


Hazards Associated with Diesel Exhaust Emissions

A resource for all industries

Workplace Safety North™

Hazards Associated with Diesel Exhaust Emissions

After reviewing this resource, you will be able to:

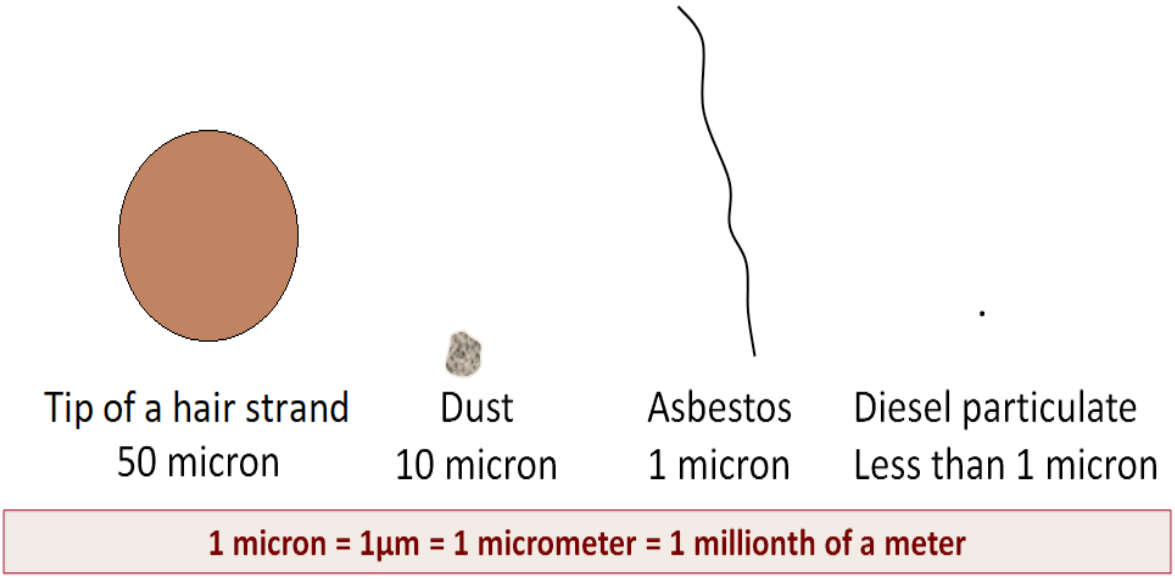
1. Understand the composition of diesel and reasons it is dangerous
2. Discuss the debilitating effects (short-term and long-term) of diesel exhaust inhalation
3. Identify sources of diesel in various industries
4. Read and recognize legislation applicable to diesel-powered equipment use
5. Apply the RACE principle to curb the negative effects associated with diesel exhaust emissions

Notes:

Understanding Diesel Composition

Consider the width of one strand of your hair. Is it visible to your naked eye? You likely answered, "barely" (if you can see it at all). When thinking of the size of this 'dot' that the tip of a strand of your hair makes, you know you are unlikely to see anything much smaller than that.

The interesting part: if you can't see the tip of your hair strand, then you definitely cannot see a speck of diesel exhaust particulate. It is one fiftieth (1/50) the size of the tip of your hair strand!



It gets worse: consider this. The tip of one hair strand measures 50 microns in length. Microns equal one millionth of a metre. A piece of diesel particulate is one micron! How incredibly tiny!

Now, it gets even worse: the lighter and smaller the particle, the longer it stays in the air, and the easier it is to breathe in. Furthermore, respirable dust (with a diametre of 10 microns or less) can enter the deepest part of the human lung when breathed in... not to mention other body tissues and the bloodstream.

...and worse: the International Agency for Research on Cancer, under the World Health Organization, now classifies diesel exhaust as a definite human carcinogen (where, in 2012, it was labelled a probable carcinogen). Carcinogens are agents or substances that can cause cancer.

Here is the issue: there are millions of diesel exhaust particulates in the air that workers from various industries routinely breathe in, and research in recent years has proven diesel exhaust to have severe impacts on human health.

Understanding Diesel Composition

Here are some other facts about diesel composition:

- Visually, diesel exhaust appears as a cross between a black and grey smoke cloud with a blue tinge. (Think of the colour of exhaust that you see from your vehicle: it's that colour.)

  Having said that, you can be working in an environment with higher-than-acceptable diesel emissions and not see anything. You don't need to see smoke to be in danger.

- It is made of four parts: gases, vapours, mist, and particulates (soot). Gas is made of carbon dioxide, carbon monoxide, nitric oxide, nitrogen dioxide, sulphur oxides, and hydrocarbons, including polycyclic aromatic hydrocarbons (PAHs). Soot is the diesel particulate matter (DPM), and it is made of carbon, PAHs, and some metallic compounds.
- PAHs affect the skin, liver, and immune system, and they are also formed when coal, oil, gas, garbage, and tobacco are burned. Several PAHs are in DPM.
- The Department of Health and Human Services (in the United States) found that some PAHs may be carcinogenic. However, not all PAHs are bad; some PAHs are also used in making medicines. Others are used in manufacturing dyes, plastics, and pesticides.

