Impact of diesel equipment on ventilation in Quebec underground mines

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Presentation Outline

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Context

According to medical studies in the United States conducted by the Environmental Protection Agency (EPA), workers in underground mines are exposed to levels of DPM 100 times higher than people living in urban centers and 10 times higher than the most exposed workers in other industries (e.g. railway locomotives operators and trucks operators)

DPM exposure level for some occupational group (Schnakenberg and al.,2002)

Occupational group	Exposure , level
	µg/m³
Underground miners, coal , no aftertreatment[1]	900 -2100
Underground miners, coal , disposable diesel exhaust filter[1]	100 - 200
Underground miners, coal , wire mesh filter[1]	1200
Underground miners, metal/non metal, no aftertreatment[1]	300 - 1600
Surface miners[1]	< 200
Urban fire station [2]	100 - 480
Forklifts operators, docks workers, railroad workers[2]	20 - 100
Truck drivers[2]	4 - 6

1 Haney et al. [1997]

2 Diesel Net [1999b]

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Scope of the project

- Use of diesel-powered equipment in Quebec underground mines,
- Determine the composition of equipment fleets and their use,
- Impact of the diesel powered equipment on the airflow quantity and quality,
- Search for means to mitigate the impact of diesel-powered equipment,
- The concentrations of air contaminants and,
- The conformity to provincial air quality regulations for the majority of the participating mines.

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Methodology

- 17 mines contacted
- 8 mines visited

Seven mines in the Abitibi region and one in Saguenay

Contact remote mines by email and phone

- Data received from 13 mines
- Complete data obtained from seven mines
- Partial data obtained from six mines
- No data obtained from four mines

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DPM Estimation

- First estimation index of the amount of DPM: the respirable combustible dust (RCD).
- Obtained by gravimetric method - less expensive and easiest method to measure DPM

- Second estimation index of DPM: total carbon (TC)
- Obtained by the NIOSH 5040 method: more accurate and sensitive

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DPM threshold around the world

Values of DPM exposure threshold are based on the belief that they are economically and technically feasible (Belle, 2008).

There is evidence that, it is technologically possible to keep the concentration of DPM below 90 µg /m^3 (Schnakenberg, 2001)

DPM threshold for some country and organisation (Schnakenberg, and al., 2002)

Country or organization	Value	DPM Measurand
Current Limits:	mg/m^3	
U.S.: MSHA metal/nonmetal underground mines [66 Fed. Reg. 5706 (2001)]	July 19, 2002: 0.4 January 19, 2006: 0.16	Total carbon (EC + OC) as determined by NIOSH Method 5040
U.S.: MSHA underground coal mines [66 Fed. Reg. 5526 (2001)]	Emissions rates set for various classes of equipment, e.g., heavy duty equipment: 2.5 g/hr	Emissions rates set for various classes of equipment, e.g., heavy duty equipment: 2.5 g/hr
Germany: General occupational environment	0.1	EC, coulometric
Germany: Underground metal and nonmetal mines and construction sites	0.3	EC, coulometric
Canada: Underground, metal and nonmetal mines	1.5	RCD
Quebec	0.6	RCD
Switzerland [Majewski 1999]	0.1	EC, coulometric
	Proposed Limits:	
	mg/m^3	
ACGIH [1995]	0.15	Particles <1 µm in size
ACGIH [1998]	0.05	Total carbon in particles <1 µm in size
ACGIH [2001]	0.002(EC = 40% of DPM)	(EC particles <1 µm in size

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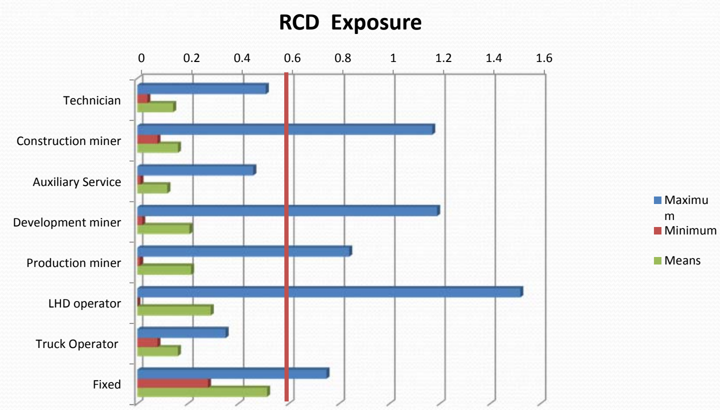
DPM Exposure in Quebec underground mines



Some miners are exposed to higher values of DPM that can reach the double of the threshold value allowed in Quebec.

