A Representative Sample of

Fairfax County Public Schools Buses

Found to be Free of Significant Diesel Exhaust

Department of General Services
Dean A. Tistadt, Assistant Superintendent

Johnie Forte Support Center
6800B Industrial Road
Springfield, Virginia 22141

Office of Security and Risk Management Services
Prepared by Douglass O'Neill, Registered Environmental Health Specialist

March 2001

The Executive Summary

Fairfax County Public Schools (FCPS) owns and operates a fleet of 1,428 school buses of various makes and models to transport, daily, approximately 105,000 students to 234 schools and centers. The Fairfax County Department of Vehicle Services maintains the fleet on a regular, scheduled basis. In addition, each bus undergoes an annual safety inspection that includes the exhaust system. Approximately half of the buses are more than ten years old, and all but seven of the 1,428 buses are powered by diesel engines.

FCPS transportation officials were concerned by recent media reports about research findings on the possible negative health effects of diesel exhaust from older school buses. Because of this concern, FCPS officials asked the Environmental Health Section of the FCPS Office of Security and Risk Management Services, Department of General Services, to conduct a study to determine whether the contamination of FCPS bus air is a problem that needs to be addressed.

Twelve buses, representing different makes, models, sizes, ages, and engine types were selected for evaluation. Those selected included diesel fueled general education buses and special education buses with wheel chair lifts, a bus fueled by compressed natural gas, and one dual-fuel bus. The buses were monitored without student passengers during a simulated ninety-minute bus run in normal traffic with periods of loading, unloading, and idling.

Diesel exhaust is a mixture of gases and particles. To measure for the presence of diesel exhaust, the interior bus air was monitored for the following particle elements of diesel exhaust:

- Respirable Particulates – Dust that is small enough to breathe deep into your lungs.
- Organic carbon – Carbon particles more associated with automobile exhaust.
- Elemental Carbon – Carbon particles that make up 75 percent of diesel exhaust particles. Elemental carbon is considered the definitive diesel exhaust marker.

Air samples were collected by filtration in accordance with standardized methods prescribed by the Occupational Safety and Health Administration (OSHA), (respirable particulates), and the National Institute of Occupational Safety and Health (NIOSH), (elemental and organic carbon particulates). Analyses of the filtrates were performed by independent, certified laboratories following standard methods NIOSH 0600 and NIOSH 5040, respectively.

The study concludes that the concentration of diesel exhaust on FCPS school buses is below the limits of detection and that there is no significant age-related difference in the bus air quality. In other words, **breathing the air on Fairfax County Public Schools buses poses no health risks to our students and staff**.

Introduction

This study was conducted to assess environmental conditions on a representative sample of school buses owned and operated by Fairfax County Public Schools (FCPS). It was designed to quantify the presence of components of bus exhaust from various fuel-burning engines during routine operation. FCPS has a fleet of 1,428 school buses to transport 104,869 students to 234 schools and centers within a county of 399 square miles. All but 7 of these 1,428 are diesel engine buses of various makes and models. Approximately half of the buses are 10 years of age or older. Therefore, the quantification of diesel exhaust components was emphasized.

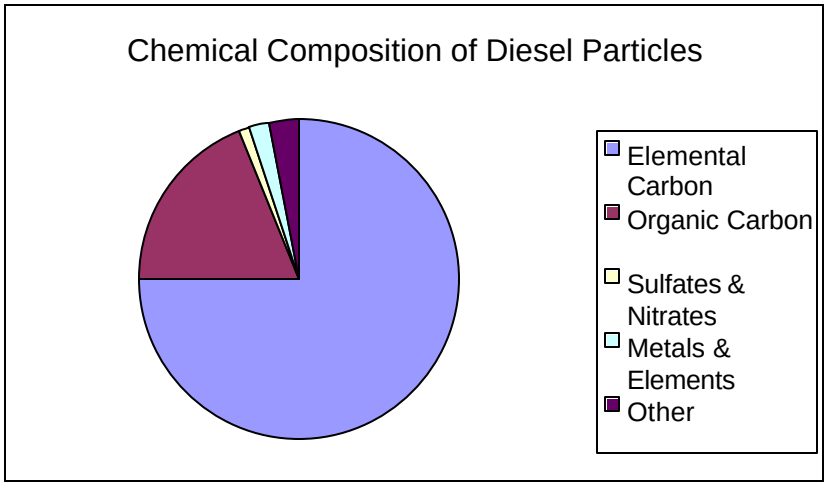
This study was conducted the Environmental Health Section of the Office of Security and Risk Management Services over a two-week period in February and March 2001 during normal traffic conditions.

What is Diesel Exhaust?

A diesel engine compresses air to high pressure and temperature. When diesel fuel is injected into this compressed air, it ignites releasing its energy. Complete and incomplete ignition of diesel fuel results in the formation of gaseous and particle exhaust. The gaseous phase of diesel exhaust is composed of carbon monoxide, oxides of sulfur and nitrogen, and partially burned/unburned hydrocarbons. The particle phase of diesel exhaust contains carbonaceous matter (elemental and organic carbon), nitrates, sulfates, metals and elements, and other particulate matter.

- Elemental carbon is carbon that has been stripped of hydrogen (pyrolysis) and is considered to be in its pure elemental form. The key marker for diesel exhaust is elemental carbon. (See pie chart below).

- Organic carbon contains molecules of carbon and hydrogen emitted in diesel exhaust largely as a result of the incomplete burning of diesel fuel and to a lesser extent, engine lubricating oil.



The chemical composition and relative percentages of diesel exhaust particles.

Methodology, Equipment, Rationale

The overall strategy of this study was: 1) to collect particulate samples from a relatively similar location (rear of bus and height from deck) in each bus; 2) to follow the exact bus route during each sampling run; 3) to operate the bus in the same manner (windows closed, heaters on, three-minute stops at each location) during each bus run; and 4) make observations during each bus run as to wind direction during bus stop, exhaust odors, general bus information, and other conditions.

The following samples were collected using a portable, battery-operated SKC pump.