More on Diesel Composition

Diesel particulate matter (DPM) leaves a sooty residue, and this due in part to its chemical makeup. DPM is composed of both solid and liquid aerosol particles of varying sizes. The smallest recorded particles can be as small as 50 nanometres in size. That's 0.00005 millimetres!

To give you a clearer idea of the relative size of a nanometre, take a look at the image below. Also, consider this: the head of an eraser on a regular pencil is 5 millimetres in diameter. (That's 5,000,000 nanometres... meaning **100,000 DPM particles could fit on the tip of a pencil**. That's a lot of particles.)

A nanoparticle of four nanometres in diametre

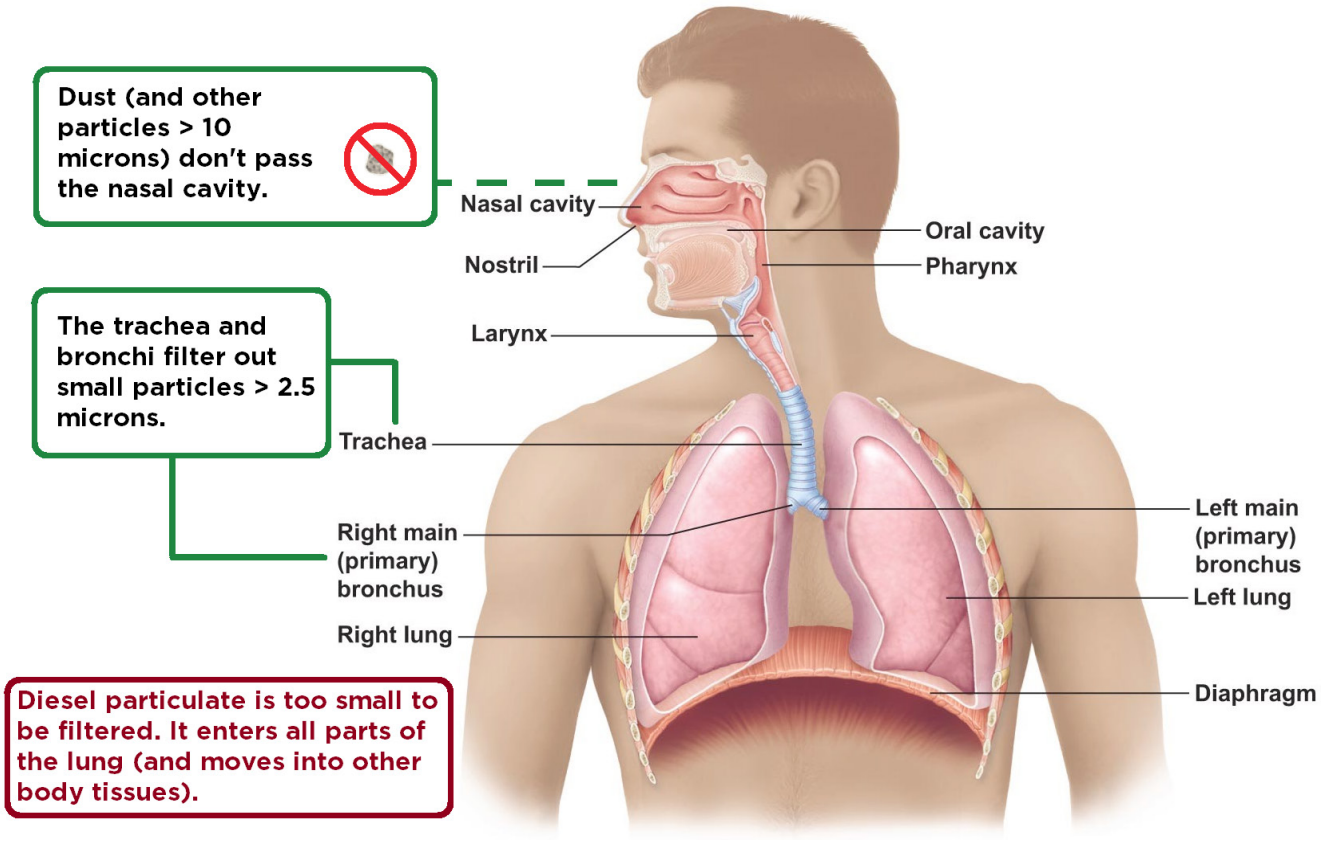
An ant of 4,000,000 nanometres in length

There are several known carcinogens in the chemical makeup on DPM, and these result from incomplete combustion of diesel fuel in machine engines. Lung inflammation and other health effects are also associated with exposure to DPM. We will take a look at these effects after seeing how DPM enters our body systems.

What Makes Diesel Exhaust so Dangerous?

Well, simply put: **size matters**.

Our respiratory systems are great machines that prevent us from breathing in a lot of dust and other garbage. Think of how you don't breathe in sand when you're at the beach. You might get some in your nose, but it doesn't pass through your nasal cavity and enter into your system. This diagram shows how our breathing process is able to filter the air we breathe to get the best quality of air that it can.



The human body is built to filter out toxins and other harmful agents in the air that are 10 microns or greater in size. We can cheer our systems on for their hard work; this means, luckily, that we filter out most specks even thinner than the diametre of a human hair strand! Unfortunately, while we are able to keep specks of sand (90 microns in diametre) out of our systems, DPM (which is much smaller in size) can still pass our sinuses and enter our body systems, right down to our bloodstreams.

