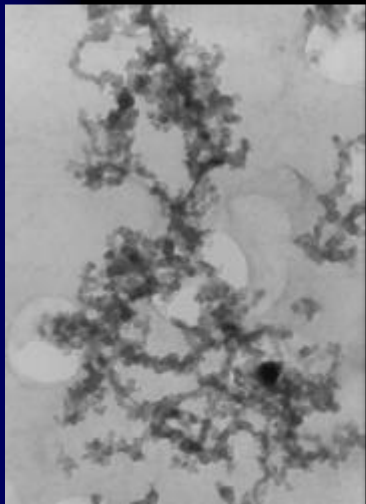


Occupational Health Clinics for Ontario Workers Inc. (OHCOW).

Diesel Exhaust

Need to monitor exposure and further reduce occupational exposure limit

Dr. Kevin Hedges (COH, CIH)

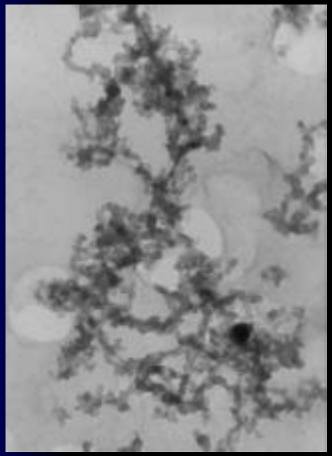
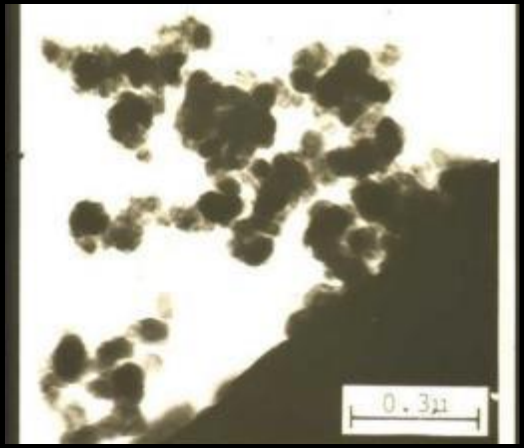
Occupational Hygienist (OHCOW)
khedges@ohcow.on.ca

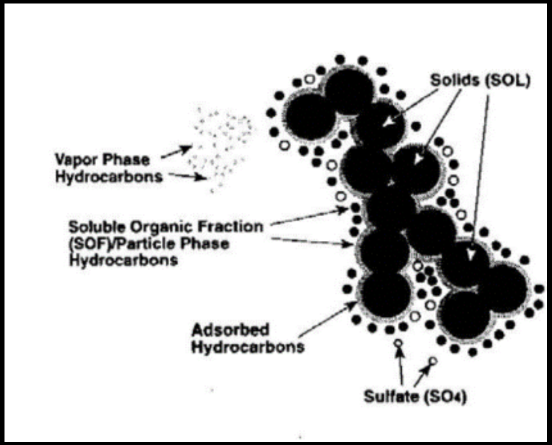
http://www.ohcow.on.ca/

Weight of the evidence or Wait for the Evidence? Protecting Underground Miners from Diesel Particulate Matter

"It doesn't look to *me* like it could do any chromosomal damage."

Diesel emission what does it consist of?



Diesel particulate matter (DPM)

- Organic carbon (PAH, Nitroarenes) ↔
- Elemental carbon
- Sulphate
- (other trace)

Vapours

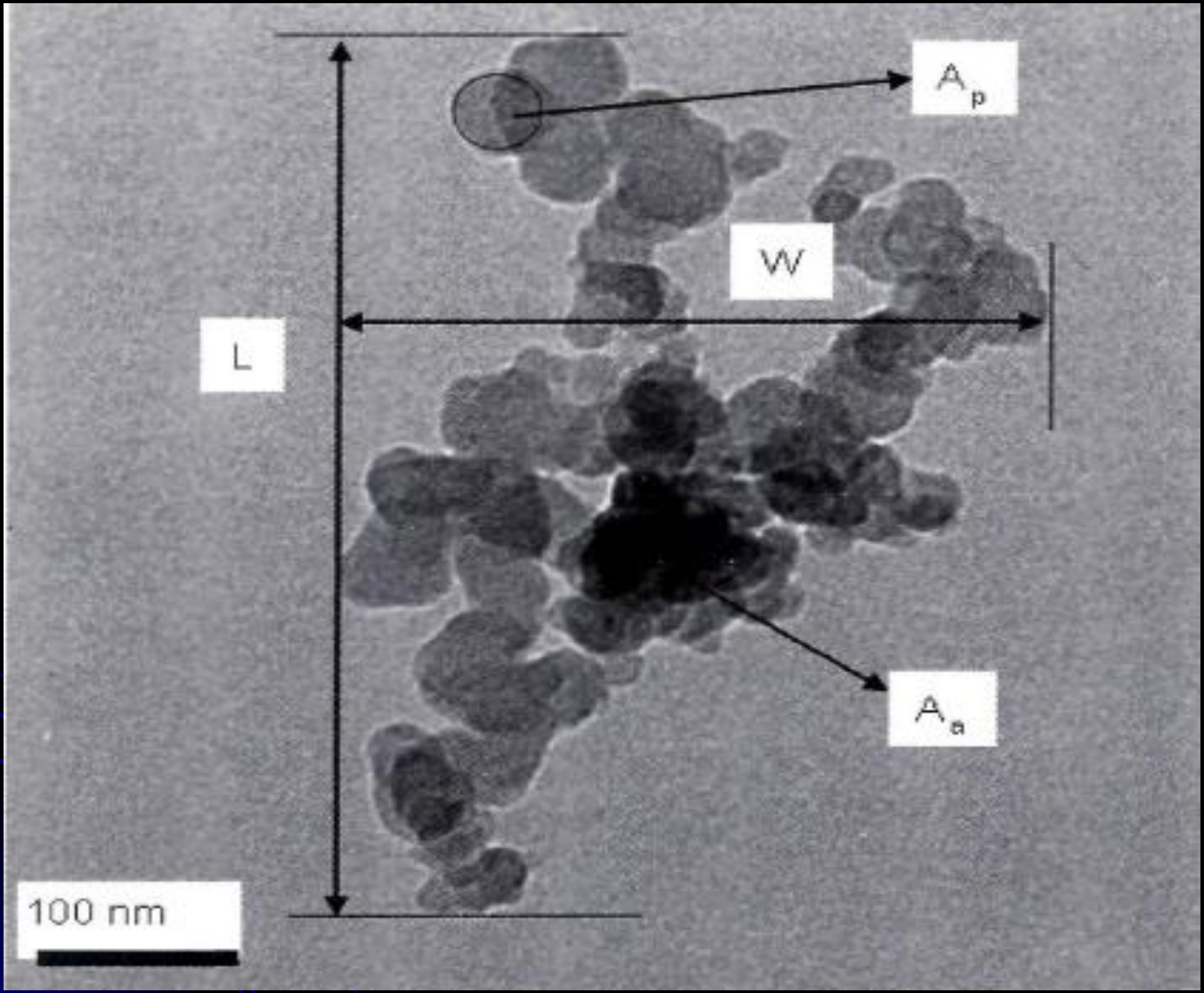
- Organic carbon (ie. aldehydes)
- Other organics

