onto site, or drive up to 2 hours to a different site, and make sure that the radius is set up for hoisting procedures. Pick up object, hoist, repeat tasks as required, then fold up the truck and drive back to original site. Hoisting might take around three hours, and it might take half an hour to go in, half an hour to go out. But the time can vary from day to day, from location to location. When I'm hoisting, the engine will vary at idle. I'll have a throttle control, which I use with my foot. I'm at the back of the truck, standing, completely exposed to all the elements, with the exhaust quite close to me. As opposed to being in the rough-terrain, or all-terrain, where the operator is in an enclosed space, completely rotational and independent from the driving structure of the vehicle.”*

From a welder: *“There are two trucks in the building, they bring them in, fire them up, you finish yesterday's project, and it completely fills the shop with diesel smoke. Where you can't see past the end of your fingertips. They turn the exhaust fan on, but it's this little squirrel fan. You could open the door, though it's 30 below for 10 months out of the year. You try to get the blue and black smoke out of there, black smoke means over-fueling and the fuel is raw, and that's a bad sign for the economy, for engine efficiency, and also for whoever is breathing it; it'll gag you and give you a headache. You pull another piece of equipment out and bring in another one. Everyone's huddled around wherever the heat's coming from, and breathing in more fumes from the coal.”*

From a lab technician: *“The diesel engine is outside of the lab which is located in the basement of a research building, and on [study] days with DE exposure, I would have to set up the engine and run it. That's the day when I'm most exposed to DE.”*

3.3 Work Site Descriptions

Work sites varied widely between the participants. Out of 30 subjects, two subjects worked mostly outdoors (e.g. fuel dock supervisor and airport crew member), while four subjects worked mostly indoors (e.g. vehicle inspector, heavy duty mechanic, welder, lab technician). Seventeen subjects worked mostly in a vehicle or vessel and a piece of heavy equipment, whether that was a crane, an excavator, a ferry, a locomotive, or a bus (e.g. transit operators, locomotive engineers, marine oiler, ferry engineers, heavy equipment operators). Three subjects worked a combination of outdoors and in a vehicle or a vessel (e.g. bus service clerks, commercial fisherman). The four remaining subjects worked a combination of outdoors and indoors (e.g. firefighters). Shown below are a few representative answers of the different work sites:

From a fuel dock supervisor (working mostly outdoors): *“I don’t ever go on the vessels, I just stay outdoors on the dock except for occasionally when I work at the cash register in the retail store or to go into a storage room to change oil tanks.”*

From a heavy duty mechanic (working mostly indoors): *“The shop is maybe half a million square feet. I don't really know, but it's pretty big. There are two separate sides, the running side, where they run the locomotives, and there's poor ventilation, which we feel is inadequate. There are supposed to be sensors in there, to detect carbon dioxide. And the sensors are not working properly.”*

From a heavy equipment operator (working mostly in a piece of heavy equipment): *“My work site is, on my left side when I'm in the excavator, is a very large retaining wall, and on my right side is traffic, and the traffic is 90% tractor-trailers, and belching black smoke, and people driving like morons. It's very hectic, because of the amount of traffic, because of what's in the ground where I'm digging. There is so much infrastructure where I am. It really adds to the stress of the job.”*

From a ferry engineer (working mostly on a vessel): *“The ferry that I work on was built in 1969 and it used to generate a lot of exhaust, and leaked fuel more than it can consume. There would be nightly service. It was repowered in 1998 where they changed the main engines. Now it's enclosed, there's no leakage, and it has created a very clean environment.”*

From a bus service clerk (working a combination of outdoors and in a vehicle): *“It's outdoors, under cover, it's open to elements. It's like a gas station where the vehicles pull up. I'm also in and out of the buses constantly, collecting boxes and taking them out of there.”*

From a firefighter (working a combination of outdoors and indoors): *“On average in a 10-hour shift, 5-6 hours are spent in the fire hall, and 4-5 hours on the field. In the fire hall, you get exposed to DE when you're the one connecting the extraction hose to the truck as it's coming into the fire hall. On the field, the truck is running when we're running our drills. That's when we go through scenarios, and we run the truck because it has a pump in it, to simulate water pressure and volume. Then we also do emergency calls, in the middle of traffic.”*

3.4 Safety Training

The subjects were asked if they have received any safety training at work. If so, they were asked to describe any training that was relevant to DE. Out of 28 subjects who responded to this question, nine subjects reported not having received any safety training at work. Two subjects reported receiving safety training through safety bulletins *“such as from WorkSafeBC”*. One subject reported receiving safety training by learning on the job. Sixteen subjects reported having done some kind of safety course. Additionally, four of the subjects disclosed that they have been part of the health and safety committee at their workplace, and have been accordingly trained for that role. Out of all 28 subjects, all subjects reported that they have not had any safety training that was specific to DE.

Here are some of their responses:

“[Since I have] a role on the health and safety committee, I have attended, and I will be attending a safety conference, and go to various safety workshops that are for when you take on that role, and also with my years of experience, I have taken hazardous materials and exposure in confined spaces training.”

“[I’ve had] very little safety training. It is ongoing though it is not so much for what you breathe on the job, it’s more for the fact that I have laborers working around me while I’m on an excavator, so there’s more safety training for operating equipment [and preventing injury] around other people than for personal health.”

“I’m on the safety committee, and I’ve had training on safety issues, WorkSafe regulations, but nothing that has to do with DE.”

“I was the safety rep, and I had training about the labor code, though nothing that has to do with DE exposure.”

“I’ve had training for if something happens and we’re trapped in the tunnels, how to use the respirators. But that’s just for emergencies, to get out of the tunnels, that’s not for exposures. You couldn’t stay inside the tunnel with this type of mask, it doesn’t have a separate canister; it’s just a filter. Other than that, that’s about it.”

“I’ve had WHMIS training, though nothing relevant to DE.”

“No training, [but] because I have been working, I know what makes [the engines] run, what makes [the diesel] smoke blue, why it smokes black, and how to get the right air-fuel mixture.”

“We have safety courses, about high voltage, but nothing about exhaust. We just know it’s there.”

“Not specific to DE. I teach occupational safety and health and you have to make sure that you protect yourself as much as possible.”

3.5 Exposure to DE

When the subjects were asked *“how much DE are you exposed to at work?”* the first subject reported not knowing the level of DE that he was exposed to, and subsequently did not have an answer for that question.

After the first interview, a ranking system was developed. The study subjects were instead asked *“On a scale of one to five, how much DE do you think you are exposed to at work, one being minimal, two being tolerable, three being irritating, four being unhealthy and five being life-threatening?”* The subjects were allowed to give half-points, and therefore with the ranking system between one and five, there were a total of nine possible answers. Twenty-nine subjects answered, as shown in Figure 2.

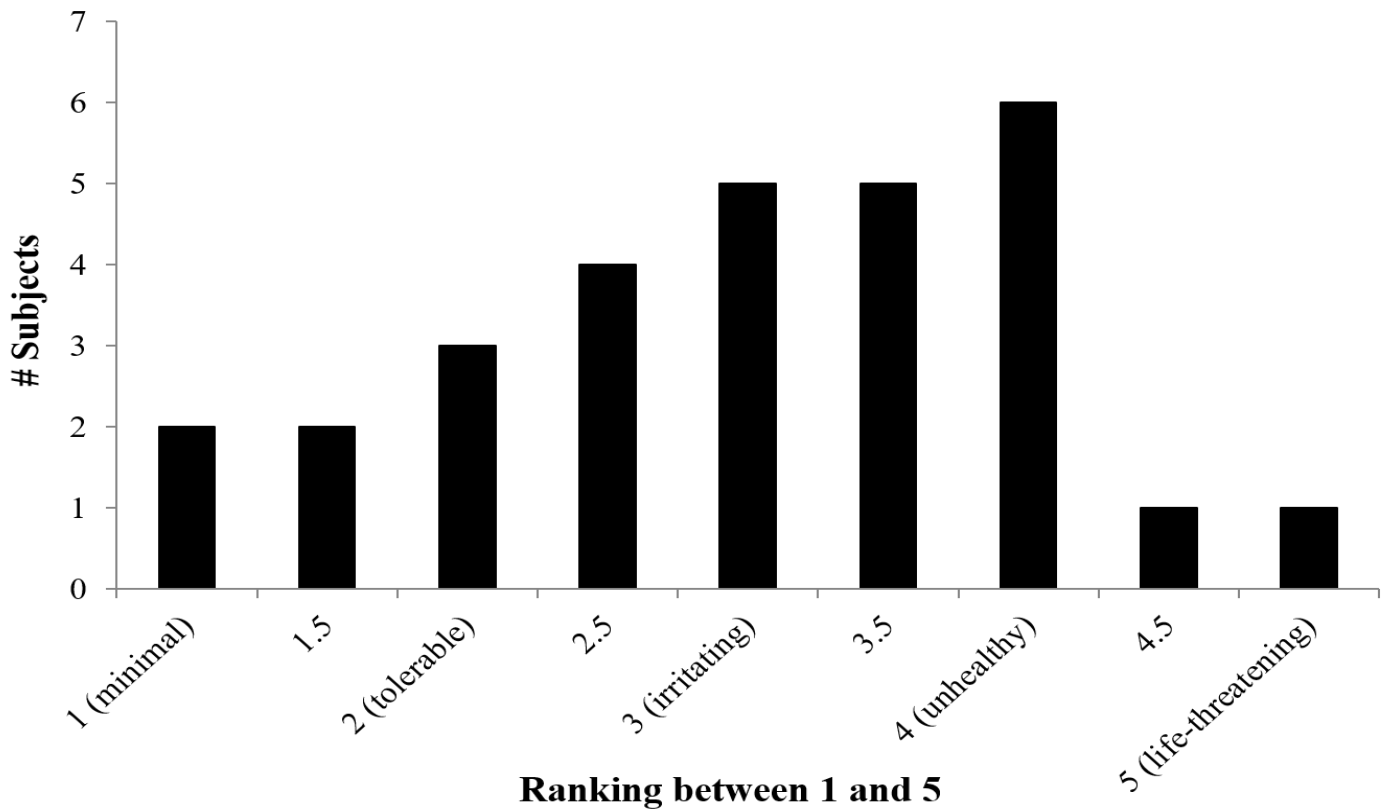


Figure 2. Subjects’ Perceived Level of DE that they were Exposed to at Work.

After the first 15 subjects were interviewed, the supervisory committee suggested asking the subjects, in addition to their perceived level of occupational DE exposure, if they knew the actual level of DE that they were exposed to at work. Out of 15 subjects who were asked this question, 14 subjects reported not knowing. One of the 14 subjects said,

“How much? I don’t know. It’s hard to quantify. I don’t know what to compare it to?”

While another of the 14 subjects said,

“I’m not sure how to measure it.”

Other than subjects who didn’t know how DE was measured, there were subjects who didn’t know the actual level because DE has not been measured recently to their knowledge, with one of the 14 subjects saying,

“There are no regular monitors for CO, CO₂, NO₂, so we usually don’t know the actual levels. But if we suspect that the levels went up, [only] then we can use a monitoring device. Also, it’s a big space so

we're not too worried about it."

Another of the 14 subjects said,

"I'm aware that they checked the levels in the engine room as well as the car deck maybe around four to five years ago. But I'm not sure what the results were."

The remaining subject out of the 15 who were asked about the actual exposure of DE had a very specific answer,

"27.68 parts per million in a volume of [a workplace] that was 50 x 60 ft. with a 16-foot ceiling."

Then he went on to say,

"We have no clue what [substance] that ppm is, at what stage, was that just after starting the truck, or when you've worked in it all day, or after letting it smoke out. You don't know how much of it is going through your gas mask if you wore one."

Most of the 15 subjects seemed interested in knowing the level of DE at their workplace. One of the subjects said,

"No, I've never been told and that's one of the problems of working there. I've talked to the manager many times and I just have never gotten any clear answers from them."

3.6 Thoughts and Concerns about DE

The subjects were asked for their thoughts and concerns about being exposed to DE. Most subjects were aware of the presence of DE and said that it was *"part of the job"*.

Two subjects wanted more information; one subject said,

"I wish I could wear a mask and measure what's going in my lungs, it would be interesting to know. But it's a hazard of the job, so that's about it. No, it would be interesting to know how many drivers died recently from DE; that might make me quit tomorrow, but other than that, no [other thoughts about DE]."

The other subject said,

“I'm concerned and I don't get clear answers. I've done some research online, and I wonder how it is affecting my brain. I think it's an unhealthy workplace, and I thought it should be enjoyable to work on a boat.”

Two subjects were not concerned about DE; one subject said,

“If the engines are properly maintained, there should only be minimal exposure.”

The other subject said,

“We all need to take ownership of ourselves.”

Two subjects were irritated with being exposed to DE though did not mention about taking any precautions about it. One subject said,

“I hate it. I don't like it. It's very annoying.”

The other subject said,

“I certainly am not happy about it. I don't like it. That's why I hold my breath when I can. And every time I get a mouthful of it, I always think to myself, dammit! Because it's one of those things, that for me, I try to avoid, not because anything will happen, but why inhale something if you can avoid it. For me, I don't like it, it's like walking through asbestos by choice.”

Seven subjects acknowledged that exposure to DE was not healthy, though they were not concerned about it. One subject thought that DE was less of a problem than other workplace exposures and contextualized his response within a framework of risks,

“It's better than being exposed to silica dust, or recirculated office air. Nothing that stops me from doing the work that I do. We worry about the health effects of anything that we're exposed to in our industrial world. We do see warning labels on diesel things. Diesel fuel, solvents, hydrocarbons. But

it's not something that we stress about. DE being an aerosol, but it's cleaner than years ago, doesn't seem to be that big of a deal. We don't have trucks spewing big puffs of smoke, in our site anyhow. I do see it occasionally on the highways, but not as much as before. It's not as bad as it had been."

Another subject was not concerned because of the level of exposure,

"I don't think it's a good thing, but at the same time it's not a huge amount, so it doesn't really bother me. If it was avoidable, I'd avoid it. But in my situation, it's not."

Another subject believed that the exposure has gotten much better,

"It never occurs that much to me. When I was younger I was more worried, because I also had a sinus problem. I also used to work on 2 boats where one had inadequate ventilation and the other had constant leaks. In 1999 I needed nose surgery because of the nose lining. Now it's much better."

Another subject believed that his current workplace was doing all it could, compared to his previous workplaces,

"I'm aware of it, and it's not enjoyable to breathe in air that you know is polluted by DE. I would consider it a work hazard. We can smell when there's a leak, and occasionally we might not be able to repair it right away. It's irritating, I haven't really thought of it as a health hazard when I'm working in [my current workplace] in the last several years, but I have worked with other less scrupulous employers. [My current workplace] runs a tight ship."

Three of the seven subjects felt that almost all the mitigation strategies possible were being implemented. One subject said,

"It's hard to avoid it. It's unhealthy, it's been proven to be unhealthy. The management has done a pretty good job of providing us with a way to avoid it by installing the extraction system. I'm pretty comfortable with the system that they have. Yeah, I'm pretty comfortable with it, and I don't think you can make it much better. There is that point when you are exposed [during a work task], when you are connecting the hose to the truck, but there's no way to avoid it. I mean, it's not going to do it itself."

Another subject said,

“My thoughts are that we've realized that it's not good to be exposed to DE, there's a certain amount of exposure that we can't get away from when we work with diesel vehicles, we're conscious of it, and we do a good job to limit and minimize our exposure, I think there's still room for improvement, we can do different things with the way our vehicles are designed, when you look at a bus for example, at the top of a commercial vehicle, the DE comes out on top out of stacks, whereas on a firetruck the DE comes out on road level underneath like it would on your car, so it puts the exhaust down where we work, and so again there are ways to improve.”

One subject was not concerned until she herself encountered health issues,

“Well, prior to my medical situation that happened, to be honest, I think I thought nothing of it. But since I developed a serious medical problem, I wonder if accumulating toxicities made me predisposed to having a medical problem. I mean, there were many issues involved, like age, getting older, weakening immune response, sleep deprivation with the job, but also the toxic burden on my body, they may have amplified my exposure to DE.”

One subject was concerned, though she did not specify what in regards to the exposure that she was concerned with,

“It's concerning, I know that DE is heavy, so it comes back down, it doesn't just get evaporated straight up, so when I'm working underneath it, I do feel that I am exposed to quite a bit. Just the general of, there's DE that I'm inhaling and things like that.”