Activity: Effects of Working in the Presence of Diesel Exhaust

There are several effects associated with working in environments containing larger quantities of diesel exhaust particulate, and they can affect more people than just the workers who are in direct contact with the hazard. The following exercise is meant to get you thinking about what, and how deep, these effects can be.

Read the following two questions and write your answers in the spaces provided. The best way to brainstorm answers to these questions is to work with a partner. Follow your instructor's directions to complete this task.

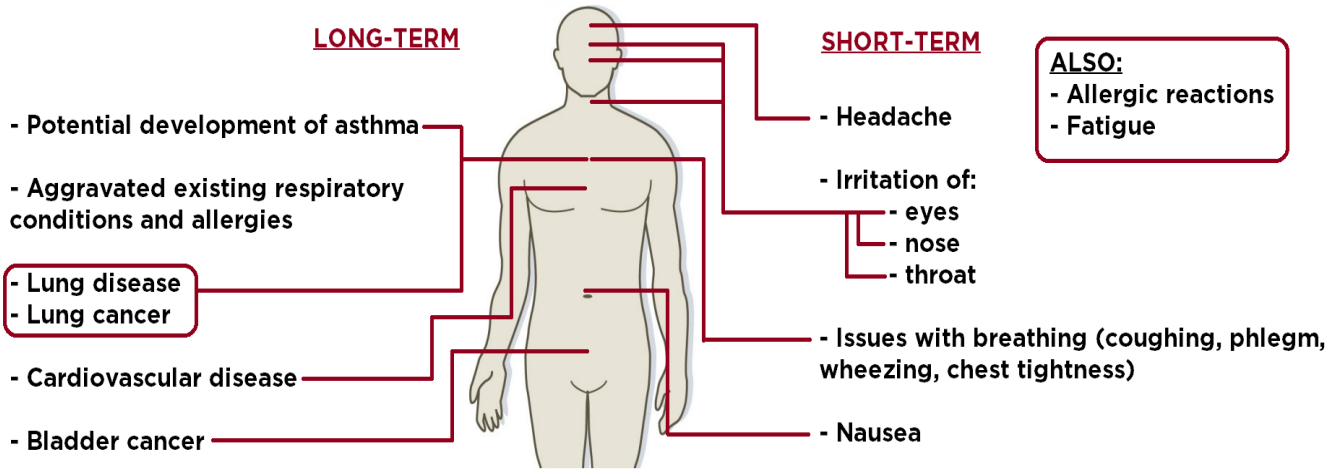
You may be asked to share your responses with the class in a follow-up discussion.

Can you think of three potential negative health effects associated with working in diesel exhaust-rich environments? List them here.

If you know of anyone who was affected by diesel exhaust in any way you mentioned above, share your story.

Effects of Working in the Presence of Diesel Exhaust

The list of effects associated with diesel exhaust exposure is quite extensive. The following diagram points out the most common ones, with short-term effects on the right, and long-term effects on the left.



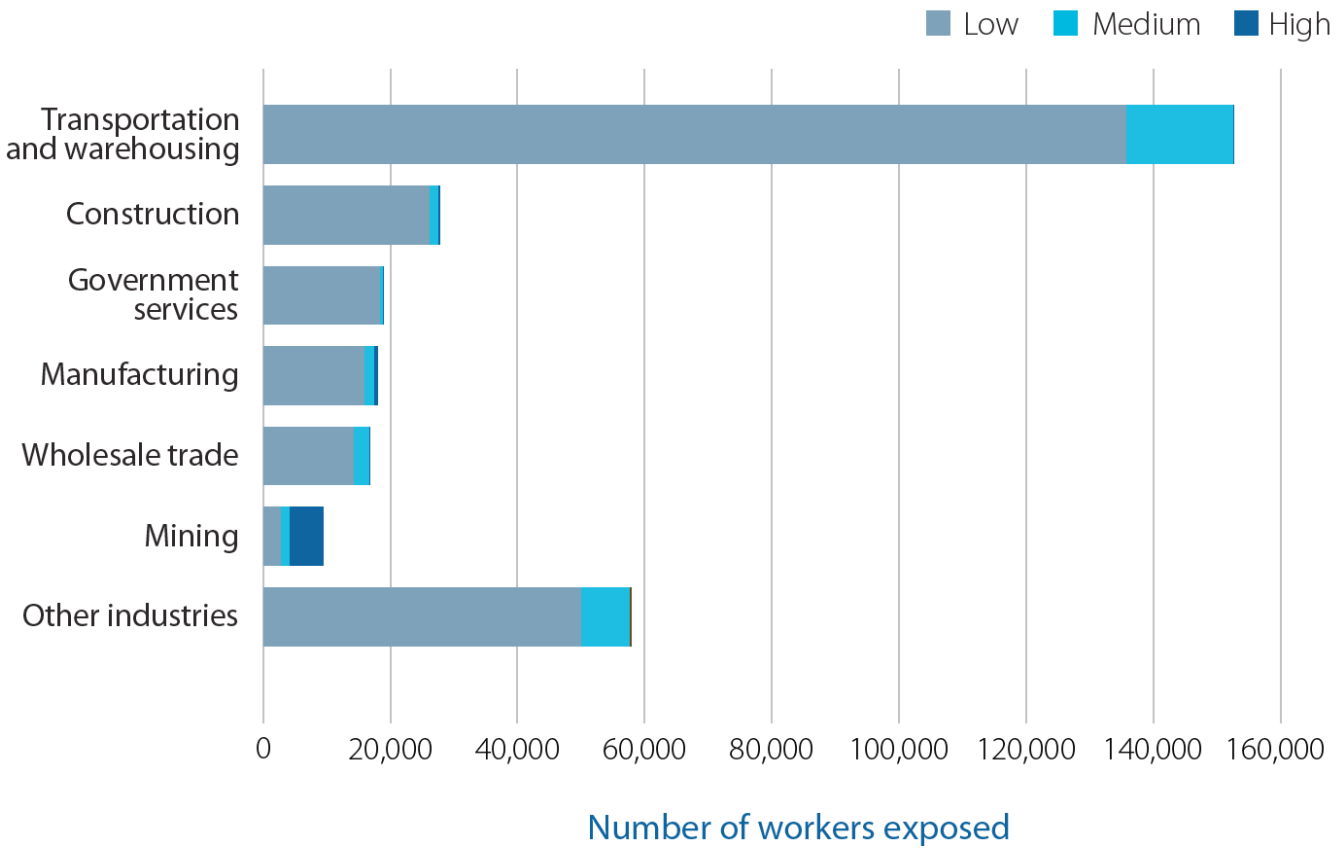
It is important to remember that **you do not need to suffer any short-term effects in order to suffer from the long-term ones!** For example, you may never feel ill when working; you may only begin to realize something is wrong (if at all) years after things take effect in your body.