Gases

- Carbon monoxide (CO)
- Carbon dioxide (CO_2)
- Nitric oxide (NO)
- Nitrogen dioxide (NO_2)

International Agency for Research on Cancer
IARC (2013) Monograph 105

"Diesel engine exhaust is carcinogenic to humans (Group 1)"



Park et al, 2004, Structural Properties of Diesel Exhaust Particles Measured by Transmission Electron Microscopy (TEM): Relationships to Particle Mass and Mobility. http://www.tandfonline.com/doi/abs/10.1080/027868290505189

So what is the big deal?

Organisation	Year	Comments
HEI[1]	1999	**Evidence not strong enough**
ACGIH[2]	2002	Recommended 0.02mg/m^3 (measured as REC)
ACGIH[2]	2003	Recommended limit withdrawn
MSHA[3]	2008	**Evidence becoming stronger -** Effective date for Occupational exposure limit (OEL) in the US for underground metal / non-metal 0.16mg/m^3 (TC) ~ 0.12 (REC)
IARC[1]	2012	**Strong evidence –** IARC monograph – confirmed carcinogen.
NCI / NIOSH[4]	2010 - 2013	Study findings support a much lower OEL which may have a significant impact on UG mining.
HEI[1]	2013	**Expert panel established**
HEI[1]	2014 6 March	Workshop held in Boston – open to public, academia, regulators , industry and engine manufacturers.
HEI[1]	November 2015	Expert panel review released. **Strong evidence! Likely significant impact especially in UG mining!**

What Review?

Health Effects Institute - Selected "Expert Panel"

"NEW REPORT EXAMINES LATEST STUDIES OF LUNG CANCER RISK IN WORKERS EXPOSED TO EXHAUST FROM OLDER DIESEL ENGINES:
Studies Withstand Scrutiny, Require Care in Efforts to Calculate Risk "

The Diesel Exhaust in Miners Study (DEMS) studied a cohort of more than 12,000 male U.S. non-metal miners; and the Trucking Industry Particle Study that examined a cohort of about 31,000 male workers employed in the unionized U.S. trucking industry.

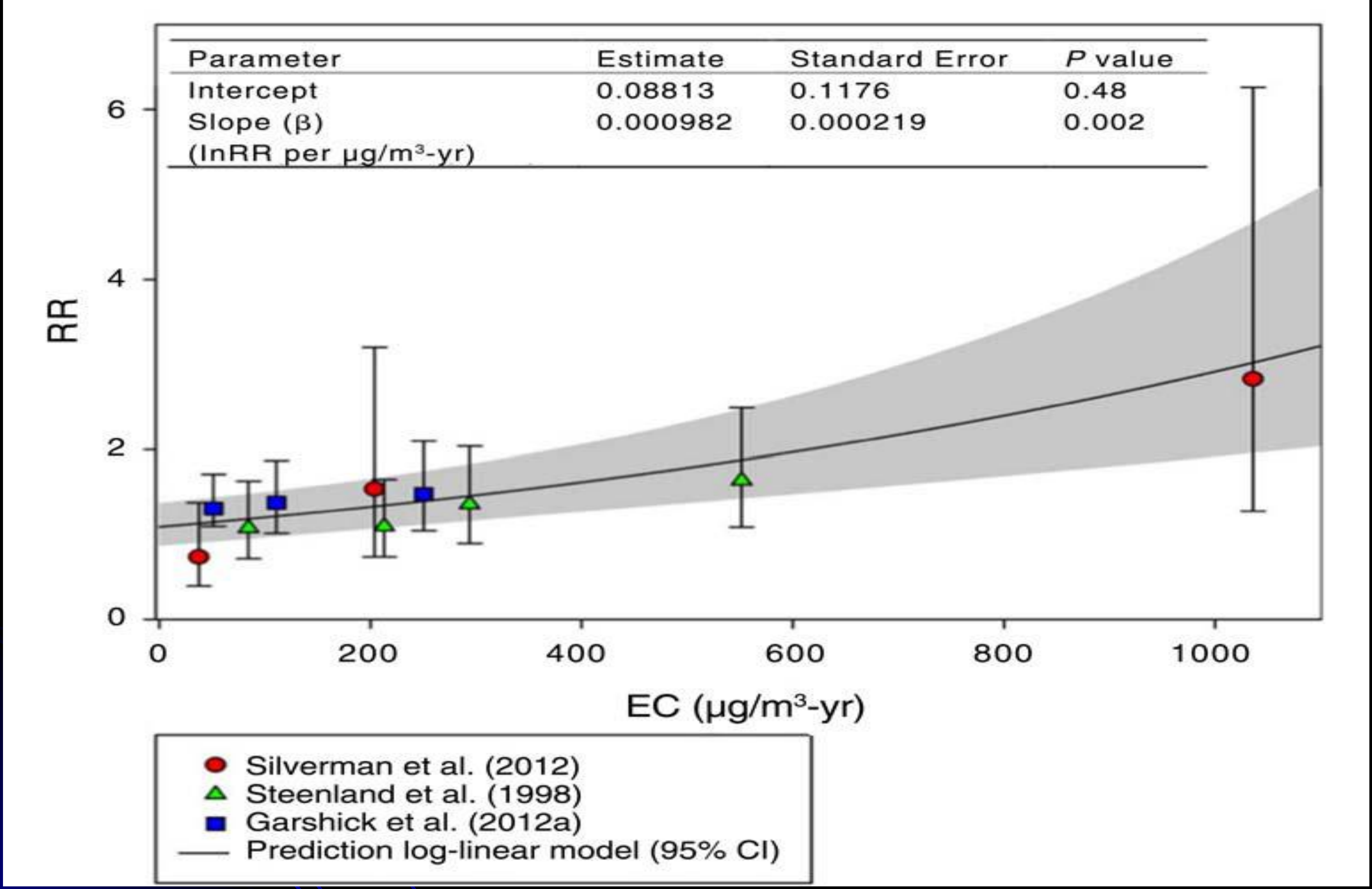
HEI Press Release For Immediate Release: November 24, 2015

Overall Panel Conclusions

- Both studies were well-designed and conducted according to high standards of epidemiological research.
- Both studies addressed many of the deficiencies that had limited earlier studies for quantitative risk assessment
- The results and data from both the Truckers and the DEMS can be usefully applied in quantitative risk assessments.
- The uncertainties within each study should be considered in deriving and characterizing an exposure-response relationship.
- The detailed evaluations of these studies by the HEI Panel and other analysts have laid the groundwork for a systematic characterization of the exposure-response relationship and associated uncertainties.

