SCHOOL BUS DIESEL EXHAUST SAMPLING REPORT

ANCHORAGE SCHOOL DISTRICT
TRANSPORTATION SERVICES
3580 EAST TUDOR ROAD
ANCHORAGE, ALASKA

June 10, 2002

EHS-ALASKA, INC.
ENGINEERING, HEALTH & SAFETY CONSULTANTS
10928 EAGLE RIVER ROAD, SUITE 202
EAGLE RIVER, ALASKA 99577-8052

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TABLE OF CONTENTS

PAGE NO.

APPENDICES

SCHOOL BUS DIESEL EXHAUST SAMPLING REPORT
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1.0 EXECUTIVE SUMMARY

EHS-Alaska, Inc. sampled for diesel exhaust on school buses during morning and afternoon routes on February 20 - 22, 2002. The sampling was performed at the request of Mr. Steven Kalmes, Anchorage School District (ASD) Transportation Services Director.

The purpose of the sampling was to determine if diesel exhaust was being entrained inside school buses during "worst-case" atmospheric sampling conditions, i.e. cold, dry, calm, and dense ambient air conditions.

Mr. Greg Lomax, EHS-Alaska, Inc. Industrial Hygienist, performed the sampling. The following parameters indicative of diesel exhaust were sampled: (1) Carbon Dioxide (CO_2), (2) Carbon Monoxide (CO), (3) Sulfur Dioxide (SO_2), and (4) Particulate Matter 2.5 microns in diameter or less (PM 2.5).

The sampling results indicated the following for each sampled parameter: (1) CO_2 concentrations generally increased when buses were stopped, idling, or stationary and decreased when buses were moving or windows were opened. None of the averaged CO_2 concentrations exceeded the Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) nor exceeded the American Society of Heating, Refrigerating, and Air-conditioning Engineers (ASHRAE) recommended indoor air quality guideline. (2) CO concentrations were not detected inside any of the school buses. However, outdoor concentrations were detected during the study. None of the outdoor CO concentrations exceeded the Alaska Department of Labor (AKDOL) PEL nor exceeded the Environmental Protection Agency (EPA) National Ambient Air Quality Standard (NAAQS) primary 8-hour average. (3) SO_2 concentrations did not correlate consistently with the type of activity with which the buses were engaged. Instead, the levels tended to fluctuate randomly and trends associated with bus activity were unable to be consistently established. None of the averaged SO_2 concentrations exceeded the AKDOL PEL nor exceeded the EPA NAAQS primary 24-hour average. (4) PM 2.5 concentrations generally increased when buses were stopped, idling, or stationary and decreased when buses were moving or windows were opened. The averaged PM 2.5 concentrations exceeded the EPA NAAQS primary 24-hour average for Route 708 and were below the NAAQS 24-hour average for Routes 11 & 33.

Based upon the sampling results, EHS-Alaska, Inc. concluded: (1) CO_2 and PM 2.5 concentrations increased when buses were stopped or idling and decreased when buses were in motion. (2) PM 2.5 concentrations were 2 to 3 times higher during afternoon sampling periods when compared to morning levels. (3) With the exception of PM 2.5 concentrations during

Route 708, all of the parameters averaged concentrations inside the school buses were below regulatory or recommended guidelines. (4) The four sampled parameters averaged concentrations were highly variable and did not consistently correlate with each other. This may indicate that levels are affected by parameters other than diesel exhaust (ambient levels of particulates). (5) The PM 2.5 concentrations varied widely among the buses dates of manufacture and did not vary with date of manufacture as expected, i.e. the newest bus (2002) had the highest level and the oldest bus (1990) had one of the lowest levels.

EHS-Alaska, Inc. recommends: (1) Bus drivers keep bus idling episodes to a minimum. (2) Students and bus drivers open windows as often as practical to dilute potential CO_2 and PM 2.5 concentrations.

