TORONTO STAFF REPORT

January 4, 2006

To: Board of Health

From: Dr. David McKeown, Medical Officer of Health

Subject: Reducing Children's Exposures on Board School Buses - Ontario and Toronto

Purpose:

To examine children's exposures to air pollutants on board school buses and consider actions that can be taken nationally, provincially and locally to reduce those exposures.

Financial Implications and Impact Statement:

There are no direct financial implications associated with this report.

Recommendations:

It is recommended that the Board of Health:

(1) request that Environment Canada establish a multi-year Healthy School Bus Fund to support programs developed by provincial governments and other organizations that are directed at the dual goals of reducing childhood exposure to diesel-related air pollutants and improving local air quality;

(2) request that the Ontario Ministry of the Environment establish a multi-year Healthy School Bus Program that has the dual goals of reducing childhood exposure to diesel-related air pollutants and improving local air quality by:

(a) ensuring the retirement of all pre-1994 model year school buses by 2007;
(b) encouraging the replacement or retrofitting of all 1994-2003 model year school buses by 2011;
(c) encouraging the use of catalyzed diesel particulate filters when retrofitting 1994-2003 model year school buses;

(d) encouraging the installation of closed crankcase filtration devices in all school buses in Ontario;

(e) supporting demonstration projects that promote the development of alternative technologies and fuels; and

(f) developing, in collaboration with Natural Resources Canada, the Ontario School Bus Association, and Ontario school boards, a module on proper idling, fuel management, and low emission driving practices, to be included in the provincial training program for school bus operators;

(3) encourage Toronto school boards to work with their school bus operators to develop:

(a) Healthy School Bus Plans that identify the actions that can be taken to reduce childhood exposure to diesel-related air pollutants;

(b) formal school bus idling policies designed to reduce childhood exposure to diesel-related air pollutants;

(c) education for school bus operators that emphasizes proper idling and fuel management practices;

(4) send copies of this report to all Ontario Medical Officers of Health, the GTA Clean Air Council, the Canadian Partnership for Children's Health and Environment (CPCHE), the Association of Local Public Health Agencies, the Canadian Public Health Association (CPHA), the Ontario School Bus Association (OSBA) which represents the school bus operators in the province, and the Ontario Public Health Association (OPHA); and

(5) the appropriate City Officials be authorized and directed to take the necessary action to give effect thereto.

Background:

In November 2005, the Ontario Public Health Association (OPHA) released a report entitled, "School Buses, Air Pollution and Children's Health: Improving Children's Health & Local Air Quality by Reducing School Bus Emissions" which was prepared with technical support from Toronto Public Health.

The OPHA report summarizes findings related to exposures on board school buses, assesses the health impacts potentially associated with those exposures, estimates the emissions associated with school buses in Ontario, assesses the options that could be used to reduce emissions from and exposures on board school buses, and makes recommendations that are directed primarily at the provincial and federal governments.

The maximum emission standards for air pollutants from new diesel school buses will be much more stringent for school buses built for 2007 and beyond. The OPHA report notes that emissions from school buses built before 1994 are up to six times higher than emissions from school buses built between 1994 and 2003, and that emissions from school buses built to 2007 emission standards will be up to ten times lower than emissions from school buses built between

1994 and 2003. The development of technologies and fuels required to meet the new emission standards presents opportunities to reduce emissions from existing school buses and air levels inside the cabins of those buses. Given that most school buses remain in service for more than a decade, mechanisms to upgrade the existing fleet deserve serious consideration.

This report summarizes the findings of the OPHA report, examines the school bus situation in Toronto, and identifies actions that can be taken at a local level, while supporting the OPHA recommendations that are directed at the provincial and federal governments.

Comments:

School Bus Exposures:

There are two major reasons to focus attention on emissions from school buses. Firstly, most school buses are heavy-duty diesel vehicles that emit substantial quantities of particulate matter (PM) and nitrogen oxides (NO_x) that contribute to poor air quality. Secondly, school buses can be self-polluting, exposing children and drivers on board to elevated levels of diesel-related air pollutants.

Diesel exhaust is a complex mixture of hundreds of air pollutants. It is composed of particulate matter, a large variety of hydrocarbons, a number of which are known to be carcinogenic, and gases such as nitrogen oxides and carbon monoxide. Diesel particulate matter (DPM) is considered particularly harmful because it is composed largely of fine particulate matter ($PM_{2.5}$) (80 to 90%) and ultra-fine particles that are less than 0.1 microns in diameter ($PM_{0.1}$) (1 to 20%). These fine and ultra-fine particulate matter can adsorb large quantities of hydrocarbons and penetrate deep into the lungs, cross into the bloodstream, and travel to distant organs of the body (US EPA, 2002).