HEI

Courtesy of Katherine Walker Senior Scientist HEI



Relative risks were estimated using exposures lagged 15 years in Silverman et al. (2012) and 5 years in both the Garshick et al. (2012a and Steenland et al. (1998), based on the best model fit in each study. The authors presented sensitivity analyses to lag choices in supplemental material, available online. Elemental carbon was measured as REC in DEMS, as SEC in Garshick et al. (2012a), and as EC in Steenland et al. (1998). SOURCE: Vermeulen R, Silverman DT, Garshick E, Vlaanderen J, Portengen L, Steenland K. 2014b. Exposure–response estimates for diesel engine exhaust and lung cancer mortalitybased on data from three occupational cohorts. Environ Health Perspect 122:172–177. doi: 10.1289/ehp.1306880.

Health Canada (2016) – Human Health Risk Assessment for Diesel Exhaust

Health effects	Evidence
Lung cancer	**Sufficient**
Acute adverse r	**Sufficient**
Chronic advers… s	**Sufficient**
Acute adverse c… es	**Sufficient**
Immunological (	**Sufficient**
Bladder cancer	Suggestive
Chronic adverse … s	Suggestive
Reproductive and developmental effects	Suggestive
Central nervous system effects based on acute neurophysiological symptoms in overexposed workers	Suggestive

Occupational Cancer Research Centre (OCRC) (2017)

The Occupational Cancer Research Centre recommends reducing personal exposure to **0.02 mg/m^3** measured as elemental carbon.

More than a **10-fold reduction** from the current ON mining limit

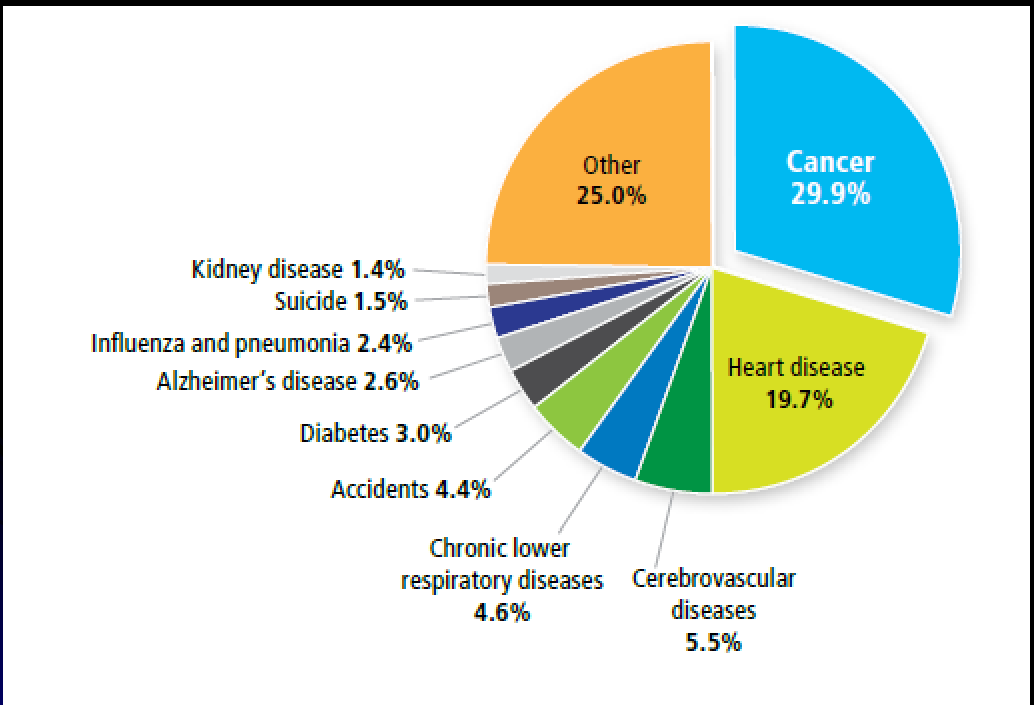
Reg. 854: MINES AND MINING PLANTS 183.1 (4)

The current regulatory occupational exposure limit (OEL) does not offer an acceptable level of protection!

http://www.occupationalcancer.ca/2017/controlling-dpm-in-mining/

To put it in context!

Canadian Cancer Statistics 2015



Males 41,000 Deaths		Females 37,000 Deaths	
Lung	26.6%	Lung	27.0%
Colorectal	12.4%	Breast	13.6%
Prostate	10.1%	Colorectal	11.5%
Pancreas	5.6%	Pancreas	6.2%
Bladder	4.0%	Ovary	4.7%
Esophagus	3.9%	Non-Hodgkin lymphoma	3.3%
Leukemia	3.8%	Leukemia	3.1%
Non-Hodgkin lymphoma	3.5%	Body of uterus	2.8%
Stomach	3.1%	Brain/CNS	2.3%
Brain/CNS	3.0%	Stomach	2.1%
Kidney	2.7%	Bladder	1.8%
Liver	2.1%	Kidney	1.8%
Oral	2.0%	Multiple myeloma	1.7%
Melanoma	1.8%	Esophagus	1.2%
Multiple myeloma	1.8%	Melanoma	1.1%
Larynx	0.8%	Oral	1.1%
Breast	0.1%	Cervix	1.0%
All other cancers	12.5%	Liver	0.7%
		Larynx	0.2%
		All other cancers	12.8%

https://www.cancer.ca/~/media/cancer.ca/CW/cancer%20information/cancer%20101/Canadian%20cancer%20statistics/Canadian-Cancer-Statistics-2015-EN.pdf

Canadian Cancer Society Statistics Canada

Burden of cancer attributable to occupational diesel engine exhaust (DEE) exposure in Canada (1961 – 2001) ~ 1.4 million workers exposed

Exposure period 1961 - 2001

Gender	Attributable fraction % Lung Cancer
Male	**4.92**
Female	**0.29**
Overall	**2.70**

Occup Environ Med 2014;71(Suppl 1):A1–A132

1 in 20 men and about 1 in 37 overall

1Joanne Kim, 2Cheryl E Peters, 2Chris McLeod, 3Sally Hutchings, 3Lesley Rushton, 1Manisha Pahwa, 1,4Paul A Demers. 1Occupational Cancer Research Centre, Toronto, ON, Canada; 2University of British Columbia, Vancouver, BC, Canada; 3Imperial College London, London, UK; 4University of Toronto, Toronto, ON, Canada