2.0 TEST PROCEDURES

Diesel exhausts contain a variety of components. Some of the most common components include CO_2, CO, SO_2, and PM 2.5. Three real time continuous monitoring instruments capable of data logging averaged 1-minute samples were chosen to collect samples based upon their limits of detection and field portability. The instruments were calibrated or zeroed prior to each day's use. The specification data and factory calibration certificate for each instrument was provided as part of Appendix C.

Mr. Kalmes identified three school bus routes (708, 11, & 33) that were sampled (one route per day) during morning and afternoon runs beginning February 20-22, 2002. Two routes were located in Anchorage (11 & 33) and one route (708) was located in Eagle River. Each route consisted of three consecutive runs in the following order: high school, middle school, and elementary school (except for the afternoon Route 708 order which was high school, elementary school, and middle school). Route 708 serves Eagle River Valley. Due to the length of Route 708, Chugiak High School and Ravenwood Elementary School are normally served. In order to be consistent with the rest of the sampling, a third Gruening Middle School run was added. Maps of the bus routes were provided by Mr. Kalmes and were included as Appendix E.

A total of four different buses were used throughout the study with the following dates of manufacture: 1990, 2001, and 2002. Each bus had an exhaust tail pipe located at the rear underside of the bus on the driver's side, and was equipped with emergency exits as required at the time of manufacture including roof and side window emergency exits. The 1990 bus used on Route 33 and the 2002 bus used on route 708 had a rear emergency door. The bus used on Route 11 was equipped with rear and side emergency windows. The sampling was conducted on fully warmed-up empty school buses, which followed the actual buses (buses involved in actual student transportation) and corresponding routes by approximately 5-10 minutes. The empty school buses mimicked the actual buses by making stops and opening doors to simulate student loading or unloading. The test procedures and objectives were discussed with the bus driver so that data could be collected completely and efficiently. An ASD observer accompanied the driver during Route 11 and 13 bus runs. Interior bus ventilation controls were set on re-circulation.

The sampling was performed near the front of the bus (driver's side 4th seat back) approximately 25% of each run and near the back of the bus (driver's side back seat) the majority of the run, because exhaust entrainment would most likely occur in areas of the bus wake. Sampling was performed outdoors for 1-2 minutes at three stops during each run and during loading or unloading at the schools. Windows were opened during the morning and afternoon Route 708 runs for approximately 15% of each run. The monitor was located in the back of the bus while windows were open. Windows were not opened during Routes 11 and 33. Minute-by-minute field notation, describing route and bus activity (starting, stopping, uphill, downhill, congested, quiet, idling, fast, slow, and windows open or closed) and instrument location (back of bus, front of bus, and outdoors), was maintained during each run and was provided as Appendix D.

3.0 DISCUSSION & RESULTS

Background

Some parents of ASD students have expressed concern that the levels of diesel exhaust inside school buses may cause adverse health effects in student passengers. Studies of this potential problem have been conducted in California, Connecticut, West Virginia, and Pennsylvania. The California study, in particular, identified elevated levels of respirable airborne particulates inside diesel-powered school buses. This study, conducted jointly by the University of California - Berkley, the National Resources Defense Council, Inc., and the Coalition for Clean Air, Inc., reported high levels of diesel exhaust particulates inside older school buses relative to outdoor ambient levels. The study's authors analyzed these results using a health effects model to conclude that students who used bus transportation had an increased risk of developing respiratory diseases and cancer.

EHS-Alaska, Inc. was contacted by the ASD to perform sampling similar to the aforementioned California study. The purpose of the sampling was to determine if diesel exhaust was being entrained inside school buses on normal routes during "worst-case" atmospheric sampling conditions, i.e. cold, dry, and dense ambient air conditions. The following table was provided as a summary of morning and afternoon ambient conditions for each route.