- Respirable dusts less than 10 microns – collected on 37-millimeter (mm) pre-weighted PVC filter utilizing a 10-micron cyclone.
- Diesel Exhaust Components (Elemental and Organic Carbon) – collected on open-faced 37 mm quartz fiber filter.

Before and after each sampling period the portable, battery-operated SKC pumps were calibrated using a Gillian "The Gillabrater" rotometer. The air sample volume was determined by using the average of the before and after calibration flow rates.

- All respirable samples were collected at a flow rate of 1.7 liters per minute per OSHA sampling methodology for respirable dusts.
- All diesel exhaust components (elemental and organic carbon) samples were collected at 3 liters per minute per NIOSH 5040 sampling methodology for diesel exhaust components.

All particulate samples were drawn by pump from the top of a cart, approximately 41 to 42 inches above the bus deck.

The 37-millimeter (mm) pre-weighted PVC filter and the 37 mm quartz fiber filter, sampling media were supplied by American Medical Laboratories (AML) located in Chantilly, Virginia.

All sampling media was opened on each bus and attached to its respective portable, battery-operated SKC pump. At the end of each run the sampling media was capped and placed into a clean holding bag with the field blank. Samples were kept in a locked room until six samples were collected, when they were delivered to AML with custody papers.

The respirable dust samples were analyzed at AML. Respirable dust samples are measured by a gravimetric procedure using NIOSH method 0600. Respirable dust was calculated as the total mass of particulate found on the filter during analysis, and is not compound specific. Respirable dusts were reported as a mass--milligrams (mg)--and calculated as a concentration--milligrams per cubic meter (mg/M^3)--using the sample volumes.

The diesel exhaust components (elemental carbon and organic carbon) were analyzed by Data Chem Laboratories, Salt Lake City, Utah. Elemental carbon and organic carbon were analyzed using NIOSH method 5040. Elemental carbon and organic carbon were reported as a mass--micrograms (ug)--and calculated as a concentration--(milligrams per cubic meter (mg/M^3)--using the sample volumes.

Bus Selection

Twelve buses were selected to represent the 1,428 buses within the FCPS transportation system. Of the 1,428 buses, all but 7 use diesel fuel. Over 600 of the buses were put into service prior to 1991.

- 10 of the 12 buses use diesel fuel
- 1 of the 12 uses Compressed Natural Gas (CNG)
- 1 of the 12 use both CNG and diesel fuel
- 8 of the 12 buses were put into service prior to 1991
- 1 of the 12 had never been put into service (February 2001)
- 8 of the 12 were general education buses
- 4 of the 12 were special education buses; 3 of these had wheelchair lifts

Run Date	Bus Number	Year	Make	Model	Description	Fuel	Engine Maker	Engine Type	Odometer Reading
2/20/01	**1044**	**1987**	**IHC**	**Ward**	**64 passenger, conventional front**	**DSL**	**International Harvester**	**9.0 Liter**	**175182**

Bus 1044 was received by FCPS on November 1, 1986, and is primarily used as a spare general education rig. This 64-passenger conventional (engine separated from the bus and accessed by a hood) diesel bus is stationed at the Newington Garage and was last serviced on February 14, 2001.

Run Date	Bus Number	Year	Make	Model	Description	Fuel	Engine Maker	Engine Type	Odometer Reading
2/21/01	**1220**	**1987**	**Ford**	**Wayne**	**34 passenger, front right lift, conventional front**	**DSL**	**Ford**	**6.6 Liter**	**104820**

Bus 1220 was received by FCPS on January 29, 1988, and is primarily used as a spare special education rig. This 34-passenger conventional diesel bus has a wheelchair lift on the front, right side of the bus. Bus 1220 is stationed at the Newington Garage and was last serviced on January 31, 2001.

Run Date	Bus Number	Year	Make	Model	Description	Fuel	Engine Maker	Engine Type	Odometer Reading
2/21/01	**722**	**1988**	**GMC**	**Wayne**	**64 passenger, conventional front**	**DSL**	**Detroit**	**8.2 Liter**	**132464**

Bus 722 was received by FCPS on February 1, 1988, and is primarily used as a training rig at the Transportation Training Center. This 64-passenger conventional diesel bus is stationed at the Newington Garage and was last serviced on February 16, 2001.

Run Date	Bus Number	Year	Make	Model	Description	Fuel	Engine Maker	Engine Type	Odometer Reading
2/23/01	97	1991	Bluebird	TC-2000	78 passenger, transit front, inside engine	DSL	International Harvester	9.0	123568

Bus 97 was received by FCPS on December 6, 1990, and is used primarily as a general education rig used in Area II. This 78-passenger transit (snub-nosed) diesel bus has access to the engine from inside the cab of the bus. Bus 97 is stationed at the Newington Garage and was last serviced on February 14, 2001.

Run Date	Bus Number	Year	Make	Model	Description	Fuel	Engine Maker	Engine Type	Odometer Reading
2/26/01	1407	1993	Thomas	MVP-ER	78 passenger, transit front	CNG	Cummins	5.9 G	63066

Bus 1407 was received by FCPS on September 10, 1993, and is used primarily as a general education rig in Area I. This 78-passenger transit Compressed Natural Gas (CNG) is stationed at the Newington Garage and was last serviced on February 14, 2001.

Run Date	Bus Number	Year	Make	Model	Description	Fuel	Engine Maker	Engine Type	Odometer Reading
2/26/01	1380	1991	Bluebird	TC-2000	48 passenger, Rear right lift, Transit front	DSL	Cummins	5.9	116369

Bus 1380 was received by FCPS on November 27, 1990, and is used primarily as a training special education rig used at the Transportation Training Center. This 48-passenger transit diesel bus has access to the engine from inside the cab of the bus and a rear right side wheelchair lift. Bus 1380 is stationed at the Newington Garage and was last serviced on January 11, 2001.