Remember Claude Fortin: he was an active nonsmoker who never experienced health issues until his diagnosis. His situation was severe, and he went into rapid decline.

Notes:

Why is Diesel Exhaust Important to Me?

People working in a number of different occupations are exposed to startling concentrations of diesel exhaust emissions. Take a look at the following graphic showing the number of workers exposed by industry in Ontario, specifically.



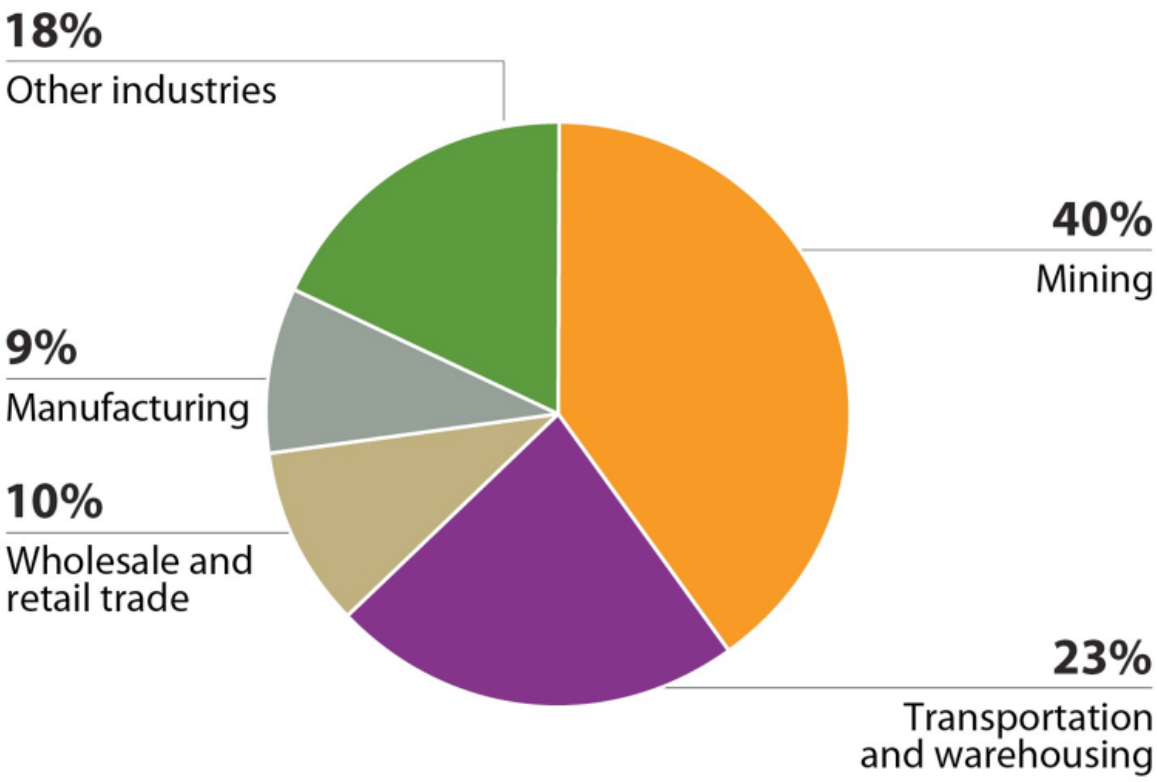
Occupational Cancer Research Centre, 2017

You may be thinking that 301,000 exposed workers is a small number, especially when comparing it to the 14,000,000 people living in Ontario (according to a 2017 estimate). Though exposed workers make up just over two percent of Ontario's population, the number does not come close to reflecting just how many people in the province are exposed to diesel through other means, in relation to where they live or what activities they participate in outside of work.