Summary Table - Ambient Weather Conditions February 20-22, 2002

Weather Parameter	Route #					
	708 Morning 2/20/2002	708 Afternoon 2/20/2002	11 Morning 2/21/2002	11 Afternoon 2/21/2002	33 Morning 2/22/2002	33 Afternoon 2/22/2002
Temp (°F)	-1	4	1	13	11	18
Wind	E 2 mph	N 1 mph	ESE 3 mph	N 7 mph	N 6 mph	N 6 mph

Mr. Greg Lomax, EHS-Alaska, Inc. Industrial Hygienist, performed the sampling February 20-22, 2002. The following parameters indicative of diesel exhaust were sampled: (1) Carbon Dioxide (CO_2), (2) Carbon Monoxide (CO), (3) Sulfur Dioxide (SO_2), and (4) Particulate

Matter 2.5 microns in diameter or less (PM 2.5). The following table was provided as a summary of the averaged concentrations for each sampled parameter. Time history graphs and tabulated data for each parameter and bus route are provided as Appendix A and B, respectively.

Summary Table-Diesel Exhaust School Bus Averaged Sampling Results							
Route #							
Sampling Paramete r	708 Morning	708 Afternoon	11 Morning	11 Afternoon	33 Morning	33 Afternoon	Recommended Guideline
CO_2 (ppm)[1]	519	553	743	524	616	1153	No >700 + outdoors[2]
CO (ppm)	0.24	0.08	0.29	0.14	0.41	0.18	9
SO_2 (ppm)	0.101	0.059	0.136	0.097	0.016	0.035	0.14
PM 2.5 (mg/m^3)[3]	**0.083**[4]	**0.149**	0.007	0.021	0.024	0.048	0.065

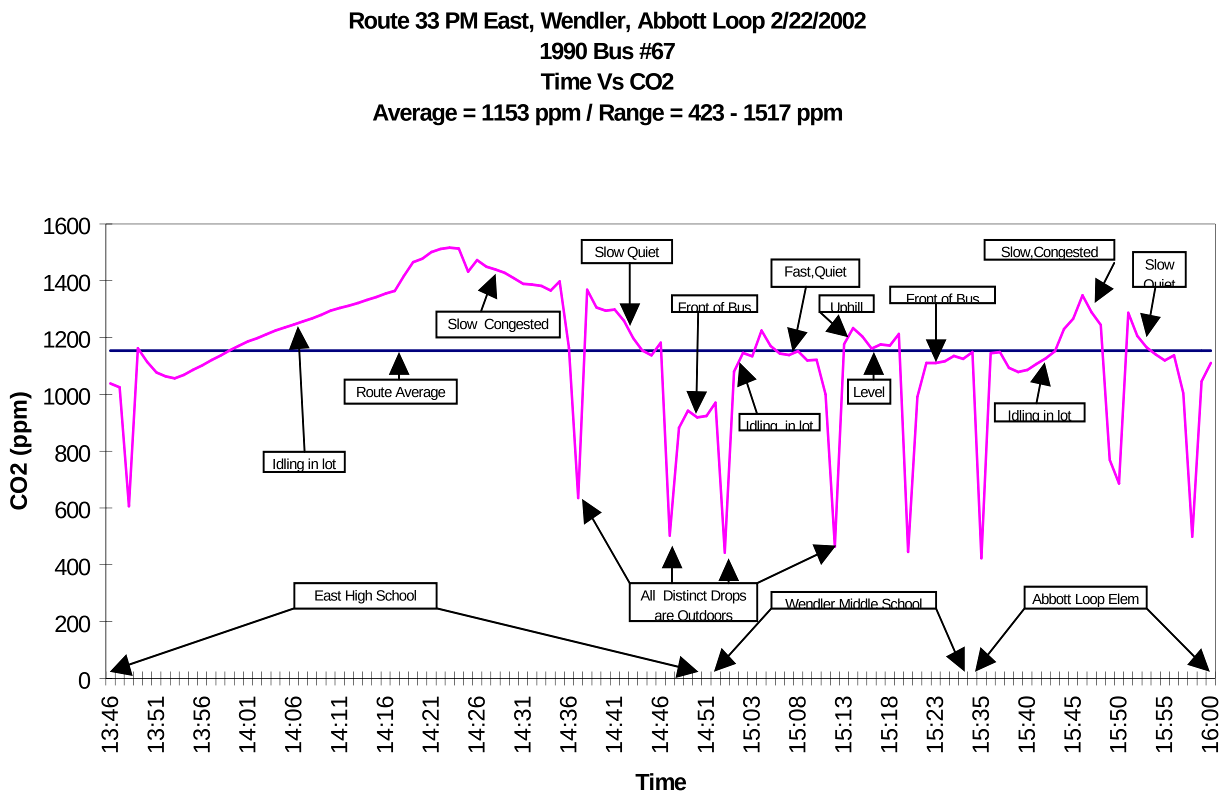
1 = parts per million
2 = No greater than 700 ppm above outdoor levels. (All runs averaged below this criterion)
3 = milligrams per cubic meter of air
4 = Bold Indicates Above Recommended Guideline.