Seven subjects were concerned about long term effects. One of the seven subjects said,

“I would say that [the exposure]'s a concern over a long period of time - that over a period of time, it might have an effect on a person's lungs or body.”

Another of the seven subjects said,

“I wish I did not take my health for granted.”

Another subject said,

“Well, I think the fumes might give you cancer, but who knows. UBC has done a study with BC ferries, and I go in and get breathing tests and lung function tests, and thankfully nothing's changed over the years.”

Yet another subject said,

“A concern would be over 30-odd year career. Like if it has any long term health consequences. You wonder if there's a latency period, with a 30-year career where you work around diesel equipment if it has an effect on my health, so yeah I guess I have concerns.”

One of the subjects identified the issue being that his employer was not aware of the long term effects,

“I'm not sure that the company is totally aware that there are issues, in terms of [a protocol that subsequently will have employees in an area with more exhaust exposure]. They've made some attempts to correct the problem, but I don't think that they are aware of the long-term health effects on their employees.”

Two subjects were worried about certain health effects because they had seen what happened at their workplace with their colleagues over the years. One subject said,

“Cancers, I definitely think about that. My lungs are somewhere in my body, and down the road, I've seen older retired conductors and engineers not live too long after retirement. They have all kinds of respiratory issues, and I'm not sure if it's all related to DE over the years, or how it all came about. But I have noticed that, I worry about that, I think about it, and I try to avoid it if I can.”

The other subject said,

“At the time, being ignorant, for the first 20 years plus, you are blissfully happy. And as one ages, and you're succumbing to diseases, and you're burying your friends, the picture gets bleaker.”

Two subjects felt that the exposure has taken its toll on their health; one subject said,

“Well, it took its toll on me, I was always concerned about the continuous exposure, but sometimes it didn't bother me, and it took some time to build up to the point that I'm now hypersensitive to it, to all petro-chemicals actually.”

The other subject said,

“But other than that, it's like exposure to red cedar, it doesn't affect everybody, it just affects some, and I'm one of the people who is really affected by the DE.”

3.7 DE Perceived as a Hazard

The subjects were asked *“what are top five hazards at your workplace, if you could name any hazard?”* See Appendix A for the order in which this was asked related to other questions. Out of 29 subjects who responded, 19 (66%) included DE as one of their top five perceived hazards, while the other 10 subjects did not.

Table 5 shows the top five perceived occupational hazards in categories determined with guidance from a list of hazards from Occupational Safety and Health Administration (99).

Table 5: Subjects' Perceived Top Five Occupational Hazards.

| Hazard Categories | Top Perceived Hazards Listed by Subjects (Frequency) |
|--------------------------|---|
| Safety | Motor Vehicles (14), Slips Trips and Falls (13), Physical Injury (10), Fire (4), Electrical Hazards (4), Machinery Failure (4), Weight of Diesel Engine (3), Explosions (3) |
| Biological | Pathogens (3), Viruses (3), Toxins (2), “Needles” (2) |
| Physical | Aggressive People (7), Drowning (3), Noise (3), Vibration (2), Dehydration (2) |
| Ergonomic | N/A |

| Hazard Categories | Top Perceived Hazards Listed by Subjects (Frequency) |
|-------------------|--|
| Chemical | DE (19), Asbestos (4), Fiberglass (4), Fire Smoke (3), Paint Enamel (3), Other Fumes (3), Solvents (2), Cleaning Agents (2), Welding Exhaust (2), Chemical Hazards (2), Handling of Fuel Systems (2) |
| Work Organization | Stress (6), Fatigue or Sleep Deprivation (4), Shiftwork (2), Workplace Violence (2), Unhealthy Lifestyle (2), Cardiac Issues (1) |

After the subjects named their top five perceived hazards, they were asked to put each of the named hazards on a scale of one to five, in terms of likelihood that the hazard would occur at the workplace, with one being “will not happen”, two being “might happen”, three being “likely to happen”, four being “very likely to happen”, and five being “sure to happen”. Then, they were asked to put each of the named hazards on another scale of one to five in terms of severity of the consequences, if the hazard was to occur, with one being “normal”, two being “mild”, three being “moderate”, four being “severe”, and five being “extreme”.

The ranking results for DE vs. the other named hazards were compared, using only the 19 subjects that included DE as one of their top five perceived hazards. The other hazards listed by each subject were grouped together and the average was obtained. Regarding the subjects’ perceived likelihood of the hazard occurring at the workplace, the average was 4.0 for DE, and 3.2 for the other hazards. According to a Wilcoxon signed-rank t-test, the difference was statistically significant ($p < 0.01$). Regarding the subjects’ perceived severity of consequences if the hazards were to occur, the average value was 3.7 for DE, and 3.2 for other hazards ($p > 0.05$).

3.8 Exposure of DE vs. Other Inhalational Hazards

Twelve inhalational hazards other than DE were named by the subjects as their top five hazards. These were “*pathogens*”, “*toxins*”, “*viruses*”, “*fire smoke*”, “*chemical hazards*”, “*paint enamel*”, “*solvents*”, “*cleaning agents*”, “*welding exhaust*”, “*asbestos*”, “*fiberglass*”, and “*fumes*”.

The inhalational hazards that were ranked lower in likelihood as compared to DE were “*pathogens*”, “*toxins*”, “*viruses*”, “*asbestos*”, “*fiberglass*” and “*chemical hazards*”, as Figure 3A shows. “*Fire smoke*”, “*paint enamel*”, “*solvents*”, “*cleaning agents*” and “*welding exhaust*” were ranked the same as DE in likelihood, while “*fumes*” were ranked to be more likely to occur than DE. Meanwhile, the inhalational hazards that were ranked lower in severity by comparison to DE were “*pathogens*”, “*viruses*”, and “*cleaning agents*” as Figure 3B shows. “*Solvents*”, “*welding exhaust*” and “*fumes*” were ranked to be as severe as DE. Meanwhile, “*fire smoke*”, “*chemical hazards*”, “*asbestos*”, “*fiberglass*”, “*toxins*”, and “*paint enamel*” were perceived to be more severe than DE.

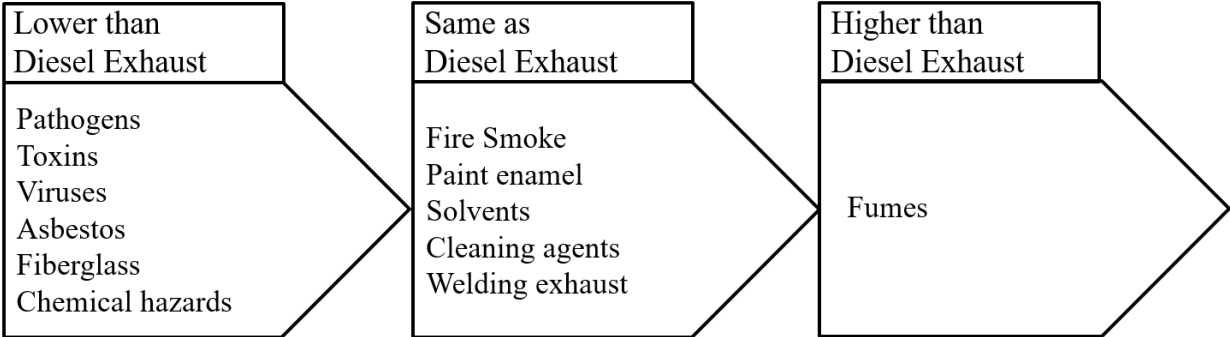


Figure 3A. Subjects' perceived likelihood of DE vs. other inhalational hazards.

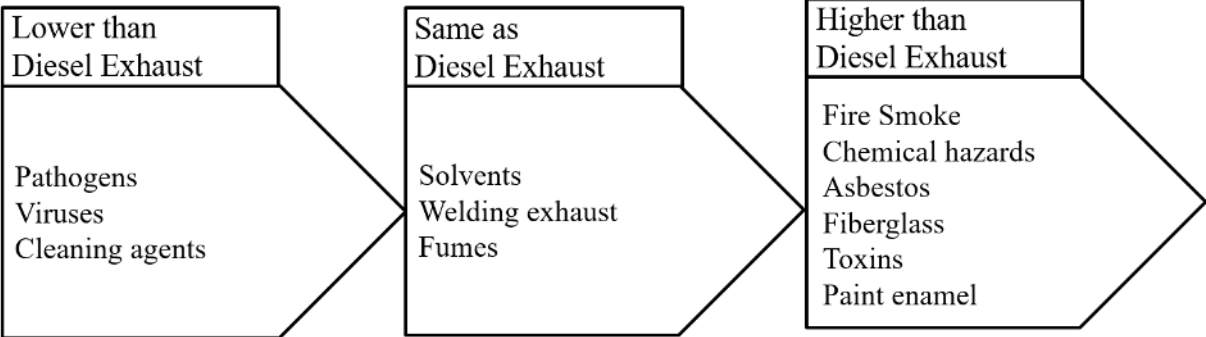


Figure 3B. Subjects' perceived severity of consequences due to DE vs. other inhalational hazards.

The reasoning for the rankings of DE and other inhalation hazards seemed to be subjective and based on personal experience. One subject said:

“I would say particles and exposure from fires, and same from DE. Everyone knows how dangerous smoke is. Those two things are number one.”

Another subject said:

“I would say paint enamel is a four or a five. That really put me over the edge, that stuff is dangerous.”

3.9 Health Effects of DE

The subjects were asked about the health symptoms that they experienced after describing a situation at their workplace when they felt like they were being exposed to DE. Twenty-six subjects answered this question, as shown in Table 6.

Table 6: Subjects’ Symptoms during Exposure to DE.

| Symptoms Mentioned | # with Symptoms |
|--------------------------------|------------------------|
| Feel nauseous | 6 |
| Have headaches | 6 |
| Have difficulty with breathing | 6 |
| Cough or wheeze or gag | 6 |
| Have sore throat | 3 |
| Feel dizziness | 2 |
| Need inhaler | 1 |
| Need to go to hospital | 1 |
| Feel lethargic | 1 |
| Get it on skin | 1 |

Eight of the 26 subjects did not have any symptoms, though five of the eight subjects thought that the DE was still “smellable” or “noticeable”, while three of the eight subjects thought that the DE was

“overwhelming” or “noxious”. Therefore, the symptoms mentioned in Table 6 were mentioned by 18 of the study subjects.

The subjects were asked “*Can you tell me what you think would happen to a person as a result of DE exposure?*” They were asked to name as many health effects as they could. Out of 30 subjects who answered this question, 21 subjects (70%) mentioned some form of respiratory issue, 17 subjects (57%) mentioned cancer, three subjects (10%) mentioned headaches, three subjects (10%) mentioned throat irritation, two subjects (7%) mentioned eye irritation, two subjects (7%) mentioned circulatory system issues, two subjects (7%) mentioned nervous system issues, and one subject (3%) mentioned each of the following: nausea, throat deterioration, birth defects, allergy to diesel, and toxicity to body. One subject mentioned multiple sclerosis, and then said,

“I’m thinking of terminal diseases linked to diesel, but I don’t know which one.”

Four out of the 30 subjects (13%) said that they did not know and did not participate in naming any of the health effects mentioned above.

The 21 subjects who mentioned some sort of respiratory issue used the words “*issues*”, “*problems*”, “*damage*”, “*disorder*”, “*disease*”, or “*failure*” to describe the “*airway*”, “*respiratory system*”, “*lung*”, “*bronchial system*”, or “*breathing*”. Seven study participants mentioned asthma. There were four mentions of Chronic Obstructive Pulmonary Disease (COPD), and four mentions of emphysema; two people mentioned both COPD and emphysema (which is part of COPD), two people mentioned COPD without mentioning emphysema, and two people mentioned emphysema without mentioning COPD, while one of the subjects said,

“Emphysema, but is that something along the lines of cancer, or is that different?”

There was one mention of reduced lung function, and one mention of bronchitis.

Out of the 17 subjects who mentioned some form of cancer, 11 said “*cancer*” without specifying the type of cancer, while one person specified that the cancer would occur “*only in late 60’s or 70’s*”. There were two mentions of “*some kind of cancer*” without specifying the type of cancer. There were two mentions of specifically “*lung cancer*” while one subject added,

“I wouldn’t be surprised if it causes lung cancer.”

One subject specifically mentioned leukemia and another subject said that the “*nanoparticles are carcinogenic.*”

Four subjects did not name any health effects. One of the subjects added,

“Well, to be honest, my coworkers and I have worked there many years together, and they worked there for 30 years or more, and they retired at 55, and they seem to be living! I actually don't see people really dropping like flies, so if I didn't know better, people seem to be resilient to it.”

Another subject said,

“Cumulatively over a number of years, who knows? Because we are exposed to it on a daily basis, we're exposed to urban air on a daily basis as well. You hear studies releasing that hydrocarbons are bad, who knows what the effects could be.”

Another subject said he did not know but specified the breathing and lungs at the same time,

“I have no clue, I was hoping that you would tell me. I don't know. I don't know if it affects their breathing, or their lungs, or long-term, or not.”

Yet another subject said:

“With prolonged exposure - well I'm not really sure, and it's one of the reasons I wanted to be in the interview.”

These subjects said they did not know which health effects were caused by DE, but it is worth noting that they did not say that DE did not cause any health effects. Two of these subjects stated that they would like to know more about the health effects.

Regardless of whether or not the subject mentioned cancer, each subject was asked later in the interview, “do you think DE is a carcinogen, meaning something that causes cancer?” Out of 30 subjects, 23 subjects (77%) said yes, five subjects (17%) said that they did not know, and two subjects (7%) said no. Regardless of whether the subject agreed or disagreed to DE being a carcinogen, or admitted that they did not know, it seemed that none of the subjects had any evidence to support their opinion. One subject after agreeing that DE was a carcinogen said,

“That's common sense, isn't it? Is there any healthy smoke on this planet?”

Another subject said,

“I do, but again, it's an assumption, it's something that I believe but I don't know why, I can't validate why I think so, but I feel like I have this knowledge that it's carcinogenic.”

When one subject disagreed on DE being a carcinogen, he said,

“I don't think so, no. But I don't know enough, I'm not a doctor. But I don't think so.”

When one subject admitted that she did not know, she said,

“It could be, I don't know. I definitely think it's unhealthy though.”

Another subject said,

“Uh-oh. I hope not! I assume it would, but I don't know that. It can't be good for you. I'm going on the blissful ignorance method here; it might not be the best.”

3.10 Trusted Sources of Information

The subjects were asked about the sources of information that they would trust, as Table 7 shows. Some of the most mentioned sources included WorkSafeBC, the internet, doctors, Health Canada, and the workplace. When answering this question, some subjects also disclosed the sources that they might trust but that they had hesitation about, or the sources that they did not trust.

Table 7: Subjects' Sources of Information.

| Sources of Information | # Subjects that Mentioned Source | % (within the # <i>Subjects that Mentioned Source</i>) that Trust Source |
|--|---|---|
| WorkSafeBC | 22 | 59 |
| Internet | 21 | 90 |
| Doctors | 14 | 86 |
| Employer | 14 | 36 |
| Unions | 10 | 30 |
| Health Canada | 9 | 100 |
| Health and safety committee | 7 | 29 |
| Universities and research studies | 5 | 100 |
| Libraries | 5 | 100 |
| Colleagues | 4 | 50 |
| Government | 4 | 50 |
| NIOSH | 3 | 100 |
| BC Cancer Research Centre | 2 | 100 |
| US Environmental Protection Agency | 2 | 100 |
| Newspapers | 2 | 100 |
| Firefighter associations | 2 | 100 |
| Information recommended by media | 2 | 100 |
| PubMed | 1 | 100 |
| National journals and reference materials | 1 | 100 |
| Centers for Disease Control and Prevention | 1 | 100 |
| OSHA | 1 | 100 |
| Coastal Health | 1 | 100 |
| Ministry of Health | 1 | 100 |
| Health authorities | 1 | 100 |
| National Resources Defense Council | 1 | 100 |

| Sources of Information | # Subjects that Mentioned Source | % (within the # Subjects that Mentioned Source) that Trust Source |
|------------------------------------|----------------------------------|---|
| Green Fleets | 1 | 100 |
| Canadian Auto Workers | 1 | 100 |
| BC Medical Association | 1 | 100 |
| BC Lung Association | 1 | 100 |
| Environment Canada | 1 | 100 |
| Mayo Institute | 1 | 100 |
| Government-issued American studies | 1 | 100 |
| Television | 1 | 100 |
| Private agencies | 1 | 0 |

Out of 30 subjects, 22 subjects mentioned the health and safety agency WorkSafeBC, with 13 naming the agency as a source of information that they would trust; one subject said,

“WorkSafeBC would be one of the first resources that I’d look to.”