Run Date	Bus Number	Year	Make	Model	Description	Fuel	Engine Maker	Engine Type	Odometer Reading
2/27/01	432	1994	International	Thomas Vista	42 passenger, transit front	DSL	International Harvester	7.3	119001

Bus 432 was received by FCPS on May 26, 1994, and is used primarily as a special education rig. This 48-passenger transit diesel bus has access to the engine from inside the cab of the bus and has no wheelchair lift. Bus 1380 is stationed at the Newington Garage and was last serviced on January 29, 2001.

Run Date	Bus Number	Year	Make	Model	Description	Fuel	Engine Maker	Engine Type	Odometer Reading
03/01/01	1248	1989	Bluebird	All American	84 passenger, transit front, inside engine	DSL	CAT	3208	101330

Bus 1248 was received by FCPS on February 9, 1989, and is used primarily as a training general education rig used at the Transportation Training Center. This 84-passenger transit diesel bus has access to the engine from inside the cab of the bus. Bus 1248 is stationed at the Newington Garage and was last serviced on February 26, 2001.

Run Date	Bus Number	Year	Make	Model	Description	Fuel	Engine Maker	Engine Type	Odometer Reading
03/02/01	**1563**	**2001**	**Amtran**	**RE**	**78 passenger, transit front, rear engine**	**DSL**	**Navistar**	**T444E**	**1100**

Bus 1563 was received by FCPS on February 1, 2001, and is used primarily in Area III. This 78-passenger transit diesel bus has a rear engine. Bus 1563 is stationed at the West Ox Garage and was last serviced on February 14, 2001.

Run Date	Bus Number	Year	Make	Model	Description	Fuel	Engine Maker	Engine Type	Odometer Reading
03/02/01	**1405**	**1995**	**Thomas**	**MVP-ER**	**78 passenger, transit front, rear engine**	**CNG/ DSL**	**Cummins**	**5.9**	**71896**

Bus 1405 was received by FCPS on December 12, 1994, and is used primarily as a general education rig used in Area II. This 78-passenger transit duel fuel (CNG/diesel) bus has a rear engine. Bus 1405 idles using diesel fuel and its primary locomotive fuel is CNG. Bus 1405 is stationed at the Newington Garage and was last serviced on February 14, 2001.

Run Date	Bus Number	Year	Make	Model	Description	Fuel	Engine Maker	Engine Type	Odometer Reading
03/05/01	**687**	**1987**	**IHC**	**Ward**	**34 passenger, front right lift, conventional front,**	**DSL**	**International Harvester**	**6.9**	**199460**

Bus 687 was received by FCPS on November 11, 1986, and is primarily used as spare special education rig. This 34-passenger conventional diesel bus with a front right wheelchair lift is stationed at the Newington Garage and was last serviced on February 14, 2001.

Run Date	Bus Number	Year	Make	Model	Description	Fuel	Engine Maker	Engine Type	Odometer Reading
03/05/01	**297**	**1984**	**Ford**	**Wayne**	**64 passenger, conventional front**	**DSL**	**Detroit**	**8.2**	**150589**

Bus 297 was received by FCPS on July 1, 1984, and is primarily used as a general education-training rig at the Transportation Training Center. This 64-passenger conventional diesel bus is stationed at the Newington Garage and was last serviced on February 14, 2001.

The Bus Route

All 12 buses followed the exact 19.9-mile route during the collection of particles and gasses. The bus run always started at the Johnie Forte Support Center. The bus run had five stops during the run to mimic actual bus stops (each three minutes long). These locations were:

- Parklawn Elementary School
- Glasgow Middle School
- Glen Forest Elementary School
- Montgomery Ward Shopping Center, Seven Corners
- Beechtree Elementary School

The bus run ended with a 15-minute idle at the Johnie Forte Support Center. During the 12 sampling runs the longest bus run took 100 minutes with the shortest taking 90 minutes. The average bus run over 12 sampling runs was 93 minutes and 45 seconds. The bus route was as exactly as follows:

- Start at the Johnie Forte Support Center, 6800B Industrial Road; 0.0 miles.
- Right onto Industrial Road, right onto Backlick Road, right onto Braddock Road until left into Parklawn Elementary School, 4116 Braddock Road; 4.1 miles.
- Right onto Braddock Road, left onto Hillcrest Place, left onto Summit Place, right onto Fairfax Parkway into Glasgow Middle School, 4101 Fairfax Parkway; 5.1 miles.
- Right onto Fairfax Parkway, right onto Columbia Pike, left onto Leesburg Pike, right onto Glen Forest Drive into Glen Forest Elementary School, 5829 Glen Forest Drive; 7.8 miles.
- Left onto Glen Forest Drive, right onto Leesburg Pike, right onto Glen Carlyn Road, left onto South Manchester Drive, left onto Arlington Boulevard, right into Montgomery Wards Shopping Center, Arlington Boulevard; 10 miles.
- Right onto Arlington Boulevard, left onto Annandale Road, left onto Beechtree Lane into Beechtree Elementary School, 3401 Beechtree Lane; 13.5 miles.
- Left onto Beechtree Lane, right onto Rose Lane, left onto Hickory Hill Road, left onto Annandale Road, left onto Gallows Road, forward onto Annandale Road, forward onto Ravensworth Road, left onto Jayhawk Street, right onto Backlick Road, left onto Industrial Road into the Johnie Forte Support Center; 19.9 miles.

The Bus Run Observations and Sample Results

During each sampling run, general observations were made as to wind direction during bus stop, exhaust odors during runs and stops, general bus information and conditions, general traffic conditions.

Sampling Run 1 - February 20, 2001 Bus 1044 94 minutes

- 10:33 - Johnie Forte Support Center - The overall hygienic condition of the bus was considered poor with visible dust and dirt on the deck and interior shell of the bus.

- 10:50-10:53 - Parklawn Elementary School -- no noticeable exhaust odor; wind from the rear of the bus.
- 10:57-11:00 - Glasgow Middle School -- no noticeable exhaust odor; wind from the right side of the bus.
- 11:09-11:12 - Glen Forest Elementary School -- no noticeable exhaust odors; wind from the rear of the bus.
- 11:22-11:25 - Montgomery Ward Shopping Center, Seven Corners -- no noticeable exhaust odors; wind from the rear of the bus.
- 11:35-11:40 - Beechtree Elementary School -- no noticeable exhaust odors; wind from the rear of the bus. *Note: The Channel 9 Television cameraman was let off the bus to film the bus during the first two minutes of this stop*.
- 11:52-12:07 - Johnie Forte Support Center -- no noticeable exhaust odors; wind from the rear of the bus.