Carbon Dioxide (CO_2)

Carbon dioxide (CO_2) is a combustion by-product of fuel and a normal metabolic by-product of human respiration. CO_2 levels from exhaled human breath can reach 10,000 ppm. It has become a recognized standard indicator for indoor air quality in occupied buildings. Studies have shown that complaints of headaches, fatigue, upper respiratory and eye irritations are reported at CO_2 levels indoors that are 700 ppm above ambient outdoor levels. CO_2 above the 8-hour time weighted average (TWA) OSHA PEL of 5,000 ppm is considered harmful to the working population. The ASHRAE Standard on Ventilation for Acceptable Indoor Air Quality (62-1999) states that maintaining CO_2 levels no greater than 700 ppm above outdoor levels will satisfy a substantial majority of occupants.

Typically, outdoor CO_2 levels range from 300 - 500 ppm in Anchorage. Outdoor carbon dioxide levels averaged as high as 523 ppm during the afternoon Route 33 runs. The highest averaged CO_2 level for this study occurred during the afternoon Route 33 runs and was 1153 ppm. All routes, including Route 33, had CO_2 concentrations, which averaged below the ASHRAE recommended guideline of no more than 700 ppm above the outdoors. It is important to note that the buses were empty during the monitoring and that the CO_2 levels during normal bus occupancy were not sampled.

A labeled graph of the afternoon Route 33 runs (the highest averaged route for CO_2) was provided on the following page and as part of Appendix A. In general, the graph demonstrated that during stationary, stopped, or idling bus activity CO_2 levels increased. Conversely, the CO_2 levels decreased while the bus was in motion. The increased CO_2 levels may have been a result of human respiration from the field technician, ASD observer, and bus driver.



The CO_2 sampling results indicated that none of the averaged CO_2 concentrations exceeded the OSHA PEL of 5,000 ppm nor exceeded the ASHRAE recommended guideline of no greater than 700 ppm above outdoor levels.

Carbon Monoxide (CO)

CO is a colorless and odorless gas with no warning properties. CO combines with the oxygen carrying sites on the hemoglobin molecule with an affinity ranging from 210-240 times greater than oxygen. The carboxyhemoglobin (COHb) that is formed is unable to carry oxygen, and interferes with the release of oxygen carried by unaltered hemoglobin. Risks to angina pectoris (heart pains) and coronary infarctions (heart attacks) are increased because the oxygen supplied to the blood in the heart is lowered.

CO above the 8-hour TWA AKDOL PEL of 35 ppm is considered harmful to the working population. The Clean Air Act required the EPA to set NAAQS for pollutants considered harmful to public health and the environment. The Act established primary and secondary standards. Primary standards set limits to protect public health, including the health of “sensitive” populations such as asthmatics, children, and the elderly. Secondary standards set limits to protect public welfare, including protection against decreased visibility, damage to animals, crops, vegetation, and buildings. The EPA NAAQS for CO is 9 ppm as an 8-hour average and is designated as a primary standard.