Several exposures studies have found that concentrations of diesel-related air pollutants such as fine particulate matter ($PM_{2.5}$) and/or DPM can be several times higher on board school buses than concentrations in ambient air or in other vehicles on the road (Wargo, 2002; CARB, 2003; NB Lung Association). One study conducted in New Brunswick demonstrates that children can experience greater exposure to air pollutants on board school buses than children who walk to school (see Table 1). While these studies indicate that air pollution in outdoor air and along traffic corridors contributes to pollutant concentrations on board school buses, they also indicate that school buses can be self-polluting.

The exposure studies demonstrated that pollutant concentrations on board school buses were greater than concentrations inside cars traveling in front of school buses on the same roadways (CARB, 2003; CATF, 2005). With tracer gases added to the fuel of school buses, researchers were able to demonstrate that school buses themselves were significant contributors of the pollutants measured inside their cabins (Marshall, 2005).

In one study, researchers found that concentrations of black carbon (an indicator of DPM), ultra-fine particles and polycyclic aromatic hydrocarbons (PAHs) on board school buses could be traced directly to the tailpipes of the school buses, while concentrations of $PM_{2.5}$ could be traced directly to emissions from the engine crankcase that is vented under the hood of the bus through a “road draft tube”. They also found that little $PM_{2.5}$ entered the bus when doors and windows were closed tight. Once doors were opened however, pollutant levels rose rapidly and steadily and the magnitude of air levels was dependent upon wind direction (CATF, 2005).

Several investigators have concluded that school bus exposures can be a significant source of exposure to $PM_{2.5}$ and/or DPM for children (Wargo, 2003; CARB, 2003; Marshall & Behrentz, 2005; CATF, 2005). For example, in California, researchers estimated that while children spend only about 10% of their time on board school buses, their exposures on board accounted for about one third of their exposures to DPM (Behrentz, 2005). These exposures are a concern because diesel-related air pollutants have been associated with a broad array of acute and chronic health effects.

Health Effects associated with Diesel-Related Air Pollutants:

Short-term exposures to DPM have been associated with headaches, eye irritation, asthma-like reactions, and increased sensitivity to allergens, while prolonged exposures have been linked to chronic bronchitis, reduced lung function, increases in allergic reactions and asthma symptoms, and an increased risk of lung cancer (US EPA, 2002).

Short-term exposures to $PM_{2.5}$ have been clearly associated with increases in premature deaths, hospital admissions and emergency room visits for respiratory and cardiovascular disease; increases in respiratory symptoms, respiratory infections, school absences, work day absences and restricted activity days; and reductions in lung function, while prolonged exposures have been linked to increases in chronic cardiovascular and respiratory diseases including asthma and lung cancer, and reduced life expectancy (US EPA, 2004; Krewski, 2000; Pope, 2002; Pope, 2004). These health effects are occurring at ambient air levels that are commonly experienced in Toronto.

Air Pollutants and Children’s Health:

School bus exposures represent a particular concern because children are known to be more sensitive to air pollutants than adults. For example, one study found that 18% of children and 21% of asthmatics experience acute reductions in lung function in response to increases in ozone exposure compared to 5% of the elderly and 5% of athletes (Hoppe, 2003).

In addition, a large number of studies have identified particulate matter as one of the air pollutants that trigger acute health effects among children. For example, in one study, a 20% increase in severe asthma attacks was documented among asthmatic children ranging from 5 to 13 years in age with a 10 ug/m^3 increases in daily $PM_{2.5}$ (Slaughter, 2003). In another study, a statistically significant exposure response trend was observed for emergency room visits for asthma attacks among asthmatic children with short-term increases in ambient air levels of ozone and particulate matter (PM_{10}) (Tolbert, 2000).

One long-term study of children also suggests that air pollutants can affect the long-term health of children. The Children's Health Study that has followed about 6,000 children living in 12 communities in Southern California since 1993, has documented a 5 fold increase in clinically significant deficits in lung function among adolescents who grew up in communities with high levels of pollution (i.e. particularly for NO_2, $PM_{2.5}$, PM_{10} and atmospheric acidity) (Gauderman, 2000; Peters, 2004). It has also found that children living near roadways with high traffic have a greater risk of being diagnosed with asthma than children who live near roadway with low traffic (Peters, 2004).

