Detailed results of DEEP projects are available at ***www.deep.org***

Contribution of Light-Duty Vehicles to the Underground Atmosphere Diesel Emissions Burden

About the Project

The DEEP light-duty vehicle study was conducted at the Falconbridge, Kidd Mining Division, a copper/zinc operation located in Timmins, Ontario, Canada.

The study was conducted by the CANMET Mining and Mineral Sciences Laboratories in cooperation with the mine operator, Falconbridge Limited. Detailed description of the study is available in two documents:

- *Phase I Report, completed in 2000*
- *Final Report (Phase II), completed in 2003*

Background and Objective

Most efforts to control diesel particulate matter (DPM) exposures in underground mines have been focused on heavy-duty engine emissions. It was assumed that underground DPM emissions originate predominantly from heavy-duty production equipment, due to the size of the engines involved and the intensive nature of the work performed. While heavy-duty (HD) vehicles are no doubt major contributors, new data suggests that light-duty (LD) vehicles could be responsible for a significant and possibly increasing portion of the airborne diesel emissions burden in the mining environment.

The aim of the study was to estimate the relative contributions of DPM exhaust emission from LD and HD vehicles in an underground metal mine. This was achieved through direct DPM emission measurement from a sample group of LD and HD vehicles and extrapolation of the results onto the entire diesel vehicle population in the mine.

Test Program and Methodology

The study was divided into two phases. Issues examined during Phase I included mine selection and selection criteria, characterization of the mine's diesel fleet, duty cycle assessment method, raw exhaust DPM sampling issues and determination of the cross-section of the fleet to be tested during Phase II.

The Phase II—covering the actual field study—was further divided into two parts. Part one focused on DPM sampling from five HD vehicles. Part two focused on DPM measurement from eight LD vehicles.

In the study, vehicles (regardless of horsepower) that were not used in regular production cycles were categorized as LD units. Higher horsepower units involved regularly in ore, waste or fill handling were considered HD vehicles.

The Kidd Mine diesel equipment fleet is comprised of 156 underground vehicles. It was technically feasible to test a mixed LD/HD sample fleet of vehicles representing about 10% of the entire fleet. The total number of vehicles in different categories and the number of vehicles selected for testing is shown below.

Vehicle Type	Number	Tested
Load Haul Dump (LHD)	20	4
Haulage Trucks	2	1
Pickup Trucks	42	3
Tractors	18	2
Utility Vehicles	74	3
Total	***156***	***13****
* The number of tests was 15 (2 HD vehicles tested twice)		

Perhaps the most important task in the study was to determine the amount of DPM produced by selected diesel vehicles over a specified sampling period and, indeed, during a full-shift period. The mass of DPM produced during the sampling period was calculated as the product of the exhaust DPM concentration—as measured by the DPM sampling apparatus—and the total exhaust gas volume produced over the sampling period.

Vehicle duty cycles were also evaluated in the study to provide insight into the utilization for each vehicle and vehicle type. On electronically controlled engines (such as those in all tested HD vehicles), the percent engine load was recorded from the engine control unit data stream. In mechanically controlled engines (such as in most of the tested LD vehicles), duty cycle data was determined based on the engine speed, exhaust gas flow and temperature.

At the beginning of each testing day, CANMET personnel installed the in-exhaust DPM sampling system, data loggers and ambient DPM and dust monitors on each tested vehicle. Each operator wore a personal sampling pump for NIOSH 5040 analysis of total/elemental carbon exposure. The vehicle would then proceed to its normal working area to perform its normal duties during the shift. The duty cycle would be interrupted briefly (1-2 minutes) to change the DPM sample filter as required. After a sufficient number of duty cycles were recorded, the vehicle would return to the shop area where the sampling system was removed.

Results and Conclusions

DPM emissions from the sample fleet are shown in the following table.

Vehicle	DPM Mass	DPM Rate
	g	*g/hr*
LHD 33635 8-yd	45.8	22.0
LHD 33616 6-yd	43.2	15.6
LHD 33626 3.5-yd	37.8	23.6
LHD 33638 8-yd	43.1	22.1
Truck 33661	50.4	19.9
Truck 33661 repeat	43.5	12.0
Chevrolet truck 33348	4.0	3.3
Ford truck 33325	2.6	1.6
Dodge truck 33336	4.3	3.1
Kubota Tractor 33966	24.5	22.7
Kubota Tractor 33952	16.2	13.3
Driftec Shotcreter 33973	12.4	6.3
Getman Scissorlift 33872	10.8	6.0
Getman Boom Truck 33899	19.5	12.9

"DPM Mass" denotes the total DPM collected during sampling from raw exhaust. "DPM Rate" is the *average DPM emission rate* (in grams per hour), weighted against the time spent at each distinct operating mode.

The results clearly show that the LD contribution to DPM exposures is significant. In the case of one of the tractors (suspected engine problem) the mine was only getting an estimated 27 hp of power while absorbing the same DPM "burden" as from an 8–yard LHD.

Differences in DPM emission rates exist between different types of vehicles and engine technology. The impact of duty cycle is apparent in the repeat test of the truck, taken during a different type of duty.

The sample fleet results were extrapolated, taking a number of assumptions, onto the entire underground vehicle fleet in the mine. Based on the equipment utilization rates (in hrs/yr), DPM burdens was calculated (in kg/yr) for each vehicle type. The relative contributions from different vehicle categories are shown in the following chart.

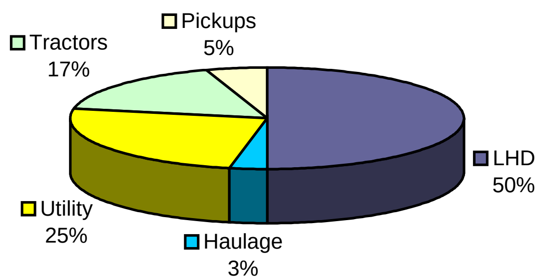

Figure 1. DPM Sources at Kidd Creek Mine

For the entire model fleet, HD vehicles (LHDs and haulage trucks) were responsible for 53% of the total underground DPM burden. LD vehicle (tractors, pickups, utility) were responsible for 47% of the DPM burden.

The study concluded that the underground DPM burden was fairly evenly split between the HD and LD vehicles. While LHDs remained major DPM emitters, LD contribution accounted for nearly half of DPM emission, due to high vehicle numbers and—in some cases—high emission rates. Therefore, LD vehicles must be a part of any DPM control strategy.