CO concentrations were not detected inside any of the school buses. However, outdoor concentrations were detected during the study and were represented on the CO graphs as part of Appendix A. None of the outdoor CO concentrations exceeded the AKDOL PEL of 35 ppm nor exceeded the EPA NAAQS 8-hour average of 9 ppm during the sampling.

Sulfur Dioxide (SO_2)

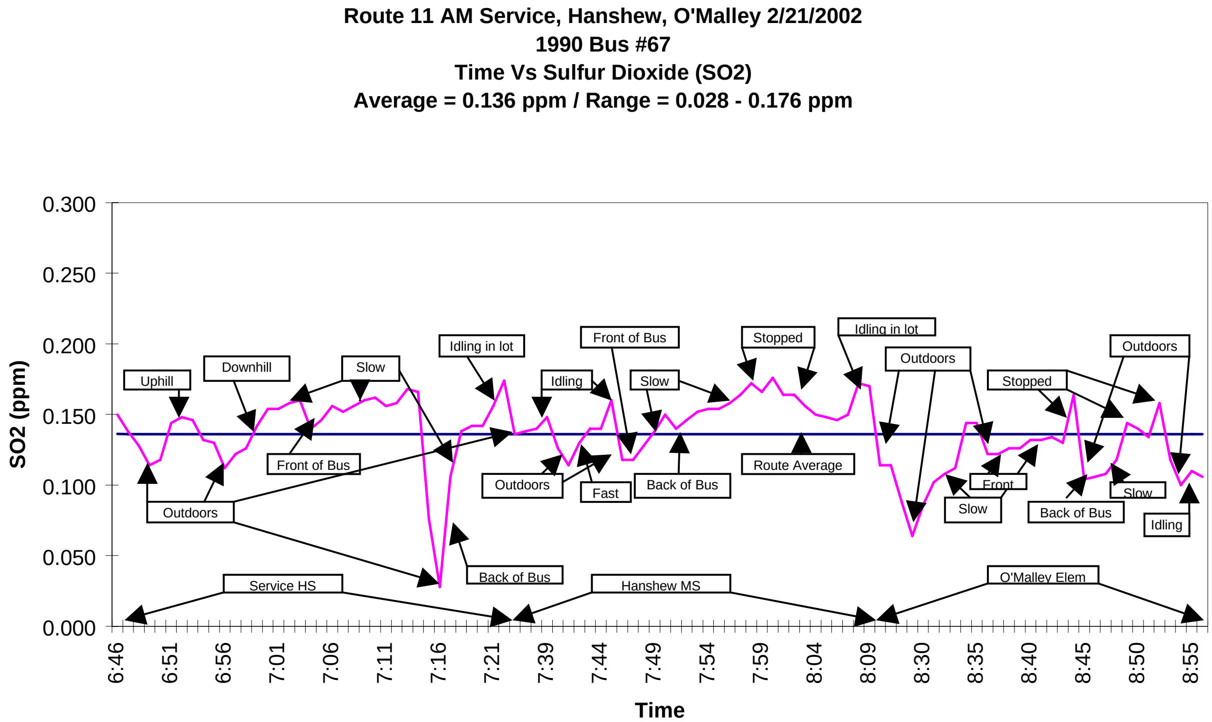
SO_2 is a colorless gas with an irritating, pungent odor that is formed when fuel containing sulfur is burned. SO_2 is a potential problem in Alaska since the state received a waiver from the EPA fuel sulfur content limit of 15 ppm. Diesel fuel in Alaska may contain up to 500 ppm of SO_2.

SO_2 is a major precursor to PM 2.5. Some of the health concerns associated with exposure to SO_2 include effects on breathing, respiratory illness, alterations in the lungs' defenses, and aggravation of existing cardiovascular disease.

SO_2 above the 8-hour TWA AKDOL PEL of 2 ppm is considered harmful to the working population. The EPA NAAQS for SO_2 is 0.14 ppm averaged over 24 hours and is designated as a primary standard.