There is also a concern about how childhood exposures may affect the health of those exposed when they are older. For example, a small shift in the average lung function among a population of children can translate into a substantial increase in the number of adults who are more susceptible to respiratory disease and premature death later in life (WHO, 2005). Also, given that both $PM_{2.5}$ and diesel exhaust have been found to increase the risk of lung cancer among adults, it is likely that childhood exposures to these air pollutants can increase the risk of lung cancer in later life as well (WHO, 2005).

Respiratory diseases are responsible for a significant burden of illness among children in Ontario. In 1999, they were responsible for over 8,000 hospital admissions and almost 20,000 days in the hospital among school-aged children in Ontario (CIHI, 2005). Current estimates suggest that about 12.2% of all Canadian children have been diagnosed with asthma (Health Canada, 1999). It is a leading cause of absences from school and places a significant strain on the health care system (TPH, 2005). It has been reported that over one-third of the Ontario Health Insurance Plan (OHIP) expenditures for children in the province each year are directed at children with asthma (To, 2004). With approximately 800,000 children taking school buses in Ontario and a 12.2% asthma rate among children in this country, it is possible that 96,000 asthmatic children are transported by school buses in Ontario (OPHA, 2005).

It is also recognized that actions taken to protect the health of children transported by school buses will also provide health benefits to the school bus operators who may experience greater exposures to air pollutants on board school buses because they spend longer period of time on board than school children.

Emissions Analysis - Ontario's Fleet of School Buses:

In order to determine how best to reduce exposures on board school buses, the OPHA examined the emission standards that apply to school buses, the age of Ontario's fleet of school buses, and the technologies and fuels that could be used to reduce emissions from existing or new school buses.

To facilitate analysis of emissions from Ontario school buses of different ages, the OPHA allocated school buses into "model year cohorts" that are defined by the years in which significant changes were introduced to the emission standards for particulate matter (PM), hydrocarbons (HC) and nitrogen oxides (NO_x) (see Table 2). As indicated in Table 3, emissions from buses built before 1994 are several times greater than those from buses built between 1994 and 2003, while emissions from buses built to meet 2007 emissions standards, will be up to ten times lower again (see Table 3).

For the purposes of analyzing emissions associated with Ontario's school buses, it was assumed that:

(a) all school buses in Ontario seat 72 passengers;
(b) the total number of buses will remain at 15,000 until 2016;
(c) buses will be retired at a rate of 50% per year once they reach the age of 15 years;
(d) all school buses travel 22,000 kilometres (km) per year; and
(e) diesel school buses have a fuel economy of 32.5 Litres/100 km (OPHA, 2005).

The OPHA estimated the quantity of air pollutants and greenhouse gases emitted from Ontario's school buses over the last two years and over the next decade by model year cohort. It found, for example, that Ontario's 15,000 school buses emitted approximately 114 tonnes of PM, 718 tonnes of HC, 2,601 tonnes of NO_x, and 285 kilotonnes of greenhouse gases (CO_2) in 2005 (OPHA, 2005) (see Table 4).

The emission estimates indicate that school buses in the 1994-2003 model year cohort will dominate annual emissions from Ontario's school buses for most years between 2004 and 2016 (see Tables 4 and 5). On a cumulative basis, this cohort is expected to be responsible for 57% of all PM emissions, 83% of all HC emissions, and 68% of all NO_x emissions from Ontario's school buses between 2006 and 2016 (see Table 5). These numbers suggest that the most effective way to reduce emissions from Ontario's school buses in the short and medium term is to retrofit or replace the buses in this cohort (OPHA, 2005).

The emission estimates also indicate that the school buses in the pre-1994 model year cohorts will be responsible for a disproportionate share of PM emissions until about 2008 when they are expected to be almost eliminated from the fleet. In 2008, when it is expected that they will make up only 6% of the buses in Ontario's fleet, they are still expected to emit about 17% of the PM emissions from the fleet (see Table 4). These numbers suggest that it is important to ensure that pre-1994 model year school buses are retired and replaced as quickly as possible (OPHA, 2005).