Risk estimate

Exposure setting	Average EC exposure (μg/m^3)	Excess lifetime risk through age 80 years (per 10,000)
Worker exposed, age 20–65 years	25	689
Worker exposed, age 20–65 years	10	200
Worker exposed, age 20–65 years	1	17
General public, age 5–80 years	0.8	21

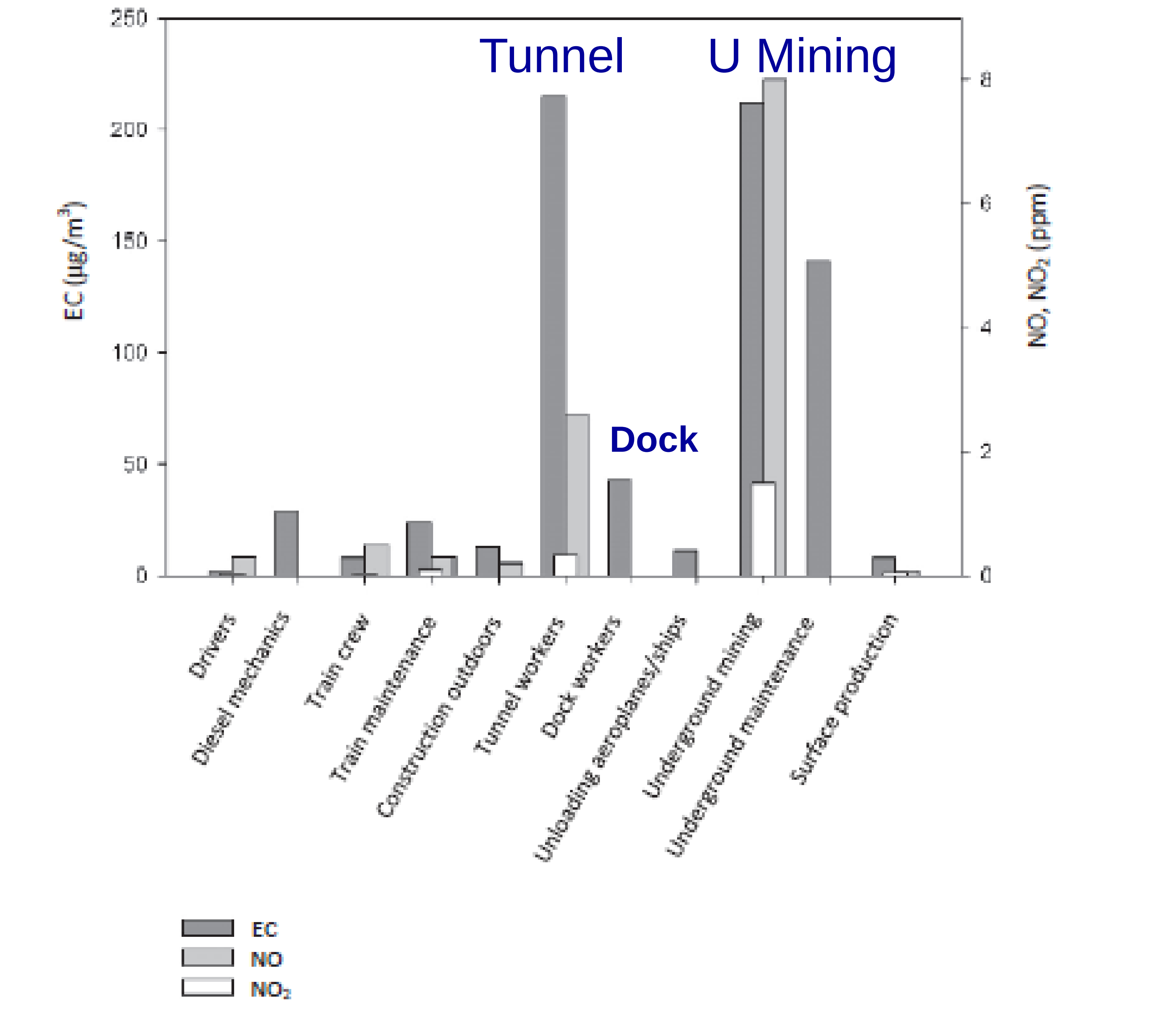
Based on linear risk function, lnRR = 0.00098 × exposure, assuming a 5-year lag, using age-specific (5-year categories) all cause and lung cancer mortality rates from the United States in 2009 as referent.

Source: Vermeulen et al, 2014 p.175.

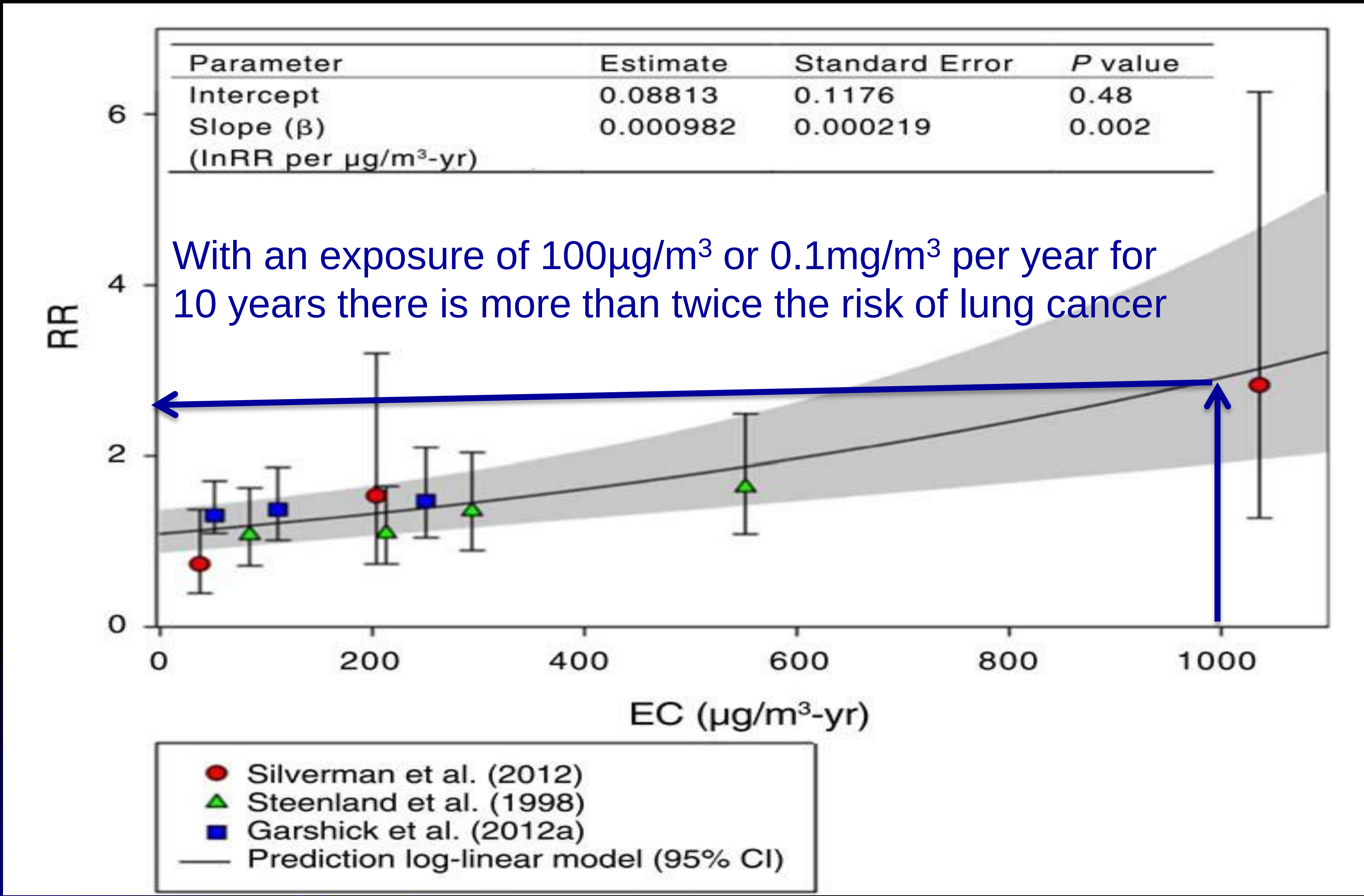
This shows that there is a relatively high (excess) risk from relatively low exposures.