Bus 1044	Respirable Particulates	Organic Carbon	Elemental Carbon
Mass	< 0.010 mg *	26.97 ug	None Detected
Airborne Concentration	< 0.051 mg/M^3 *	0.0864 mg/M^3	< 0.0041 mg/M^3 *

(*) Sample Result was less than the detection limit (shown) of the sampling method.

Sampling Run 2 - February 21, 2001 Bus 1220 90 minutes

- 09:17 - Johnie Forte Support Center -- The overall hygienic condition of the bus was considered poor with visible dust and dirt on the deck and interior shell of the bus.
- 09:31-09:34 - Parklawn Elementary School -- noticeable diesel exhaust odor; wind from the rear of the bus.
- 09:38-09:41 - Glasgow Elementary School -- noticeable diesel exhaust odors; wind from the right side of the bus; used the front right wheel chair lift.
- 09:50-09:53 - Glen Forest Elementary School -- noticeable diesel exhaust odors; wind from the rear of the bus.
- 10:02-10:05 - Montgomery Ward Shopping Center, Seven Corners -- noticeable diesel exhaust odors; wind from the back of the bus.
- 10:16-10:19 - Beechtree Elementary School -- noticeable diesel exhaust odors; wind from the back of the bus.
- 10:36-10:51 – Johnie Forte Support Center -- noticeable diesel exhaust odors; wind from the rear of the bus.

Bus 1220	Respirable Particulates	Organic Carbon	Elemental Carbon
Mass	< 0.010 mg *	26.44 ug	None Detected
Airborne Concentration	< 0.051 mg/M^3 *	0.0921 mg/M^3	< 0.0045 mg/M^3 *

(*) Sample Result was less than the detection limit (shown) of the sampling method.

Sampling Run 3 - February 21, 2001 Bus 722 90 minutes

- 12:00 - Johnie Forte Support Center -- The overall hygienic condition of the bus was considered poor with visible dust and dirt on the deck and interior shell of the bus.
- 12:10-12:13 - Parklawn Elementary School -- noticeable diesel odor; wind from the rear of the bus.
- 12:17-12:20 - Glasgow Middle School -- no diesel exhaust odor; wind from the right side of the bus.
- 12:30-12:33 - Glen Forest Elementary School -- no odor; wind from the back of the bus.
- 12:42-12:45 - Montgomery Ward Shopping Center, Seven Corners -- no odor; wind from the back of the bus.
- 12:57-13:00 - Beechtree Elementary School -- trace of diesel odor; wind from the back of the bus.
- 13:17-13:32 – Johnie Forte Support Center -- no odor; wind from the back of the bus.

Bus 722	Respirable Particulates	Organic Carbon	Elemental Carbon
Mass	< 0.010 mg *	20.39 ug	None Detected
Airborne Concentration	< 0.052 mg/M^3 *	0.0721 mg/M^3	< 0.0045 mg/M^3 *

(*) Sample Result was less than the detection limit (shown) of the sampling method.

Sampling Run 4 - February 23, 2001 Bus 97 90 minutes

- 09:30 - Johnie Forte Support Center -- The overall hygienic condition of the bus was considered average with some dust and dirt on the deck and interior shell of the bus.
- 09:45-09:48 - Parklawn Elementary School -- trace of diesel exhaust odor; wind from the rear of the bus.
- 09:52-09:55 - Glasgow Middle School -- trace of diesel odor; wind from the right side of the bus.
- 10:03-10:06 - Glen Forest Elementary School -- trace of diesel odor; wind from the rear of the bus.
- 10:15-10:18 - Montgomery Ward Shopping Center, Seven Corners -- trace of diesel odor; wind from the rear of the bus.
- 10:27-10:30 - Beechtree Elementary School -- trace of diesel odor; wind from the rear of the bus.
- 10:45-11:00 – Johnie Forte Support Center -- no diesel odor; wind from the rear of the bus.

Bus 97	Respirable Particulates	Organic Carbon	Elemental Carbon
Mass	0.027 mg	20.84	None Detected
Airborne Concentration	0.14 mg/M^3	0.0731 mg/M^3	< 0.0045 mg/M^3 *

(*) Sample Result was less than the detection limit (shown) of the sampling method.

Sampling Run 5 - February 26, 2001 Bus 1407 90 minutes

- 8:52 - Johnie Forte Support Center -- The overall hygienic condition of the bus was considered excellent with little to no visible dust or dirt on the deck and interior shell of the bus.
- 09:06-09:09 - Parklawn Elementary School -- no odors; wind from the back of the bus.
- 09:13-09:16 - Glasgow Middle School -- no odors; wind from the right side of the bus.
- 09:19-09:22 - Glen Forest Elementary School -- no odors; wind from the back of the bus.
- 09:35-09:38 - Montgomery Ward Shopping Center, Seven Corners -- no odors; wind from the back of the bus.
- 09:47-09:50 - Beechtree Elementary School -- no odors; wind from the rear of the bus.
- 10:07-10:22 – Johnie Forte Support Center -- no odors; wind from the rear of the bus.

Bus 1407	Respirable Particulates	Organic Carbon	Elemental Carbon
Mass	< 0.010 mg *	13.22 ug	None Detected
Airborne Concentration	< 0.065 mg/M^3 *	0.0474 mg/M^3	< 0.0046 mg/M^3 *

(*) Sample Result was less than the detection limit (shown) of the sampling method.