Five people trusted the agency with hesitation; one subject said,

“I trust WorkSafeBC but I don’t think they do nearly enough; the people who need it are denied privileges and benefits, and you get the other half who are scamming who don’t have an actual injury who’s milking the system and it costs employers.”

Four subjects said that they did not trust WorkSafeBC because of prior experience with the agency; one subject said,

“I’m a little skeptical of WorkSafeBC, as I have had dealings with them throughout the years. I’m skeptical to their mandate that is not necessarily in the workers’ best interest.”

And another subject said:

“WorkSafeBC is, well, corrupt. They are going to cover [the employer]’s butt, no matter what.”

Twenty-one subjects, or more than two-thirds, mentioned the internet, with 19 trusting the internet. Eleven of the 19 subjects said that if they needed information, the first thing that they would do was to “Google”, meaning to use a search engine such as Google to find information online. Other subjects have used the words “*easy*” and “*accessible*” to describe Google. Some of the subjects had interesting strategies for their Google searches. One subject said,

“I would Google it. But if it were some massive corporation like WorkSafeBC, I would take it with a grain of salt because I don't think they would be posting the truth.”

When asked further about which groups she trusted for information, she said,

“Well, I would read all the information, what they are posting about everything, and if I agree with things that I already know, then I would find that information more credible.”

Another subject said,

“[...] I would Google the 'health effects of diesel', with all the stuff that would come up, I'd tend to look at stuff that's more familiar to me, or more reasonable, and with links to university projects and things like that.”

Another subject suggested Googling “*the health effects of diesel fumes*” while another subject suggested “*the health effects of driving a bus*”.

Three Google search phrases were suggested, and so a Google search was conducted with each of the three phrases as Appendix E, F and G show. When the search phrase “*health effects of diesel*” was used, the first page of results showed articles from reputable sources such as US Environmental Protection Agency, American Cancer Society, and OSHA. It also provided a link to a scientific journal from 2001 describing health effects of DE emissions: “*Epidemiological studies have demonstrated an association between different levels of air pollution and various health outcomes including mortality, exacerbation of asthma, chronic bronchitis, respiratory tract infections, ischemic heart disease and stroke (100)*”. Furthermore, the journal went on to describe that “*acute effects . . . include irritation of the nose and eyes, lung function changes,*

respiratory changes, headache, fatigue and nausea. Chronic exposures are associated with cough, sputum production and lung function decrements.” There was also a Wikipedia entry about DE on the first page of results that included results from the DEMS study conducted by NIOSH, as well as health effects associated with DE exposure such as cardiopulmonary disease and lung cancer (101).

When the search phrase “*health effects of diesel fumes*” was used, the first page of results showed many of the same articles as the results from the phrase “*health effect of diesel*” such as US Environmental Protection Agency, American Cancer Society, and OSHA. It also included the Wikipedia entry. Instead of the 2001 scientific journal, it featured the IARC announcement of its re-classification of DE as *carcinogenic to humans* in 2012 (43).

When the search phrase “*health effects of driving a bus*” was used, the first page of results showed articles from sources such as International Transport Workers’ Federation, and a Transit Union in the United States. However, the health effects described by the articles were not related to DE, and instead with hazards such as stress, assault from passengers, and poor ergonomics (102, 103). There was also an article from the European Agency for Safety and Health at Work, which included in the list of “main physical hazards and risks” for the transport section: “*inhalation of vapours and fumes, handling dangerous substances (exhaust fumes, chemicals on-board, fuel, road dust exposure while loading, unloading and at rest stops, washing and preparing vehicle* (104).” However, no health effects were listed on this web page.

Other subjects used the internet but used methods other than “Google” to search for information online. One subject said,

“I would go on the internet. NIOSH has a bunch of websites, and there are all sorts of research papers online, in PDF, so you can look at them.”

Another subject had a similar method,

“I have gone on the internet, and checked the Health Canada websites and the EPA in the States, reading some articles on there. I wouldn’t believe everything, but I’d look at it, and think whether it’s reasonable and if so, then I would believe it. It’s as simple as that. I’ve come to learn that at the end of the day I have two options, either I continue to work in this environment or I don’t. And if I continue to work here, then I have to minimize the exposure or else I’m putting myself in long-term risk.”

Two subjects would trust the internet but with hesitation; one subject said:

“Everything that I read on Google, I take it as somebody’s opinion, and not written as law.”

None of the subjects who mentioned the internet said that they would not trust the information from the internet, but did not provide a reason.

Fourteen subjects mentioned their doctor, with 12 trusting their doctor and two trusting with hesitation; one subject said,

“I don’t know where I would go, maybe my family doctor but only if I’m quite ill or something.”

Out of 30 subjects, 14 mentioned the employer, with five trusting the source, five trusting with hesitation, and four not trusting their employer. One subject who would trust information from his employer said simply,

“I would trust my boss.”

While another subject said,

“I would refer to material safety data sheets available [at work]. I would look for toxicity warning on the product cans that had diesel in it.”

One subject, by the nature of her job, felt that even though she would trust the workplace, she did not have access to the information because of logistics reasons,

“Sure, there are bulletin boards, and WHMIS for the stuff that’s on the work site, but when it comes to being [a heavy equipment operator], you really don’t see a lot of it, because you’re in an industry

where you're always moving. I might be at one job for two weeks, then I'll be at another job for two weeks, and so on."

Another subject would trust information from his workplace, with a caveat,

"Surprisingly enough, I would trust the info if it came through the company's health department, because [in his personal experience, there was another scenario he described], where they would go away or around from any reasonable steps. Since they usually wouldn't disclose things, if they are to disclose that DE does this and that, I would trust them."

There seemed to be mainly two reasons for subjects to not trust their workplace, either that they didn't believe that the workplace had adequate resources, or that the workplace had interests other than safety. One subject said,

"I would say that there are no resources here at [the workplace] because I am not aware of anything offhand, and I'm pretty good at knowing what's available around here, so if I don't know easily, then probably others won't know either. So I would say there's nothing readily available around here."

Another subject said,

"I would not trust [the workplace] because they have other interests other than safety."

Out of 10 subjects who mentioned unions, three subjects trusted the source, while one subject had hesitation, and six subjects would not trust the source. Said one subject,

"I used to work [at another workplace] where we would have tailgate meetings. These were the workers themselves doing the conversations with the bosses telling the employees to be careful of this and that, and that only happens where you have strong unions."

To the contrary, said another subject,

"From past experience, they just don't bother, it's extra work and they just sweep it under the rug."

Nine people mentioned Health Canada, with all nine of them trusting information from the agency, although one subject said,

“I might say Health Canada but I’m still not sure if they would have the information.”

Out of 30 subjects, seven subjects mentioned the health and safety committee at their workplace, with two people trusting, two people trusting with hesitation, and three people not trusting the committee. One subject who would trust information from his committee said,

“[I would] talk to our health and safety committee; they're really good about putting us on documentation, or give us online stuff, or books.”

On the contrary, another subject said,

“I don’t trust [the safety committee at the workplace] would have the answers or care to say the truth, because then it would be held against them, which has happened in different situations.”

Out of five subjects who mentioned universities and research studies, all five said that they would trust the information, while one subject said,

“I want to know where the study is coming from, and I like your study being from UBC (University of British Columbia), and it has to do with the workplace.”

Five out of 30 subjects mentioned libraries, and all five subjects said that they would trust the information from libraries but did not provide any reason.

Out of four subjects who mentioned their colleagues, two subjects said that they would trust the information; the first thing that one subject said was,

“Well, the people at my [workplace], yeah.”

On the contrary, two subjects said that they would not trust their colleagues; one subject said,

“I was [wearing a mask], and people make smart-ass remarks, from all the [colleagues], there’s no help from them.”

Out of four subjects who mentioned the government, two subjects said that they would trust the information; one subject said,

“[I would trust] anything that’s regulated by the government.”

Another subject said,

“I would look for any sort of studies that were government-issued, and what I would look for is something that’s not of private interest. I’d like to see something where someone is giving me information as opposed to giving me an opinion.”

Meanwhile, two subjects said that they would not trust the government. One subject said,

“I probably won’t trust any government agencies; I tend to take with a grain of salt. Not-for-profit agencies, I tend to have a bit more faith in because they have no reason to skew things one way or another.”

Other sources of information that were mentioned that some of the subjects would trust are included in Table 3, listed from most-mentioned to least-mentioned: “*NIOSH*” (US National Institute for Occupational Safety and Health), “*BC Cancer Research*”, “*EPA*” (US Environmental Protection Agency), “*newspaper*”, “*Firefighter Associations*”, “*info recommended by media*”, “*PubMed*”, “*national journals and reference materials*”, “*CDC*” (was not clear whether the subject was referring to the US Centres for Disease Control and Prevention or the British Columbia Centre for Disease Control), “*OSHA*” (US Occupational Safety and Health Administration), “*Coastal Health*”, “*Ministry of Health*”, “*health authorities*”, “*National Resources Defense Council*”, “*Green Fleets*”, “*Canadian Auto Workers*”, “*BC Medical Association*”, “*BC Lung*”, “*Environment Canada*”, “*Mayo Institute*”, “*government-issued American studies*”, and “*television*”.

One group mentioned by one subject that was not deemed as trustworthy was “*private agencies*”.

3.11 Talking to Others about Their Exposure of DE

The subjects were asked to describe in detail a scenario where they talked to someone at their workplace or outside of their workplace about their exposure to DE. The purpose of this question was to get more information about their thoughts and concerns, as well as sources of information that they trust, that may not have been covered in other sections.

Six subjects discussed talking to their colleagues about their shared experience of being exposed to DE; one subject shared how he and his colleagues were motivated to keep working because they had to make a living,

“Once in a while, someone is coughing up a lung, and we would say that this is the work, we got to do what we got to do, there's no way around it, we want to get a paycheque, so we got to do it.”

Another subject shared about his colleagues and his collective concern,

“[DE] comes up in day-to-day conversations, talking with my coworkers. We are curious what the health effects are, we're not happy about it, and also we are concerned.”

Another subject said,

“Everyone agrees that it can't be good because all around our work location, you can see where the DE went, the dark spots where the DE shoots out, and we think if it's going there, then it's obviously going into our lungs. We've talked about it and we're aware of it, but that's as far as it goes, just talking about it. Though there are some coworkers who just don't care, they seem to be older, and think that if I'm okay for this long, that I'll be okay for however much longer.”

Yet another subject talked about training his more junior colleagues,

“Well, I have the most seniority in my level now so I do training with the newer guys, and I'd touch on it. When it's really bad, I'd tell them to use HEPA filter masks, though I don't wear them as much as I

should myself. The younger guys are actually pretty good with safety because they were in that generation where they hear more about the safety stuff. The big one is getting the fans on and ventilation going.”

Six subjects, when mentioning about talking to their colleagues, also mentioned that they have had colleagues die, and one subject mentioned his colleagues sustaining carbon monoxide poisoning and taken to hospital. Here are some of their experiences,

“There’s quite a bit of solidarity at work, we went to the funerals of 5 employees who died of cancer, mostly after working there for 30 years or more and retiring, one before [retiring]. We also supported them while they were living.”

“Since I’ve been there for 6 years, we’ve had 4 guys die of cancer, out of 30. They don’t say that it’s directly linked to [DE] but we know that it plays a part.”

“I talk about it with colleagues. We have a guy who just retired, and he ended up with lung cancer. He was never a smoker, he had throat cancer, and now lung cancer. He was exposed to burning sulfur, and people are talking about how that could have caused the cancer, but I think it is the long term effects of DE. Also, we’re exposed to coal. [...] We’ve had a lot of exposure to different stuff.”

“It’s really too bad, my [colleague and] neighbor, that he died because he would’ve been a great guy, and perfect for your study. He was around when there was heavy-duty diesel since 18 and he died at 48. The DE has gotten better, but I still believe that it’s dangerous. I only have a few years until I retire, that’s why I’m hanging in there. [The employer] would always argue, well you can go and find another job, if you believe that. Some of the stories that [my colleague] told me over the years about his exposure to DE. That’s why they never did an autopsy on him. He got cancer, and 3 weeks later he

was dead. It's too bad because his widow was grieving and you don't go and ask those questions.”

“When colleagues make remarks about my mask, I'd say ‘Hey remember this fella? He worked here for 20 years, and what happened? Three years later, he died of lung cancer’, you know? It's usually the young guys. I try to educate them and tell them ‘if you're going to be here for a long time, protect yourself now’ because you have no idea what is the effect of prolonged breathing in the DE. The only thing that you're taught in training is about the bus, make sure you have all your paperwork filled out.”

“We had a problem with the small buses, where we had half a dozen drivers throughout the province, when they were out on the route sustain what it seems carbon monoxide poisoning, and a couple of them were taken to the hospital. We have not been able to pin down why or where or how those fumes got into the drivers' bodies.”

One subject gave a run-down of how his colleagues' and his complaint to the health and safety committee, the employer, and WorkSafeBC didn't go anywhere,

“[WorkSafeBC] never said that they can't help us. What happened is that we made a formal complaint to the health and safety committee, and they make a formal complaint to the company, it is formal and in writing, then they have a meeting, and then it never goes further than that. When we asked WorkSafeBC to come in, they say that you have to go through the health and safety committee first, before they can do anything. Then when WorkSafeBC gets involved, they don't have any authority to make changes at our workplace. They can't even get on the property.”

When asked whether WorkSafeBC gave the subject and his colleagues any suggestions, he said,

“Wear respirators. But a lot of time, the respirators are cumbersome, and they're very difficult to wear on a daily basis. They hinder our job performance.”

Another subject talked about how the resources at her workplace were not very helpful,

“When we had the occupational health nurse come out to the property, I asked her why there aren't any fans that blow the exhaust away from my workspace, and she said that it's minimal exposure that I have to DE, and it's not a worry. After that, I [have taken down my sails] of thinking that my company would look into it. Yeah, she's a company hired nurse. Probably 3 years ago. Yeah, I've also talked to the union, and same reply, it's minimal, the company has told them that it's minimal, don't worry about it. But I haven't seen any paperwork that proves it.”

Five subjects discussed with their doctors though their doctors weren't able to help much, said one subject,

“There's not a whole lot that [the doctors] can do. [They just recommended] pretty much all that we've said, minimize contact, stay away from [DE] as much as possible, but it's not really feasible.”

Another subject said,

“I told [my doctor] about when I went to the hospital [after exposure to DE], and he said what can you do about it? And I told him I'm wearing a mask, and he told me to keep wearing my mask, if it's helping me, to keep wearing my mask. Maybe if I wear my mask every day, then I would get more exposure and start conversations.”

Yet another subject said,

“I went in for something else, and an allergy specialist and a lung specialist, wanted me to be tested, because I was having a lot of problems breathing, and I had these nasal polyps, and as I said, the allergy specialist checked me out, and said that the other allergies that I have were environmental and were very minor, but it's the DE that was getting to me. But since I've been away from the work site, and not exposed on a daily basis, I'm feeling better. But the damages also have been done.”

Outside of the workplace, most subject chose not to talk to anyone about the occupational exposure

other than doctors. However, one subject talked to his mother, who was familiar with the exposure herself,

“It's funny, I speak to my mother because she actually works for a trucking company. She is the safety rep. So I've spoken to her about it, what she thinks about it, and she has told me that she has paperwork about how it links to leukemia and other cancers, and there's long term effects for it. And to be honest with you, I haven't talked to her about it in a while, but I talked to her about it today, because I was coming here, and she was going to pass off all the information that she has about DE as well, so hopefully I'll learn a little bit more from her. So that's about it, just my mother outside of work. She knows it's bad, she knows it can't be good, and she says that her workplace, they're very strict about that, they can't be around diesel that they need to have exhaust fans and she's quite shocked that I don't have that at my workplace being a government agency and everything. But we don't.”

Two subjects chose not to talk to anyone at the workplace or outside of the workplace. One said,

“To be quite honest, I just choose not to, because [the employer] would just minimize it and not consider it, and people would do it day-in and day-out and no one says anything about it because it's their job. That's the real sad reality, and I feel sorry for the mechanics because they work in a closed environment, and they have these things where the DE comes out and they have monitoring devices ‘blah blah’, but they're closer to the exhaust, and they have to check the buses, and in my opinion, they're closer to it more than I am. Would be cool to get a perspective from someone at the garage.”

