Finding 4 (Continued): Bus Idling and Air Quality

- When windows were open while buses were idling, interior particulates and carbon levels increased rapidly.

- Mean concentrations of both black carbon and particulates are higher in idling buses when windows are open.

Queued Buses: Proximity of Doors to Tailpipes

- Idling creates a legacy effect of particulate and carbon pollution in bus interiors that lingers during bus runs. The duration of the legacy appears to depend upon the length of the idling period, the window configuration once the bus is underway, and it is likely to be affected by traffic type and intensity.

Figure 27: Mean Idling Concentrations of Black Carbon

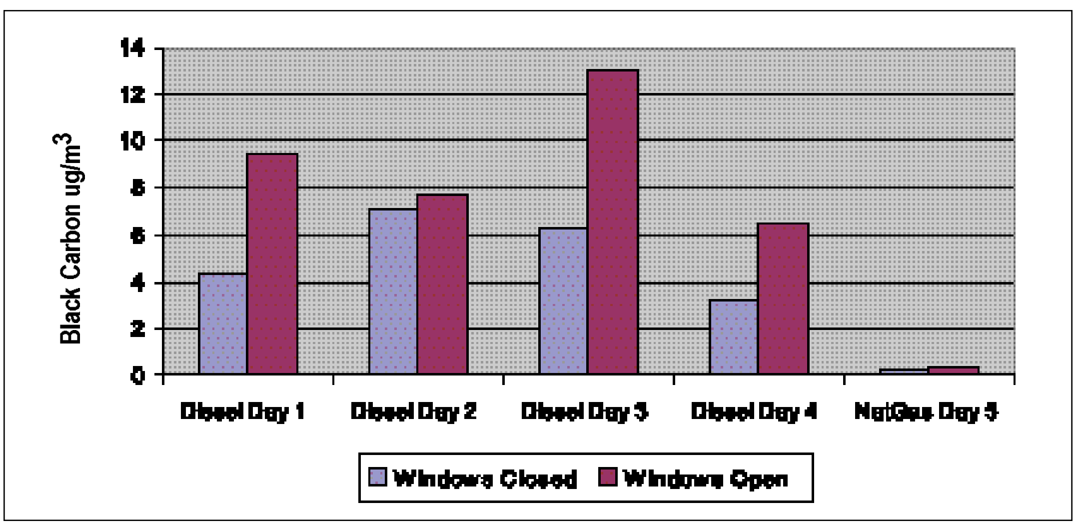


Figure 27 demonstrates that mean levels in idling buses with open windows exceed mean levels when windows are closed.

- The effect of idling on interior carbon concentrations was tested among 22 bus runs on an experimental bus run in rural Connecticut. Following 4 days of monitoring, we averaged carbon levels detected when idling, and compared these levels to moving buses. Average daily results are demonstrated in Figures 27 and 28: the first shows average results, and the second distribution of carbon levels.

Figure 28: Carbon Levels in Idling Buses

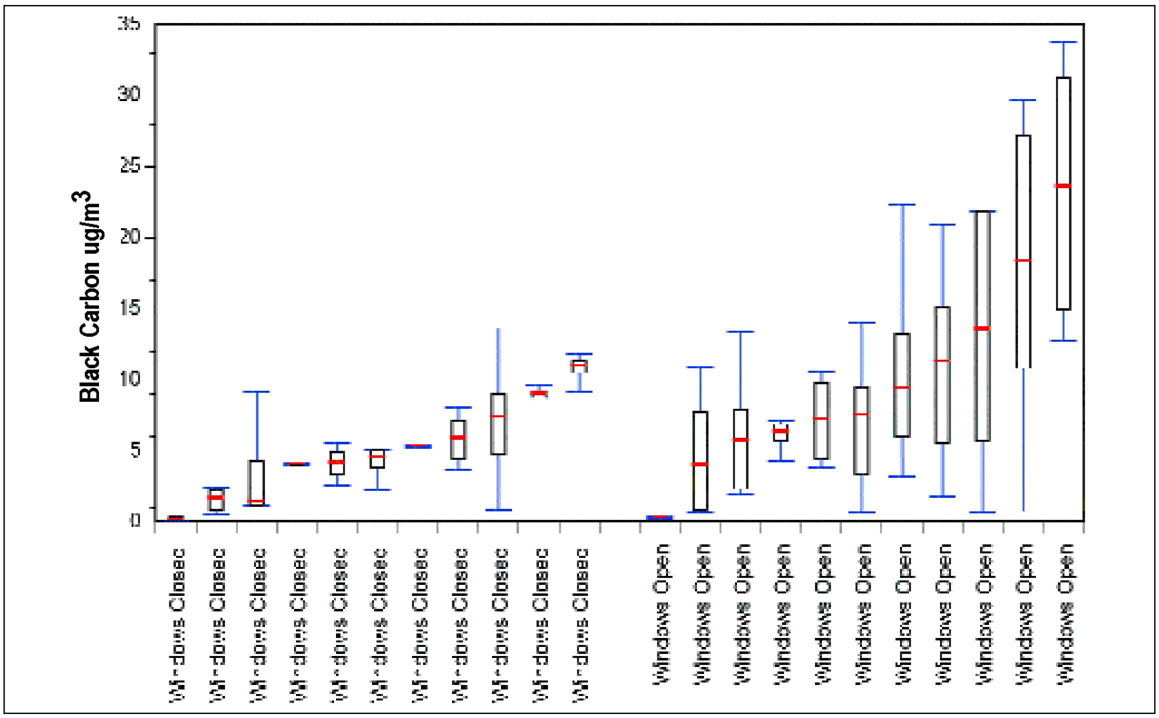


Figure 28 demonstrates separate bus runs with windows closed or opened. If windows of idling buses were open, then variability in interior concentrations was usually higher than if windows were closed. This might be explained as exhaust both enters and exits the bus through the windows and doors. Readings were reported as 1-minute averages, indicating some persistence of the pollutants once they entered the buses. This effect is the opposite of that found in moving buses, where open windows were associated with lower levels of particle and carbon concentrations.

- Several school administrators and teachers complained that bus queuing and idling practices often resulted in high levels of detectable diesel odor within schools. These emissions may enter schools from open doors and windows, or from air intake vents located near bus loading zones. If indoor air is contaminated by diesel emissions, ventilation may be far slower than rates detected on moving buses, with higher outdoor-interior exchange rates.

Finding 5: Natural Gas Emissions

- We tested several school buses powered by natural gas, and found the levels of particulates and carbon to be far lower than those found on diesel buses operated on the same routes.

- Natural gas bus emissions of particulates were tested both within and outside of buses. *Particulate emissions ($PM_{2.5}$) within 1 foot of the tailpipe were lower than levels found in the interior of many of the diesel buses tested.*

- Interior concentrations of $PM_{2.5}$ within natural gas-powered buses were essentially the same as average background levels (11-13 ug/m^3 of $PM_{2.5}$) reported from State of Connecticut monitors.

Figure 29: Mean Daily Black Carbon Levels

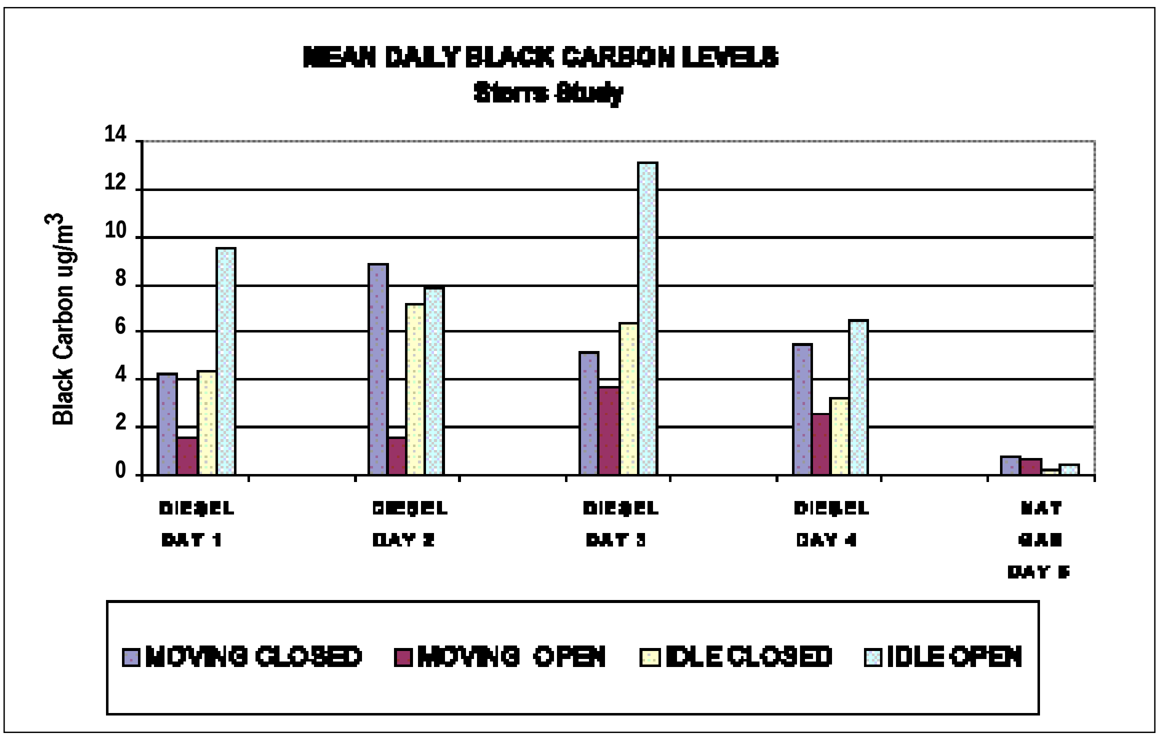
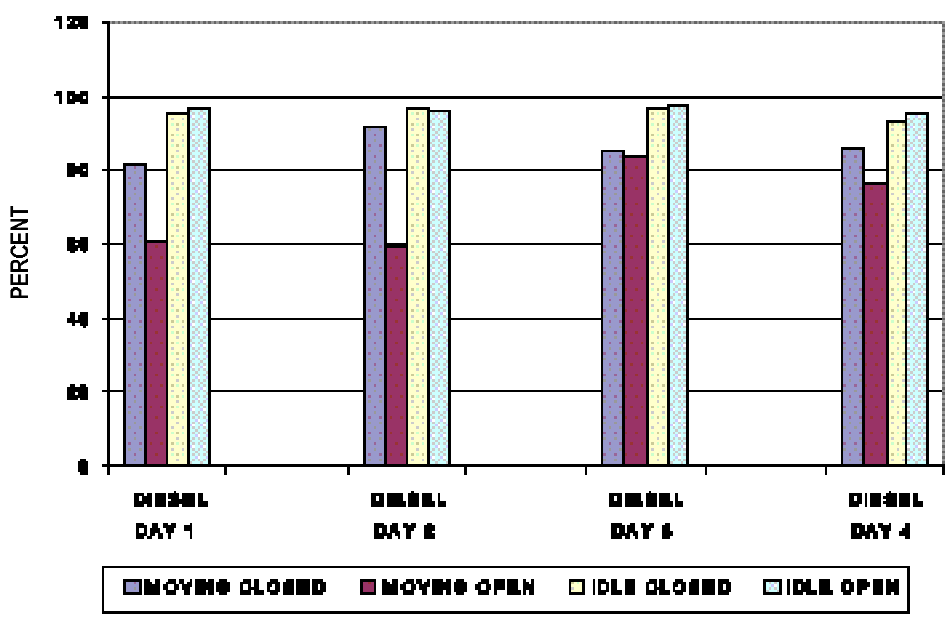


Figure 30: PERCENT CARBON REDUCTION NATURAL GAS COMPARED WITH DIESEL



Carbon levels detected in natural gas buses were less than 5% of carbon levels found in idling diesel buses, and less than 20% of carbon levels found in moving diesel buses, when windows were closed. The percent reduction was least for moving buses (maroon) as concentrations were also lowest in diesel buses when sampled while moving through bus runs—unless windows were closed.

Finding 6: Variability in Pollution Levels Within Individual Buses

- We found no significant differences in carbon or particulate levels when our monitoring equipment was placed in the front seat versus the rear seat of the bus.

Figure 31: Black Carbon Levels in Moving Buses
Front vs. Back of Bus

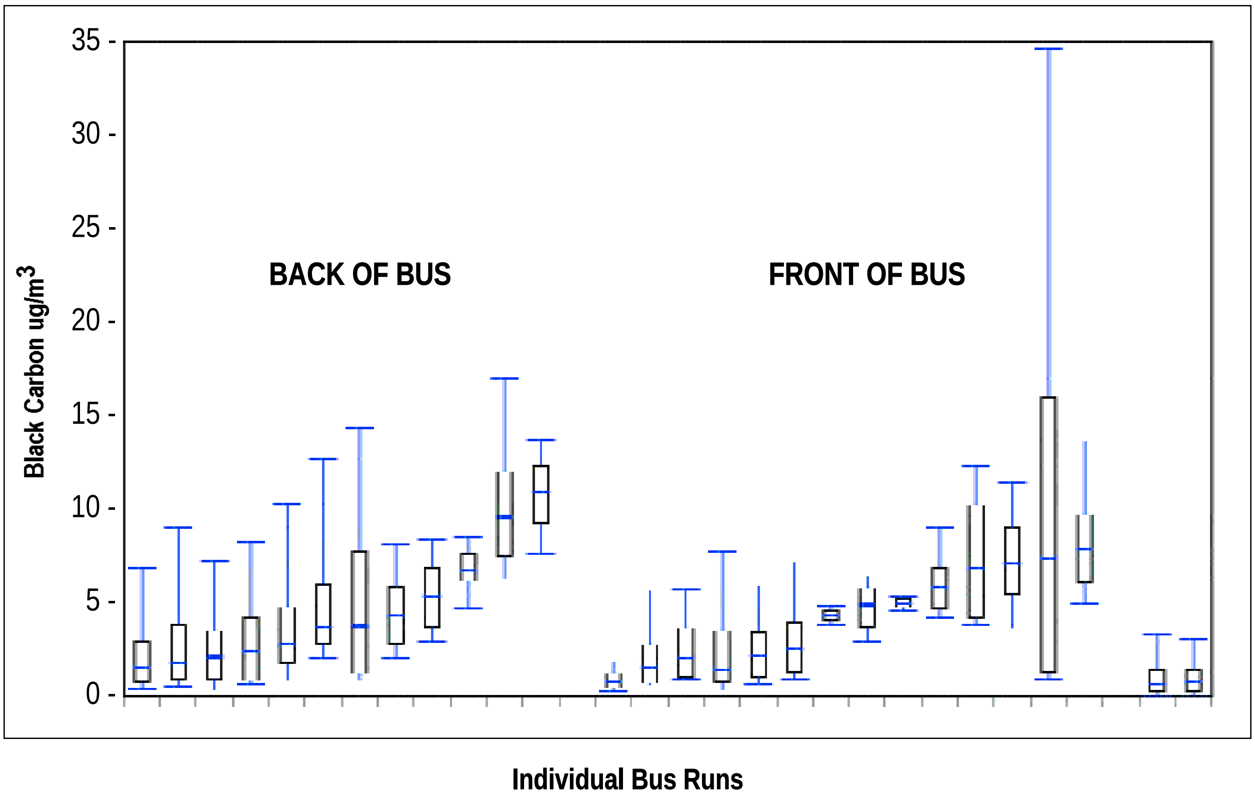


Figure 32: Range of Particulate Concentrations

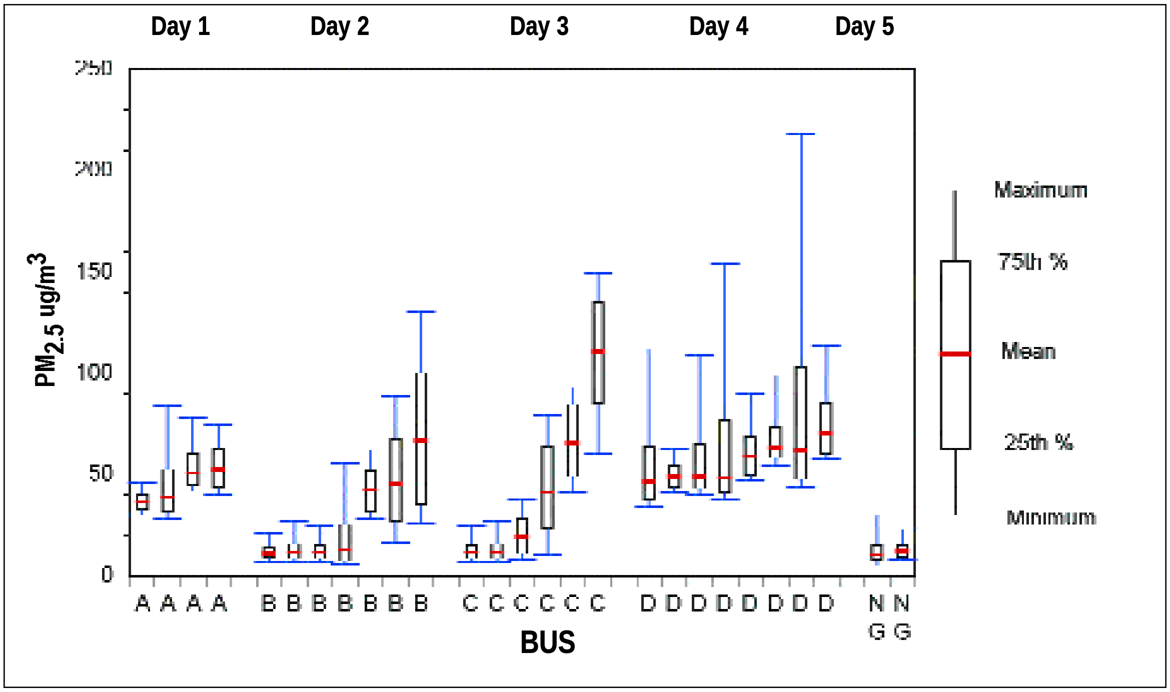


Figure 32 demonstrates variability in detected $PM_{2.5}$ levels within the same bus when different runs are compared. Mean levels differ significantly within the same bus, but on different runs, on days 2 and 3 (buses B and C). The same bus may have clean and dirty runs on the same day. This could be explained by differing window configurations, load conditions, weather conditions, ambient outdoor concentrations, or traffic intensity.

Factors that may affect variability in particulate concentrations on buses:

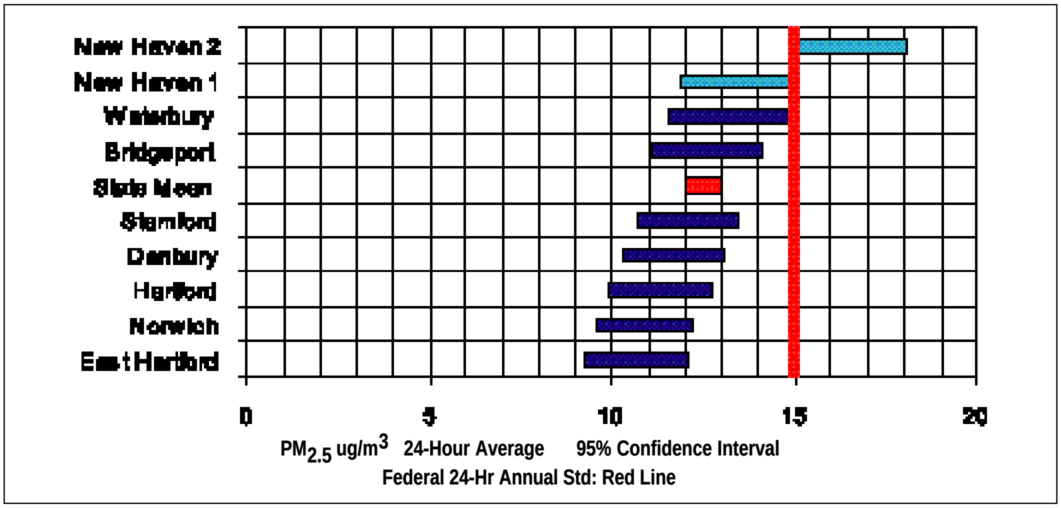
Window configuration: open vs. closed	Condition of exhaust system
Idling practices	Exhaust pipe location (left or right rear)
Queuing practices	Heating and ventilation: fans, filters
Sampling location on the bus	Fuel Type: sulfur content
Route: length, elevation change, stops	Temperature, humidity, and wind
Traffic intensity	Passenger load and student movement
Ambient outdoor air quality	Engine maintenance
Engine type	Engine age

Finding 7: Connecticut Background Particulate Levels

- Connecticut created a monitoring network to measure fine airborne particulate matter (less than 2.5 micrometers in diameter) in response to regulations adopted by EPA in 1997. The standard was designed to provide additional protection for children, the elderly and others with respiratory problems.

Figure 33:1999 $PM_{2.5}$ Levels at Connecticut Monitoring Sites [118]

95th% Confidence Interval of Average Daily Levels



The turquoise bars in Figure 33 demonstrate the levels of $PM_{2.5}$ at two monitoring stations in New Haven. The location of monitoring stations may influence judgments regarding compliance with federal standards. In this case, the State could simply move the monitoring facility to an area removed from traffic, industrial activity or areas of known fuel or waste combustion and the full state would be judged to be compliant.

- The new standard restricts $PM_{2.5}$ to 15 ug/m^3 (24-hour arithmetic means are again averaged over 3 years); and to 65 ug/m^3 as a maximum allowable average over any single day (calculated as the 98^{th} percentile daily levels, averaged over 3 years.) Sufficient data (3 years) have not yet been collected to judge compliance.

- Particulate levels ($PM_{2.5}$) in Connecticut average between 10.8 and 17.9 ug/m^3, with the highest levels recorded in urban areas of the state near highway corridors. The highest average level was recorded in New Haven, and the lowest in East Hartford. $PM_{2.5}$ is measured at 13 fixed stations in the State.

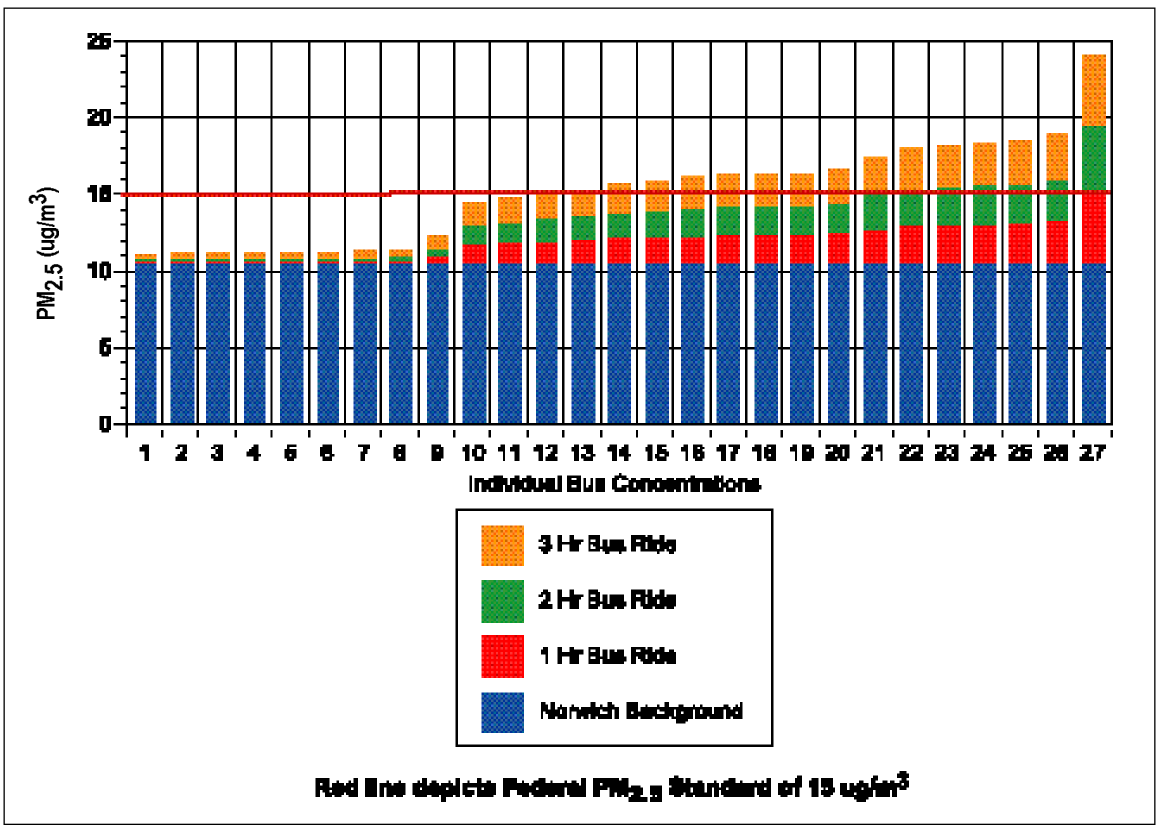
- Other researchers have concluded that ambient particulate levels are uniformly distributed across space, providing justification for a limited fixed monitoring system.[119] These findings suggest instead, that personal and vehicle monitoring will demonstrate significant variability across space and time.

Finding 8: Cumulative Particulate Exposure

- The following four charts (Figures 34, 35, 36 and 37) demonstrate the addition of school bus exposures to average background levels of $PM_{2.5}$ detected in 4 Connecticut communities. The school bus exposures presented are average levels detected during the experimental bus runs conducted in Storrs, reported above.

Figure 34: Average Daily Concentrations During School Year

Norwich Background + School Bus $PM_{2.5}$ Levels



- New Haven background levels would exceed the federal standard—using data from the Stiles St. monitoring station, if current trends continue—thus any additional school bus exposure would push average daily concentrations further from compliance. In the worst case, assuming the longest duration ride of 3 hours per day, the average daily concentrations would be nearly double the federal standard.

Figure 35: Average Daily Concentrations During School Year

New Haven Background + School Bus $PM_{2.5}$ Levels

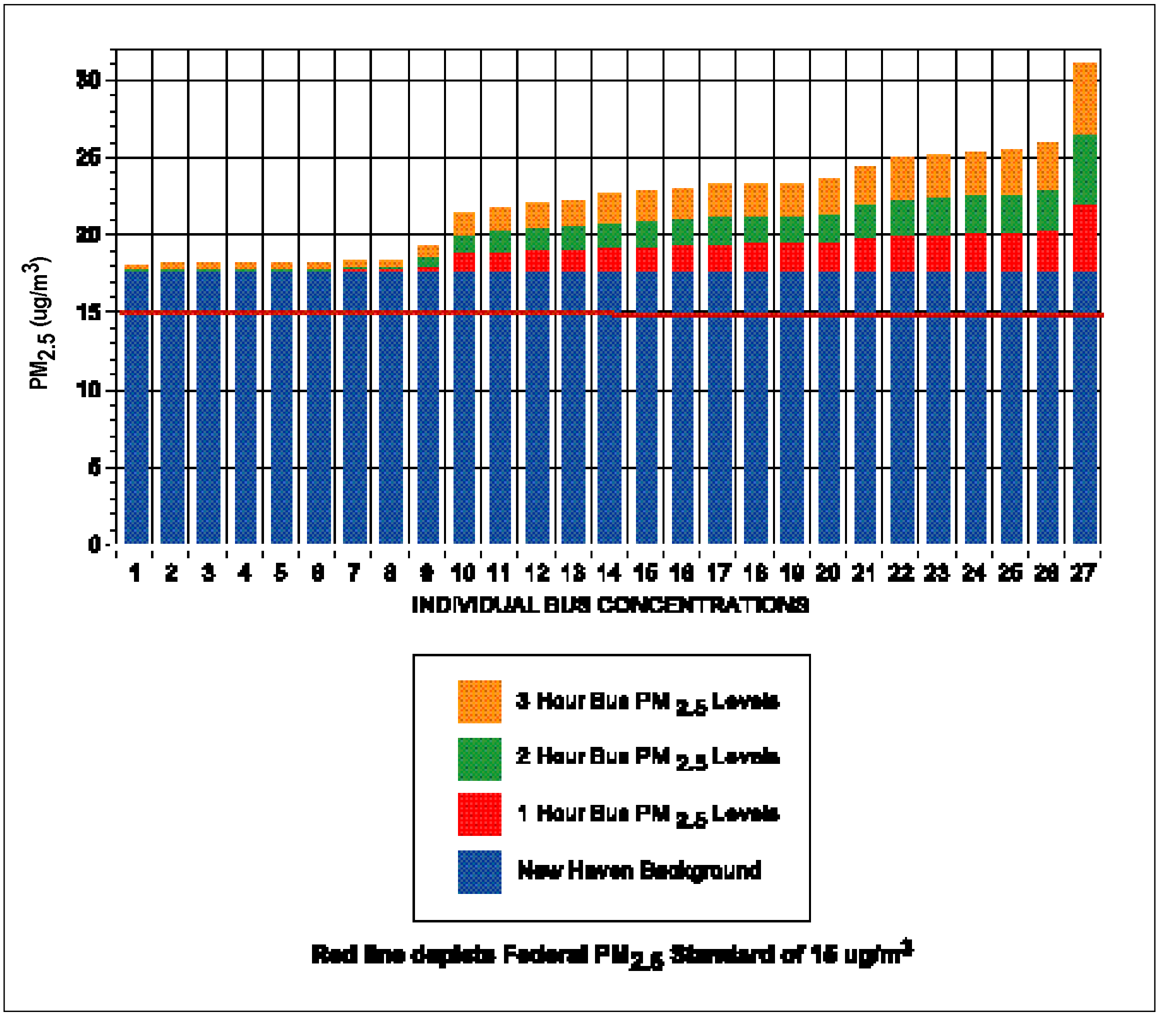
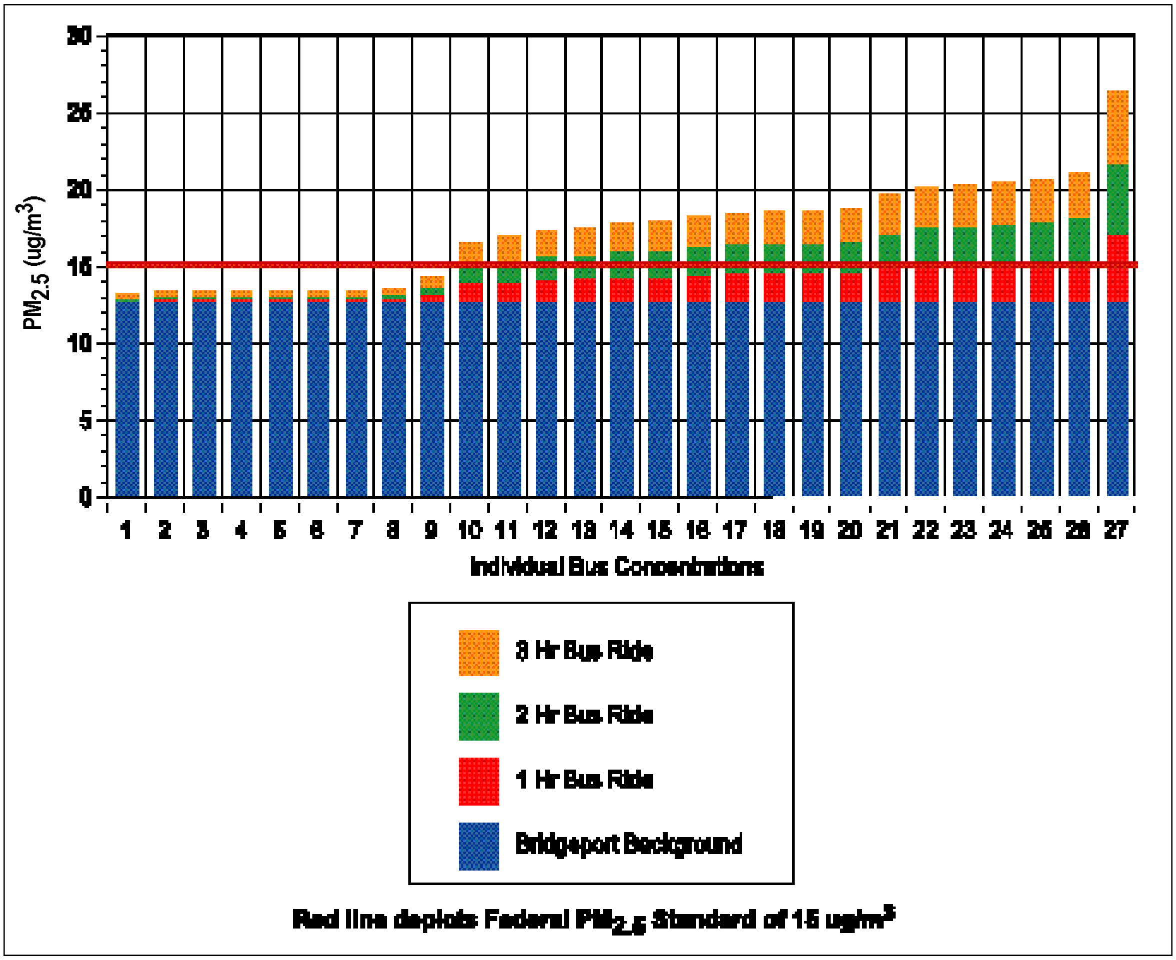


Figure 36: Average Daily Concentrations During School Year

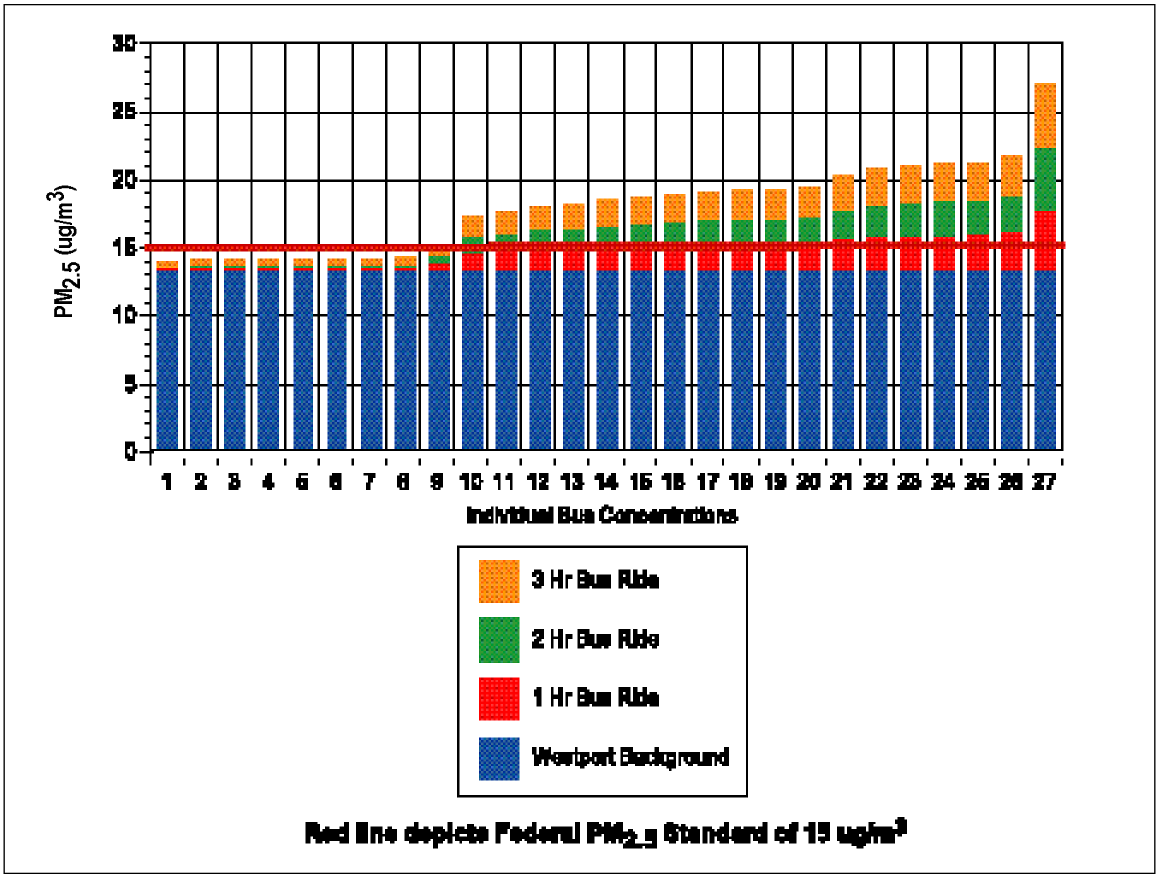
Bridgeport, CT Background + Bus $PM_{2.5}$ Levels



These charts demonstrate how exposures to particulates might accumulate from outdoor, vehicular and indoor sources. Average daily community levels of $PM_{2.5}$ are held constant. School bus concentrations were time-weighted and added to background levels. Color differences represent the effects of bus routes of different durations. These data demonstrate the close proximity of background levels to the federal standard. Note: the federal standard is calculated by averaging 24-hour levels over 3 years, while students are in school for only 180 days per year. Thus, the bars represent the range of cumulative $PM_{2.5}$ concentrations averaged daily during the school year.

Figure 37: Average Daily Concentrations During School Year

Westport, CT Background + Bus $PM_{2.5}$ Levels



Finding 9: Averaging Away the Diesel Exhaust Problem

- Levels of $PM_{2.5}$ found within diesel-powered school buses are far higher than those detected by State of Connecticut's fixed monitoring facilities. State detected levels are beneath the national $PM_{2.5}$ standard of 15 ug/m^3 per day (24 hour average) with the exception of one site in New Haven. Differences between state averages and our findings may be explained in part by the location of sampling equipment. Also, the State averages its findings over 24 hours for 365 days, over three years (when complete data are available). This ensures that nights and weekends (when traffic and industrial activity are minimal) will reduce reported levels of particulates.

- Averaging air pollution over long periods of time will normally reduce reported levels of pollution. This is well demonstrated by the following chart. As the averaging period increases, reported concentrations diminish. The bursts of particulate and carbon concentrations within school buses found in this study—depicted by the blue peaks in the chart—are reported by state and federal regulatory agencies as negligible—depicted by the red line.

- It is important to measure and report detected levels of air pollution at a frequency relevant to respiratory health problems that may be caused or exacerbated by the air pollutants.

Figure 38: 6 Ways to Report the Same Data: Averaged Over Different Periods of Time

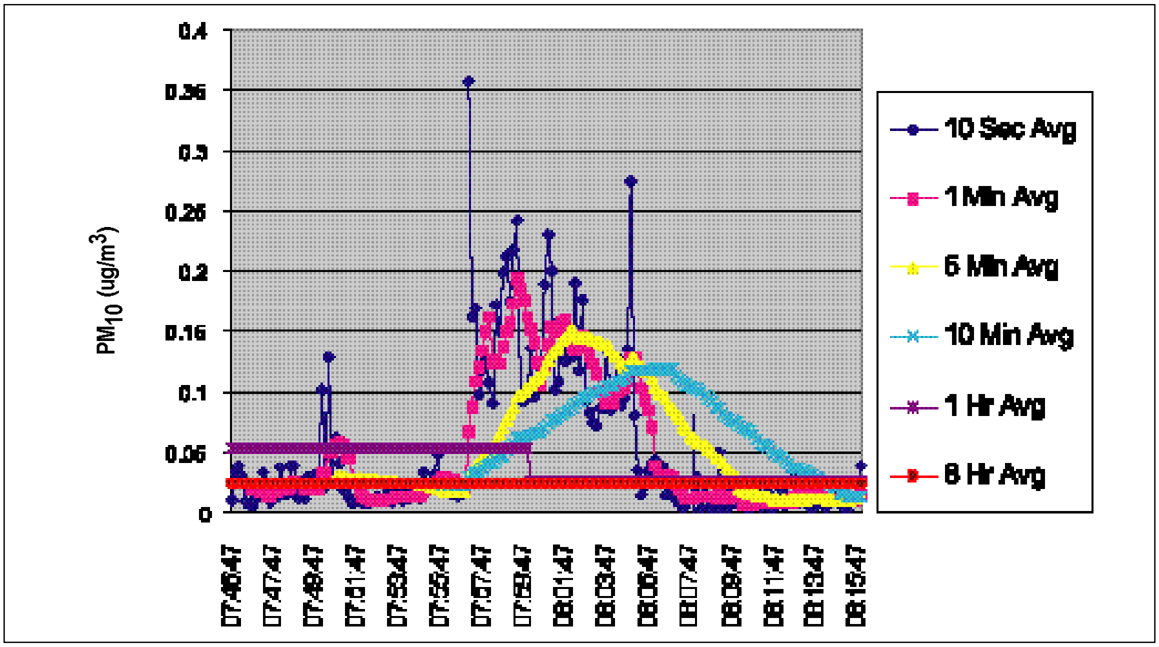


Figure 38 above demonstrates the effect of averaging the same PM_{10} data over different periods of time. Short-term high exposure events, such as those experienced by children on school buses, are neglected by current monitoring and reporting practices. PM levels are now reported from a limited number of fixed monitoring stations. Both the daily averages, and the 98th percentile levels of the daily averages are again averaged over 3 years. High exposure events of short-duration remain unrecognized. The underlying presumption of current practice is that intense short duration exposures are irrelevant to respiratory health.

6. Recommendations By Level of GovernmenT

Recommendations for the Federal Government

1. ***Retrofit Diesel Buses To Lower Emissions:*** The federal government should require the retrofit of existing school buses with particle traps and catalytic converters designed to reduce emissions. Retrofit of the existing fleet should be completed by 2003.

2. ***Require Buses to Use Ultra Low Sulfur Fuels:*** The federal government should require the use of ultra low sulfur diesel fuel (<15 ppm) on school buses. The effect would be to substantially reduce acid aerosols, ozone precursors, and fine particulate emissions in the immediate vicinity of children.

3. ***Replace Bus Fleet With Low Emission Vehicles:*** The federal government should require and provide financial support for eventual replacement of existing diesel fleets with low emission vehicles, especially in areas of the country beyond compliance with current federal pollution standards.

4. ***Test Tailpipe Emissions:*** The federal government should require periodic tailpipe emissions testing of all school buses, unless they have been retrofitted with particulate traps and converters, and use ultra low sulfur fuels.

5. ***Set Passenger Cabin Air Quality Standards:*** The federal government should establish health protective standards for air quality within vehicles. Standards should provide an ample margin of safety for children.

6. ***Require School Bus Air Filtration Equipment:*** The federal government should require the design and installation of air filtration equipment capable of removing vehicle exhaust from air entering bus passenger cabins. This is especially important when buses travel in areas with high traffic intensity, or high outdoor background concentrations of pollutants such as urban environments.

7. ***Federal Standards Should Assume Indoor and Vehicular Exposures:*** EPA should adjust outdoor air quality standards to account for probable indoor and within-vehicle exposures to air pollution. The Clean Air Act demands that standards be set to provide "an adequate margin of safety," yet governments' neglect of particulate levels within homes, schools, and vehicles makes it impossible to conclude that current standards protect health.

8. ***Expand Air Quality Monitoring Network:*** The federal government should require states to develop air quality monitoring programs that capture variability in regulated air pollutants. The existing stationary monitoring network should be supplemented with both additional stationary sources, and with personal monitoring data collection to better understand variability in exposure, especially among susceptible populations.

Recommendations for State Governments

1. ***Prohibit School Bus Idling:*** Idling should be restricted by State law. Bus drivers should be required to turn off bus engines immediately upon reaching their destinations. Buses should not be turned on until fully loaded. This is especially important when buses are queued while loading and unloading at schools and transfer stations. Exceptions should include conditions that would compromise passenger safety—e.g., extreme weather conditions, idling in traffic. In cases where engine operation is necessary to activate safety equipment such as flashing lights, buses should be retrofitted to permit battery operation. Idling restrictions should be defined by state statute and include enforcement power, rather than by the present DEP regulation 22a-174-18 (a)(5).

2. ***Retrofit Diesel Buses To Lower Emissions:*** The State should plan and implement a school bus retrofit program to ensure that buses are refitted with particle traps and catalytic converters designed to reduce emissions. Retrofit of the existing fleet should be completed by 2003.

3. ***Require School Buses to Use Ultra Low Sulfur Fuels:*** The state should facilitate and monitor the suggested federal requirement that school buses use low sulfur diesel fuel (<15 ppm).

4. ***Replace Bus Fleet With Low Emission Vehicles:*** The state should work with federal agencies (EPA, DOE, DOT) to plan for the replacement of the existing diesel fleet with new low-emission and alternative-fueled vehicles.

5. ***Set Priorities to Reduce Emissions and Exposure:*** The State should plan for, guide, and set priorities to retrofit buses and convert to ultra low sulfur fuels. Priority should be assigned to communities with the poorest outdoor air quality. Within communities, priority should be assigned to the routes that have highest traffic intensity.

6. ***Require Routine Maintenance:*** The State should require that routine maintenance be conducted to ensure that emissions remain at their lowest possible level. Special care should be taken to be certain that exhaust systems are fully intact and secure, and that engine compartments are completely sealed from interior passenger space.

7. ***Test Tailpipe Emissions:*** The State should be responsible for periodic tailpipe emissions testing of all school buses.

8. ***Expand $PM_{2.5}$ Monitoring Network:*** The State should substantially expand its monitoring network to more fully capture local variability of air pollutants.

Recommendations for Local Governments

1. ***Prohibit Bus Idling:*** Local governments and school districts should immediately adopt policies that require drivers to turn off bus engines upon reaching their destinations. Buses should not be turned on until fully loaded. This is especially important when buses are queued while loading and unloading at schools and transfer stations. Exceptions should include conditions that would compromise passenger safety—e.g., extreme weather conditions, idling in traffic. In cases where engine operation is necessary to activate safety equipment such as flashing lights, buses should be retrofitted to permit battery operation. School districts should inform drivers about the effects of idling on both indoor and outdoor air quality. This idling restriction will improve air quality within buses, and in the vicinity of schools.

2. ***Adjust Contract Provisions to Lease Retrofitted Vehicles and Require Clean Fuels:*** School districts should adjust their contracts with bus service companies and fuel providers to require the use of ultra low sulfur fuels, particle traps and catalytic converters, without waiting for federal or state requirements to take effect.

3. ***Set Priorities:*** School districts and local governments should allocate buses with the lowest emissions to the longest routes.

4. ***Limit Ride Duration:*** School districts should reduce students' exposure to air pollution by limiting time spent on buses. This is already regulated by some town policies. Limiting ride duration would reduce exposure to pollution generated by diesel buses, and by other traffic.

5. ***Require Routine Maintenance:*** Local governments should ensure that buses are monitored and maintained so that emissions remain at their lowest possible level. Special care should be taken to be certain that exhaust systems are fully intact and secure, and that engine compartments are completely sealed from interior passenger space. Maintenance requirements to ensure health protective air quality should become a routine contract provision between bus companies and local governments.

6. ***Reconsider Location of Bus Parking Lots:*** Local governments should consider whether the location of bus parking facilities contribute to routine air pollution in the vicinity of schools, playgrounds, and residential areas. Some relief may be provided by setting limits on bus idling within parking lots.

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