Emission Reduction Options:

A number of options were assessed for their ability to reduce emissions of air pollutants and greenhouse gases, their costs, and applicability to Ontario's school buses. It was concluded that:

(a) Proper maintenance, idling and vehicle operation practices can be used to reduce emissions of air pollutants and greenhouse gases from all model year school buses by about 10% at a relatively low cost;

(b) By retrofitting a 1994-2003 model year school bus with a diesel oxidation catalyst (DOCs), emissions can be reduced substantially (PM by 25% and HC by 85%) for about $2,500 per bus;

(c) By retrofitting a 1994-2003 model year school bus with a catalyzed diesel particulate filter (DPF) and calibrating it for low NO_x emissions, emissions can be significantly reduced (PM, HC and air toxics by 90 to 95% and NO_x by 25%) for about $10,000 per bus;

(d) By refuelling a 1994-2003 model year school bus with a 20% biodiesel fuel (B20), emissions of air pollutants and greenhouses can be reduced (PM and HC by 10%, air toxics by 12 to 18%, and CO_2 by about 20%) at a fuel cost premium that can be as high as 20% (about $1,000 per year or $10,000 over a 10 year period);

(e) By replacing pre-1994 model year school buses with new diesel school buses that meet the 2007 emission standards, emissions can be significantly reduced (PM by 97%, HC by 90% and NO_x by 78%) for an incremental cost increase of $10,000 per bus compared with a conventional new bus;

(f) By replacing 1994-2003 model year school buses with new diesel school buses that meet the 2007 emissions standards, emissions can be significantly reduced (PM by 90%, HC by 90%, and NO_x by 70%) for an incremental cost increase of $10,000 per bus compared with a conventional new bus;

(g) While replacing an older school bus with a compressed natural gas (CNG) school bus could significantly reduce emissions of PM and NO_x, this replacement would increase HC emissions by about 50%, while costing about $50,000 more in capital costs and about $5,000 more per year in maintenance costs; and

(h) While replacing an older school bus with a diesel-electric hybrid (HEV) school bus could significantly reduce emissions of all air pollutants and greenhouse gases, it is expected that this technology will have to be well developed for the public transit sector before it becomes an affordable option for the school bus sector (see Table 6) (Torrie, 2005; OPHA, 2005).

Exposure Reduction Options:

When the emission reduction options were examined for their potential to reduce exposures on board school buses, it was found that:

(a) The use of a diesel oxidation catalyst (DOC) did not have a substantial impact on concentrations of $PM_{2.5}$, DPM (black carbon and ultra-fine particles) or PAHs on board school buses, although it is possible that it reduces the toxicity of the fine and ultra-fine particles by removing HC that can be adsorbed on them;

(b) The use of a diesel particulate filter (DPF) and ultra-low sulphur diesel significantly reduced concentrations of DPM and PAHs on board school buses (almost to ambient air levels);

(c) The use of a closed crankcase filtration device and ultra-low sulphur diesel significantly reduced concentrations of $PM_{2.5}$ on board school buses (almost to ambient air levels);

(d) The use of a diesel particulate filter (DPF), a closed crankcase filtration device, and ultra-low sulphur diesel, significantly reduced concentrations of $PM_{2.5}$, DPM and PAHs on board school buses (almost to ambient air levels) even under idling conditions with doors open; and

(e) When a compressed natural gas (CNG) school bus was used, concentrations of $PM_{2.5}$, DPM and PAHs on board were very low, although not as low as the levels on a diesel school bus outfitted with a diesel particulate filter and a closed crankcase filtration device that is run on ultra-low sulphur diesel (CATF, 2005; OPHA, 2005).

The closed crankcase filtration device discussed above is an emission control device that is installed in the engine compartment. It filters the emissions from the engine crankcase for PM before recycling them back into the engine intake. Verified as an emission control device by the U.S. Environmental Protection Agency (US EPA), it costs about $400 to $600 per bus and has a filter cartridge that has to be replaced every 25,000 miles or every 500 hours (OPHA, 2005).

Several exposure studies suggest that on board exposures can also be reduced to some extent by keeping doors and windows closed when buses are idling, avoiding idling when buses are waiting in front of schools, and avoiding travelling together on roadways (CATF, 2005; CARB 2003; and Wargo, 2002).