Another subject said,

No, I understand the risks of my job. I have a choice, if I don't want to be exposed, I don't have to stay there. I can get away. Or I can get transferred, or I can quit. But at this point in my career, I won't be going anywhere. Because I really just have five and a half years left, so I'll just be sticking it out now.

3.12 Information from Recent Media Sources Regarding DE

The subjects were asked if they have heard anything in the media recently regarding DE. Out of 30 subjects, 23 said that they did not hear anything in the media recently regarding DE. One of the 23 subjects said,

“No I haven’t heard anything, and I’m a news junkie.”

Out of the seven subjects who heard something in the media recently regarding DE, four subjects mentioned something that was specific to the health effects of DE. One mentioned hearing something on the BBC radio about individuals working with DE having higher incidences of cancer,

“It was maybe six months ago? And it didn’t sound favourable.”

When asked for thoughts on hearing about this, she said,

“I wondered about it, and I was talking with a coworker friend. I can’t believe people are dying, from a terrible lifestyle and diet, and being overweight, and now also breathing in diesel fumes. But people seem to be living afterwards. So I question it, it seems to not fit with what I see at the workplace. I would love to shoot down DE, but I have to be honest, what I see is shocking that people are living. My friend is working, so I think he doesn’t want to admit that DE is bad for him. People just accept that DE is there, I don’t think people are really thinking of the negative implications of DE.”

Another subject mentioned hearing on the radio about the World Health Organization’s declaration of DE as carcinogenic. Another subject mentioned seeing newspaper headlines about it being cancerous and that it was just as bad as smoking. Yet another subject said,

“Over the years I’ve heard stuff on TV or in newspapers where they write articles about it being bad for your health and is toxic,” adding the caveat that *“there isn’t that much information out there really.”*

Another subject said that he has not seen anything about DE “*for a long time actually*”, but that he watched a documentary approximately five years ago, about “*transportation workers in the United States.*” Another subject talked about the emission levels listed in trucking magazines. Lastly, one subject mentioned hearing that the local transportation company was going to stop testing passenger vehicles and instead focused more on buses and heavy trucks, but did not mention about the source of the information.

3.13 Actions to Address the Exposure of DE

The subjects were asked about all the actions that they took at their workplace to address DE exposure and they were asked to name as many as they could. Their responses here are organized by the different methods of hazard control: personal protective equipment, administrative controls, and engineering controls. The 4th hazard control, elimination, is not listed here as none of the responses fits into that category. Here is an additional category of no action, applied to occasions when the subjects decided to not take any actions to address the DE exposure.

3.13.1 Personal Protective Equipment

Five out of 30 subjects mentioned using personal protective equipment to address the DE exposure, via a mask with either a filter or a cartridge. Only one of the five subjects said that she and her coworkers wore the masks regularly. The other four subjects mentioned using a mask with a few caveats: one subject only used it for a few weeks,

“I did buy a mask or a respirator. And I used it for a while. And then I asked the safety and training rep, ‘When is the company going to purchase masks for us?’, and he just laughed. He said ‘It’s not going to happen’. It’s too expensive to buy on our own. I don’t wear it anymore. It’s kind of a pain in the neck. And people make smart-ass remarks, from all the other drivers. I stuck with it for a few weeks. I only use it when it’s really cold out, zero to two degrees, or below zero, then I’ll wear it.”

One subject only used it during leaks or during chemical spills while another subject only used it while he was painting,

“What could I do [when responding about the actions that he takes to address being exposed to DE at his workplace]? I was wearing a respirator when I was painting, but other than keeping ventilation fans going, there was not much that I could do.”

Another subject believed that masks were only for some people, and he himself chose to not wear masks,

“Some people react to it more than others, so if one person reacts to it, then he should wear a filter mask.”

Other than masks, two people mentioned the use of rubber gloves when handling the diesel fuel, with the caveat that only “*the kids*”, meaning the younger employees, would wear them.

3.13.2 Administrative Controls

The subjects mentioned addressing DE by an administrative control, meaning a control that altered the way the work was done. Specifically, 14 out of 30 subjects mentioned being aware of sources of DE and avoiding these sources, which one of the subjects called “*situational awareness*” and described it as being aware of “*the weather conditions, which direction the wind is blowing, trying not to be downwind from the exhaust*”. One of the other subjects talked about avoiding DE with the caveat of hurrying parts of the job,

“Many [of us] will go and do [a part of our job] quickly and it’s getting more rigorous and there’s more paperwork, so if we miss something in [a part of our job] and there’s an accident because we didn’t want to smell the diesel fumes, the law will come down onto us”.

Six subjects mentioned holding their breath as a strategy to address the exposure of DE. One subject believed that this action is sufficient because “[*the exposure*] only take a few seconds, right?” This is how another subject described this action,

“Geez, I can't think of anything [else]. I hold my breath when a big cloud is coming towards me, but that probably doesn't help.”

Another subject said,

“[I'd] hold my breath for as long as I can. I'll put a cloth or part of my shirt over my nose and mouth.”

Yet another subject said,

“If I see a situation where there's a lot of diesel smoke, I try to avoid it, like holding my breath or turning to another direction.”

Two subjects filled out exposure or incident forms. However, the two subjects had different thoughts on how best to keep records of occupational exposure: one advocated for keeping a record of all the exposures that one had throughout a career, while the other subject thought that it was not a useful system as he would realistically have to fill out paperwork every day which he did not do. He said,

“I've only documented when I went into the hospital. Or else I'll be filling out one every shift. Which is probably what it would take, for it to be recognized when it comes time of retirement. All of a sudden, your lungs are not working.”

The subject who advocated for keeping a record for all of his exposures said,

“[I've filled out the form] usually for smoke inhalation, or chemical exposure, or diesel, or unknown gases. The form asks about the kind of exposure, the duration, the kind of protective equipment you have on at the time, what did you do about it, what kind of medical attention was necessary, did you seek medical attention, and there are a couple of other things on there that I can't remember. We submit them to our health and safety committee. If we feel ill, then it becomes a workplace accident. If you seek medical attention, then it's a WCB thing. And these submissions follow you throughout your career. So at the end of your career, you can bring up your exposure list, and it'll tell you how many times you've recorded an exposure.”

Two subjects used a monitor or a carbon monoxide tester. One said,

“Some of the [other people] that I work with, they have monitors and they carry them on the waist of their belts, and if the exhaust gets really bad where they're working, because we do a lot of work besides traffic, and if it gets really bad, there's no wind and it's stale, the alarms go and we put on a mask, not quite a respirator, I have used respirators before, but most of the time it's just a mask, or you close your door or windows.”

The other subject said,

“whenever I'm [at work], I have my own carbon monoxide tester unit up on the dash with me, it has never ever gone off, so I don't know [if the level has been high enough for me to get sick as well].”

He went on to say,

“[A colleague] and I got our own units, little battery-operated units, and I went to the company and said you know what? It only costs me \$29.95, why doesn't the company just get everyone one, and they said no, because they might hold it down by the exhaust pipe and make it go off and say that the [vehicle] is no good.”

Four subjects mentioned fixing leaks as soon as possible to minimize the amount of DE in the air. Two subjects changed the timing and type of shift so that they were exposed to lesser levels of DE.

Four subjects mentioned idling less; one subject said,

“We try to shut down the engines as soon as possible, and as much as possible.”

One of the subjects was involved with a company-wide campaign to reduce idling,

“We've done public relations events, and instead of just having me do it myself, we had people from environmental consultant side, and there were displays up talking about the effects of the DE on the human body, and we also had up the numbers of how often the [vehicles] are sitting idling which we look at quarterly,

and also have it on a bulletin board. And we also put stickers on the ignition switch, “help clear the air, and reduce idling” to put the thought into the guys’ heads.”

Two subjects attended tailgate safety meetings to discuss with fellow coworkers about the exposure of DE. One subject said,

“We’ll have tailgate meetings to remind [colleagues], like ‘don’t let the [vehicles] idle, if it doesn’t have to be on, then shut it off”

Meanwhile, another subject said of tailgate meetings,

“Those are our safety meetings, [though] the most important hazard that we discuss is slips, trips, and falls.”

Each of the following actions was mentioned by one out of 30 subjects: Using better grade diesel, sending in maintenance requests, being familiar with equipment, and cleaning soot from pipes. One subject talked to the manager *“several times about my concern and tried to work shorter hours and less shifts, and ultimately I quit.”*

3.13.3 Engineering Controls

The subjects mentioned addressing DE by an engineering control which included modifying equipment, systems, and processes that reduced the source of exposure.

Three subjects mentioned using a more efficient engine with newer technology. One subject said, *“Mechanically it’s getting the DE burned more efficiently, then you’re not breathing in raw fuel.”* while another subject said that the newer engines are *“more efficient and less leaky.”*

Nineteen subjects mentioned ventilation, and many different methods were mentioned, to either increase airflow that introduced fresh air into an area, or to redirect or decrease airflow that included DE. Said one subject,

“Ventilation is key. They have exhaust systems, that’s all good. They’re pushing in cleaner, fresher atmospheric air. I’m in Prince George with two pulp mills, and they tell you that the air quality is so poor to stay in the house. But that’s hard to do when you have to go to the shop with the diesel fumes.”

In order to redirect fumes, one subject said,

“Two or three of us made fiberglass covers in the [area where the DE is] to avert the fumes. And it actually did make [the situation with the diesel fumes] better.”

Three subjects mentioned using an extraction system. Some of the firefighters mentioned having an extraction system that they hooked up to the fire truck when it went back to the fire hall, in order to extract the DE from the fire truck so that it didn’t distribute within the fire hall. Another suggested method to redirect exhaust was to have differently pressurized areas; one firefighter mentioned that the living quarters in the fire hall were more positively pressurized than where the fire truck was parked so that *“the DE goes out that way.”* In order to increase airflow, two subjects with occupations different from firefighters kept doors open. Said one of the subjects,

“That is natural ventilation, with the large doors opening, we’d have cross-ventilation.”

Five subjects mentioned using a fan; this could be a stationary fan if the workplace was indoors, or a portable fan if the workplace was outdoors on the field. In order to decrease DE in the workplace, three subjects mentioned using filters. Said one subject,

“The new and modern excavators, they have internal and external filters for the cab, or the part that you sit in. So keep your windows and doors closed. And use the ventilation system, and you have the ability to choose from drawing the air from within the cab, or from the exterior. If you’re smart, you can really control the diesel fumes in that respect.”

Meanwhile, another subject mentioned decreasing airflow close to the sources of the DE,

“If I’m next to a vehicle that’s spewing exhaust, then I would close my window. Oh, also there’s a vent at our feet at the front of the bus, [which] opens up in the summer. You can open it anytime that you want. It’s right at your toes, it lets cold air in, and it comes up your feet. I never, never, never, ever, open that. I always close it. Because it’s right at the height of the tail pipe. And a lot of other people open that vent and I can’t believe it!”

3.13.4 No Action

Two subjects said that they did not take any actions and so did not mention about any of the actions that were discussed above. It is worth noting that these two subjects, when asked if they knew the actual levels of DE at their workplace said they did not know. Said one of these two subjects,

“Since [they are] not high levels, I don’t really do much. I don’t wear masks. I just continue like nothing is going on. I just smell it.”

3.14 Recommendations to Better Address the Exposure of DE

The subjects were asked to share their recommendations for how to better address the exposure of DE at their workplace, whether it was by themselves, fellow coworkers, the workplace, the government, etc. They were asked to name as many recommendations as they could think of. Their responses here are organized by the different methods of hazard control: personal protective equipment, administrative controls, and engineering controls. The 4th hazard control, elimination, is not listed as none of the responses fits into that category. There is an additional category of ‘no recommendations’, applied to occasions when the subjects did not have any recommendations for how we could better address the exposure.

3.14.1 Personal Protective Equipment

The study participants had recommendations regarding the use of personal protective equipment. In summary, they recommended for the workplace to provide protective equipment as well as training to use the protective equipment. The equipment also needed to be practical to be use at their workplace.

Four subjects wanted the workplace to provide adequate protective equipment and the appropriate training to use the equipment. Said one subject,

“[The workplace] can provide proper protective equipment and training and let people know the actual hazards, potential hazards, basically give them all the tools to make the right decisions.”

Another study participant commented on the availability of masks and alternatives,

“What we’ve been given are not suitable. I’m sure there are other ones in the market that could work, but once again, it comes with a price. The workplace is not going to supply it, that’s the biggest thing, the expense. Even if there’s a regulation for the workplaces to provide the masks, I think they can come up with a better system to ventilating the exhaust out, there’s got to be better ways.”

Four subjects commented on masks being impractical for workplace use, and wanted another personal protective method other than masks to be provided. Said one subject,

“It’s not realistic to think that all workers will be wearing masks, we won’t. We have to talk a lot on two-way radios. So it can be dangerous if we’re not audible and heard clearly. Masks can be hot. It’s just impractical.”

Another subject agreed that the masks were impractical and had a suggestion for an alternative,

“[Workers] are still eating and breathing [the DE] because there’s no way around it, they can’t wear masks because it’s cumbersome and restricting, I don’t think the boss would go for it. Or the next one is the little gas masks, look at the Chinese and Japanese, they wear it daily from work, to work, to try

to get a little bit more life on this planet. We're not quite that bad at the workplace, but we can still have an improved filtration.”

Two study subjects wanted to see the use of personal protective equipment and training be made mandatory. One subject said,

“People need to be reminded that it is not optional to use [the protective equipment], your employers are telling you to use it, and the expectation is that you use it.”

3.14.2 Administrative Controls

The study participants had recommendations regarding the use of administrative controls, meaning controls that altered the way the work was done. In summary, the participants recommended for their workplace to formally recognize DE as a hazard, and to implement education, training, regular testing and regulations for such a hazard at the workplace.

Out of 30 subjects, nine of them recommended for workplaces to formally recognize DE as a hazard and to offer education or training about DE and health effects, actual or potential hazards, and appropriate actions to take. On the topic of education or training, one subject believed that the education would have made a difference on his career,

“The workplace can better educate their employees, with our bad habits, when I was younger, it’s because I wasn’t aware of the long-term health effects, but if we had proper education on exposure and how to avoid exposure, I wouldn’t have allowed myself to get into some situations that I got myself into.”

Regarding logistics, one subject recommended for the health and safety agency WorkSafeBC to conduct the education or training, while another subject recommended that it be done through the union or the employee assistance program at work. Another subject wanted education but not on bulletins,

“More education would be good, so more people would hold their breath [when they are near the DE].

I know I would hold my breath. Maybe with more education, because people are so sick of bulletins!”

This person went on to recommend for a suitable time for the education,

“Unfortunately if someone dies from something, maybe capitalizing from that, we really need to expose that, like why they died, and what they died from, and education people like ‘look, this person could be healthier and have a healthier life if they weren’t exposed to this or did everything they could to avoid it.’”

Another subject agreed, though he had a different recommendation for a suitable time for the education,

“I think there can be more [formalized education] when someone is hired. There should be more awareness made that [DE] is one of the things that you're dealing with at this workplace. And this is what you could do to help prevent, [for example] wearing masks, finding a different shift time, or [picking up the diesel vehicle somewhere else]. If the exhaust is causing you discomfort, these are things that you can do.”

Yet another subject agreed that education about the health effects of DE needed to be taken seriously,

“It would be great to give more information to employees who are affected, give links about studies that have been done on it. It needs to be taken more seriously. For years for me, I just put up with it. I suppose info [should go] to anyone who works with anything that emits exhaust, like DE, gasoline, etc.”

Four subjects wanted to see air quality testing for DE done at their workplace, while one subject said,

“I don't know if the technology is there yet, but if they can have some sort of sensor by where the workers work the vast majority of the shift, and they can see what percentage they're inhaling per shift.”

Another subject believed that it had been too long since air quality testing was done at her workplace,

“Well [the workplace] can definitely come down here for a visit and bring the air sniffers and measure the levels. In the 35 years that I've worked here, I've only seen people come here twice, once to

measure sound levels, and the other time it looks like it was for the fumes, it was around 25-30 years ago, they walked around with meters, but they didn't do anything else, and we never saw a report. There was probably a report to the higher-ups, but we were never notified of anything. I'd like to see them spend more money on studies and doing measurements.”