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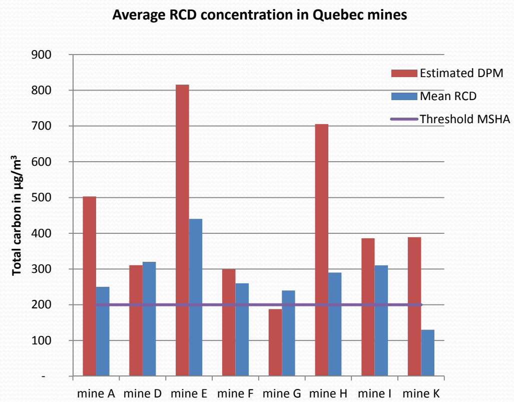
DPM Exposure in Quebec underground mines

The concentrations of DPM estimates are 30% to 40% higher than the concentrations measured on the field. This difference is due to lower DPM emission measured on the field than that obtained in the laboratory and the variation of the estimated engine duty cycle in operation. A correction factor of 1 on 1.4 is applied to the estimated values.



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Contribution of load and haul equipment to the DPM emissions

Load and haul equipment contribute to the majority of DPM, especially because they have a higher engine power and they accumulate more engine hours per shifts. The only exceptions are the mines G and F where the contribution to DPM emissions is divided equally between the load and haul equipment and support equipment

Contribution of equipment to the mine fleets emissions

Mines	Load and Haul		services		Total emissions
	emissions DPM	Contribution	emissions DPM	Contribution	
	g/min	%	g/min	%	g/min
mine A	1,676	88%	0,239	12%	1,915
mine D	2,507	70%	1,072	30%	3,579
mine E	1,956	60%	1,29	40%	3,246
mine F	1,473	49%	1,505	51%	2,978
mine G	3,966	57%	3,4046	49%	7,012
mine H	1,248	86%	0,208	14%	1,456
mine I	6,729	67%	3,31	33%	10,039
mine K	2,987	76%	0,969	24%	3,956

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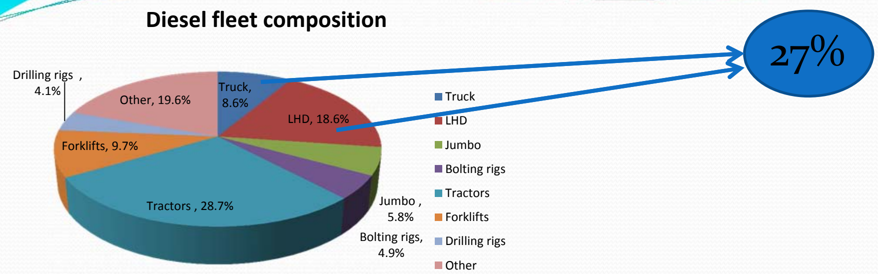
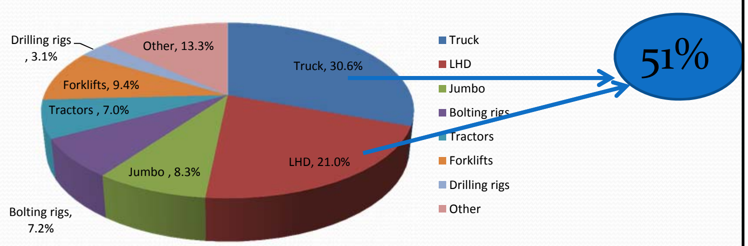
Distribution of equipment number and power

Diesel fleet composition



Distribution of diesel power



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Index calculation

$$\boldsymbol{Index} = \frac{\boldsymbol{sample\ in\ compliance\ with\ the\ threshold}}{\boldsymbol{Total\ sample}}$$

RCD maximum concentration permitted in Quebec is 0.6mg/m^3 (RSSTM, 2013)

Maximum concentration of CO permitted in the main ventilation system in Quebec is 10 ppm (RSSTM, 2013)

Maximum concentration of CO permitted at the exhaust of equipment in Quebec is 750 ppm (RSSTM, 2013)