Average EC exposure mg/m^3	Excess lifetime risk	As a %
0.025 mg/m^3	689/10,000	7
0.01 mg/m^3	200/10,000	2

What about UG mining?



EXPOSURES - Source IARC Monograph 105 p.96



Parameter	Estimate	Standard Error	*P* value
Intercept	0.08813	0.1176	0.48
Slope (β) (lnRR per μg/m³-yr)	0.000982	0.000219	0.002

Relative risks were estimated using exposures lagged 15 years in Silverman et al. (2012) and 5 years in both the Garshick et al. (2012a and Steenland et al. (1998), based on the best model fit in each study. The authors presented sensitivity analyses to lag choices in supplemental material, available online. Elemental carbon was measured as REC in DEMS, as SEC in Garshick et al. (2012a), and as EC in Steenland et al. (1998). SOURCE: Vermeulen R, Silverman DT, Garshick E, Vlaanderen J, Portengen L, Steenland K. 2014b. Exposure–response estimates for diesel engine exhaust and lung cancer mortalitybased on data from three occupational cohorts. Environ Health Perspect 122:172–177. doi: 10.1289/ehp.1306880.

Underground miners face high risk of lung cancer death from diesel exhaust exposure: study

By the National Reporting Team's Jessicah Mendes

Updated 17 Nov 2016, 9:45pm

Diesel exhaust could be causing fatal lung cancer in underground miners at a rate up to 38 times the accepted occupational risk, according to a new study.

It shows underground production workers, including diesel loader operators and shotcreters, face the highest risk — and researchers are calling for strict controls to limit their exposure.

The study, published in Occupational and Environmental Medicine, marks the first phase of a landmark investigation sponsored by the National Health and Medical Research Council.

Using Department of Mines and Petroleum data from 2003 to 2015 and other studies, it modelled the average levels of exposure among employees in a range of occupations on Western Australian mine sites.

It then estimated the number of lung cancer deaths caused by those levels with stark results.

"If somebody were to be exposed as an underground miner, we saw that that person would be exposed to on average 44 micrograms per cubic metre (ug/m3)," lead investigator Dr Susan Peters from the University of Western Australia told the ABC.

PHOTO: Underground miners face a higher risk of lung cancer due to exposure to diesel exhaust. (Supplied: Newcrest Mining)

RELATED STORY: Black lung disease no longer contained to underground mining

RELATED STORY: Mine industry risks still very real, support group says

RELATED STORY: WHO confirms diesel fumes carcinogenic

MAP: WA

Key points:

- There is no national occupational standard for exposure to diesel emissions
- Researchers are calling for exposure limits to diesel to be lowered
- Diesel exhaust is the second most common cause of cancer after UV exposure

http://www.abc.net.au/news/2016-11-18/study-shows-miners-face-high-lung-cancer-risk-from-diesel/8035798

R.R.O. 1990, Reg. 854: MINES AND MINING PLANTS 183.1 (4)

The flow of air must reduce the concentration of toxic substances in diesel exhaust emissions to prevent exposure of a worker to a level in excess of the limits prescribed under section 4 of Regulation 833 of the Revised Regulations of Ontario, 1990 (Control of Exposure to Biological or Chemical Agents) made under the Act. O. Reg. 265/15, s. 11.

(5) The flow of air must,

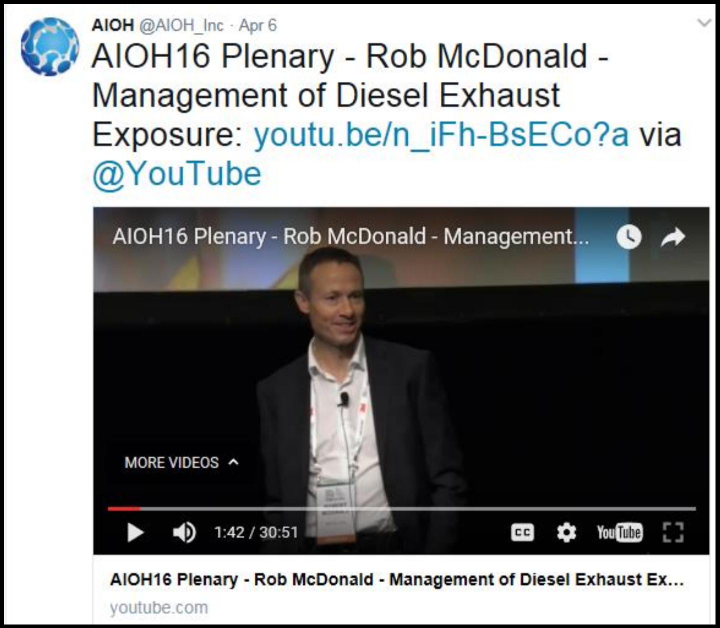
(a) reduce the time-weighted average exposure of a worker to total carbon to not more than 0.4 milligrams per cubic metre of air; or

(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.