Conclusions Respecting Ontario's School Buses:

After examining the school bus exposure studies and the emission reduction options, the OPHA concluded that:

(a) Significant emission reductions and exposure benefits could be achieved by replacing the pre-1994 model year school buses with new diesel buses that meet the 2007 emission standards. On a provincial basis, this scenario could cost about $17 million to implement in the 1,700 pre-1994 school buses because of the incremental costs associated with the new technology relative to new buses that meet the 2004 emission standards. This scenario is expected to produce significant exposure benefits for the 90,000 children per year who may ride those 1,700 school buses over the next 15 years because buses built to 2007 emission standards are expected to be outfitted with diesel particulate filters (DPFs) (OPHA, 2005);

(b) Significant exposure benefits could be achieved if all school buses in Ontario were retrofitted with closed crankcase filtration devices. The cost of installing these devices on all 15,000 school buses in Ontario would be about $7.5 million. This scenario would provide exposure benefits to all of the 800,000 Ontario children who are transported each year by school buses (OPHA, 2005);

(c) Significant emission reductions and exposure benefits could be achieved by retrofitting 1994-2003 model year school buses with catalyzed diesel particulate filters (DPFs). If this scenario were applied to 9,000 1994-2003 model year school buses, cumulative emissions of PM, HC and NO_x from Ontario's entire fleet of school buses could be reduced by 51%, 75%, and 15% respectively between 2006 and 2016 for a cost of about $90 million. This scenario could produce exposure benefits for the 477,000 children per year who may ride those 9,000 school buses over the next 4 to 13 years (OPHA, 2005);

(d) Significant emission reductions and exposure benefits could also be achieved if 1994-2003 school buses were replaced with new buses that meet the 2007 emission standards (OPHA, 2005); and

(e) Proper maintenance, idling practices and vehicle operation could potentially produce modest reductions in emissions of greenhouse gases and air pollutants, while producing exposure benefits (OPHA, 2005).

If all of the actions identified above were taken, it would cost up to $115 million or $23 million per year over 5 years; a cost which represents about 3.2% of the $700 million spent on student transportation in Ontario each year (OPHA, 2005).

School Bus Programs in North America:

In the United States, several programs have been established to reduce emissions from, and exposures on board, school buses. The US EPA has established the Clean School Bus USA Program which funds projects directed at reducing school bus idling, retrofitting existing buses, and replacing old buses with new, cleaner buses. When approving grants for this Program, the US EPA considers whether the applicant is located in an area of poor air quality (US EPA, 2005; OPHA 2005).

In 2000, the California Air Resources Board (CARB) established a Lower-Emissions School Bus Program that aims to reduce the exposure of school children to both toxic and smog-forming air pollutants by funding the replacement of the oldest, highest-polluting buses with new, lower-emitting buses that meet the latest emissions standards; and funding the retrofitting of in-use school buses with technologies that significantly reduce PM emissions (CARB, 2003; OPHA, 2005).

The New York Power Authority (NYPA) has voluntarily established a program in New York City to fund the retrofitting of 1,500 to 2,000 school buses with diesel oxidation catalysts (DOC) or diesel particulate filters (DPFs) to off-set emissions associated with its electricity generating facilities in the City (OPHA, 2005).

Idling Policies:

In the United States, the US EPA Clean School Bus USA program includes an anti-idling program that is implemented at the State level. The EPA provides resources to local counties and school departments to develop and implement anti-idling campaigns and policies. At a minimum, the EPA suggests that an anti-idling policy should require the following:

(a) As a general rule, buses should be moving whenever the engine is on. The engine should be turned off as soon as possible after arriving at loading or unloading areas. The school bus should not be restarted until it is ready to depart; and

(b) Limit idling time during early morning warm-up to the time recommended by the manufacturer (generally no more than five minutes).

A number of school boards across North American have developed anti-idling policies including the New Brunswick Board of Education. Anti-idling policies usually include language to address extreme weather temperatures to ensure that children are protected from the stress of weather extremes and to accommodate the warm-up period required by engines in extreme weather conditions (usually 5 minutes or less at start-up) (EPA, 2005; OPHA, 2005). The public and separate school boards in the City of Toronto do not have formal idling policies but do have clauses in their contracts with school bus operators that prohibit idling over 5 minutes (OPHA, 2005).

The City of Toronto's idling control by-law limits idling to no more than three minutes in a sixty-minute period. The three-minute limit for idling applies to school buses within the City of Toronto. There are exemptions related to extreme temperatures (below 5°C and above 27° C) to protect vehicle occupants from potential heat and cold-related harm.