The highest averaged SO_2 level in this study occurred during the morning Route 11 runs and was 0.136 ppm. The SO_2 monitoring instrument was not internally equipped with a data logger. Therefore, an auxiliary data logger was used to collect sampling data. Output voltage fluctuations from the SO_2 instrument's batteries manifested drift on the data logger's digital readout. Under most circumstances drift is inconsequential, but when sampling at low limits of detection (0.02 ppm in this case) minor negative drift can skew and lead to false negative results. Therefore, we chose to intentionally zero the instrument slightly positive to avoid negative drift. The morning Route 11 SO_2 average may reflect this positive bias. All routes, including Route 11, had SO_2 concentrations, which averaged below the EPA NAAQS 24-hour primary standard of 0.14 ppm. It is important to note that the EPA considers PM 2.5 a major precursor to SO_2 and that the average PM 2.5 levels during the morning Route 11 runs was the lowest over the course of this study. This reinforced the hypothesis that the morning Route 11 average was most likely a result of the intentional positive bias discussed previously and not a result of diesel exhaust entrainment.

A labeled graph of the morning Route 11 runs (the highest averaged route for SO_2) was provided on the following page and as part of Appendix A. In general, the graph demonstrated that SO_2 levels did not consistently correlate with the type of activity with which the bus was engaged. Instead, the levels tended to fluctuate randomly and reliable trends associated with bus activity were unable to be established. This indicated that significant SO_2 levels were not entrained and that the fluctuations represented graphically may have been due to voltage output variations.



The SO_2 sampling results indicated that none of the averaged SO_2 concentrations exceeded the AKDOL PEL of 2 ppm nor exceeded the EPA NAAQS 24-hour average of 0.14 ppm during the sampling.

Particulate Matter 2.5 Microns in Diameter or Less (PM 2.5)

Particulate matter is the general term used for a type of air pollution that consists of complex and varying mixtures of particles suspended in the air. Particulate matter may be made up of a combination of fine solids such as dirt, soil, dust, pollens, molds, ashes, and soot; and aerosols that are formed in the atmosphere from gaseous combustion by-products. Particulate pollution comes from such diverse sources as factory and utility smokestacks, vehicle exhaust and tires, wood burning, mining, construction activity, and agriculture. Particles of special concern to the protection of lung health are those known as fine particles, less than 2.5 microns in diameter. These particles are easily inhaled deeply into the lungs where they can be absorbed into the bloodstream or remain embedded for long periods of time. Exposure to particulate air pollution can trigger asthma attacks and cause wheezing, coughing, and respiratory irritation. Those at greatest risk are children, the elderly, and individuals with pre-existing respiratory or heart disease.

The EPA NAAQS Primary 24-hour average for PM 2.5 is 0.065 mg/m^3. The AKDOL does not have a PEL for PM 2.5.