What does this mean?

This limit is 3 times higher than other international occupational exposure limits (OEL) such in the US and Australia.

Is this acceptable?



Dr. Rob McDonald VP Health and Hygiene, BHP Billition.

Australian Institute of Occupational Hygienists (AIOH), plenary December 2016.

- “Significant **lag** that exists between regulatory action and the level of science that informs health risk”.
- “Should be managing exposure to diesel exhaust to as low as technically feasible”.
- Interim target to be managing diesel exhaust to **0.03mg/m^3** TWA 8-hrs measured as elemental carbon.

https://www.youtube.com/watch?v=n_iFh-BsECo&feature=youtu.be&a

Management of Diesel Emissions

CONTROLLING DIESEL PARTICULATE MATTER IN UNDERGROUND MINES

More effective ← **ELIMINATION | SUBSTITUTION | ENGINEERING CONTROLS | ADMINISTRATIVE CONTROLS | PPE** → Less effective

PROACTIVE CONTROLS

Reduce or eliminate diesel particulate emissions before they enter the workplace air

Proactive controls — More effective

Elimination

Alternative Energy
Involves replacing diesel equipment with alternatives such as electric. ↓↓↓↓

Substitution

Replacing or repowering old equipment
Newer engines must meet much stricter emissions regulations. Replacing an engine or a piece of equipment with a newer model will significantly decrease emissions. The level of reduction depends on the old and replacement equipment. ↓↓↓

Rebuilding engines
Manufacturers often offer upgrade kits that can be incorporated into an engine rebuild to improve emissions. ↓

Engineering Controls

Aftertreatment systems
A variety of different aftertreatment systems are available. Emissions reductions depend on the type of filter chosen, as well as the engine and load. Particulate reductions can range from 20-95%. ↓↓

Idling technology
Idling technology works by automatically turning off the engine when the vehicle idles. The emissions reductions will be greater for equipment that spends a high proportion of time idling. ?

Administrative Controls

Preventive maintenance
Maintenance keeps all parts of the engine, as well as any emissions control systems, functioning optimally. Poorly maintained engines can produce significantly more emissions than an engine in good condition. ↓

Idling policies
Idling increases both emissions and engine wear. Idling policies limit the amount of time an engine can be idled. ?

AVERAGE REDUCTIONS

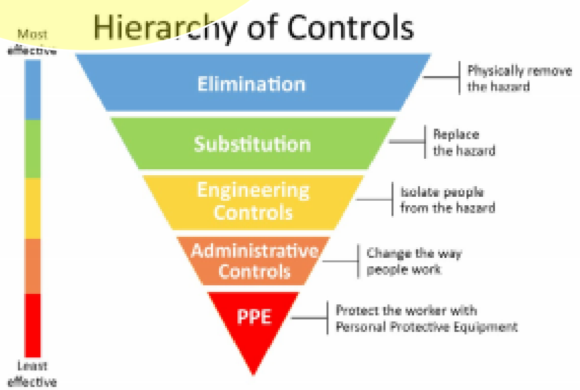
Average particulate matter exposure reductions based on published data

- <50% ↓
- 50-85% ↓↓
- 85-99% ↓↓↓
- 100% ↓↓↓↓
- Varied/Unknown: ?

REACTIVE CONTROLS

Remove diesel particulate emissions from the workplace air, or reduce the likelihood that workers will inhale particulate emissions

Reactive controls — Less effective



Engineering Controls

General ventilation
General ventilation dilutes emissions by bringing clean air into the area. The reductions vary depending on the volume of air provided. It also helps reduce ambient air concentration of non-diesel hazards, as well as helping with temperature control. ?

Enclosed cabs
When properly functioning, enclosed cabs protect the operator, but do not protect the surrounding workers. ↓↓

Tele-operating
Tele-operation allows the operator to be in a safe location, such as a filtered control room on the surface. Reductions in exposure can be up to 100% if the operator is completely removed from the site. Other workers may still be exposed if they enter the work area, or if emissions circulate to other areas of the mine. ↓↓↓

Administrative Controls

Operator training
Training can include driving skills, how to recognize maintenance issues, proper use of diesel control technologies, and the health effects of diesel exhaust. ?

Scheduling and site planning
Control the number of diesel engines operating in an area. Schedule workers during times when fewer diesel engines are working. ?

Monitoring emissions
An emissions monitoring program is critical for ensuring that diesel controls are functioning properly. ?

PPE

Respirators
PPE should be used as a last resort, and is not a replacement for other controls. The concentration of diesel exhaust in the air should still fall below the regulatory limit. When used, respirators should be fit-tested, and training should be provided to wearers. ?

OCRC Occupational Cancer Research Centre
Towards a cancer-free workplace

GE and BHP Billiton announce global partnership to improve efficiency and reduce emissions in the mining sector

http://www.genewsroom.com/press-releases/ge-and-bhp-billiton-announce-global-partnership-improve-efficiency-and-reduce

Using battery powered vehicles ie. battery powered scoop used underground.
https://gereports.ca/breathing-easier-underground/

We have the technology!

- Nominate a champion.
- Establish a team.
- Measure the tail pipe emissions by carrying out a baseline assessment.
- Measure and monitor personal exposures.
- Ensure that there is an emissions based maintenance program.
- Have a short and longer term strategy.

Reduce / eliminate emissions from the engines!

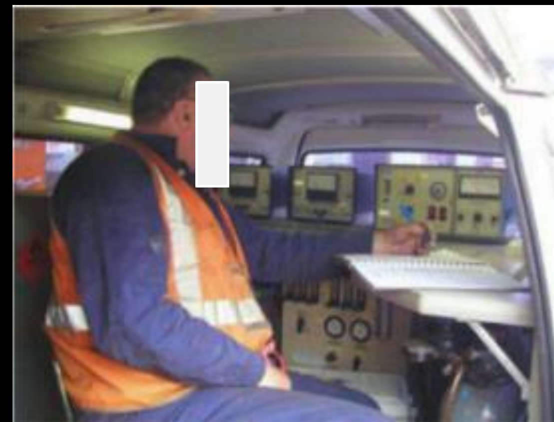
Engage with experts:

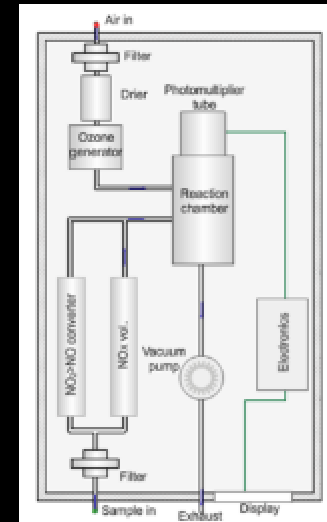
Canadian resource: Sean McGinn
http://www.mknizdfactors.com

It is important to continually review and lower limits - this drives exposure reduction and continuous improvement

Can it be measured?