Toronto School Buses:

In Toronto, there are approximately 400,000 children attending approximately 800 schools run by the Toronto District School Board (TDSB) (about 560 schools), the Toronto Catholic District School Board (TCDSB) (about 200 schools), and the French School Board (about 15 schools). About 35,000 of these children are provided with transportation services on one of 1,200 vehicles; about 15,000 from the TDSB and about 20,000 for the TDCSB. School bus services are provided on a contract basis by school bus operators. The TDSB has contracts with three different school bus operators who transport about 15,000 children, while the TCDSB has contracts with four different school boards operators who transport about 9,000 children per day (Zumpano, 2005; Hodgkinson, 2005). Approximately 10,000 children have special needs and are transported to and from school or child care centres in smaller buses, vans or taxis. The Ministry of Education reports that only 350 of the 1,200 vehicles used to transport children in Toronto are 72-passenger school buses (Ho, 2005).

The TDSB has a policy which stipulates that the maximum age of a 72-passenger school bus used to transport children and of other vehicles used to transport children will be 10 years (Christie, 2005; TDSB, 1998). This policy suggests that buses are retired at a faster rate in Toronto than is general practice for the province as a whole. This means that there should be a smaller percentage of heavy-emitting school buses (pre-1994 model year) operated in Toronto than in other parts of the province.

The TDSB policy also stipulates that children will not be transported by bus more than 1.25 hours each way or 2.5 hours per day (TDSB, 1998). The TDCSB reports that children are not to be transported more than 1 hour each way or 2 hours per day (Hodgkinson, 2005). The Ministry of Education reports that, in the 2004-2005 school year, the average commute for children transported by bus in Toronto was approximately 31 km (Ho, 2005).

Given the road congestion experienced in many parts of Toronto, and the average ambient air levels of $PM_{2.5}$ (annual mean about 9 ug/m^3 and maximum about 50 ug/m^3) (MOE, 2003), it is likely that children riding on school buses in Toronto would be exposed to concentrations of air pollutants that are greater than those reported in the study conducted in New Brunswick. It is also likely that roadway sources contribute more to concentrations on board school buses in Toronto than in many other parts of the province.

Local Action on Toronto School Buses:

While it is recognized that there are limits on the actions that can be taken by school boards to reduce childhood exposures on board school buses without additional funding from the provincial or federal governments, there are things that can be done at a local level.

First of all, school boards can develop formal school bus idling policies and educational fact sheets that clarify that:

(a) School bus drivers should turn school bus engines on only after children have boarded the bus and the doors on the bus have been closed; and

(b) If school buses must be warmed up or cooled down because of extreme weather conditions, this should be done before children leave the school if at all possible, and limited to a maximum of 5 minutes.

Secondly, school boards can request that school bus operators develop Healthy School Bus Plans that:

(a) Identify the model year and size of each bus;
(b) Describe the school routes travelled by time, distance and number of children;
(c) Ensure that the oldest school buses (pre-1994 model year) are used for the shortest trips;
(d) Encourage the use of newer school buses (post 2003 model year) for the longest trips or where multiple trips are required;
(e) Assess the best way to reduce exposures from the operator's fleet given the age of the fleet, the size of the buses, and the budget of the operators; and
(f) Give high priority to the retirement of pre-1994 school buses and the retrofitting of all school buses with closed crankcase filtration devices.

Conclusions:

Children who are transported by school buses can be exposed to concentrations of $PM_{2.5}$ and DPM on board school buses that are several times higher than the concentrations in ambient air. These exposures can add substantially to the daily and annual exposure of children to these air pollutants. Given that significant health impacts are associated with the concentrations of $PM_{2.5}$ and other air pollutants in Ontario's ambient air, and the large number of Ontario children who are transported by school buses, these exposures represent a significant public health concern.

Exposure studies indicate that concentrations of $PM_{2.5}$ on board school buses can be significantly reduced when school buses are retrofitted with closed crankcase filtration devices. These devices, which cost relatively little, are recommended as retrofits for every school bus in Ontario.

Exposure studies indicate that concentrations of DPM on board school buses can be significantly reduced when school buses are outfitted with diesel particulate filters. Diesel particulate filters can be installed on all school buses built over the last decade and will be standard equipment on buses built to 2007 emission standards. Buses equipped with diesel particulate filters must be fuelled with ultra-low sulphur diesel that will become the standard diesel fuel for on-road vehicles in southern Ontario beginning in the fall of 2006. Diesel particulate filters will also significantly reduce emissions of particulate matter and hydrocarbons from school buses, thus providing local air quality benefits along traffic corridors and around school properties.

Children's exposures on board school buses can also be reduced, although to a much smaller degree, by ensuring that school buses do not idle with doors open, windows on school buses are kept closed, and travelling with other school buses is avoided.