Looking at Cancers from Diesel Exhaust in Ontario

The Occupational Cancer Research Centre (OCRC) determined the percentages of workers from various industries who were diagnosed with lung and bladder cancers, likely from occupational exposure to diesel exhaust emissions. Research into the link between bladder cancer and diesel exhaust exposure is still ongoing. These next pie charts break down the percentages of workers by trade.

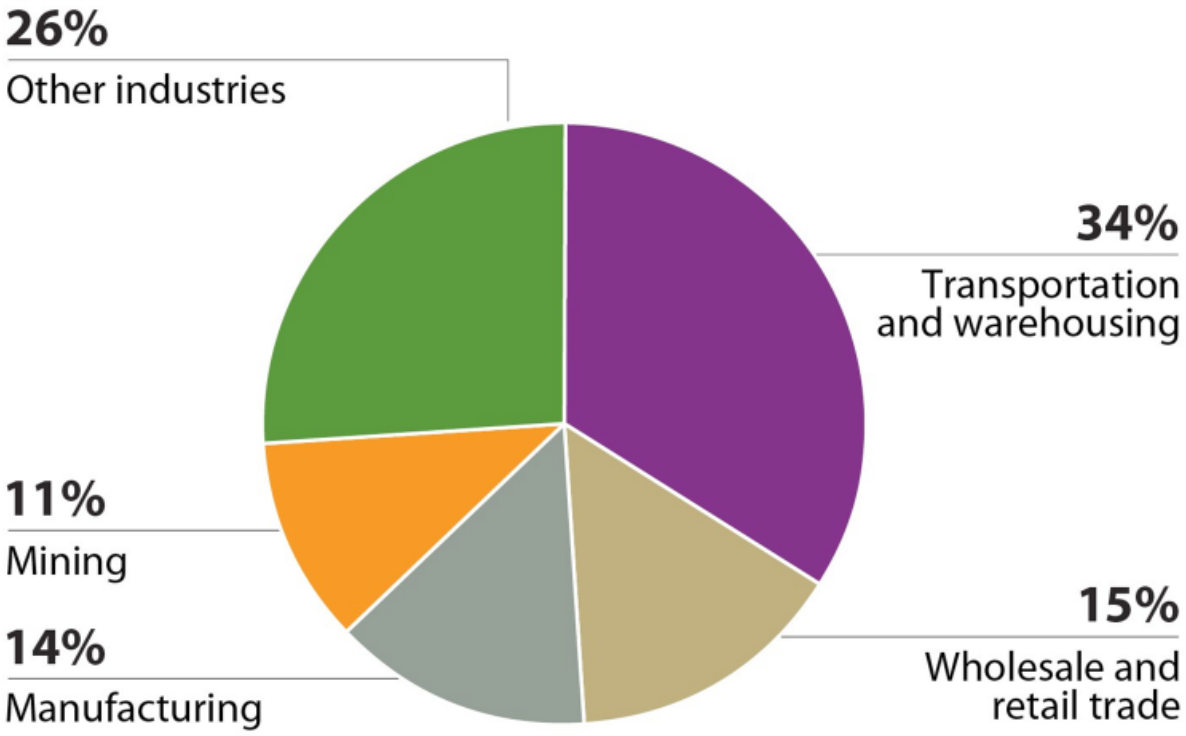
Industry breakdown of total lung cancers attributed to occupational diesel engine exhaust (DEE) exposure (170 cases)



Annually, approximately 2.1 percent of lung cancer cases diagnosed in Ontario are attributed to occupational exposure to diesel exhaust. Mining employees have been found to be especially susceptible to diesel emissions because of the concentrated quantities of exhaust they are faced with, particularly in underground mining operations.

Looking at Cancers from Diesel Exhaust in Ontario (cont'd)

Industry breakdown of total bladder cancers that may be attributed to occupational diesel engine exhaust (DEE) exposure



The OCRC found that 2.3 percent of bladder cancer diagnoses may be from occupational exposure to diesel exhaust. More workers from transportation and warehousing industries have been diagnosed with bladder cancer from this exposure, while more workers from the mining industry are affected by lung cancer.

For more information on the impact that diesel exhaust emissions - or other substances, such as asbestos, benzene, crystalline silica, and UV rays, among other factors - has on Ontario workers in terms of occupational cancer, look online for the *Burden of Occupational Cancer in Ontario* (2017) report by the OCRC. It is available for free, and is accompanied by a presentation with graphs addressing various substances, similar to the ones you see above.

Activity: Sources of Diesel Exhaust at Your Workplace

Consider your current workplace. Using the space provided, list and briefly describe exposure to diesel exhaust to you and your colleagues when at work.

Name one piece of equipment at your current workplace that is powered by diesel fuel.

How many people use that equipment? How often is it used?

How do you currently protect yourself from DPM at work? Are there any policies at your workplace that you can think of that address this hazard, specifically?

Share any personal stories or thoughts you have about diesel emissions in your workplace.

Sources of Diesel Exhaust in Various Industries

The following table lists common types of diesel-powered equipment used in various industries.

Lift Trucks		**Dump Trucks**	
Pickup Trucks		**Bulldozers**	
Backhoe Loaders		**Excavators**	

As you look at these pieces of equipment, think about these important points:

- Is any one of these pieces of equipment used where you work?
- What other industries rely on this type of equipment?
- Do you know whether the equipment at your workplace is diesel-powered? (There are alternatives; we will discuss these later.)