Sampling Run 6 - February 26, 2001 Bus 1380 99 minutes

- 11:32 - Johnie Forte Support Center -- The overall hygienic condition of the bus was considered average with little dust or dirt on the deck and interior shell of the bus. This bus has a rear right wheelchair lift access. So there are more rubber openings adjacent to the exhaust than any other school bus sampled.
- 11:48-11:51 - Parklawn Elementary School -- trace of diesel odor
- 11:55-11:58 - Glasgow Middle School -- no odors; wind from the right side of the bus.
- 12:07-12:10 - Glen Forest Elementary School -- trace of diesel odors; wind from the rear.
- 12:18-12:21 - Montgomery Ward Shopping Center, Seven Corners -- trace of diesel odor; wind from the rear of the bus.
- 12:32-12:35 - Beechtree Elementary School -- operated the rear right wheelchair lift during stop; trace diesel odor; wind from the right of the bus.
- 12:56-13:11 – Johnie Forte Support Center -- trace diesel odor; wind from the back of the bus.

Bus 1380	Respirable Particulates	Organic Carbon	Elemental Carbon
Mass	< 0.010 mg *	19.15 ug	None Detected
Airborne Concentration	< 0.060 mg/M^3 *	0.0647 mg/M^3	< 0.0043 mg/M^3 *

(*) Sample Result was less than the detection limit (shown) of the sampling method.

Sampling Run 7 - February 27, 2001 Bus 432 94 minutes

- 10:40 - Johnie Forte Support Center -- The overall hygienic condition of the bus was considered excellent with little to no dust or dirt on the deck and interior shell of the bus.
- 10:54-10:57 - Parklawn Elementary School -- trace of diesel odor; wind from the rear of the bus.
- 11:00-11:03 - Glasgow Middle School -- trace of diesel odor; wind from the right side of the bus.
- 11:11-11:14 - Glen Forest Elementary School -- trace of diesel odor; wind from the rear of the bus.
- 11:23-11:26 - Montgomery Ward Shopping Center, Seven Corners -- no odors; wind from the rear of the bus.
- 11:35-11:38 - Beechtree Elementary School -- trace of diesel odor; wind from the rear of the bus.
- 11:59-12:14 – Johnie Forte Support Center -- no odors; wind from the rear of the bus.

Bus 432	Respirable Particulates	Organic Carbon	Elemental Carbon
Mass	0.025 mg	25.37	None Detected
Airborne Concentration	0.15 mg/M^3	0.0881 mg/M^3	< 0.0045 mg/M^3 *

(*) Sample Result was less than the detection limit (shown) of the sampling method.

Sampling Run 8 – March 1, 2001 Bus 1248 100 minutes

- 13:30 - Johnie Forte Support Center -- The overall hygienic condition of the bus was considered excellent with little to no dust or dirt on the deck and interior shell of the bus. It was noted that there was a burning motor oil smell in the bus.
- 13:45-13:48 - Parklawn Elementary School -- oil odor; wind from the rear of the bus.
- 13:52-13:55 - Glasgow Middle School -- oil odor; wind from the right of the bus.
- 14:04-14:07 - Glen Forest Elementary School -- oil odor; wind from the rear of the bus.
- 14:15-14:18 - Montgomery Ward Shopping Center, Seven Corners -- oil odor; wind from the rear of the bus.
- 14:31-14:34 - Beechtree Elementary School -- oil odor; wind from the rear of the bus.
- 14:55-15:10 - Johnie Forte Support Center -- oil odor; wind from the rear of the bus.

Bus 1248	Respirable Particulates	Organic Carbon	Elemental Carbon
Mass	0.021 mg	26.32 ug	None Detected
Airborne Concentration	0.123 mg/M^3	0.0869 mg/M^3	< 0.0042 mg/M^3 *

(*) Sample Result was less than the detection limit (shown) of the sampling method.

Sampling Run 9 – March 2, 2001 Bus 1563 95 minutes

- 08:35 - Johnie Forte Support Center -- The overall hygienic condition of the bus was considered excellent with little to no dust or dirt on the deck and interior shell of the bus. Brand new bus that has never been on the road.
- 08:50-08:53 - Parklawn Elementary School -- no odors; wind from the rear of the bus.
- 08:57-09:00 - Glasgow Middle School -- no odors; wind from the right side of the bus.
- 09:07-09:10 - Glen Forest Elementary School -- no odors; wind from the rear of the bus.
- 09:20-09:23 - Montgomery Ward Shopping Center, Seven Corners -- no odors; wind from the rear of the bus.
- 09:33-09:36 - Beechtree Elementary School -- no odors; wind from the rear of the bus.
- 09:55-10:10 – Johnie Forte Support Center -- no odors; wind from the rear of the bus.

Bus 1563	Respirable Particulates	Organic Carbon	Elemental Carbon
Mass	< 0.010 *	28.86 ug	None Detected
Airborne Concentration	< 0.061 mg/M^3 *	0.1023 mg/M^3	< 0.0045 mg/M^3 *

(*) Sample Result was less than the detection limit (shown) of the sampling method.

Sampling Run 10 – March 2, 2001 Bus 1405 93 minutes

- 11:40 - Johnie Forte Support Center -- The overall hygienic condition of the bus was considered excellent with little to no visible dust or dirt on the deck and interior shell of the bus; bus has a rear engine; bus smells like air fresheners; bus 1405 is a CNG/diesel bus.
- 11:52-11:55 - Parklawn Elementary School -- no odors; wind from the rear of the bus.
- 12:00-12:03 - Glasgow Middle School -- no odors; wind from the right side of the bus.
- 12:11-12:14 - Glen Forest Elementary School -- slight CNG odor; wind from the rear from the bus.
- 12:25-12:28 - Montgomery Ward Shopping Center, Seven Corners -- no odors; wind from the rear of the bus.
- 12:38-12:41 - Beechtree Elementary School -- no odors; wind from the rear of the bus.
- 12:58-13:13 – Johnie Forte Support Center -- no odors, wind from the rear of the bus.

Bus 1405	Respirable Particulates	Organic Carbon	Elemental Carbon
Mass	0.033 mg	18.17	None Detected
Airborne Concentration	0.205 mg/M^3	0.0665 mg/M^3	< 0.0047 mg/M^3 *

(*) Sample Result was less than the detection limit (shown) of the sampling method.