It is recommended that the Ontario Ministry of the Environment establish a Healthy School Bus Program to encourage emission reductions from school buses that will improve children's health while improving local air quality. It is recommended that Environment Canada establish a Healthy School Bus Fund to support the program recommended for Ontario and programs like it across the country. It is also recommended that Toronto school boards work with their school bus operators to develop Healthy School Bus Plans, idling policies, and educational fact sheets to reduce childhood exposures to air pollution.

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List of Attachments:

Appendix 1 - References
Appendix 2 - Tables

Appendix 1
References

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Appendix 2
Tables

Table 1: Comparison of Average Concentrations of Air Pollutants, Walking vs. Riding on a School Bus, New Brunswick				
	$PM_{2.5}$ (µg/m^3)	$PM_{1.0}$ (particles/cc)	Black Carbon (µg/m^3)	PAHs (ng/m^3)
Walking	9.7	4,028	0.2	265.4
Bus Ride	32.1	10,786	0.7	775.3
Ambient	5.0	N.R.	N.R.	N.R.

Table 2: Model Year Cohorts for Ontario School Buses in OPHA Emissions Analysis			
Model Year Cohorts	Maximum Emissions (grams/brake horsepower-hour)		
	PM	HC	NO_x
Pre 1991	0.60	1.3	6.0
1991-1993	0.25	1.3	5.0
1994-2003	0.10	1.3	4.0
2004-2006	0.10	0.14	2.25
2007-2009	0.01	0.14	1.2
2010 and later	0.01	0.14	0.2

Table 3: Maximum Emission Standards for New Heavy Duty Diesel Engines Used for Urban Buses				
	(grams/brake horsepower-hour)			
Bus model year	PM	CO	HC	NO_x
1989	0.60	15.5	1.3	6
1991	0.25	15.5	1.3	5
1994	0.10	15.5	1.3	5
1998	0.10	15.5	1.3	4
2004	0.10	15.5	2.4 NMHC + NO_x	
2007	0.01	15.5	0.14	0.2

Table 4: Annual Emissions Estimated for Ontario School Buses by Model Year Cohorts, Business as Usual, 2004 to 20016							
	A Pre 1991	B 1991-93	C 1994-03	D 2004-06	E 2007-09	F Post 2009	Total
2004							
VKT (thousands)	37,840	59,931	197,809	34,419	-	-	330,000
PM (kg)	42,323	27,930	36,874	6,416	-	-	113,543
HC (kg)	91,700	137,973	479,360	8,983	-	-	718,015
NO_x (kg)	423,231	558,594	1,474,954	144,364	-	-	2,601,143
CO_2 (tonnes)	35,148	55,667	165,361	28,773	-	-	284,950
Percentage by Model Year Cohort							
2004							
VKT (thousands)	11%	18%	60%	10%	0%	0%	100%
PM (kg)	37%	25%	32%	6%	0%	0%	100%
HC (kg)	13%	19%	67%	1%	0%	0%	100%
NO_x (kg)	16%	21%	57%	6%	0%	0%	100%
CO_2 (tonnes)	12%	20%	58%	10%	0%	0%	100%
2008							
VKT (thousands)	1%	5%	60%	19%	15%	0%	100%
PM (kg)	4%	13%	62%	20%	2%	0%	100%
HC (kg)	1%	7%	87%	3%	2%	0%	100%
NO_x (kg)	1%	8%	73%	13%	5%	0%	100%
CO_2 (tonnes)	1%	6%	60%	19%	15%	0%	100%
2012							
VKT (thousands)	0%	0%	43%	19%	18%	20%	100%
PM (kg)	0%	1%	64%	29%	3%	3%	100%
HC (kg)	0%	1%	87%	4%	4%	4%	100%
NO_x (kg)	0%	1%	71%	18%	9%	2%	100%
CO_2 (tonnes)	0%	0%	42%	19%	17%	22%	100%
2016							
VKT (thousands)	0%	0%	18%	19%	18%	46%	100%
PM (kg)	0%	0%	41%	44%	4%	11%	100%
HC (kg)	0%	0%	66%	8%	7%	19%	100%
NO_x (kg)	0%	0%	49%	30%	15%	6%	100%
CO_2 (tonnes)	0%	0%	17%	18%	17%	48%	100%

Table 5: Cumulative Emissions Estimated for Ontario School Buses by Model Year Cohorts, Business as Usual, 2006 to 2016