Another subject recommended having a bylaw:

“Let's say if a company knows that their employees are exposed, then they should measure the levels [of DE], and the policy makers can say if it's this level or above, then they have to wear a mask.”

When the subject was asked what that level of DE should be, she responded,

“I'm not too sure what is the daily limit in Vancouver, maybe 20ug/cubic meter on a daily basis then they have to wear a mask.”

In addition to testing the air quality, three study subjects suggested for the workplaces or health and safety agencies to check the employees' health or their lungs, to obtain a record of a baseline when they were hired and then regularly during their employment to obtain exposure-dependent data. One subject compared DE studies with hearing tests and said:

“Workers' Compensation Board or WorkSafeBC has a yearly or every two years hearing test requirement so that if you have hearing problems later on in life, they would have a record that you've been tested 30 times in 30 years, and your hearing has slowly gotten worse, even though you have worn the industry hearing plugs. Now they should do the same for diesel so you could test the person's blood or urine or lung capacity, I'm not sure how they actually test the lungs, but I think that's a recommendation in regards to going to the next step. If this is a pilot project, maybe that's where this should go, because [stuff] in the DE affects the human body the same way everything else does, so maybe this is something to look at.”

Another subject wanted a baseline from when he started his career as he shared,

“I know no employer would do it, but they should test people when they hire people on, like lung

capacity, to get a baseline. There are other factors too, like if you smoke, but if you have a baseline, then you can tell if there's a problem later on. With people like me, we don't have a baseline to say, this guy was perfectly healthy when they were hired on and now he has this asthma problem that we think has to do with DE.”

Three other study subjects suggested creating an inventory of the health effects of those exposed individuals; one subject said,

“[Either the workplace itself] or health researchers can go to the workplace to survey the employees, specifically one-by-one, what are your thoughts, your feelings, how are you doing, have you had any lung problems, any respiratory issues, and essentially research enough people so that you can get a straight answer.”

Seven subjects recommended for more regulations regarding minimizing or avoiding exposure in order to change how work was done. This could be done by minimizing the production of DE, for example with less idling. One subject believed that we needed to push harder to change the system,

“My company can actively go after all employees who are leaving vehicles idling unnecessarily. In other words, get the managers more involved, rather than just turning a blind eye. Big companies, it's hard and slow to change opinions and attitudes but we need to do that. We need to get people realizing that newer vehicles don't take a long time to warm up. [...] So the company can do more PR, and also go after people. Everyone wears seatbelts now, but in the 60's, you didn't. You also don't smoke in restaurants and hotels anymore. You have to swing the pendulum and push harder. You have to start somewhere and push it. We're not giving enough pressure.”

Said another subject,

“[There are] different measures that you can probably use, both facility-wise and procedure-wise to minimize potential exposure.”

Said yet another subject,

“[In situations with an extreme amount of DE], there can be some sort of regulation, like stand back 50 feet, or something, I don’t know if that’s enough to make a difference.”

The subjects’ statements such as the below suggested that if the management got involved, then it would be easier and faster to change individuals’ behaviour:

“My company can actively go after all employees who are leaving vehicles idling unnecessarily. In other words, get the managers more involved, rather than just turning a blind eye. Big companies, it's hard and slow to change opinions and attitudes but we need to do that. We need to get people realizing that newer vehicles don't take a long time to warm up. [...] So the company can do more PR, and also go after people. Everyone wears seatbelts now, but in the 60's, you didn't. You also don't smoke in restaurants and hotels anymore. You have to swing the pendulum and push harder. You have to start somewhere and push it. We're not giving enough pressure.”

At the same time, some subjects believed that they could do their own part in being responsible for their health and safety and physically removing themselves from certain situations to avoid the exposure. Said one subject,

“I’d say that we can’t really limit the exposure but we could remove ourselves from the environment.”

Other recommendations by the study participants included more signage about DE and health effects by one subject, while another subject recommended for more education and less signage. Also, one study participant recommended for the government to do regular inspection on all diesel engines and another suggested raising awareness about idling.

3.14.3 Engineering Controls

The study subjects had recommendations regarding the use of engineering controls, meaning modification of the equipment, systems, and processes that would reduce the source of exposure. In summary,

subjects recommended for more equipment maintenance and facility improvements, in addition to changes in the workplace that would increase ventilation, cut down on emissions, and change the fuel or the engine.

Four subjects recommended increasing ventilation:

“There would be ventilation for each [area section], that would essentially bring fresh air from outside, process the DE and put it on the other side of the [area where workers work at].”

This subject summarized by saying,

“Be a bit more aggressive with tactics to remove it from enclosed areas, proper ventilation to minimize exposure, tougher regulations.”

Another suggestion by two subjects was for the government to get involved and be stricter in cutting down emissions; one subject said,

“The government needs to crack down on emissions. The time frame or the allowed threshold is too generous. You have five or 10 or 15 years to cut down on your emissions to an acceptable level. They gave corporations 20 years to bring it down. I might not even be here in 20 years! I think it should be a short period of time, get it down, or you get fined. Same with these trucks, these big four-wheel drives, with black smoke. That's how you get black smoke with diesel, the filters are clogged down. There's a penalty, here's a ticket, get your truck maintained.”

Another subject said,

“I believe the provincial or the federal government, and I am not holding my breath on this one, should do regular inspections on all heavy equipment, heavy diesel engines, doesn't matter if it's a pick-up truck, a boat, a tractor-trailer, a bulldozer, a loader, or an excavator. Every piece of diesel equipment on planet earth, should be inspected by a federal inspector, can be passed off to provincial, whatever, that's fine with me. But I do not see an inspection that is working for DE. But only if you have license plates do you have to get your dump truck checked. But I don't think they check DE. It's very

unregulated. It needs to be as regulated as the automotive industry is in regards to making the gasoline engines run, not so much in terms of efficiency, but in environment sensitivity.”

Two people suggested for the government to regulate using better-grade fuel or a more efficient engine or an electrical vehicle at workplaces. One of the subjects said,

“Ideally, it would be great if we can go to electric vehicles, with less particles. I know [my workplace] has some, but the majority are diesel.”

The other subject suggested,

“Maybe the policy makers can regulate the DE a little better. I know that the new pick-up trucks, the exhaust is way better. You don't notice it as much, but they have that for pick-up trucks but not for trains.”

Another subject was happy with either better-grade fuel or a more efficient engine while he said,

“The government could put in place a law that requires all diesel engines to be converted to be able to run the ultra-low-sulfur diesel, and if not the engine can be treated with a catalytic converter so that the exhaust can be as clean as possible. I say that because I believe that the government will be requiring vehicles to have certain inspection criteria. That will be a good situation. I want to see something being done with the kind of fuel that they're burning, or how it's burned. It seems that that's a big source of the smog and particular matter in the air.”

Two subjects wanted to see more maintenance done on equipment; one of the subjects said,

“More maintenance, more vigilance with checking with [equipment that contains the DE], possibly that can help down the road.”

One subject recommended for facility improvements among other things; he said,

“[I’d like to see them] continue with improvements, facility improvements, make sure ventilation systems are incorporated into the building, I think new vehicles are more efficient and less polluting than the old equipment, they start better, produce less emissions, so I guess to just keep up with continued improvements.”

3.14.4 No Recommendations

Five subjects did not have any recommendations to better address the exposure of DE. Said one subject,

“I honestly don't know, because of the nature of the beast, [referring to the exposure of DE]. Those engines have to run to do what they have to do.”

Another subject said,

“I don't know other than being aware of it and cleaning it up a little bit, but it's the most efficient fuel that we have, and that's all people care about, how much money they can save. So I don't see it changing a huge amount, until people get sick, and it costs them more to keep them healthy than it does to get rid of the diesel. That's what I see.”

Yet another subject said,

“I think they're doing a great job already, and they're pretty strict on policies that they've put in place regarding [DE]. And they do a good job following up whenever they hear of people slacking off a bit. They put in notices to remind people. So no, I think it's as good as it gets.”

CHAPTER 4: DISCUSSION

This section addresses each objective as well as the strengths, limitations and future recommendations associated with this study.

4.1 Domain Experts' Beliefs

As mentioned, the domain experts' beliefs informed the study questionnaire and the initial coding schema for data analysis. The experts' beliefs in this study were established by a review of relevant grey and research literature as suggested by three domain experts, and an example was websites of WorkSafeBC, CCOHS, NIOSH, and OSHA. At the outset, it was expected that best practices were established by and easily accessible from health and safety agencies. A study limitation was that the websites of the four health and safety agencies that attributed to the domain experts' beliefs did not provide consistent, comprehensive and up-to-date information. For example, each of the websites should use the ALARA "as low as reasonably achievable" principle since DE was reclassified as *carcinogenic* (Group 1) in 2012 but none did. DE should be consistently named as DE since that was how the study participants referred to it as well. If the DE was referred as "diesel particulate matter" or "diesel fuel, as total hydrocarbons, inhalable", it might be misinterpreted as another substance. In the future, it may yield more accurate results if the domain experts' beliefs are elicited by interviewing the experts in the domain with questions similar to those asked from the individuals exposed to DE.

Education and recommendations should be consistent and comprehensive across all resources as it was unrealistic to expect people exposed to DE to know that they needed to peruse information from multiple sources. See below for a comprehensive list of pertinent information that should be provided by each resource:

- Exposure route

- Types of occupations at high risk
- Smoke colour indicators
- Health effects and mitigation strategies
- IARC re-classification
- DE Miners Study results
- Servicing engines according to manufacturer
- Using more than CO as exposure indicator
- Restrict amount of diesel-powered equipment in an area to not exceed ventilation capacity
- Use reformulated diesel or biodiesel
- User low-emission, cleaner-burning engines
- Use DE filters, and oxidation catalysts
- Use exhaust extractor hoses
- Use respirators if other methods not effective or suitable

4.2 Study Participant Characteristics

As expected based on the job sectors from which participants were recruited, 83.3% of the subjects were male. For example, 75% of the people in the transportation industry were male, while 88% of the people in the construction industry were male (105). Overall, 53% of the labour force in British Columbia were male (106).

Smokers made up 7.1% of the subjects surveyed. This was lower than expected, as a survey conducted in 2013 by the Conference Board of Canada found that 14.2% of British Columbians were smokers, and the

percent was higher in some occupations representative of the subjects surveyed, such as 24% in processing, manufacturing and utilities, and 28% in trades, transport and equipment operators (107).

Taha *et al.* conducted a study to determine the knowledge and practice of employees regarding their mitigation strategies to address occupational hazards in Saudi Arabia (108). Taha *et al.* found that a low level of education could form a barrier to effective knowledge translation at the workplace and might contribute to the inadequate knowledge and non-use of personal protective equipment (PPE); all the employees who used PPE had secondary or diploma education. However, contrary to Taha's study, in which 42% had secondary or diploma education, 92% had such education and not all of them used PPE in our study.

The job titles and job sectors represented in this study were expected from subjects working in British Columbia. However, some of the largest exposed groups were not represented, such as truck drivers, subway drivers, couriers, and taxi drivers, despite efforts to recruit them for this study (109).

4.3 Safety Training

When the subjects were asked about safety training, a third of the study participants reported not having any training. None of the subjects believed that they had any training relevant to DE. However, one or two people out of all of the study subjects were able to recall some of the information related to DE when prompted, such as the smoke colour indicators or how to use respirators.

Some of the subjects mentioned that their safety training was obtained through working on the job instead of through formal training. Another study also found it typical for employees to learn from one another and to draw on more experienced individuals as a source of knowledge, rather than from written information or through formal training (110). This informal training might confer dangerous practices, as well

as training inconsistency and undue dependency on a given employee's colleagues. WorkSafeBC started to enforce orientation and training for new workers in 2007, which included training specific to the workplace and the hazards, and training to non-new workers on new processes and equipment (111). However, upon review of online resources from several health and safety agencies, there were no explicitly-stated requirements for workplaces to provide DE-specific education or training to employees. WorkSafeBC and other health and safety agencies needed to understand workers' culture of learning through one another while putting more emphasis on checking employer due diligence and enforcing regulations and accountability on DE-specific education and training.

4.4 Exposure of DE at the Workplace

As mentioned, the employees were one of several parties responsible for their own health and safety at the workplace; they shared responsibilities with the government, the employer, the manager or supervisor, and the health and safety committee if available. All of the subjects were at least aware of the exposure of DE at work. The majority of the subjects were bothered by the exposure. Almost a third of the subjects rated their perceived level of exposure to be unhealthy and a cause for concern. This coincided with the proportion of subjects who, when asked for thoughts and concerns about exposure, voiced concern.

The subjects' opinions about the exposure of DE were in stark contrast to their knowledge of the exposure. Fourteen out of fifteen subjects did not know the actual level of DE that they were exposed to. The one subject who answered with a specific measurement did not know what marker of DE the measurement was for, or for what kind of work setting. Upon a review of the transcripts, there was a general lack of knowledge about the method of quantifying DE, the surrogates used for measuring DE, and also the individuals' right to know about their occupational exposure of DE.

Information about the actual level of DE at the subjects' workplace and methodology for quantifying DE needed to be available in subjects' preferred channels of communication to address the subjects' existing or lack of concern of their occupational exposure.

4.5 DE Perceived as a Hazard

The majority of the study participants mentioned DE as one of their top five perceived occupational hazards. Furthermore, subjects' perceived likelihood of DE was significantly higher than other hazards, whereas subjects' perceived severity of consequences due to DE compared to other hazards was not significantly different. Upon a closer look at the other listed hazards, it was apparent that DE was perceived as more likely to occur at their workplace than hazards such as asbestos and shiftwork, and just as severe as life-threatening hazards such as motor vehicles, and explosions.

The difference in the rankings in terms of likelihood and severity of DE exposure suggested that the study subjects used different metrics to assess the likelihood and severity of a hazard, though it was not clear what those metrics were.

Other researchers have attempted to establish a relationship between likelihood and severity information and risk perception. Young *et al.*, determined that the severity of injury and not likelihood of injury was the single best predictor of people's risk perception, for items that the people encountered on a daily basis, which was the case for this study's participants with DE (112). They hypothesized that the severity information played a bigger role in forming risk perception until the severity reached a certain level for example, if it could cause very severe injury or death, at which case the likelihood information was expected to play a role in forming risk perception. Considering that 1) our study subjects encountered DE on a daily basis, and 2) it could cause severe injury or death, it was unclear from Young *et al.*'s conclusions whether likelihood or severity information played more of a role in forming risk perception in our study.

Contrary to Young *et al.*, Weinstein argued that likelihood and severity information did not act independently; they both contributed equally to forming risk perception and subsequent motivation to act (83). A recent paper by Janmaimool *et al.* was a case study conducted in a Thai chemical industry hub where the most serious issue was polluted air and the number of cancer patients in the area was higher than the national average (113). Their results indicated that for moderately- or highly-exposed individuals such as those in our study, a linear combination of three risk factors (perceived probability of environmental contamination, perceived probability of receiving impacts, and perceived severity of catastrophic consequences) could predict the degree of risk perception.

4.6 Exposure of DE vs. Other Inhalational Hazards

Within the list of twelve perceived top hazards mentioned which were also inhalational hazards, one of them was asbestos. Asbestos, like DE, has been reclassified (upgraded) to being *carcinogenic to humans* (Group 1) (114). Asbestos is similar to DE in that it is present in occupational settings, is inhalational and causes lung cancers (among other cancers). In contrast to DE, the health and safety agency WorkSafeBC listed asbestos as a hazardous material, provided IARC re-classification information, a 128-page booklet as well as educational videos on safe work practices for handling asbestos which includes information regarding health effects, responsibilities of different parties on the employees' health and safety, monitoring exposure, and multiple methods of hazard control (70, 115, 116). The resources available for asbestos demonstrate what is possible to provide to individuals exposed to DE. It is worth pointing out that it took many years for education and regulations about asbestos health and safety to get to this point. Research about health effects associated with asbestos was done as early as the 1920's (117). However asbestos production and consumption continued; in fact, the consumption of asbestos did not peak until 1973 (118). Regulations and bans on the use of asbestos only began in the 2000's. We hope that progress for DE is made more swiftly.

Unfortunately, most of the inhalational hazards mentioned in this study were not specific enough to associate with a particular hazardous material and to provide a further evaluation and discussion, such as “exposure to known pathogen”, “toxins”, “exposure to virus”, “chemical hazards”, “paint enamel”, “solvents”, “cleaning agents”, “welding exhaust”, “fiberglass”, and “invisible fumes”, and “smoke and fire”.