What does the Ontario Law have to say about Diesel Exhaust Emissions?

There are no rules enforcing occupational exposure limits set specifically for diesel exhaust in most industries (mining excepted). However, there is some legislation regarding occupational exposure to dangerous products related to diesel exhaust. It is summarized for you below.

Regulation 833: Control of Exposure to Biological or Chemical Agents

This regulation communicates workplace exposure limits according to data from Table 1 in the regulation, or from a series of values by the American Conference of Governmental Industrial Hygenists (ACGIH). Each source specifies exposure according to different time measurements depending on the substance. According to the regulation, time-weighted average limits (TWA) are meant to determine the *time-weighted average airborne concentration of a biological or chemical agent to which a worker may be exposed in a work day or week*. Meanwhile, short-term exposure limit (STEL) refers to the *maximum airborne concentration of a biological or chemical agent to which a worker may be exposed in any fifteen-minute period.*

This table contains notable references to occupational exposure limits for some substances found in diesel exhaust. You will see that they are either measured in milligrams per cubic metre (mg/m^3) or in parts per million. Note that this information is current to February 2018.

Occupational Exposure Limits for Ontario Workplaces

Agent	*TWA*	*STEL*
Carbon dioxide	5,000 ppm	30,000 ppm
Carbon monoxide	25 ppm	
Nitrogen dioxide	3 ppm	5 ppm
Diesel fuel as total hydrocarbons	100 mg/m^3 (inhalable fraction and vapour)	

It is important to remember that, as per Regulation 833, *every employer shall take the measures required to limit the exposure of workers to a hazardous biological or chemical agent in accordance with the rules that apply to it*.

Regulation 854: Mines and Mining Plants

There are additional guidelines set out for the mining industry for total carbon and elemental carbon. According to Section 183.1(5):

The flow of air must,

(a) reduce the time-weighted average exposure of a worker to total carbon to not more than 0.4 milligrams per cubic metre of air; or

(b) reduce the time-weighted average exposure of a worker to elemental carbon, multiplied by 1.3, to not more than 0.4 milligrams per cubic metre of air.

Introducing the RACE Principle and Applying it to Diesel Exhaust Emissions Safety

Do you know the RACE principle?

Recognize	**Identifying hazards relevant to your workplace**
Assess	**Ask yourself: what is the likelihood that this could do harm? What are the potential consequences?**
Control	**Implementing measures to deter or remove the hazard**
Evaluate	**Ask yourself: how effective were the controls at reducing/preventing the hazard?**

Before attempting to apply the RACE principle to diesel exhaust emissions, you need to know the different methods related to the "C" in RACE.

- **Eliminate** the hazards causing diesel exhaust emissions
- **Substitute** the way we get the work done with better, more health-conscious solutions
- Apply **engineering controls** where possible
- Add **administrative controls** when other above methods cannot be used
- Use **personal protective equipment** to protect workers at the individual level

Activity: Recognizing the Hazards

Use your personal experience and reflections to answer the following questions. Consider using this exercise in the future as a working record for what you will look for when you return to your worksite.

Think about the diesel equipment you listed in one of the previous exercises. Focusing on one piece of equipment, consider where it is positioned, and recall whether you think its working area is well ventilated and safe.

Think about whether you see air quality tests taking place at your worksite, particularly in areas affected by diesel-powered equipment. Write your reflections on the tests in the space provided. (How often do you see the tests? Do you know anything about what they measure? Who runs the tests?)

Based on what has been discussed so far, jot down key points you wish to remember to discuss with your workplace's Joint Health and Safety Committee (JHSC) or Health and Safety Representative.

Activity: Assessing the Hazards

You have come to learn about what to recognize as a potential diesel emissions hazard in the workplace. By the end of this exercise, you will know some ways you can assess the hazards and attempt to control them.

Consider the following scenario:

During John's circle check inspection, he noticed that the lift truck he is to use today in the loading bay is smoking a little bit.

...and answer the related questions.

What is the hazard?

What can it do?

Who is in danger?

What should John do, and when?

Controlling Diesel Emissions Hazards

Elimination

Elimination is the most effective of the five methods discussed in the controlling phase of RACE. It is most effective because, as its name suggests, it requires the removal of the hazard from the worksite.

The main elimination strategy is the complete removal of diesel-powered equipment, replacing it with electrically-powered or battery-powered alternatives. In recent years, electrically-powered devices and machines have gained popularity.

If you wish to make notes about the discussion you have with your class about elimination practices, feel free to do so in the space below. The questions you will be discussing are also included on this page for your convenience.

1. Can you think of any equipment in your workplace that relies on electricity or battery power (instead of diesel)?

2. List possible pros and cons to altogether eliminating diesel-powered equipment in the workplace.

Pros	Cons

Controlling Diesel Emissions Hazards

Substitution

Substitution is another effective way to control diesel emissions; however, it is not as effective as the elimination (or complete removal) of diesel noted earlier.