	A Pre 1991	B 1991- 1993	C 1994- 2003	D 2004- 2006	E 2007- 2009	F Post 2009	Total
VKT (thousands)	18,664	115,500	1,624,254	697,256	553,217	621,141	3,630,033
PM (kg)	20,875	53,827	302,779	129,976	10,313	11,579	529,349
HC (kg)	45,229	265,903	3,936,133	181,967	144,376	162,103	4,735,712
NOx (kg)	208,750	1,076,530	12,111,179	2,924,469	1,237,512	231,576	17,790,016
CO_2 (tonnes)	17,336	107,283	1,357,820	582,881	462,470	576,947	3,104,737
Percentage by Model Year Cohort							
VKT	1%	3%	45%	19%	15%	17%	100%
PM	4%	10%	57%	25%	2%	2%	100%
HC	1%	6%	83%	4%	3%	3%	100%
NOx	1%	6%	68%	16%	7%	1%	100%
CO_2	1%	3%	44%	19%	15%	19%	100%

Table 6: Annual Emission Reductions Estimated for Individual School Buses by Model Year Cohorts for Various Emission Reduction Options

	PM	HC	NO_x	eCO_2	Estimated Implementation Cost
	grams per year			kg per year	
Cohort A – Pre 1991					
Baseline Emissions per Bus	24,600	53,300	246,100	20,400	
Per Bus Emission Reductions per Year					
Maintenance and Driver Behaviour	2,500	5,300	24,600	2,000	Low cost
Replace with New (Cohort D) Bus	20,500	47,600	153,800	2,000	Buses this old would be fully depreciated. Best technology would cost estimated $10,000 more than conventional new bus. CNG would cost $50,000 more per bus, plus $5,000 per year.
Replace with Best Technology (Cohort E)	24,200	47,600	196,900	2,000	
Replace with a CNG Bus[1]	23,370	(26,650)	82,100	1,484	
Diesel Oxidation Catalyst (DOC)	6,200	45,300	-	-	$1300-4000 ($2500)*
Run on B20	2,500	5,300	(4,900)	3,300	Fuel cost premium of 20%, around $1,000 per year
Cohort B – 1991-1993					
Baseline Emissions per Bus	10,300	50,600	205,100	20,400	
Per Bus Emission Reductions per Year					
Maintenance and Driver Behaviour	1,000	5,100	20,500	2,000	Low cost
Replace with New (Cohort D) Bus	6,200	44,900	112,800	2,000	Buses fully depreciated. Best technology would cost $10,000 more than a conventional new bus. CNG would cost $50,000 plus $5,000/yr more.
Replace with Best Technology (Cohort E)	9,900	44,900	155,900	2,000	
Replace with a CNG Bus[2]	9,070	(29,350)	41,100	1,484	
Diesel Oxidation Catalyst	2,600	43,000	-	-	$1300-4000 ($2500)*
Run on B20	1,000	5,100	(4,100)	3,300	Fuel cost premium of 20%, around $1,000 per year
Cohort C – 1994-2003					
Baseline Emissions per Bus	4,100	53,300	164,000	18,400	
Per Bus Emission Reductions per Year					
Maintenance and Driver Behaviour	400	5,300	16,400	1,800	Low cost
Replace with New (Cohort D) Bus	-	47,600	71,700	-	Dependent on the undepreciated value of the bus being replaced.
Replace with Best Technology (Cohort E)	3,700	47,600	114,800	-	
Replace with CNG Bus[2]	2,870	(26,650)	-	1,064	
Diesel Oxidation Catalyst	1,000	45,300	-	-	$1300-4000 ($2500)*
Diesel Particulate Filter (Catalyzed)	3,690	47,970	-	-	$6500-10,000*
Diesel Particulate Filter (Catalyzed) Low NO_x configuration	3,690	47,970	41,000	(920)	$7800-12,000 ($10,000)*
Run on B20	400	5,300	(3,300)	2,900	Fuel cost premium of 20%, around $1,000 per year
Cohort D – 2004-2006					
Baseline Emissions per Bus	4,100	5,700	92,300	18,400	
Per Bus Emission Reductions per Year					
Maintenance and Driver Behaviour	400	600	9,200	1,800	Low cost
Replace with Best Technology (Cohort E)	3,700	-	43,100	-	$3250*.
Run on B20	400	600	(1,800)	2,900	Fuel cost premium of 20%, around $1,000 per year