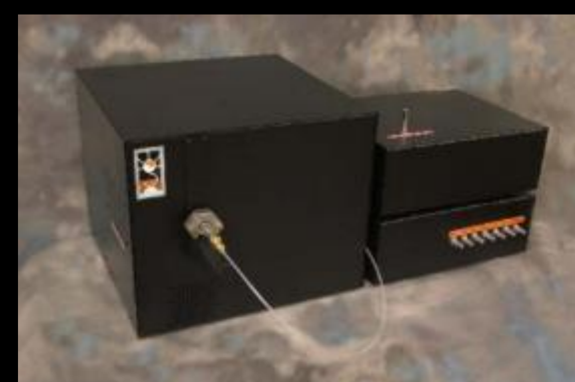
Raw exhaust monitoring	Personal exposure monitoring
√	√





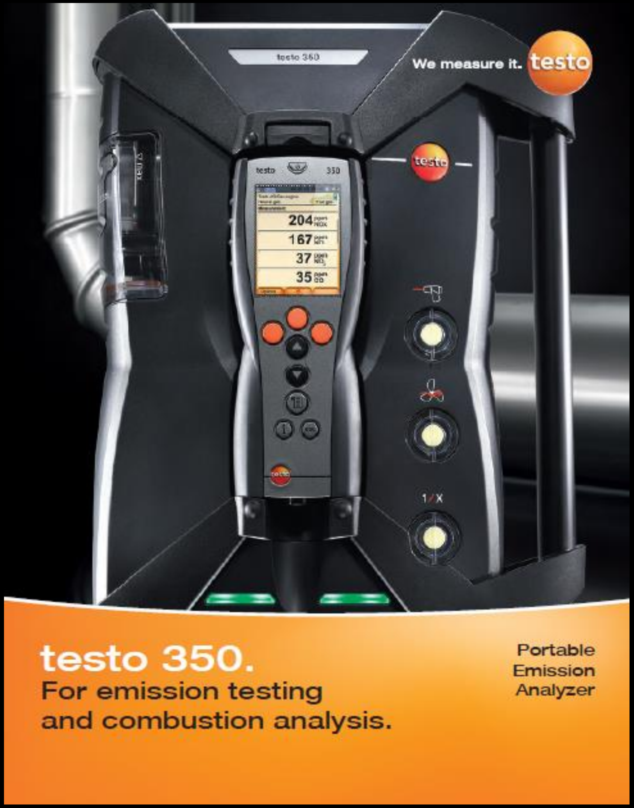
Chemiluminesence

Source: https://www.qld.gov.au/environment/pollution/monitoring/air-pollution/nitrogen-oxides/



Yes but ensure that measurement is precise and accurate

ECOM



testo 350

Ensure precision and accuracy

Diesel ChekMate® Mark Ⅱ
E.R.P Engineering Pty Ltd.

Australian guideline (NSW MDG 29)

4.1 GASEOUS EXHAUST EMISSIONS

When tested in accordance with SECTION 5 *Monitoring of Diesel Engine Pollutants* the raw exhaust gas of the diesel engine shall;

a) not exceed the limits specified in *Table 3* below, and

b) be compared against the baseline limits as specified in *Table 4* below.

Description	CO (ppm)	NO (ppm)	NO_2 (ppm)	NO_x (ppm)
Type testing of new engines for under[illegible] coal mines without methane injection[1]	[illegible]	900 ([illegible].09%)	100 (0.01%)	-
Type testing of new engines for under[illegible] coal mines with methane injection[2]	[illegible]	900	100	1,000
In-service engines in underground co[illegible]	[illegible]	-	[illegible]00	7[illegible]0 (0.[illegible]75%)
Engines in other underground environment	1,100	900	[illegible]00	[illegible]00

Table 3 – Raw exhaust gas limits for diesel engines operating in underground environments

XX

Notes:

1. Based on the coal legislation

ON Limit CO 600 ppm

In ON there is no requirement to measure NO, NO_2 , or NOx

"In NSW Australia Where "**failed**" must be withdrawn from use underground"

Any engine which fails to meet the specified limits above must have the licensed laboratory report stamped with a 'FAIL' and must be withdrawn from use in the underground environment.

Source MDG 29 (2009) Guideline for the management of diesel pollutants underground.

Nitrogen dioxide:

Caution there may be an **increase in nitrogen dioxide after installing a diesel oxidation catalyst (DOC)**. NIOSH note

> “ ***The concentration of nitrogen dioxide should also be monitored before and after the DOC. A history of this data should be stored to assess the activity of the DOC in increasing the concentration of this compound*”**.

NIOSH (2011): **Diesel Aerosols and Gases in Underground Mines: Guide to Exposure Assessment and Control**

See also MSHA: HEALTH HAZARD ALERT Underground Coal Mines Increased Nitrogen Dioxide (NO2) Emissions

Need to understand what the exposures are by carrying out a baseline exposure assessment for diesel particulate matter (DPM) measured as total and elemental carbon.

NIOSH 5040

Important - Occupational Exposure Limits are not fine dividing lines between safe and unsafe exposure.

The case of Claude Fortin (Lavery Lawyers 18 Feb 2013)

Mining Companies and Occupational Disease: Regulatory Standards Are Not The Test

On December 17, 2012, the Quebec Superior Court upheld a decision which could have far reaching consequences.