4.7 Health Effects of DE

The value for individuals exposed to hazards such as DE to have specific and a more complete understanding of the health effects is worth noting. Researchers have found that a lack of awareness of health effects on the part of the exposed individuals made the correct diagnosis of occupational disease very challenging and that this would likely lead to delays in reporting and under-reporting of diseases (119, 120). Ultimately, individuals exposed to DE need to know and understand the health effects of DE so that they are more likely to report accurately to their doctors with a valid claim, and perhaps more likely to get compensation through WorkSafeBC and the Workers’ Compensation Board.

Subjects were asked about health effects in two different questions: What health symptoms did they experience when they were being exposed to DE, and what they thought would happen to a person as a result of DE exposure. One of the study strengths was that both questions were asked. It was evident that different responses were given for each of the two questions.

The first question captured symptoms that the subjects have personally experienced that they would associate with their exposure to DE. They were able to name many of the symptoms that were commonly associated with exposure, such as difficulty with breathing, coughing, throat irritation, possibly needing an inhaler and being admitted into the hospital. Of particular interest were the issues of nausea, headaches, dizziness, and feeling lethargic as these have not been noted by health and safety agencies. However, at least one scientific journal described headaches and nausea as symptoms (121). More research needed to be done to

confirm that these were in fact symptoms of exposure to DE, and if so, more attention needed to be paid to provide individuals with a comprehensive understanding of all the health symptoms associated with DE exposure.

The second question captured potential risk perceived by the study participants. It is worth noting that not all the symptoms the subjects experienced firsthand were included as answers for the second question; it was as if when some of the subjects were answering “what would happen to a person as a result of DE exposure?” that they did not think of themselves. For example, six study participants experienced feeling nauseous firsthand. However, only one person said that people would get nausea as a result of DE exposure. In addition to what they have experienced firsthand, the answers that they gave for the second question seemed to be through a combination of: observation of and conversations with their colleagues, what they heard in media, what was available and what they remembered from safety training, plus their own research if they were inclined to do so. However, when prompted, they were not able to articulate the sources of their information, which was not surprising.

Respiratory issues, cancer, circulatory system issues and nervous system issues are established health consequences caused by the exposure of DE. However, many subjects were not able to recall these health issues: 30% of subjects with respiratory issues, 43% of subjects with cancer, 93% of subjects with circulatory system issues, and 93% of subjects with nervous system issues. One possible explanation for this might be that research on these health effects was more recent than research on respiratory effects and cancer associated with DE; for cognitive issues in particular, attention has been scarce until recently, whereas research on respiratory effects and cancer was done as early as the 1980s (54, 55, 122-124). Of particular interest were circulatory issues; a significant body of research has been produced on this issue in recent years (51-55, 124-128). The abundance of literature available about this particular health effect was in stark contrast to the lack of knowledge in the subjects surveyed; only two subjects mentioned cardiovascular issues. It is worth

emphasizing that more efforts needed to be made to communicate the circulatory system issues associated with DE.

A difference between the subjects' responses and the information from the health and safety agencies and scientific literature was evident in the knowledge of technical terms. For example, it was not clear what the subject meant when he said that DE caused "toxicity to the body". This was not surprising for a layperson to not have detailed and technical information on diseases that he did not have. As Sadhra *et al.* pointed out, it would be wrong to equate difficulties of articulation with lack of understanding (110).

Subjects' responses (*e.g.* that DE was associated with birth defects, multiple sclerosis, and leukemia and that cancer would occur "*only in late 60's or 70's*") indicated an incomplete, and sometimes incorrect, understanding of the health effects of DE. It was noteworthy that these responses were all serious health effects, which contrasted with results from Sadhra *et al.* which indicated that individuals tended to mention more about common health problems compared to those that were seen as more serious (110). Furthermore, this suggested that individuals were not aware of the correct sites of the body that DE could affect. It was concerning that 4 subjects (13%) said that they did not know and did not name any health effects.

4.8 Study Participants' Trusted Sources of Information

Thirty subjects listed a total of 33 different sources of information. Ninety-seven percent of subjects named two or more sources of information. One subject named as many as eight sources. This suggested that there was not one source of information that was universally perceived as the "go-to" source of information about occupational exposure of DE.

The most-mentioned source of information was WorkSafeBC, which was not surprising as the protection agency was perceived as being heavily involved in workplace health and safety and would have

numerous bulletins and safety signs with their organization name in most of the workplaces in the province. However, it was concerning that 23%, or more than one in five study participants who mentioned WorkSafeBC, had hesitation in trusting the agency. It seemed that the hesitation stemmed most from prior experience interacting with WorkSafeBC. According to its website, WorkSafeBC “works with the affected parties to provide return-to-work rehabilitation, compensation, health care benefits, and a range of other services. . .in the event of work-related injuries or diseases” (129). These study participants’ prior experience with the agency for such administrative items as compensation and benefits, unfortunately seemed to colour their perception negatively of the agency in terms of their trust in the agency’s information as well. This inherent conflict in the mandate of WorkSafeBC that both provided information as well as decided on compensation would need to be resolved.

Twenty-one out of 30 subjects mentioned using the internet, which suggested the importance of personal control when it came to informing themselves about DE. It is reiterated here that the study participants described using “Google” as being easy and accessible. The search results from “*health effects of diesel*” and “*health effects of diesel fumes*” illustrated how varied the information could be with just a slight change in the Google search phrase. The results from the three Google search phrases illustrated the myriad of information on the internet that is available for any person to access. Online articles and web pages from reputable sources such as governmental agencies are easier to update with the latest information but may not provide a complete list of information, as evidenced by the article from the European Agency for Safety and Health at Work. Scientific papers may be a reputable source, but it may only reflect the latest findings from the year that it was published, and may not necessarily have the most current information. For example, the paper from Sydbom *et al.* had excellent information about many of the health effects from exposure to DE, but did not include information that led to the IARC reclassification or thereafter. Another concern with scientific papers is that they are usually not in plain language, and so it would be difficult for a layperson to understand. A third concern is that many scientific journals pose many questions for future directions and are not practical

with solutions for employees to implement at their workplace. A source like a Wikipedia entry may or may not have the most up-to-date and current information. Another concern with individuals using the internet to gather information is that it is difficult for them to know whether they have all the information that they need. For example, if they were looking at the webpage from the European Agency for Safety and Health at Work, since there was a list of hazards and risks which included fumes, but did not include any health effects from exposure to DE, they might come to the conclusion that there were no health effects from exposure to DE.

A limitation of this study was the difficulty in ascertaining which information subjects actually accessed and read after their initial Google search. It is interesting to note that two of the people who mentioned using Google searches corresponded with two of the four people who could not name any health effects of DE.

One of the subjects who would trust Health Canada brought up the concern that Health Canada might not have the relevant information. An online search of the Health Canada website revealed that they did in fact have some of the relevant information: acute effects such as eye, nose and throat irritation and respiratory symptoms as well as long-term effects such as lung inflammation and aggravation of chronic respiratory symptoms (130). However, there was no information about cardiovascular disease or cancer associated with exposure to DE, or information for occupational exposure and actions to take to address occupational exposure.

Eighty-six percent of people who mentioned their doctor would trust them. However, it was unclear whether this could be a sustainable and realistic source of information about the exposure of DE to everyone who was occupationally exposed. A study limitation was that expert solicitation was not undertaken with interviewing experts, including doctors. Therefore, the knowledge and beliefs of doctors could not be evaluated in this study.

The concerns with online articles explored above were similar to those with resources from universities and research studies as well as books from libraries. Scientific papers and many books tended to not be in plain language or in a format that is easy to understand. Also, scientific papers and books only reflected the latest findings from the year that they were published, and did not have the most current information. Furthermore, many scientific journals posed questions for future directions and were not practical with solutions for individuals to implement at their workplace.

Upon review of the feedback from the subjects, it was not surprising that there was no one universally perceived go-to source of information as each source of information had its flaws.

Overall, it seemed that the ideal source of information that would be perceived as trustworthy and accessible regarding occupational exposure to DE needed to meet several criteria:

- 1) It was a non-profit organization.
- 2) It was perceived as being motivated to do what was needed to protect the individuals' health and safety (*e.g.* would likely exclude organizations focused on individuals' hire, compensation, or benefits).
- 3) It was able to provide up-to-date information
- 4) It was able to provide information online.
- 5) It was able to provide information about all sorts of health effects and did not exclusively report on some health effects and not others.
- 6) It provided practical solutions for individuals to implement at their workplace.
- 7) It provided information in plain language and in an accessible and easy-to-navigate format.

4.9 Information from Recent Media Sources Regarding DE

The information regarding DE from recent media sources recalled by the study participants was used to better understand whether the sources of information mentioned in section 3.10 were utilized to gain useful and relevant information.

Radio, newspaper headlines, a documentary and a “trucking” magazine were mentioned as media sources that provided accurate information regarding DE to some of the subjects. Furthermore, it was through the radio that one of the subjects knew about the carcinogenic reclassification of DE. However, these mentioned media sources didn’t account for all of the individuals’ existing knowledge of DE and its associated health effects. Meanwhile, the radio, documentary and magazine were not mentioned at all as sources of information in section 3.10.

It was interesting that nothing on the internet was cited. It was unclear whether no subject has obtained any valuable and accurate information about DE on the internet, or whether the subject didn’t perceive internet as a media source.

4.10 Study Participants’ Behaviours to Address Exposure to DE

4.10.1 Personal Protective Equipment

There were many caveats of using a mask regularly and consistently across all workplaces where individuals were exposed to DE, as mentioned by the subjects. Unless the wearing of masks was a rule implemented by the workplace or the government and everyone who had contact with DE at work were seen to wear masks, the few people who wore the masks would be judged and teased by their colleagues, or the public if they came in contact with the public, which would discourage the wearing of the masks. Also, there was no financial support for masks or respirators. Furthermore, subjects seemed to be more likely to wear protective equipment when they could smell noxious fumes, such as when they were painting. However, with

DE the fumes might not be perceived as noxious so the protective equipment could be perceived as not as necessary as with other substances. Another caveat to wearing masks regularly were instances mentioned by study participants where the wearing of masks or respirators would hinder their job performance or safety. Yet another caveat to wearing masks was the belief that some of the subjects had about DE not having any health effects or only affecting some people.

Subjects recommended for personal protective equipment to be provided along with appropriate training to use the equipment. An alternative protection method needed to be provided when masks or respirators were dangerous, cumbersome or impractical to use for certain work duties. This was aligned with the “hierarchy of control” mentioned in section 1.4.2 where elimination, engineering controls, and administrative controls were considered before personal protective equipment as they were thought to be more effective and desirable and did not burden the individual.

Unless policy changed to implement rules for everyone to wear masks in situations where masks would be appropriate and safe to use, and to provide financial support for the masks and the training, personal protective equipment was not a feasible and practical solution for individuals exposed to DE.

4.10.2 Administrative Controls

Most of the actions that individuals took to address DE exposure fell into this category. Even though experts believed that the hierarchy of control should be considered in the order that they were presented (elimination, engineering controls, administrative controls, personal protective equipment), it was found that individuals thought of PPE as the first control to which they had access, and that they had any influence (110). In this case, it was not surprising that individuals implemented administrative controls the most since they found PPE not useful and feasible for multiple reasons, while they were still able to influence multiple administrative controls.

The many responses about being aware of, avoiding, and holding their breath near DE suggested that many individuals' instinct was to avoid the DE and to control their own dose of DE, even if their actions were in fact not useful for the constant exposure of DE. Also, it was concerning that the individuals might be doing so with the caveat of hurrying parts of their job and therefore putting their job performance or their safety on the line.

The subjects' recommendations for more regulations and for management to get involved regarding minimizing or avoiding exposure at the workplace suggested that the individuals believed the action was effective against DE and therefore had the desire to see it across their workplace.

A few effective actions were mentioned but only by one to four subjects per action: fixing leaks, idling less, changing the timing and type of shift, using better grade diesel, sending in maintenance requests, being more familiar with equipment, and cleaning soot from pipes. It would be worthwhile to discuss with all individuals exposed to DE about these actions being effective to take at the workplace.

It was concerning that between the two subjects who have filled out exposure or incident forms that there was no consensus on the occasion and frequency to fill out forms. It was inadequate for health and safety agencies and workplaces to give the individuals the responsibility of filling out a form for a hazard that the individuals were constantly exposed to. The onus should be on the health and safety agencies and workplaces to more clearly communicate this procedure to the individuals.

Two subjects have used a monitor or a carbon monoxide tester. It seemed that between these two subjects, one worked at a workplace where some of the individuals received a monitoring device while the other did not receive a monitoring device from his workplace. It is also intriguing to note that in both these cases, the subjects were only aware of the monitor beeping if the exposure exceeded a certain level but did not

know what that level was or the substance that the monitor was actually measuring. These two subjects' actions aligned with the recommendation from four subjects for the level of DE to be measured at their workplace. This was a useful strategy for several reasons. First, the individuals would be better informed. Second, the individuals would be more motivated to protect their own health. Third, transparency at the workplace would foster better relationships between individuals and the management at the workplace. Workplaces needed to be aware that individuals were interested in these monitoring devices and therefore consider offering them or an alternative technology to the individuals as well as the training so that these individuals were using the devices properly. These can be especially useful in workplaces where individuals were not exposed to high levels of DE constantly but only occasionally, for example during leaks.

Even though tailgate meetings could be a useful way for individuals to get information about DE exposure and that at least one study participant thought of them as "safety meetings", the subjects' statements suggested that tailgate meetings were quite informal and information about DE might or might not be passed on to individuals while other information was communicated instead.

The action of one study subject to quit his job was an effective method to remove himself from the exposure of DE. Ideally, individuals were able to keep their jobs and be able to work safely and healthily.

Subjects' recommendations for the workplace to formally recognize DE as a hazard and to offer education or training about DE and health effects, actual or potential hazards, and appropriate actions to take were most frequently mentioned out of all the recommendations. This was aligned with the subjects' feedback that none of them have had DE-specific safety training. It was even more apparent that education was needed upon review of the subjects' feedback about needing education. For example, one subject recommended education so that more people would know to hold their breath, an ineffective strategy. The subjects'

recommendations to provide education when someone was hired, or when a colleague died, could be considered.

Other recommendations included more signage about DE and health effects by one subject, while another subject recommended for more education and less signage. It is not yet clear which one would be more effective.

The subjects' recommendations to have regular health check-ups in the context of DE exposure throughout their careers, and to maintain a health effects inventory, were excellent recommendations for several reasons. First, the information that they received during their check-up would be personalized to each individual and so each individual would be better informed and more motivated to protect their own health. Second, there was still more research that could be done about the health effects and effective mitigation strategies associated with DE, and this would be able to provide us with more information. Third, this would better inform workers' compensation boards on the effects associated with occupational exposure to DE.

The need for training and health education in an occupational setting and periodic monitoring of hazards were aligned with two top recommendations that were suggested by Taha *et al.* (108).

A few suggestions were made by the employees for how workplaces and health and safety agencies could improve in protecting individuals in many aspects of administrative controls. In summary, education or training needed to be provided in regards to the occupational exposure of DE, and associated health effects. More research needed to be conducted in order to determine whether more or less signage was more effective to communicate to employees. Both effective mitigation strategies such as filling out exposure forms and monitoring exposure levels and ineffective mitigation strategies such as holding breath needed to be discussed. It was also recommended that a regular health checkup be done and a health effects inventory be created.

4.10.3 Engineering Controls

Study subjects mentioned several effective engineering controls to reduce occupational exposure to DE such as redirecting fumes, using a more efficient engine with newer technology, maximizing ventilation, using a fan, filters, and using an extraction system.

However, it was concerning that all of these actions but one (maximizing ventilation) were only mentioned by two to five subjects, less than 20% of the subjects per action. It was unclear whether each of these controls was only implemented at the workplaces of two to five subjects, or whether these controls were implemented without the knowledge of these subjects. As mentioned above, engineering controls compared to administrative controls or personal protective equipment were more effective and desirable as they did not burden the individual nor require knowledge, understanding, cooperation or motivation from the individual to provide protection (15). It was possible that the subjects failed to recall these controls when thinking of an answer when asked the question, *“Tell me about all the actions that you take to address being exposed to DE at your workplace?”* since they might not be taking the action to implement these engineering controls themselves.