Some key substitution methods include:

- **Replacing older equipment pieces.** Older engines on diesel-powered machines were responsible for higher levels of diesel exhaust emissions. Replacing these engines with those that will combust diesel fuel more completely not only reduces these emissions, but it can also prolong the life of the machine itself.
- **Rebuilding engines.** Some manufacturers of diesel-powered equipment offer tools and pieces that can be used to repair or upgrade the efficiency of their engines. Upgrading a diesel-powered engine can also reduce diesel exhaust emissions.
- **Alternative fuels.** The use of biodiesel is becoming a more common practice. Substituting biodiesel for regular diesel can reduce the DPM released into the air. A common example of this biofuel is B20 (consisting of 20% biodiesel and 80% petroleum diesel). The Ontario government also issued new legislation (beginning in 2014, with implementation phase dates through to 2017) for the addition of up to five percent biofuel in biodiesel for motor vehicles in the province.

Consider the following questions:

Are you aware of whether diesel-powered equipment in your workplace has had work done to it, such as the replacement of its engines or exhaust manifolds?

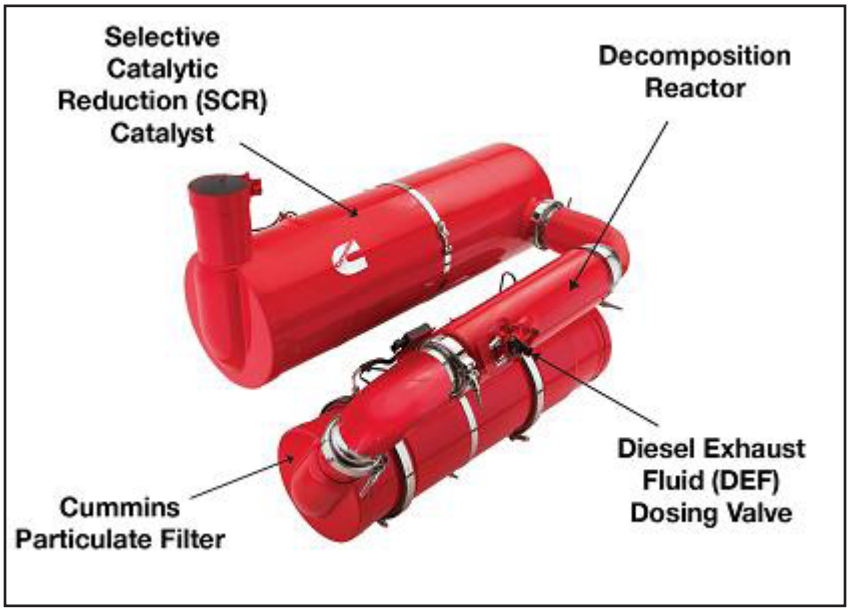
Were you aware of upgrading kits for engines on diesel-powered equipment?

Controlling Diesel Emissions Hazards

Engineering Controls

These types of controls have less of an impact than substitution methods, but they also work toward controlling emissions by making changes to the machinery or the general infrastructure of the worksite. Some popular engineering controls are listed below.

- **Aftertreatment Systems.** Examples of these types of systems are diesel particulate filters (DPFs) and diesel oxidation catalysts (DOCs). These devices refine exhaust emissions by retaining them, rather than letting these emissions be exposed to the air. According to the Occupational Cancer Research Centre, these systems can reduce emissions by anywhere from 20 percent to 95 percent.



- **Idling Technology.** Rather than letting equipment continue to idle, this innovation shuts the engine off when it is not in use. This technology can be found in modern transportation vehicles. The goal is to have idling technology that will not wreak havoc on the engine with too many instances of stopping and restarting it.

The question from the slide on engineering control methods is listed below for your convenience; feel free to record information from your discussion in the space provided.

Have you seen any of these types of controls in action in your workplace?

So How Does a DPF Work, Anyway?

Diesel particulate filter (DPF) technology has been in development since the 1980s, and it has been developed to take away particulate matter (PM) from the engine's exhaust through a filtration system that retains the particulate and prevents it from being released into the air.

As an engine runs, the PM (soot) from the combustion process is retained in the filter. When a certain level of soot has been reached in the filter, the operator will be made aware of the need for the filter to undergo a *regeneration process*. This requires additional heat to be sent to the filter to burn off the excess soot so that it is not discharged in the air.

Depending on the configuration of the filter and the engine, a DPF can use *active regeneration* to combust the particulate matter while the vehicle is being used. In other cases, the vehicle may require some downtime for the combustion process to take place.

According to a case study regarding the addition of a DPF to a John Deere backhoe, the particulate released in the air was reduced by over 90 percent, and the noise level of the muffler was also substantially reduced.

These filters are available for all types of diesel-powered equipment. From lift trucks to transport trucks, all types of vehicles relying on diesel fuel can be equipped with this filtration system.

Questions:

Were you aware of diesel particulate filter systems before now?

While the environmental impact is positive, what negative points could be made about adding DPFs to your company's equipment?

Controlling Diesel Emissions Hazards

Administrative Controls

Check out these interesting facts about maintenance as an administrative control strategy:

- Routine maintenance can decrease particulate matter emissions by up to 55% on certain machines
- Tune-ups on 'gross smoke emitting' vehicles reduce emissions by an average of 40%
- Clogged air filters cause a 40-50% increase of emissions
- Excess oil consumption (most often preventable through maintenance) causes a 100% increase in emissions
- Lubricant oil consumption causes up to 85% higher emissions

Questions from the slide on administrative control methods are listed below for your convenience; feel free to record information from your discussion in the space provided.