Despite safety measures implemented by those companies

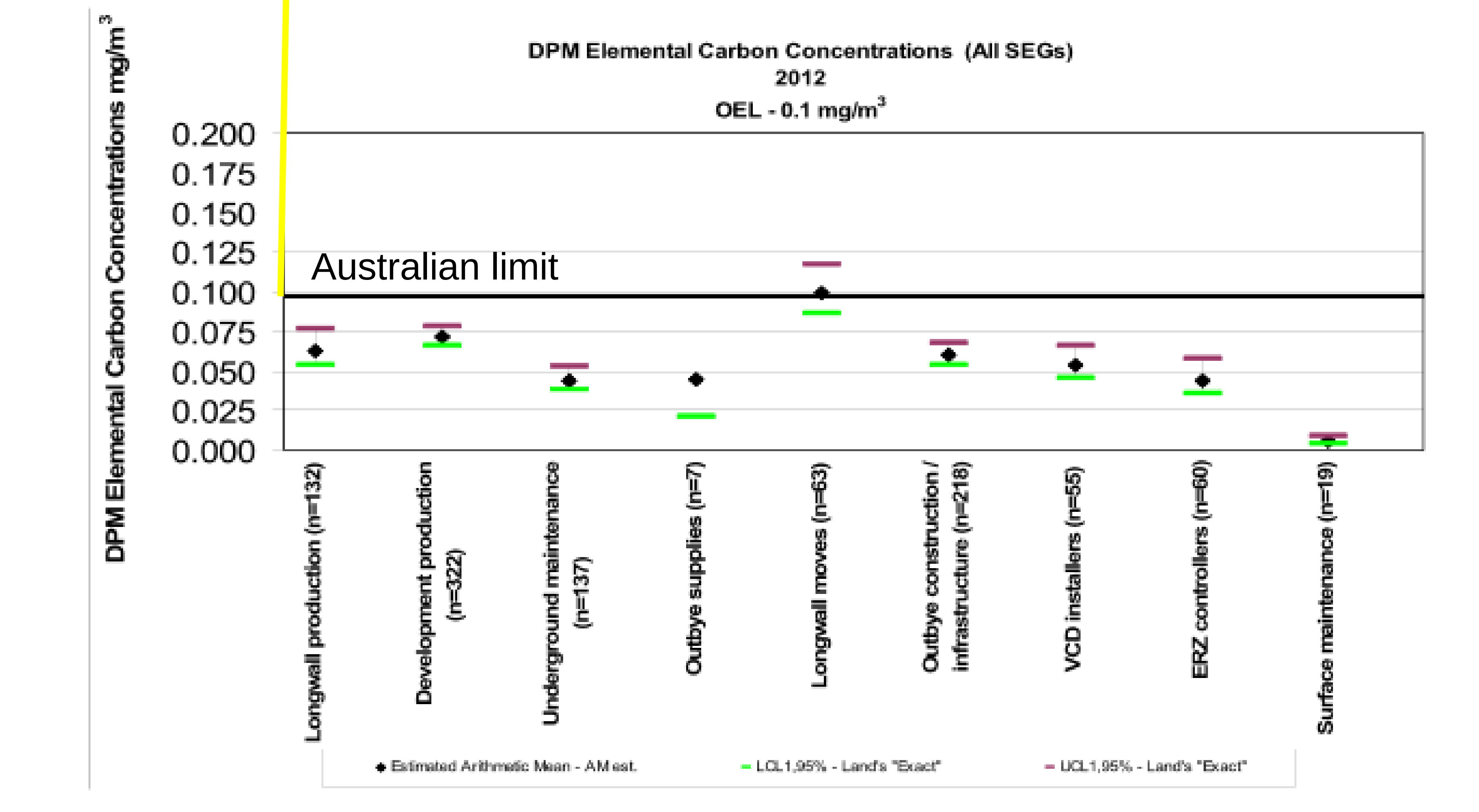
In this decision, the superior court supported that an employee, who had been diagnosed with **lung cancer**, was suffering from an "**occupational disease**" **even though the level of contaminants to which he was exposed fell below regulatory standards**.

This was a first!

http://blogueplannord.lavery.ca/en/mining-companies-and-occupational-disease-regulatory-standards-are-not-the-test/

Can exposures be lowered for underground mining in Canada?

Occupational exposure limit in ON TC 0.4 (**0.31 EC**)



Source: Manthey, G, Djukic, F, Taylor, C, 2013


WHAT
NOW?

Resources

Information, research, and technology transfer:

Diesel technology forum
http://www.dieselforum.org/

Canadian Mining Industry Research Organization
Diesel Emission Evaluation Program
http://www.camiro.org/mining/diesel-emission-evaluation-program

The Australian Coal Industry's Research Program
(ACARP)
http://www.acarp.com.au/

Centers for disease control and prevention (CDC / NIOSH)
http://www.cdc.gov/niosh/mining/topics/DieselExhaust.html

Mining Diesel Emissions Council (MDEC)
http://www.mdec.ca/

CanmetMINING, Natural Resources Canada
http://www.nrcan.gc.ca/mining-materials/green-mining/8178
http://www.nrcan.gc.ca/mining-materials/green-mining/approved-diesel-engines/8180

Resources (continued)

Information, research, and technology transfer:

Hedges et al. (2007), Diesel Particulate Matter in Underground Mines – Controlling the Risk (an update).
http://www.qldminingsafety.org.au/_dbase_upl/hedgesDiesel%20Particulate%20Matter%20in%20Underground%20Mines.pdf

McGinn (2007), Controlling Diesel Emissions in Underground Mining Within an Evolving Regulatory Structure in Canada and the United States of America.
http://www.qldminingsafety.org.au/_dbase_upl/mcginn_Controlling%20Diesel%20Emissions.pdf

Queensland Australia Mining
QGN 21 Guidance note for management of diesel engine exhaust in metalliferous mines Mining and Quarrying Safety and Health Act 1999 January 2014, Version 1
https://www.dnrm.qld.gov.au/__data/assets/pdf_file/0019/240364/qld-guidance-note-21.pdf

Western Australia Mining
Management of Diesel Emissions in Western Australian Mining Operations 2013.
http://www.dmp.wa.gov.au/Documents/Safety/MSH_G_DieselEmissions.pdf

NSW Australia Mining
Guideline for the management of diesel engine pollutants in underground environments 2008
http://www.resourcesandenergy.nsw.gov.au/__data/assets/pdf_file/0011/419465/MDG-29.pdf

Resources (continued)

Information, research, and technology transfer:

MKNIZD Factors Inc.
http://www.mknizdfactors.com

E.R.P Engineering Pty. Ltd.
http://e-r-p.com.au/useful-links/

MSHA
https://arlweb.msha.gov/01-995/dieselpartmnm.htm
https://arlweb.msha.gov/s&hinfo/diesel.htm
https://arlweb.msha.gov/s&Hinfo/toolbox/tbcover.htm
https://arlweb.msha.gov/s&hinfo/deslreg/dreg.htm

National Institute for Occupational Safety and Health (NIOSH)
Mining / Topic: Diesel Exhaust
https://www.cdc.gov/niosh/mining/topics/dieselexhaust.html

Occupational Safety and Health Administration (OSHA)
Diesel Exhaust
https://www.osha.gov/SLTC/dieselexhaust/

Previous presentations:

Memorial University of Newfoundland (MUN) SafetyNet
Diesel fumes – how hramfull are they? (December 2015).
https://www.youtube.com/watch?v=Gruu8iyZJps&feature=youtu.be

Occupational Health Clinics for Ontario Workers Inc (OHCOW).
Diesel Exhaust Occ-tober (October 2016).
https://youtu.be/zCoBdAvjhgI