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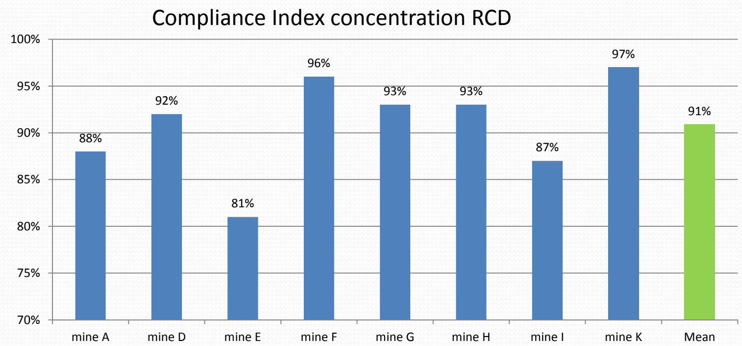
Compliance Index concentration RCD



The compliance index of RCD concentration varies between 81% and 97% for an average of 91% of a total of 498 samples for the entire group of mines. The threshold is exceeded only on rare occasions for all mines.

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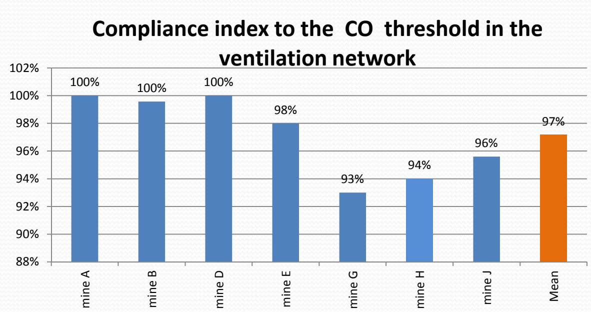
Compliance index in the main ventilation network



The index of compliance with exposure to CO in the ventilation system varies between 93 and 100%, with an average value of 97% of total samples ranging from 17 to 77,381 in the mines and 87,380 samples for entire group of mines. The concentration limit is exceeded only a few times throughout the mines.

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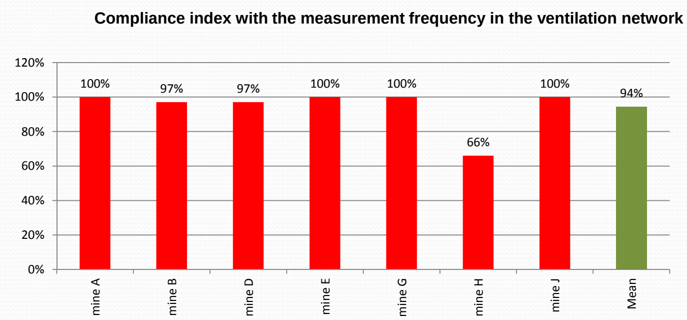
Compliance index in the ventilation circuit



The ICF_{COCV} vary between 66% and 100%, with an average value of 94%. Mines usually comply with Regulation in regard to the weekly measurement of the concentration of CO in the ventilation system. The average ICF_{COCV} is 94% due to the poor performance of mine H (small mine with little equipment), whose index is 66%, while all mines surveyed have an index that approaches 100%. Mine H is a low mechanized, moderately deep small mine, which provides 90 cfm / ton to dilute exhaust from mobile vehicles.

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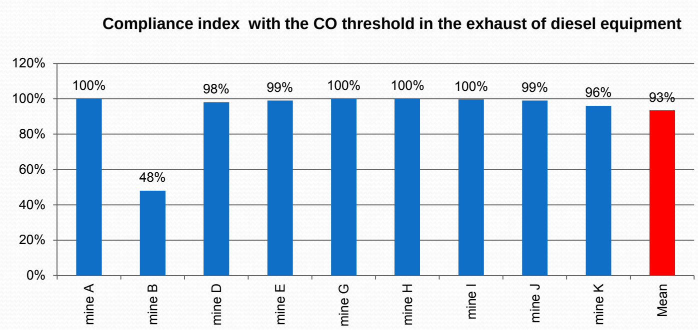
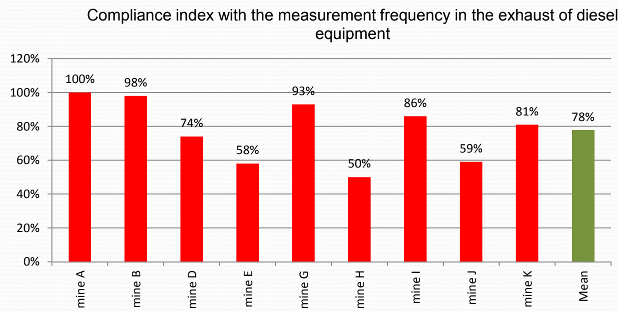
Compliance index in the ventilation circuit