Sampling Run 11 – March 5, 2001 Bus 687 100 minutes

- 08:43 - Johnie Forte Support Center -- The overall hygienic condition of the bus was considered poor with visible dust and dirt on the deck and interior shell of the bus. It was noted that there was a slight diesel fuel odor inside the bus.
- 09:02-09:05 - Parklawn Elementary School -- diesel exhaust odor; wind from the rear of the bus.
- 09:09-09:12 - Glasgow Middle School -- trace diesel odor; wind from the right of bus.
- 09:21-09:24 - Glen Forest Elementary School -- no odor; wind from the rear of the bus.
- 09:32-09:35 - Montgomery Ward Shopping Center, Seven Corners -- no odor, wind from the rear; right front wheelchair lift used during this stop.
- 09:46-09:49 - Beechtree Elementary School -- no odor; wind from the rear of the bus.
- 10:08-10:23 – Johnie Forte Support Center -- no odor; wind from the rear of the bus.

Bus 687	Respirable Particulates	Organic Carbon	Elemental Carbon
Mass	< 0.010 mg *	36.82 ug	None Detected
Airborne Concentration	< 0.057 mg/M^3 *	0.1265 mg/M^3	< 0.0044 mg/M^3 *

(*) Sample Result was less than the detection limit (shown) of the sampling method.

Sampling Run 12 – March 5, 2001 Bus 297 90 minutes

- 11:35 - Johnie Forte Support Center -- The overall hygienic condition of the bus was considered poor with visible dust and dirt on the deck and interior shell of the bus.
- 11:48-11:51 - Parklawn Elementary School -- trace of diesel odor; wind from the rear of the bus.
- 11:54-11:57 - Glasgow Middle School -- no odors; wind from the right of the bus.
- 12:05-12:08 - Glen Forest Elementary School -- no odors; wind from the rear of the bus.
- 12:17-12:20 - Montgomery Ward Shopping Center, Seven Corners -- no odors; wind from the rear of the bus.
- 12:29-12:32 - Beechtree Elementary School -- no odors; wind from the rear of the bus.
- 12:50-13:05 – Johnie Forte Support Center -- no odors; wind from the rear of the bus.

Bus 297	Respirable Particulates	Organic Carbon	Elemental Carbon
Mass	< 0.010 mg *	31.56	None Detected
Airborne Concentration	< 0.065 mg/M^3 *	0.1204 mg/M^3	< 0.0049 mg/M^3 *

(*) Sample Result was less than the detection limit (shown) of the sampling method.

Discussion and Summary of Results

The purpose of this study was to quantify the presence of components of diesel exhaust from various fuel-burning engines during routine operation. This was accomplished and the results are summarized in *table 1/graph 1 - Summary air sample results for respirable dusts and elemental/organic carbon.* The key marker component of diesel exhaust particles, making up some 75 percent of the chemical composition of diesel particles, is elemental carbon. **In all twelve sample runs there was no detectable elemental carbon and subsequently no evidence that the bus air is contaminated by diesel/exhaust at a concentration that would be of any concern.**

There does not appear to be a correlation between the age of the bus and the likelihood of an increase in diesel exhaust/respirable particles as the bus deteriorates with age. (See *Table 2/Graph 2 - Summary air sample results for respirable dusts and elemental/organic carbon sorted by years in service, 1984-2001*.)

During the sampling runs there were detectable amounts of organic carbon and respirable particulates (Particulate Matter < 10 microns). These results are summarized in *table 1/graph 1 - Summary air sample results for respirable dusts and elemental/organic carbon*. This is attributed to the region's automobile (spark ignition) traffic congestion.

The 19.9-mile sampling run averaged 93.75 minutes. If you subtract 15 minutes for the five 3-minute stops and 15 minutes for the last stop idle, the bus was on the road for 63.75 minutes. The average velocity for the bus was 18.7 miles per hour (mph). This confirms that the sampling runs were performed in traffic.

The respirable samples were attributed to the ambient air contaminants because there was no correlation with interior sanitary conditions. There was no correlation between respirable particles and elemental carbon. The highest respirable particulate concentration was found on Bus 1405. Bus 1405 is the CNG/Diesel dual fuel bus. This bus uses CNG as its locomotive fuel and uses diesel while idling. Bus 1405 was in excellent hygienic condition and there were no diesel exhaust odors detected during the run (there was a hint of CNG mercaptan at the Glen Forest E.S. stop).

All of the twelve respirable samples were below the Occupational Safety and Health Administration (OSHA) occupational threshold for respirable particulates for an 8-hour Time Weighted Average (TWA) (see *Table 3/Graph 3 – Comparison of Bus Respirable particulate as 8-hour Time Weighted Average (TWA) to OSHA 8-hour TWA limit*). To put the table/graph into perspective, a rider on Bus 1405 (the highest respirable particulate sample) was exposed to a concentration that is 125 times below the OSHA standard of 5 mg/M^3.

The detection of exhaust odor while riding a school bus may suggest to some passengers that exhaust is significantly being contaminating the bus air. The smell of the diesel exhaust is pungent and unpleasant but the intensity of an odor should not be construed to be representative of a health threat. *Table 4/Graph 4 is summary air sample results for respirable dusts and elemental/organic carbon sorted by interior bus diesel exhaust odor, most offensive to least offensive*.

This table shows that there is no correlation among odor and respirable particulate, organic carbon, and elemental carbon.

Table 1 - Summary air sample results for respirable dusts and elemental/organic carbon.

Sampling Run #	Bus Number	Respirable Particulates	Organic Carbon	Elemental Carbon
1	1044	< 0.051	0.0864	< 0.0041
2	1220	< 0.051	0.0921	< 0.0045
3	722	< 0.052	0.0721	< 0.0045
4	97	0.14	0.0731	< 0.0045
5	1407	< 0.065	0.0474	< 0.0046
6	1380	< 0.060	0.0647	< 0.0043
7	432	0.15	0.0881	< 0.0045
8	1248	0.123	0.0869	< 0.0042
9	1563	< 0.061	0.1023	< 0.0045
10	1405	0.205	0.0665	< 0.0047
11	687	< 0.057	0.1265	< 0.0044
12	297	< 0.065	0.1204	< 0.0049

Graph 1 - Summary air sample results for respirable dusts and elemental and organic carbon.

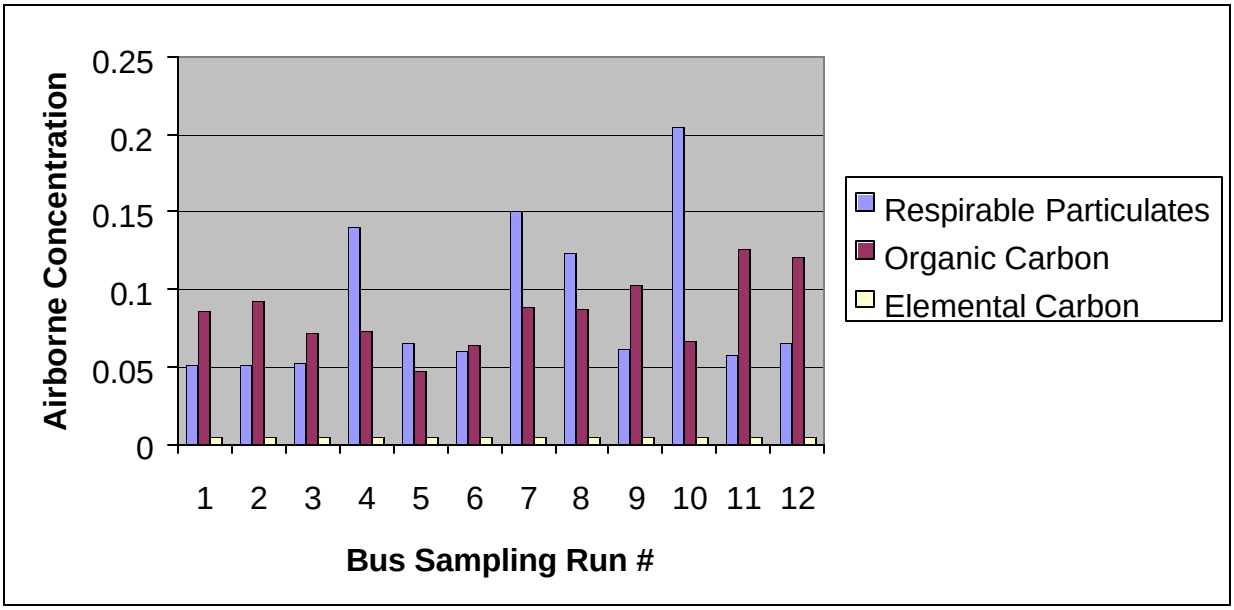


Table 2 - Summary air sample results for respirable dusts and elemental/organic carbon sorted by years in service, 1984-2001.

Year Bus put into service	Bus Number	Respirable Particulates	Organic Carbon	Elemental Carbon
(1) 1984	297	< 0.065	0.1204	< 0.0049
(2) 1987	1044	< 0.051	0.0864	< 0.0041
(3) 1987	1220	< 0.051	0.0921	< 0.0045
(4) 1987	687	< 0.057	0.1265	< 0.0044
(5) 1988	722	< 0.052	0.0721	< 0.0045
(6) 1989	1248	0.123	0.0869	< 0.0042
(7) 1991	97	0.14	0.0731	< 0.0045
(8) 1991	1380	< 0.060	0.0647	< 0.0043
(9) 1993	1407	< 0.065	0.0474	< 0.0046
(10) 1994	432	0.15	0.0881	< 0.0045
(11) 1995	1405	0.205	0.0665	< 0.0047
(12) 2001	1563	< 0.061	0.1023	< 0.0045

Table 2 - Summary air sample results for respirable dusts and elemental/organic carbon sorted by years in service, 1984-2001.

