Diesel Exhaust Emissions and its Adverse Health Effects

Presented by

Masood Ahmed MS, CRSP
Occupational Hygienist

Occupational Health Clinics for Ontario Workers (OHCOW)

Outline

- Composition of diesel exhaust
- Diesel exhaust exposure in underground mining
- Occupational Exposure Limits
- Adverse health effects from diesel exhaust exposure
- Carcinogenic effect of diesel exhaust
- Summary

Chemical composition

- Diesel exhaust is a complex mixture of hundreds of constituents in gas or particulate phase.
- It can be broadly classified into gaseous and particulate phase.
- Gaseous components include:

carbon dioxide	carbon monoxide
oxygen	sulfur compounds
nitrogen	water vapours
nitrogen compounds	
low molecular hydrocarbons	

3

Occupational Health Clinics for Ontario Workers Inc. Centres de santé des travailleurs (ses) de l'Ontario Inc.

Chemical composition

- There are some known toxicological hydrocarbons in the hydrocarbon group such as
  - Aldehydes (formaldehyde, acetaldehyde, acrolein)
  - Benzene
  - 1,3 butadiene
  - PAHs and nitro PAHs

EPA Health Assessment for Diesel Engine Exhaust 2002

4

Occupational Health Clinics for Ontario Workers Inc. Centres de santé des travailleurs (ses) de l'Ontario Inc.

Chemical composition

- The particles in the diesel exhaust are present as core elemental carbon with adsorbed organics.
- Trace amounts of sulfate, nitrate, metals, and other trace elements are also present in the diesel exhaust.
- The diesel particulate aerodynamic diameter is less than 2.5 µm (fine particles) with a subgroup of less than 0.1 µm diameter size (ultrafine particles).

EPA Health Assessment for Diesel Engine Exhaust 2002

5

Occupational Health Clinics for Ontario Workers Inc. Centres de santé des travailleurs (ses) de l'Ontario Inc.

Chemical composition

- The small particle size provides large surface area for adsorption.
- Fine and ultra fine particles are respirable particles with the ability to reach the air exchange region of the lungs
- Typical composition of particulate matter in the diesel exhaust is (EPA 2002 and HEI 2003)
  - Carbon Black 19%
  - Elemental Carbon 75%
  - Metals and elements 2%
  - Sulfate, nitrate 1%

6

Occupational Health Clinics for Ontario Workers Inc. Centres de santé des travailleurs (ses) de l'Ontario Inc.

Chemical Transformation

- Diesel exhaust is chemically and physically transformed in the environment.
  - Diluted
  - Transported
  - Adsorption of organics on PM
  - Interaction with environment
- The atmospheric lifetime of some of the constituents range from hours to days.

7

Occupational Health Clinics for Ontario Workers Inc. Centres de santé des travailleurs (ses) de l'Ontario Inc.

Variation in Diesel Exhaust Emission

- Diesel exhaust vary in chemical composition and particle size distribution according to the:
  - Engine types
  - Engine operating conditions
  - Fuel formulation
  - On road and non-road engines

8

Occupational Health Clinics for Ontario Workers Inc. Centres de santé des travailleurs (ses) de l'Ontario Inc.

Occupations with Diesel Exhaust exposure

- Ambient air, miners, forklift truck operator, fire engine operator, truck drivers, and railroad workers.
- Gangal and Dainty (1993)
  - studied diesel exhaust exposure in 21 Canadian non coal mine by collecting 223 personal and area samples. Mean estimated diesel particulate levels ranged from 0.1 to 0.9 mg/m^3 with maximum range of 0.7 to 2.1 mg/m^3 .

A critical analysis of emissions, exposure, and health effects: HEI 1995

9

Occupational Health Clinics for Ontario Workers Inc. Centres de santé des travailleurs (ses) de l'Ontario Inc.

Occupations with Diesel Exhaust exposure

- Watts and associates (1989, 1992) and Cantrell and Colleagues (1992, 1993) reported underground air quality data of 5 coal mines.
  - Area samples were taken in the clean air intake section, haulage way, diesel shuttle cars, and return airway.

Location	Mean
Haulage way	0.89 mg/m^3
Shuttle car	0.67 mg/m^3
Return airway	1.43 mg/m^3

10

Occupational Health Clinics for Ontario Workers Inc. Centres de santé des travailleurs (ses) de l'Ontario Inc.

Occupations with Diesel Exhaust exposure

- McCawley and Cocalis (1986) sampled sub micrometer size diesel aerosol in two coal mines. Mean level ranged from 0.1 to 0.8 mg/m^3 .
- Haney (1990) measured diesel particulate with a single jet impactor in five underground coal mines. Mean Level of particulate matter ranged from 0.18 to 1.0 mg/m^3 .

11

Occupational Health Clinics for Ontario Workers Inc. Centres de santé des travailleurs (ses) de l'Ontario Inc.

Occupations with Diesel Exhaust exposure

- Pronk et al (2009) reviewed literature to describe personal diesel exhaust exposure at various work sites as elemental carbon.
- The results were highest for the underground mining and construction, intermediate for working above ground, and lowest for working separated from the source.