One subject mentioned taking it upon himself and his coworkers to make a fiberglass cover over the source of DE to avert the fumes. Also, many of the subjects recommended for workplaces to be “a bit more aggressive” in increasing ventilation, which would suggest that existing mitigation strategies were inadequate.

It might be worthwhile for individuals to know what engineering controls existed at their workplace so that they were aware of the degree at which they were already protected and how much they needed to take it upon themselves to protect themselves from the exposure of DE.

A few subjects recommended for the government to be stricter in cutting down emissions. In light of

the recent emission standards introduced by the government for both on-road and off-road diesel engines in the last three years, monitoring data should help determine the effectiveness of these standards in reducing emissions over the coming years.

4.10.4 No Actions or No Recommendations

One of the two subjects who said that they did not take any action to address occupational exposure of DE corresponded to one of the four subjects who did not know of any of the health effects associated with DE.

Interestingly, all five subjects who had no recommendations to better address occupational exposure of DE did take at least one action at their workplace and knew of at least one of the health effects associated with DE. It seemed that these subjects were aware of DE and associated health effects, took action to address it, and were genuinely satisfied with their safety and health at work.

4.11 Study Strengths and Limitations

A limitation for this study was that there were only 30 subjects in the study. With the study being only in British Columbia, Canada, the information and recommendations might or might not be applicable to other cities and could not be generalized to people exposed to DE at the workplace at large. The work sites varied greatly between the subjects and so no implications and recommendations could be made for any specific occupations or work sites. Also, there were several fascinating observations and statements made by the subjects but they were only made by one or two people, or there was a contrasting statement from another subject that made it difficult to make implications, recommendations, or generalizations. For example, one subject recommended more signage about DE and health effects, while another subject recommended for less signage. As another example, two subjects mentioned that “the kids” or the younger generations were more aware or worried about safety, while two subjects mentioned that they themselves were more concerned when

they were younger – it was difficult to ascertain whether the difference had to do with the age or with the generations.

As mentioned, the employees shared responsibilities for their health and safety at the workplace with the government, the employer, the manager or supervisor, and the health and safety committee if available. Also mentioned was that the experts' beliefs were elicited by a review of literature recommended by three domain experts. A limitation was that there were multiple stakeholders in the health and safety of the individuals exposed to DE and they were not all interviewed. In the future, all the stakeholders could be interviewed to gain a fuller understanding; then for example we would understand what engineering controls already existed without the knowledge of the employees. These stakeholders would include scientific experts, doctors, representatives from all governing bodies, employers, managers, and health and safety committee representatives.

A strength for this study was that first-hand knowledge, knowledge gaps, and misperceptions from the people exposed to DE were identified. This was an exploratory study where areas of interest were identified for further research to be conducted to better understand the work culture of any of the occupations or work sectors that were mentioned in this study.

A limitation was that all the study participants knew that the study had to do with DE and therefore the study cohort could be more aware or worried about DE than the general population. It was also possible that the knowledge of this study having to do with DE could have affected their answers, such as when they were asked to list the top five perceived hazards at work. However, this made the fact that the subjects had incomplete, and sometimes incorrect understanding of the DE and health effects even more concerning.

Using the Mental Models methodology and open-ended questions to elicit the study participants' beliefs posed both strengths and limitations. As expected, the responses revealed knowledge gaps and misperceptions that might affect their decisions and behaviours, which would not have occurred if the participants were only asked structured questions. For example, if the subjects were given a panel of established health effects and asked if they agreed or disagreed to each of them, it would not have been revealed that some subjects thought DE was associated with birth defects, multiple sclerosis, and that cancer only occurred in their late 60's or 70's. At the same time, the open-ended questions resulted in not being able to evaluate some of the responses. For example, many of the answers given for the inhalational hazards could not be associated with a particular hazardous material and subsequently evaluated. In the future, an open-ended question could be asked first to elicit beliefs, and then a follow-up question could be asked regarding a panel of specific inhalational hazards, including DE, present in different occupations and the subject could be asked to compare the likelihood and the severity of each hazard.

There has been recent interest in determining if the size of a workplace, or whether the workplace was unionized was significant in the effectiveness of workplace interventions (131-133). This study's subjects were not asked about the size of their workplace or whether the workplace was unionized. In future studies, these questions could be asked.

4.12 Conclusions

In conclusion, this was the first study that has evaluated the knowledge, attitudes, and behaviours of individuals exposed to DE after the declaration from IARC about its carcinogenicity. Key findings include:

- 1) The majority of the study subjects were at least irritated with their occupational exposure of DE, and almost one-third of the subjects perceived exposure as unhealthy or life-threatening.

- 2) Many of the subjects could not recall significant health effects associated with DE; 30% for respiratory issues, 43% for cancer, 93% for cardiovascular issues and 93% for cognitive issues. More than 10% of the subjects could not name any health effects associated with DE.
- 3) One-third of the study subjects reported not having any safety training, and none of the subjects reported having training specific to DE.
- 4) WorkSafeBC was the most-mentioned source of info, but 23% of subjects had hesitation trusting the agency.

The most-mentioned action to address DE exposure is being aware of and avoiding sources of DE.

- 5) Subjects had many safety and practicality issues with using personal protective equipment to address exposure of DE.

Key needs for the future, as recommended by those included in this research project, are as follows:

- 1) The employer may help the employees by providing the following: information about the actual levels of DE, resources to measure and monitor DE levels, and education and training regarding mitigation strategies, while understanding employees' culture of learning through one another.
- 2) The employer should realize that masks are often impractical to use and other methods of exposure reduction must be prioritized.
- 3) Individuals' physicians should be aware of their exposure to DE so as to consider related health conditions.
- 4) The management and government may have more impact in DE exposure reduction at the workplace by updating regulations according to the latest scientific knowledge and then reinforcing them.

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Appendix A. Study Questionnaire.

Interview Script

Name: _____

Date of Interview: _____

Interviewer: _____

I will now interview you about your experience with DE at your workplace. Please note that this is focused on just the exhaust coming off of diesel engines at your workplace.

The interview will take about 30-45 minutes, and I will be recording the audio of this interview, which will be transcribed and analyzed.

Thank you for your willingness to participate and be interviewed. I would like to remind you that you can choose what to disclose for any of your answers and that you are free to refuse to answer any of the following questions.

I have been studying the health effects of DE, and now I am interested in understanding the experience of DE exposure at the workplace from your point of view.

1. Do you have any questions before we start? Please refrain from asking questions until the end of the interview as I would like to make sure that I have a good picture of your experience during our allotted time together.

2. Please tell me your age. _____

3. Please tell me what motivated you to participate in this study?

4. Do you smoke? (pack-years)

5. Do you exercise? (type, frequency)

6. Please tell me what is the highest level of education that you've attained *eg.* degree, diploma, special training with safety/DE)?

7. Have you been diagnosed with asthma or allergies?

8. Do you have any occupational disease/injury?

9. Do you have any other lung conditions?

10. Please tell me how many years you have been working at this work site? _____ In this industry?

11. Please tell me your job title _____

12. Job description and what your job is like day-to-day.

13. Please describe to me in as much detail as possible your work site. [might need % time if 2+ workplaces]

14. Could you describe in as much detail as possible a situation at your workplace when you feel like you are being exposed to DE? What symptoms did you experience?
- 15a. How much DE do you think you are exposed to at work? Scale of 1-5, see below _____. What is the actual level of DE at your work?
- 15b. Please specify duration _____, frequency _____, number of years _____.
- 15c. Outside of work: On a scale of 1-5, see below _____.
16. Please tell me the sources of DE at work? Outside of work?
17. What are your thoughts about being exposed to DE at your workplace?
18. What are your concerns about being exposed to DE at your workplace?
19. What are the top 5 hazards at your workplace? For each, scale of 1-5 how likely to happen? Scale of 1-5 for severity?
20. Can you tell me what you think would happen to a person as a result of DE exposure?
21. Please tell me about all the actions that you take to address being exposed to DE at your workplace.
22. If you were going to learn about the health effects of DE exposure, or maybe some of the hazards that you are exposed to at your workplace, where would you go for this sort of information? Please name all the places.
23. Please list all the persons, agencies, or groups that you would trust for information on DE and its possible associated health effects.
24. Could you describe in as much detail as possible a situation when you have talked to someone at your workplace about the exposure of DE?
25. Could you describe in as much detail as possible a situation when you have talked to someone outside of your workplace about the exposure of DE?
26. Have you ever talked to your doctor about being exposed to DE at your workplace?
27. Have you heard anything in the media recently regarding DE exposure? *
28. Do you think DE is a carcinogen (something that causes cancer)?
29. Do you have any recommendations on what health researchers, health and safety organizations, or policy makers can do to address DE exposure at the workplace? (separate them, and ask them for specific examples they've given)
30. Is there anything else that you would want to add before we end the interview?

Thank you for sharing with you your point of view. [Share with interviewee some of the main points that were mentioned.] How did you experience being interviewed about your experience with DE exposure at your workplace?

Possible follow up questions or statements to any of the above questions:

1. Pause or repeating significant words of the answer, to invite subject to go on with the description.
2. Do you have a further example of this?
3. In what condition does this occur? How frequent does this occur?
4. Is it correct that when you said... that you meant....?
5. For a scale of how much DE exposed to: 1=minimal 2=tolerable 3=irritating 4=unhealthy 5=life-threatening
6. For scale of likely to happen: 1=won't happen 2=might happen, 3=likely to happen, 4=very likely to happen, 5=sure to happen
7. For scale of severity: 1=normal, 2=mild, 3=moderate, 4=severe, 5=extreme

Notes: acknowledge concerns/questions, talk about time limit, give email/resources later

Appendix B. Study Advertisement.

RESEARCH SUBJECTS NEEDED

To better understand the experience of workers exposed to DE at their workplace

Requirements:

- 19-65 years of age
- Exposed to DE on a regular basis at their workplace
- Have worked for at least a year at their current position

If you meet the study requirements, you will be asked to dedicate 30-45 minutes of your time for an interview of open-ended questions regarding your experience with exposure to DE, associated health effects and prevention measures.

Volunteers will be appropriately compensated for their time.

Appendix C. Unions and Workplaces Formally Invited to Participate in Study

Association of BC Forest Professionals
Association for Mineral Exploration BC
BC Aboriginal Mine Training Association
BC Building Trades
BC Construction Association
BC Construction Roundtable
BC Ferry and Marine Workers' Union
BC Trucking Association
Boundary Mining Association
Canadian Union of Public Employees 401 - Vancouver Island
Canadian Union of Public Employees 7000 - Rapid Transit and Rail Workers
Cariboo Mining Association
Coast Mountain Bus Drivers (Unifor)
Construction and Specialized Workers' Union (Local 1611)
Council of Construction Associations
International Union of Operating Engineers (Local 115)
Mining Association of BC
Mining Suppliers Association of BC
Port Metro Vancouver
Teamsters Local 31 (Truck Drivers)
Teamsters Local 213 (Mining, Pipeline, Construction, Transportation)
Vancouver Regional Construction Association

Appendix D. Informed Consent Form.

UNIVERSITY OF BRITISH COLUMBIA

Study Title: DETERMINING THE KNOWLEDGE, ATTITUDE, AND BEHAVIOUR OF WORKERS
EXPOSED TO DE AT THE WORKPLACE

SUBJECT INFORMATION AND CONSENT FORM

Principal Investigator: Chris Carlsten, MD MPH
The University of British Columbia
Department of Medicine, Respiratory Division

Research Assistant: Mandy Pui, BSc
The University of British Columbia
Department of Medicine, Respiratory Division

Contact Numbers: If you have any concerns about your rights as a research subject and/or your experiences while participating in this study, contact the **Research Subject Information Line in the University of British Columbia Office of Research Services by email at RSIL@ors.ubc.ca or by phone at 604-822-8598.**

Funded by: University of British Columbia

INTRODUCTION

You have been invited to participate in this research study because you are exposed to DE at your workplace. Approximately 30 subjects will be participating in this study. This study involves only one interview with you at your workplace or another quiet and private area. Alternatively, the interview can be conducted over the telephone. You will be asked to dedicate about 30-45 minutes of your time for the entire study. The purpose of this consent form is to give you the information you will need to help you decide whether or not to take part in the study.

PARTICIPATION

Your participation is entirely voluntary, so it is up to you to decide whether or not to take part in this study. Before you decide, it is important for you to understand what the research involves. This consent form will tell you about the study, why the research is being done, what will happen to you during the study and the possible benefits, risks and discomforts.

If you wish to take part in the study, you will be asked to sign this form. If you do decide to take part in this study, you are still free to withdraw at any time and without giving any reasons for your decision. If you do not wish to take part, you do not have to provide any reason for your decision not to participate.

Please take time to read the following information carefully and to discuss it with your family, friends, and doctor before you decide.

PURPOSE OF THE STUDY

The purpose of this research is to learn more about what workers who are exposed to DE at the workplace know about the exposures, associated health effects, and mitigation strategies relating to DE. A better understanding of what the workers know will help us identify knowledge gaps and misperceptions about exposure to DE, determine societal and organization factors that influence how knowledge is transferred in an occupational context, and to determine more useful channels or pathways for health risk communication.

WHO IS CONDUCTING THE STUDY?

The Respiratory Medicine Division, University of British Columbia, is conducting the study. This study is funded through University of British Columbia. Those funds are used to cover the costs for the investigators and/or the investigators' institution to conduct the study. The investigators have no financial interests in conducting this research study. You may request more information on the funding from the investigators.

WHO CAN PARTICIPATE?

Healthy adults, aged between 19 and 65 years, who are exposed to DE on a regular basis at their workplace. They have to have worked for at least one year at their current position. Typical work sectors include but are not limited to mining, construction, forestry, and transportation.

WHO SHOULD NOT PARTICIPATE?

1. People who are not exposed to DE at their workplace on a regular basis
2. People who are unwilling to participate in an interview.

STUDY PROCEDURES

The study involves a 30-45 minute interview where you are asked open-ended questions about your experience with exposure to DE, your thoughts on the health effects, protective measures and other mitigation strategies related to DE exposure, and where you get your information on work-related health and safety. Your identity and your work location will be anonymous, but information about your job title, job description, and the industry in which you work will be collected. The audio from the interview is recorded and transcribed. Results will be compared and contrasted with data available in the health research literature. Results of interest will be published in scientific journals, disseminated in research conferences, and possibly to media, and organizations that care about workers' safety, such as WorkSafeBC.

POSSIBLE RISKS, STRESS, OR DISCOMFORT

There is minimal risk that you will experience stress and discomfort as a result of participating in this study and the interview, as you will only be asked open-ended, unbiased questions regarding your normal work habits, and your current knowledge of occupational exposure. Keep in mind that you can choose what to disclose. Also, you are free to refuse to answer any of the questions that you are not comfortable answering. There is minimal risk that your answers will adversely affect your relationship with your workplace and your colleagues, as your identity and your work location are anonymous, the data collected will be presented together, and data will not be individually linked to any participants.

BENEFITS OF THE STUDY

There is no direct benefit to you for participating in this study. However, you will learn more about how you feel about the DE that you are exposed to at your workplace. You can request for a summary of the study results at the end of this study for your reference.

As an incentive to participate in this study, we will offer you a chance at a prize in a draw. The signed consent form acts as the entry form to this draw. The prize is a \$100 gift certificate to any one of 3 places, selected by the winner: Starbucks, RONA, and Shoppers Drug Mart.

ALTERNATIVES TO TAKING PART IN THIS STUDY

If you do not wish to participate in this study, you do not have to provide any reason for your decision not to participate nor will you lose the benefit of any medical care to which you are entitled or are presently receiving. You are still eligible to win the draw even if you withdraw from the study before the interview is complete.

CONFIDENTIALITY

You should consider whether details that you provide when answering some of the questions could identify you.

Your confidentiality will be respected. However, research records and health or other source records identifying you may be inspected in the presence of the Investigator or his or her designate by representatives of Health Canada and the University of British Columbia Behavioural Research Ethics Board for the purpose of monitoring the research. No information or records that disclose your identity will be published without your consent, nor will any information or records that disclose your identity be removed or released without your consent unless required by law.

You will be assigned a unique study number as a subject in this study. Only this number will be used on any research-related information collected about you during the course of this study, so that your identity [i.e. your name or any other information that could identify you] as a subject in this study will be kept confidential. Information that contains your identity will remain only with the Principal Investigator and/or designate. The list that matches your name to the unique study number that is used on your research-related information will not be removed or released without your consent unless required by law.