How could we make sure equipment operators recognize the need for maintenance on the machine with which they work?

Apart from reduced emissions, what other benefits could result from routine equipment maintenance?

How an Effective Health and Safety Culture Enhances Administrative Controls

In the hierarchy of controls, administrative controls are at the lower end in terms of effectiveness (second only to personal protective equipment).

However, this is the first set of controls that relies more on the *worker* than anyone (or anything) else in a workplace.

- The worker is the one who will document routine maintenance done to a machine.
- The worker is the one who will apply (or not apply) his or her training to complete a task.
- The worker is the one who will use the information in a user manual to make sure the machine is working correctly (and does not create a hazard).
- The worker is the one who will experience the hazards at the front end, and therefore has more insight to communicate to the supervisor and other workers.

Companies lean more toward using administrative controls than those higher up in the hierarchy of controls as they are more cost-effective and are quicker to implement. This is why they are so important to follow.

With such emphasis placed on the worker with these controls, making sure the worker is not only compliant, but *eager* to use these controls is very important. A strong health and safety culture helps with this. The health and safety culture of a workplace ensures an effective internal responsibility system is in place, in that workers are motivated to report hazards and work with others (including their employers) to create the safest workplace possible.

How can a health and safety culture be made?

Positive health and safety cultures are demonstrated at all levels of an organization. Key factors that contribute to a positive health and safety culture include **trust, ongoing communication, respect, openness and encouragement to report and discuss potential hazards, competence,** and **commitment from all parties**.

Controlling Diesel Emissions Hazards

Using Personal Protective Equipment

Personal protective equipment use is not the best means to curb negative effects associated with diesel exhaust emissions, but it still provides some form of defence against them.

Respirators are strongly recommended for confined spaces, regardless of ventilation practices. Impervious gloves are recommended in some industries, such as forestry or transportation, if the worker could have his or her skin exposed to diesel fuel.

Questions from the slide on personal protective equipment are listed below for your convenience; feel free to record information from your discussion in the space provided.

What issues could result in ineffective use of respirators?

What other things about respirator use need to be in place to make them most effective?

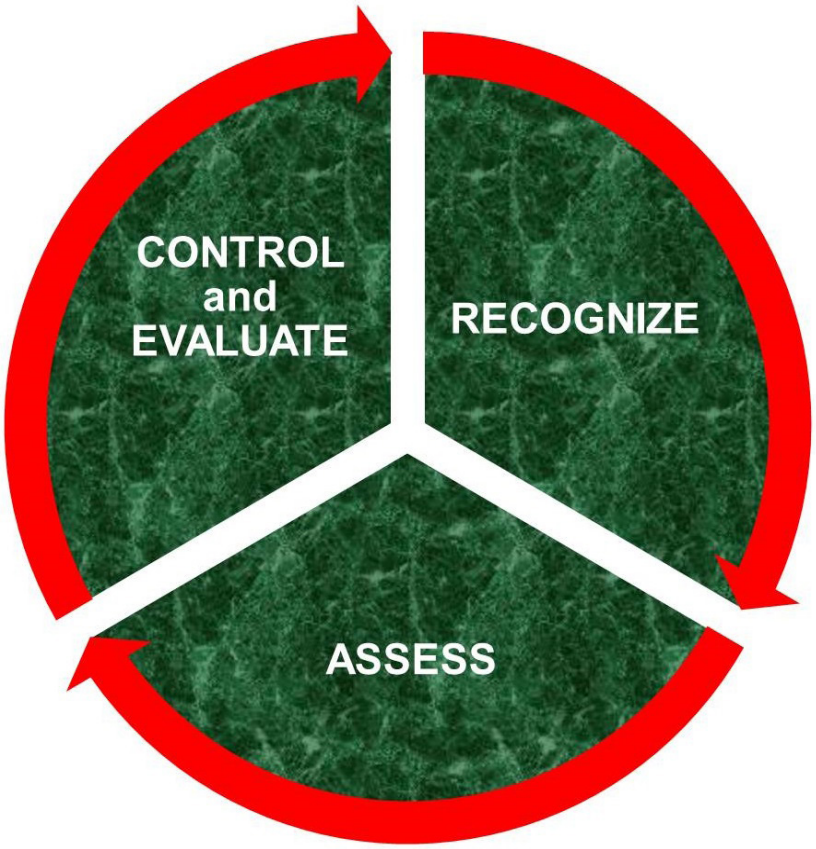
Evaluating Controls (The End of the RACE)

The RACE model applies to identifying and reducing the negative effects of diesel exhaust emissions in the workplace. Take what you learned in this resource and be sure to apply it where you work.

Inform yourself of when inspections of equipment have been done, and when routine maintenance has been done on diesel-powered machines. If unsure, find out which machines are diesel-powered, and which ones rely on electricity or battery power. Consider additional engineering and administrative controls, and when you next carry out an inspection of the equipment, determine whether it may be appropriate to use these controls to make your recommendations to your employer for ways to reduce damage to equipment and keep your colleagues safe and healthy.

Remember, however, that the RACE never ends!

The RACE model is a cycle, and it must be routinely done to ensure optimal safety mechanisms are in place for you and your team. Together, the IRS (maintained through a strong health and safety culture) works toward making sure every employee stays safe!



Notes: