TORONTO STAFF REPORT

August 27, 2003

To: Board of Health

From: Dr. Sheela V. Basrur, Medical Officer of Health

Subject: Emissions from Transit Buses

Purpose:

This report reviews data on emissions from transit buses using various fuels and technologies.

Financial Implications and Impact Statement:

There are no financial implications stemming directly from this report.

Recommendations:

It is recommended that:

(1) the Board of Health request that the Chief General Manager of the Toronto Transit Commission work with the City's Comprehensive Air Quality Strategy Working Group to develop a short and long-term strategy for reducing emissions from the transit bus fleet;

(2) this report be sent to the Commissioner, Works & Emergency Services, and the Chief General Manager of the Toronto Transit Commission for consideration; and

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

Background:

At their July 16, 2003 meeting the Toronto Transit Commission (TTC) received a report from the Chief General Manager requesting procurement authorization to purchase 250 forty-foot low floor clean diesel buses from Orion Bus Industries. The report has been forwarded to City Council for their approval.

In June 25, 2002 the Board of Health received the report entitled "Assessing the Health Impact of Diesel Exhaust in Toronto". This report reviewed evidence documenting cancer and non-cancer health effects and assessed the potential impact on Toronto populations. Also in 2002, the Board of Health received the report entitled "Ten Key Carcinogens in Toronto Workplaces and Environment: Assessing the Potential for Exposure" (March 19, 2002). Nine of the carcinogens evaluated were anticipated to exceed acceptable exposure levels in Toronto's air. One of the priority carcinogens identified for emissions reductions was polycyclic aromatic hydrocarbons (PAH), a significant component of diesel particulate matter.

Due to concerns about emissions from diesel engines, this report examines various fuels and technologies available that could reduce such emissions from the TTC bus fleet.

TTC staff were consulted in the preparation of this report.

Comments:

Air pollutants have been shown to be associated with adverse health effects including premature mortality. According to the 1995 Criteria Air Contaminant Inventory on Environment Canada's National Pollutant Release Inventory website, transportation sources contribute significantly to the overall air pollutant emissions in Toronto. For example, 65 percent of the nitrogen oxides and 75 percent of the carbon monoxide emitted in Toronto are estimated to be from transportation sources.

Toronto Public Health has recognized that diesel exhaust likely contributes to the burden of cancer in Toronto. Emissions from diesel-fuelled vehicles and equipment include gaseous pollutants and particulate matter. Recent studies have linked air pollution with an increase in lung cancer. Diesel exhaust has been classified as a probable human carcinogen. Short-term exposure to high levels of diesel exhaust has been associated with eye, nose and throat irritation as well as with nausea, cough and phlegm. Studies have found an increase in cancer risk, primarily lung cancer, among railway workers, truck drivers, heavy equipment operators and professional drivers, all occupations where exposure to diesel exhaust is high.

The 2002 report to the BOH "Assessing the Health Impact of Diesel Exhaust in Toronto" recommended that the City's Comprehensive Air Quality Strategy consider strategies to reduce emissions levels and exposure to diesel exhaust.

Transit buses and other heavy-duty vehicles are most often diesel-fuelled. Transit Authorities across North America continue to develop strategies to address the issue of diesel emissions and are considering less polluting engine technologies and controls in their long-term fleet purchase and maintenance plans. The strategies to address emissions vary. The New York Transit Authority operates compressed natural gas buses and, more recently, has invested in diesel-electric hybrid buses. In Montreal, the Societe de Transport de Montreal took part in the BIOBUS project, which tested the use of biodiesel in 155 transit buses. The Los Angeles County Transportation Authority operates mostly compressed natural gas buses (more than 1800). In Toronto, the TTC operates mostly diesel buses; however the fleet complement includes 125 compressed natural gas buses. In addition, the TTCs Bus Fleet Plan indicates that the TTC is evaluating the diesel-electric hybrid bus. Two out of three testing sessions have been completed.

Emissions Analysis:

The following analysis compares the average reported emissions associated with three engine technologies: a) diesel engine b) diesel-electric hybrid engine and c) compressed natural gas (CNG) engine. The diesel engines evaluated include both older and newer models using both low sulphur diesel (LSD) which is the diesel grade commonly available on the market and ultra low sulphur diesel (ULSD). The diesel-electric hybrid engine is a combination of a small diesel engine that powers an electrical generator, which, through rooftop batteries, powers an electric motor. During the braking cycle, some of the energy is recovered and used to recharge the batteries. This results in reduced fuel consumption. The emissions impact associated with cleaner fuel formulations and various pollution control or after-treatment technologies are also examined. CNG-hybrids (which operate on the same principle as the diesel hybrids, with a small CNG engine and an electrical generator) were not evaluated because they are currently in the development phase and emissions data were not available to Toronto Public Health.

The following data is compiled from published reports on emissions testing of transit buses in North America. In preparing this data, staff also consulted staff with Environment Canada's Environmental Technology Centre, Emissions Research and Measurement Division. TTC staff were also consulted for any available emissions data. Engine model years evaluated range from 1988 to 2001. The emissions figures presented are based on actual tailpipe measurements.

Table 1 presents a summary of emissions for nitrogen oxides (NO_x), particulate matter (PM), carbon monoxide (CO), carbon dioxide (CO_2), total hydrocarbons (THC) and non-methane organic carbon (NMOC). These summary data are a compilation of average emissions from all buses using a given fuel source. They include emissions results from buses equipped with after-treatment devices and, in some cases, using fuel with a lower sulphur content (i.e. ultra low sulphur diesel). The influence of these emission reduction measures is considered later in the report.

The diesel-electric hybrid bus had the lowest overall emissions of NO_x, CO, CO_2 and THC. The PM emissions were slightly higher for the diesel-electric hybrid relative to the CNG bus. However, limited testing data is available for the diesel-electric hybrid bus because it is the most recent on the market.

Table 1 also separates out the emissions data for model years, since 1996. In the case of diesel buses, the newer models show emissions reductions for most pollutants. PM and CO were both reduced by approximately 69% and THC were reduced by 90%. These dramatic reductions observed with newer diesel engines, referred to as clean diesel, are likely due to a combination of better, more refined engines and the use of after-treatment technologies and cleaner fuels. The diesel-electric hybrid engine is the newest technology, introduced after 1996. There were no statistically significant differences in emissions from older or newer model CNG buses.

After-treatment and Low Sulphur Fuel:

The emissions reductions reported above do not fully address the importance and influence of engine type, sulphur content in fuel and after-treatment technologies. Table 2 summarizes the emissions data relevant to the use of LSD and ULSD and the installation of after-treatment devices. The studies reviewed reported the use of various after-treatment technologies such as oxidation catalysts and PM filters. It is important to note that these technologies continue to be refined and more effective technologies continue to be developed. For example, the selective reduction catalyst has replaced the oxidation catalyst.

Table 2 shows that the greatest emissions reductions were observed with after-treatment devices installed on diesel-fuelled buses. The oxidation catalyst generally reduces emissions. ULSD improves them further and ULSD plus the installation of a PM filter improves them even more. The ULSD/PM filter combination reduced PM by 87%, CO by 97% and THC by 83%, relative to LSD without after-treatment. NO_x were reduced by only 11% and CO_2 increased by 8%.

At present LSD is used in transit fleets (300-500 parts per million (ppm) sulphur). ULSD is currently available in Canada in very limited quantities and is expensive. In June 2006 the regulations that reduce the allowable sulphur content in diesel fuel to 15 ppm will come into effect. Retrofitting existing bus fleets with PM filters becomes a more feasible option to consider since their effectiveness is dependent on very low sulphur levels in fuel.

Another fuel for use in clean diesel and diesel-electric hybrid engines is biodiesel. The reports reviewed to compile Tables 1 and 2 do not present data on emissions associated with biodiesel used in transit buses. Levels of sulphur in biodiesel are comparable to those in ultra-low sulphur petrodiesel. The U.S. Environmental Protection Agency (U.S.EPA) reports that the average concentration of sulphur in B100 (100% biodiesel) biodiesel is 54 ppm. B20 biodiesel blends (20% biodiesel mixed with petrodiesel) will, therefore, have a lower sulphur content than conventional petrodiesel. Relative to conventional diesel (LSD), the U.S.EPA has estimated that emissions for B20 would be reduced by approximately 10 percent for PM, 21 percent for hydrocarbons, and 11 percent for CO, while emissions for NO_x were estimated to increase by about 2 percent. In addition, slight reductions in air toxics emissions were estimated using the B20 fuel. However, these same emissions reductions are also expected when the cleaner ultra-low sulphur petrodiesel fuels are used. Thus, much of the improvement may be linked directly to the sulphur content of any given fuel (OPHA, 2003). While there were no emissions testing data available for biodiesel with after-treatment devices, additional emission-abatement technologies, such as PM filters, would be expected to have a similar impact on biodiesel and ULSD-fuelled vehicles, if those fuels have comparable sulphur concentrations.

Table 2 indicates that oxidation catalysts installed on CNG buses reduced emissions of NO_x by 30%, PM by 50% and CO by 34% relative to CNG buses without catalysts. However, CO_2 and THC emissions increased by 7 and 1 percent, respectively. According to Orion Bus Industries, a manufacturer of CNG buses, since October 2002 all new CNG buses are equipped with oxidation catalysts.

In the case of diesel-electric hybrids, the limited available data suggest that PM filters will reduce most emissions and greater reductions will be observed when ULSD is used.

Of the various combinations of fuel and technologies evaluated in Table 2, the following were considered the cleanest:

- Clean diesel using ULSD and PM filter;
- Diesel-electric hybrid using ULSD and PM filter; and,
- CNG with oxidation catalyst.

Both the CNG and diesel-electric hybrid buses emitted comparable NO_x and PM. However, the diesel-electric hybrid emitted much less CO, CO_2 and THC. CO and NMOC (a fraction of THC) are both linked with health effects. CO_2 is not directly associated with health effects, but its environmental effects have been well documented and is subject to reductions under the Kyoto Protocol.

Clean diesel buses using the ULSD/PM filter combination overall emitted significantly less pollutants than ordinary clean diesel buses using LSD without after-treatment. Clean diesel buses using the ULSD/PM filter emitted more NO_x and PM than CNG and diesel-electric hybrid buses. However, CO and THC emissions were lower for clean diesel buses compared to CNG buses. It is expected that the CNG-electric hybrid bus, when it becomes available, will emit less than the CNG bus with an oxidation catalyst. As noted previously, more effective after-treatment technologies are being developed (e.g. selective reduction catalyst).

The City of Toronto Environmental Plan calls for a comprehensive air quality strategy. Currently, an interdepartmental working group is preparing a draft strategy to be presented to the Toronto Interdepartmental Environment Team prior to being brought to Council. It is the intention of the strategy to include programs of the City of Toronto itself, and its agencies, Boards and Commissions, including the Toronto Transit Commission. It is therefore advisable that the strategy include a plan to work with the TTC to reduce the emissions of its fleet.

Conclusions:

The City's Comprehensive Air Quality Strategy, currently under development, will examine options for emissions reductions in various programs implemented across the corporation and the community. Consideration of options that minimize the impact of the City's bus fleet on Toronto's air quality should be included in the broad strategy.

The analysis of emissions from the three engine types indicates CNG engines and diesel-electric hybrids engines are much cleaner engine technologies than the clean diesel engine. Comparable levels of NO_x and PM were emitted from CNG with oxidation catalysts and from diesel-electric hybrid engines using the ULSD/PM filter combination. However, the diesel-electric hybrid engine emitted much less CO, CO_2 and THC. CO and NMOC are both linked with health effects and CO_2 to climate change. Therefore, based on limited emissions data, it appears that the newer diesel-electric hybrid provides emissions reductions for a greater number of pollutants. It is reasonable to expect that the CNG-electric hybrid bus, when it becomes available, will emit less than the CNG bus with an oxidation catalyst. The feasibility of using this engine technology in a transit bus application remains to be evaluated.

The TTC's long-term Bus Fleet Plan indicates that they are considering the diesel-electric hybrid technology for future bus purchases. The TTC is currently conducting an in-service evaluation of a diesel-electric hybrid bus on loan from the manufacturer.

Diesel buses emit the greatest amount of pollutants, particularly PM, relative to diesel-electric hybrids and CNG buses. Clean diesel buses are much less polluting than the older diesel buses and even greater emissions reductions are observed when ULSD and after-treatment devices like the PM filter are used. It is expected that the diesel buses that are currently in the bus fleet will be considered for after-treatment when the new sulphur content in fuel regulations come into effect in June 2006. In the more immediate future, the TTC should assess the feasibility of purchasing cleaner fuels, in combination with the installation of after-treatment devices.

Contact:

Franca Ursitti
Research Consultant
Health Promotion – Environmental Protection Office
Toronto Public Health
Tel: 416-338-8143
Fax: 416-392-7418
Email: fursitti@toronto.ca

Ronald Macfarlane
Supervisor, Environmental Health Assessment & Policy
Health Promotion – Environmental Protection Office
Toronto Public Health
Tel: 416-338-8097
Fax: 416-392-7418
Email: macfar3@toronto.ca

Fran Scott
Director, Planning & Policy and Associate MOH
Toronto Public Health
Tel: 416-392-7463
Fax: 416-392-0713
Email: fscott@toronto.ca

Dr. Sheela V. Basrur
Medical Officer of Health

Attachments:

Table 1: Summary of Emissions from In-Service Transit Buses (grams/mile)

Table 2: Summary of Emissions from In-Service Transit Buses (grams/mile) using various pollution control measures