Your rights to privacy are legally protected by federal and provincial laws that require safeguards to insure that your privacy is respected and also give you the right of access to the information about you that has been provided to the sponsor and, if need be, an opportunity to correct any errors in this information. Further details about these laws are available on request to your study doctor.

COMPENSATION FOR INJURY

Signing this consent form in no way limits your legal rights against the sponsor, investigators, or anyone else, and you do not release the study doctors or participating institutions from their legal and professional responsibilities.

CONSENT

This study has been explained to you and you have been given the chance to ask questions about taking part in this study. If you have questions you can ask Mandy Pui or Dr. Christopher Carlsten. You will be given a copy of this signed and dated consent form.

Consent Form

- I have read and understood the subject information and consent form.
- I have had sufficient time to consider the information provided and to ask for advice.
- I have had the opportunity to ask questions and have had satisfactory response to my questions.
- I understand that all of the information collected will be kept confidential and that the result will only be used for scientific objectives.
- I understand that participation in this study is voluntary and that I am completely free to refuse to participate or to withdraw from this study at any time without changing in any way the quality of care that I receive.
- I understand that I am not waiving any of my legal rights as a result of signing this consent form.
- I have read this form and I freely consent to participate in this study.
- I have been told that I will receive a dated and signed copy of this form

Please initial on the appropriate line to indicate your decision:

| |
|--|
| <input type="checkbox"/> Yes, I want a summary of the study results at the end of the study, for my reference. |
| <input type="checkbox"/> No, I do not want a summary of the study results at the end of the study. |

Please initial on the appropriate line to indicate your decision:

| |
|--|
| <input type="checkbox"/> Yes, I want to be contacted regarding future studies. |
| <input type="checkbox"/> No, I do not want to be contacted regarding future studies. |

Printed Name of Subject

Signature

Date

**Printed Name of Person
explaining the consent**

Signature

Date

**Printed Name of Principal
investigator/designated representative**

Signature

Date

Appendix E. The first page of Google search results from the phrase “health effect of diesel” (assessed on August 13th, 2014).

The image shows a screenshot of a Google search results page. The browser's address bar displays the URL https://www.google.ca/?gfe_rd=cr&ei=. The search bar contains the text "health effect of diesel". Below the search bar, there are navigation tabs for "Web", "Images", "News", "Videos", "Maps", and "More", along with a "Search tools" link. The search results are displayed below, starting with a summary: "About 45,200,000 results (0.37 seconds)". The first result is titled "Scholarly articles for health effect of diesel" and lists several academic papers. The second result is from the EPA, titled "Health Effects | Diesel Exhaust | New England | US EPA". The third result is from OEHHA, titled "OEHHA Air: Health Effects of Diesel Exhaust". The fourth result is from the NIH, titled "Health effects of diesel exhaust emissions". The fifth result is from the American Cancer Society, titled "Diesel Exhaust - American Cancer Society". The sixth result is from Wikipedia, titled "Diesel exhaust - Wikipedia, the free encyclopedia". The seventh result is from DieselNet, titled "Diesel Exhaust: A Critical Analysis of Emissions, Exposur...". The eighth result is a PDF document titled "The Many Hazards of Diesel". The ninth result is from IDEM, titled "IDEM: Health Effects of Diesel Emissions - IN.gov". The tenth result is from Mail, titled "Diesel engine exhaust fumes are 'major cancer risk' | Mail ...". The eleventh result is from OSHA, titled "Safety and Health Topics | Diesel Exhaust - OSHA".

health effect of diesel - Gc x

← → ↻ https://www.google.ca/?gfe_rd=cr&ei=

Google health effect of diesel

Web Images News Videos Maps More + Search tools

About 45,200,000 results (0.37 seconds)

Scholarly articles for health effect of diesel
Health effects of diesel exhaust emissions - Sjyloom - Cited by 302
The effect of diesel exhaust particles on cell function ... - Bayram - Cited by 201
Particulate air pollution as a predictor of mortality in a ... - Pope III - Cited by 2585

Health Effects | Diesel Exhaust | New England | US EPA
www.epa.gov - EPA New England - A-Z Index - Diesel Exhaust *
Health Effects. Diesel Exhaust and Your Health. Diesel exhaust contains significant levels of small particles, known as fine particulate matter. Fine particles are ...

OEHHA Air: Health Effects of Diesel Exhaust
oehha.ca.gov - Air - Fact Sheets *
Health Effects of Diesel Exhaust. A fact sheet by Cal/EPA's Office of Environmental Health Hazard Assessment and the American Lung Association. Download a ...

Health effects of diesel exhaust emissions.
www.ncbi.nlm.nih.gov/pubmed/11401072 *
by A Sjyloom - 2001 - Cited by 301 - Related articles
Eur Respir J. 2001 Apr;17(4):733-46. Health effects of diesel exhaust emissions. Sjyloom A, Blomberg A, Parnis S, Stenfors N, Sandstrom T, Dahlén SE.

Diesel Exhaust - American Cancer Society
www.cancer.org - ... - Other Carcinogens - Pollution *
Feb 19, 2013 - This has been, and remains, a major challenge when trying to study the health effects of diesel exhaust. People may be exposed to diesel ...

Diesel exhaust - Wikipedia, the free encyclopedia
en.wikipedia.org/wiki/Diesel_exhaust *
Jump to **Health effects** - [edit]. Exposures have been linked with acute short-term symptoms such as headache, dizziness, light-headedness, nausea, ...
Occupational health effects - Particulate health effects - Chemical components

Diesel Exhaust: A Critical Analysis of Emissions, Exposur...
www.dieselnet.com/papers/9710nauss.html *
A summary of health effects of diesel exhaust, including its carcinogenic potential. Based on the report by Health Effects Institute. October 1997.

The Many Hazards of Diesel
https://www.aft.org/pdfs/healthsafety/fts_diesel0804.pdf *
What are the Health Effects of Exposure to Diesel vapors can irritate eyes, nose, throat and lungs. Excessive short-term exposure can lead to dizziness ...

IDEM: Health Effects of Diesel Emissions - IN.gov
www.in.gov/idem/5262.htm *
Diesel exhaust contains several pollutants that contribute to the formation of ground level ozone, acid rain, and are harmful to public health alone or in ...

Diesel engine exhaust fumes are 'major cancer risk' | Mail ...
www.dailymail.co.uk/health/.../Diesel-engine-exhaust-fumes-major-canc... *
Jun 13, 2012 - "The evidence of harmful health effects of diesel, particularly for people exposed to high levels through their jobs, has been accumulating for ...

Safety and Health Topics | Diesel Exhaust - OSHA
<https://www.osha.gov/SLTC/diesel/exhaust/> *
Workers exposed to diesel exhaust face the risk of health effects ranging from irritation of the eyes and nose, headaches and nausea, to respiratory disease and ...

Appendix F. The first page of Google search results from the phrase “health effect of diesel fumes”

(assessed on August 13th, 2014).

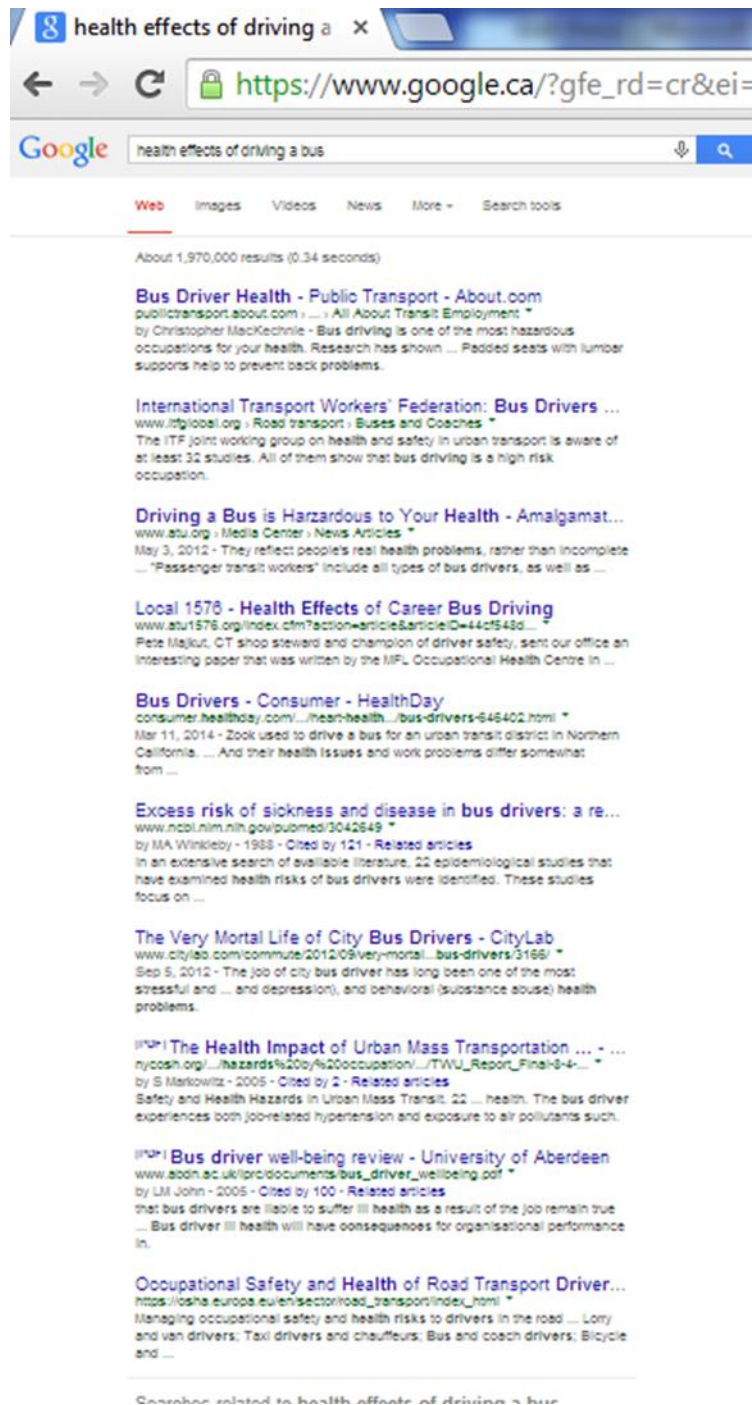
The image shows a screenshot of a Google search results page. The search bar contains the text "health effects of diesel fumes". The page displays approximately 61,700 results in 0.31 seconds. The top results include:

- The Many Hazards of Diesel** (http://www.elt.org/pdfs/healthsafety/rs_diesel0804.pdf) - Exposure to Diesel Fuel and Exhaust Can be Hazardous to your Health ...
- Diesel Exhaust - American Cancer Society** (www.cancer.org) - Feb 19, 2013 - Health concerns about diesel exhaust relate not only to cancer, but also ...
- Safety and Health Topics | Diesel Exhaust - OSHA** (http://www.osha.gov/SLTC/diesel/exhaust/) - Workers exposed to diesel exhaust face the risk of health effects ranging from irritation of the eyes and nose, headaches and nausea, to respiratory disease and ...
- Diesel exhaust - Wikipedia, the free encyclopedia** (en.wikipedia.org/wiki/Diesel_exhaust) - Jump to **Occupational health effects** - Adverse health effects have also been observed in the ... levels of diesel fumes have a threefold increased risk for ...
- IARC: DIESEL ENGINE EXHAUST CARCINOGENIC** (www.iarc.fr/en/media-centre/pr/2012/pdfs/pr213_E.pdf) - Jun 12, 2012 - Occupational Safety and Health study of occupational exposure to such ... data on the occurrence and impact of diesel exhaust are limited. You've visited this page 3 times. Last visit: 11/06/14
- Diesel engine exhaust fumes are 'major cancer risk' | Mail...** (www.dailymail.co.uk/health/.../Diesel-engine-exhaust-fumes-major-canc...) - Jun 13, 2012 - Diesel engine exhaust fumes belong in the same potentially deadly category ... The evidence of harmful health effects of diesel, particularly for ...
- IDEM: Health Effects of Diesel Emissions - IN.gov** (www.in.gov/idem/5262.htm) - The health effects of diesel exhaust are both acute, from short-term exposure, and ... diesel is used regularly or experiences repeated exposure to diesel fumes ...
- Diesel engine exhaust emissions INDG288 - HSE** (www.hse.gov.uk/pubs/indg288.pdf) - Diesel engine exhaust emissions (commonly known as 'diesel fumes') are a mixture ... assessment of the risks to your health if you are exposed to diesel fumes.
- Diesel - Tox Town - National Institutes of Health** (toxdown.nlm.nih.gov/text_version/chemicals.php?id=11) - Apr 1, 2014 - Tox Town logo: Environmental health concerns ... welding fumes, and asbestos, long-term exposure to diesel exhaust can increase ... if you think your health has been affected by exposure to diesel fuel or diesel exhaust, ...
- OEHHA Air: Health Effects of Diesel Exhaust** (oehha.ca.gov/Air/FactSheets) - Health Effects of Diesel Exhaust: A fact sheet by Cal/EPA's Office of Environmental Health Hazard Assessment and the American Lung Association. Download a ...

Searches related to health effects of diesel fumes

Appendix G. The first page of Google search results from the phrase “health effects of driving a bus”

(assessed on August 13th, 2014).



The image shows a screenshot of a Google search results page. The search bar at the top contains the text "health effects of driving a bus". Below the search bar, there are navigation tabs for "Web", "Images", "Videos", "News", "More -", and "Search tools". The search results are listed below, starting with "About 1,970,000 results (0.34 seconds)".

Bus Driver Health - Public Transport - About.com
publictransport.about.com | ... | All About Transit Employment *
by Christopher MacKechnie - Bus driving is one of the most hazardous occupations for your health. Research has shown ... Padded seats with lumbar supports help to prevent back problems.

International Transport Workers' Federation: Bus Drivers ...
www.itfglobal.org | Road transport | Buses and Coaches *
The ITF joint working group on health and safety in urban transport is aware of at least 32 studies. All of them show that bus driving is a high risk occupation.

Driving a Bus is Hazardous to Your Health - Amalgamat...
www.atu.org | Media Center | News Articles *
May 3, 2012 - They reflect people's real health problems, rather than incomplete ... "Passenger transit workers" include all types of bus drivers, as well as ...

Local 1576 - Health Effects of Career Bus Driving
www.atu1576.org/index.cfm?action=article&articleID=44cf548d... *
Pete Majkut, CT shop steward and champion of driver safety, sent our office an interesting paper that was written by the MFL Occupational Health Centre in ...

Bus Drivers - Consumer - HealthDay
consumer.healthday.com | .../health/health_.../bus-drivers-646402.html *
Mar 11, 2014 - Zook used to drive a bus for an urban transit district in Northern California. ... And their health issues and work problems differ somewhat from ...

Excess risk of sickness and disease in bus drivers: a re...
www.ncbi.nlm.nih.gov/pubmed/3042649 *
by MA Winkley - 1998 - Cited by 121 - Related articles
In an extensive search of available literature, 22 epidemiological studies that have examined health risks of bus drivers were identified. These studies focus on ...

The Very Mortal Life of City Bus Drivers - CityLab
www.citylab.com/commute/2012/09/very-mortal...bus-drivers/3166/ *
Sep 5, 2012 - The job of city bus driver has long been one of the most stressful and ... and depression), and behavioral (substance abuse) health problems.

The Health Impact of Urban Mass Transportation ... - ...
nyccosh.org | .../hazards%20by%20occupation | .../TWU_Report_Final-9-4-... *
by S Markowitz - 2005 - Cited by 2 - Related articles
Safety and Health Hazards in Urban Mass Transit. 22 ... health. The bus driver experiences both job-related hypertension and exposure to air pollutants such.

Bus driver well-being review - University of Aberdeen
www.abdn.ac.uk/prcdocuments/bus_driver_wellbeing.pdf *
by LM John - 2005 - Cited by 100 - Related articles
that bus drivers are liable to suffer ill health as a result of the job remain true ... Bus driver ill health will have consequences for organisational performance in.

Occupational Safety and Health of Road Transport Driver...
https://osha.europa.eu/en/sector/road_transport/index.html *
Managing occupational safety and health risks to drivers in the road ... Lorry and van drivers; Taxi drivers and chauffeurs; Bus and coach drivers; Bicycle and ...

Categories related to health effects of driving a bus