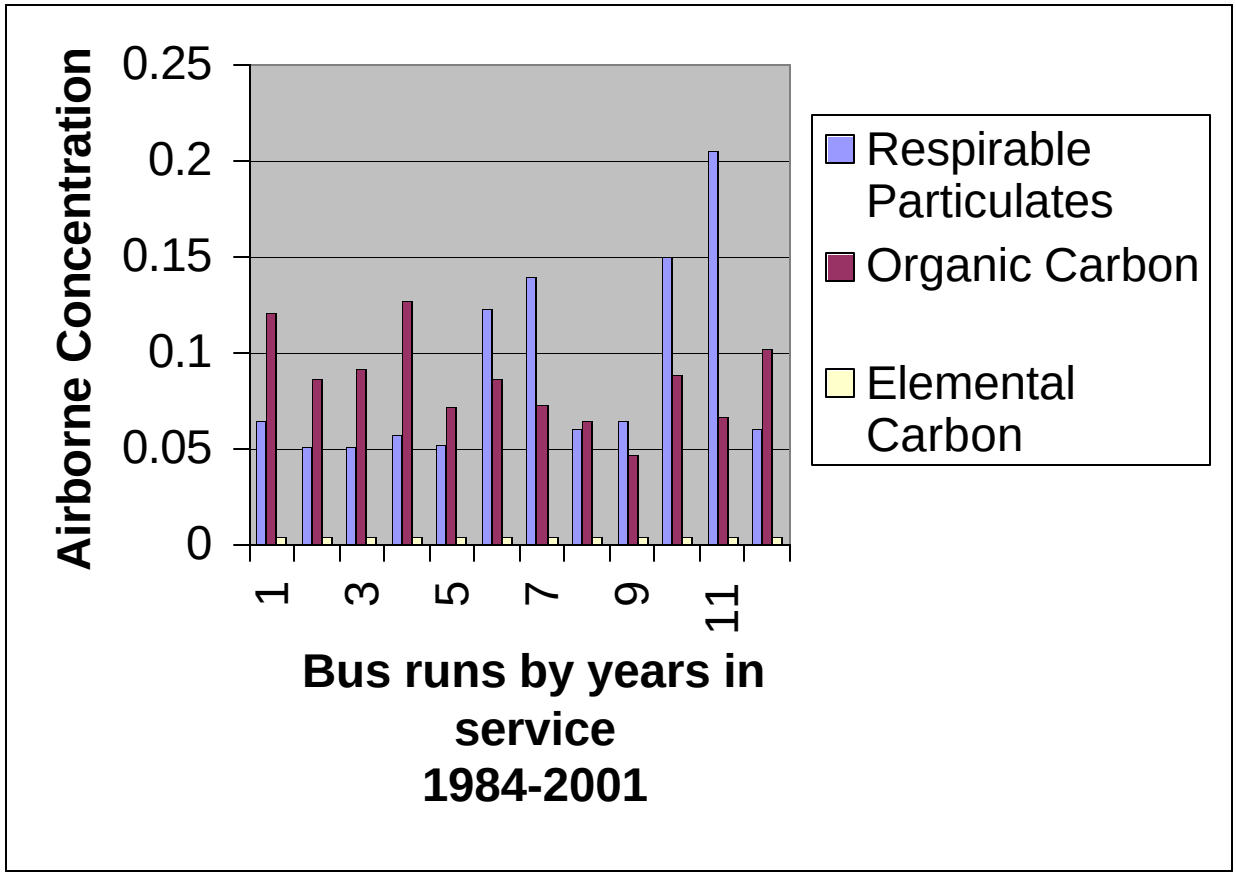


Table 3 – Comparison of Bus Respirable particulate as 8-hour Time Weighted Average (TWA) to OSHA 8-hour TWA limit.

Sampling Run	Bus Number	Respirable 8 hour TWA (mg/M^3)	OSHA 8 hour TWA (mg/M^3)
1	1044	< 0.010	5
2	1220	< 0.010	5
3	722	< 0.010	5
4	97	0.026	5
5	1407	< 0.012	5
6	1380	< 0.012	5
7	432	0.029	5
8	1248	0.026	5
9	1563	< 0.012	5
10	1405	0.040	5
11	687	< 0.012	5
12	297	< 0.012	5

Graph 3 – Comparison of Bus Respirable particulate as 8-hour Time Weighted Average (TWA) to OSHA 8-hour TWA limit.

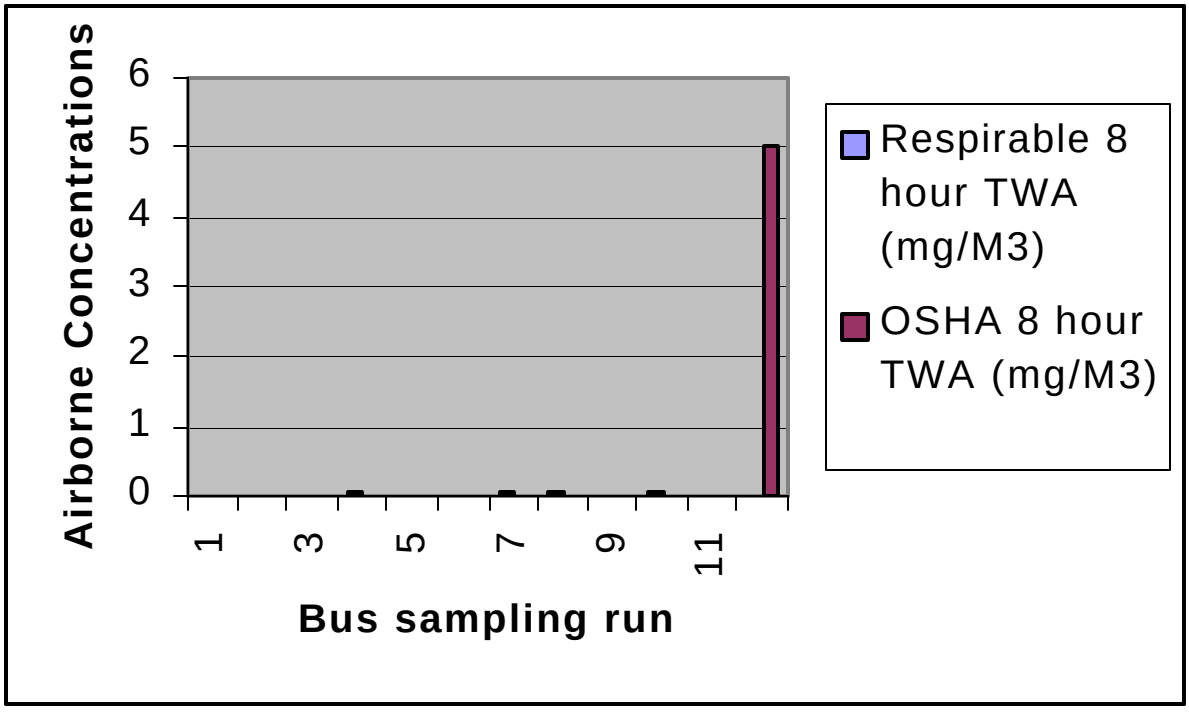


Table 4 - Summary air sample results for respirable dusts and elemental and organic carbon sorted by interior bus diesel exhaust odor, most offensive to least offensive.

X-Axis	Bus Year	Bus Number	Respirable Particulates	Organic Carbon	Elemental Carbon
1	1987	1220	< 0.051	0.0921	< 0.0045
2	1987	687	< 0.057	0.1265	< 0.0044
3	1988	722	< 0.052	0.0721	< 0.0045
4	1994	432	0.15	0.0881	< 0.0045
5	1991	97	0.14	0.0731	< 0.0045
6	1991	1380	< 0.060	0.0647	< 0.0043
7	1989	1248	0.123	0.0869	< 0.0042
8	1987	1044	< 0.051	0.0864	< 0.0041
9	1993	1407	< 0.065	0.0474	< 0.0046
10	2001	1563	< 0.061	0.1023	< 0.0045
11	1995	1405	0.205	0.0665	< 0.0047
12	1984	297	< 0.065	0.1204	< 0.0049

Table 4 - Summary air sample results for respirable dusts and elemental/organic carbon sorted by interior bus diesel exhaust odor, most offensive to least offensive.