Mining, mine maintenance, and construction	**27 - 658 µg/m^3**
Mechanics in a shop, Emergency workers in a fire stations, workers at dock, and workers loading/unloading inside a ferry	<50 µg/m^3
Drivers and train crew, surface mining, parking attendants, vehicle tester, utility service workers, airline ground personnel	<25 µg/m^3

12

Occupational Health Clinics for Ontario Workers Inc. Centres de santé des travailleurs (ses) de l'Ontario Inc.

Occupational Exposure Limits

- ACGIH proposed 20 µg/m^3 TLV-TWAE in 2002 measured as elemental carbon. The TLV was retrieved in 2003.
- NIOSH (1988) recommends an exposure limit below 1 µg/m^3 .
- EPA recommends a reference concentration (Rfc) of 5 µg/m^3 as DPM (roughly equal to 3.1-6.6 µg/m^3).
- OHCOW proposed an OEL similar to ACGIH 2002 (20 µg/m^3) at minimum if not NIOSH REL (<1 µg/m^3).

OHCOW OEL proposal submission to MOL-ON 2013
http://ohcow.on.ca/uploads/Resources/OHCOW%202013%20Submission%20to%20the%20MOL%20on%20OELs.pdf

13

Occupational Health Clinics for Ontario Workers Inc. | Centres de santé des travailleurs (ses) de l'Ontario Inc.

Adverse Health Effects of Diesel Exhaust

- Short term exposure to diesel exhaust and diesel particulate matter can cause (EPA 2002)
  - Eye irritation
  - Nasal irritation
  - Mucous membrane irritation
  - Unpleasant odour
  - Airway inflammation
- Reid et al (2012) studied lower respiratory tract immunologic response in human subjects with mild asthma and cat allergy exposed to DE and NO_2 . No reactivity was found.

14

Occupational Health Clinics for Ontario Workers Inc. | Centres de santé des travailleurs (ses) de l'Ontario Inc.

Long Term Health effects

- Non cancerous chronic respiratory effects from diesel exposure are not found in most epidemiological studies.
- Attfield et al (2011) conducted a study on a large cohort of 12 315 workers exposed to diesel exposed in 8 non-metal mines.
- The objective of the study was to
  - Estimate the total mortality and cause-specific mortality.
  - Assess lung cancer mortality in relation to diesel exhaust exposure.

15

Occupational Health Clinics for Ontario Workers Inc. Centres de santé des travailleurs (ses) de l'Ontario Inc.

Long Term Health effects

- SMR for lung cancer was 1.26 with CI of 1.09 to 1.44, oesophageal cancer 1.83, and pneumoconiosis 12.2 in total cohort.
- The hazard ratios were increased for ever underground workers with 15 years lagged cumulative REC exposure.
- Elevated hazard ratios were also observed for surface workers.
- Association of diesel exhaust exposure was found with lung cancer even after inclusion of confounding factors in the study.

16

Occupational Health Clinics for Ontario Workers Inc. Centres de santé des travailleurs (ses) de l'Ontario Inc.

Long Term Health effects

- Silverman et al (2011), performed a nested case-control study in the same cohort.
- REC exposures were estimated based on retrospective exposure for job and year, and each subject.
- Smoking and other confounding factors were also included in the study.
- Statistically significant increasing trends (OR) were found for lung cancer from increasing cumulative REC and average REC exposure.

17

Occupational Health Clinics for Ontario Workers Inc. Centres de santé des travailleurs (ses) de l'Ontario Inc.

Long Term Health effects

- Six meta-analysis have shown increased risk of bladder cancer from diesel exposure in road transportation (Manju et al 2009, Reulen et al 2008, Baena et al 2006, Kogevinas et al 2003, Boffetta and Silverman 2001, and Yamaguchi et al 1991).
- National Toxicology Program (NTP) in 2011 classify diesel exhaust as reasonably anticipated to be a human carcinogen

18

Occupational Health Clinics for Ontario Workers Inc. Centres de santé des travailleurs (ses) de l'Ontario Inc.

IARC classification

Group 1	**Sufficient evidence in humans or sufficient evidence in animals and strong mechanistic data in humans**
Group 2A	Limited evidence in humans and sufficient evidence in animals
Group 2B	Limited evidence in humans and less than sufficient evidence in animals
Group 3	Inadequate in humans and inadequate or limited in animals
Group 4	Lack of carcinogenicity in humans and in animals

http://www.fda.gov/downloads/AdvisoryCommittees/CommitteesMeetingMaterials/TobaccoProductsScientificAdvisoryCommittee/UCM215717.pdf

19

IARC classification of diesel exhaust

- IARC classified diesel exhaust as probably carcinogenic to human (Group 2A) in 1989.
- IARC re-evaluation committee recommended diesel exhaust as high priority for re-evaluation in 1998.
- IARC classified diesel exhaust as human carcinogen (Group 1) in 2012 for lung cancer.
- IARC considered evidence for bladder cancer as suggestive.

20

Summary

- Diesel exhaust is a complex mixture of chemicals
- Underground mining is the one of the workplaces with the highest exposure
- There are short term health effects from acute exposure and no non-cancerous chronic health effects reported
- Group 1 lung carcinogen. Evidence is still suggestive for bladder cancer according to IARC

21

Occupational Health Clinics for Ontario Workers Inc. Centres de santé des travailleurs (ses) de l'Ontario Inc.

Questions?

22

Occupational Health Clinics for Ontario Workers Inc. Centres de santé des travailleurs (ses) de l'Ontario Inc.