The ICC_{COE} varies between 48 and 100% with an average value of 93%. The number of samples per mine varies from 9 to 2133, for a total of 4291 samples for all mines. It appears that the threshold value is exceeded only rarely in all mines, only mine B where several measurements indicate CO concentrations above 750 ppm. Mine B is a moderately deep highly mechanized mine, which provides 427 cfm / ton to dilute the exhaust of mobile equipment.

Compliance index in the ventilation circuit

- **Sampling must be performed after 300 running hours or 180 days**



The ICF_{COE} vary between 50% and 100% with an average value of 78%. Mines have much more difficulty to comply with the sampling time slot. Indeed, mines tend to focus on one or the other of these deadlines either measurements are made regularly before 6 months, or the measurements are performed before 300 hours of work equipment. This explains the poor performance of mines in accordance with the sampling frequency.

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Mine Compliance Index

- In short, mines performances are good in regard to compliance with the regulations on air quality and the sampling frequency of the ventilation system. Nevertheless, there is room for improvement in compliance indexes for most mines. As for mine A (small mine with little equipment), high values of indexes of compliance is due to very few surveys conducted compared to other mines. On the other side, the mine G remains the most consistent in its compliance indexes values, although it has one of the most impressive fleet of equipment. This proves that compliance is an organizational concern rather than a matter of mine size or its fleet size.

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Control measures and reducing diesel emissions

Reducing the average concentration of DPM using only the ventilation would be too expensive and require too much effort to mines. For example, some mines would have to double or even triple the current supplied airflow. This could involve substantial investment in new infrastructure (new surface fan, new ventilation raise).

Mine	Airflow supplied	Airflow required 308_{EC}	Ventilation factor 308EC	Airflow required 160_{TC}	Ventilation factor 160TC
	cfm	cfm	cfm/cfm	cfm	cfm/cfm
mine A	120 000	182 435	0,66	351 187	0,34
mine D	435 000	340 980	1,28	656 387	0,66
mine E	170 000	309 235	0,55	595 278	0,29
mine F	375 000	283 691	1,32	546 105	0,69
mine G	1 400 000	623 491	2,25	1 200 234	1,17
mine H	65 000	138 722	0,47	267 039	0,24
mine I	820 000	956 396	0,86	1 841 062	0,45
mine K	320 000	376 300	0,85	725 533	0,44

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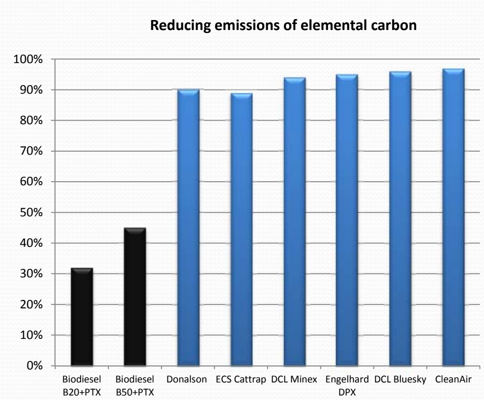
Control measures and reducing diesel emissions

The black bars in the histogram show the reduction of elemental carbon (EC) when the concentration of the latter could be quantified. The blue bars represent the reduction of EC when the resulting concentration, following the application of control technology, could not be quantified. The percentage reduction is then the minimum reduction rate estimated for the control technology. The first two tests in the figure are biodiesel while the last six are diesel particulate filters from different manufacturers



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Conclusion

- DPM quantity is estimated using RCD measurements
- Threshold value are adopted on the belief that they are economically and technically feasible , and values are very different from one country to an other
- Some miners are exposed to higher values of DPM that can reach the double of the threshold value allowed in Quebec.
- Load and haul equipment contribute to the majority of DPM
- Mines usually comply with regulations except for CO in the exhaust (300h or 180 days) however for some mines high values of indexes of compliance is due to very few surveys conducted compared to other mines
- Reducing the average concentration of DPM using only the ventilation would be too expensive and require too much effort to mines, use of control technology like catalysts and filters can help to achieve very good result.

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