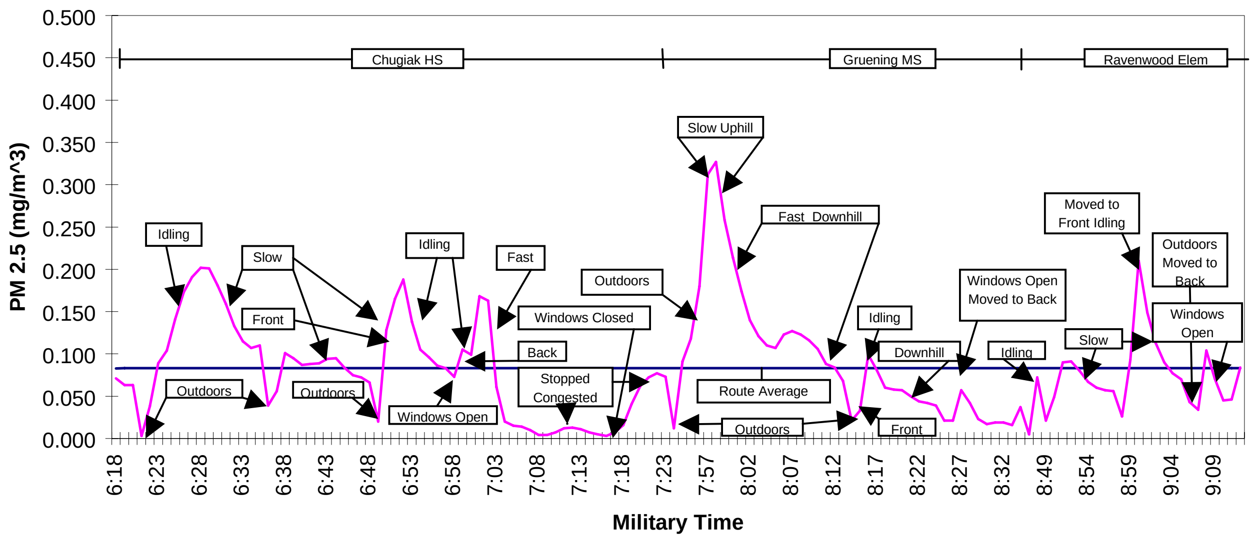
The highest averaged PM 2.5 levels for the study occurred during the morning and afternoon Route 708 runs and were 0.083 and 0.149 mg/m^3, respectively. These levels were above the EPA 24-hour NAAQS guideline for PM 2.5. Routes 11 and 33 had averaged PM 2.5 concentrations well below the NAAQS guideline.

Afternoon levels averaged approximately 2 to 3 times higher than morning levels for each route. This increase may be attributable to an increase in particulate matter due to climatic variations (wind, increased temperatures), an overall increase in particulate matter due to daytime activity as compared to nighttime, and an increase in the amount of afternoon traffic as compared to morning.

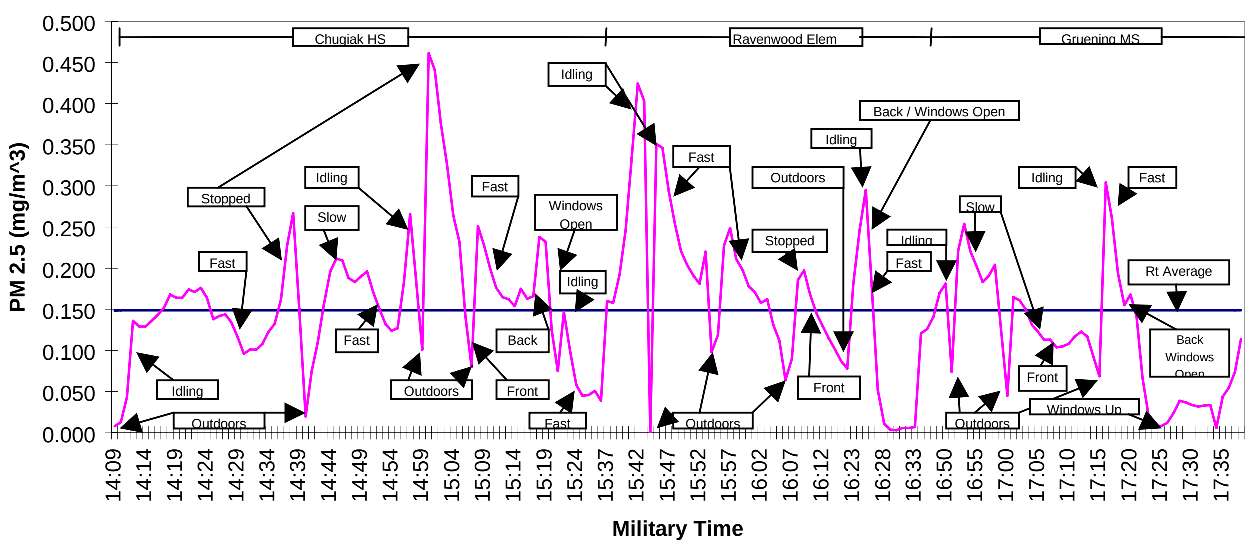
Labeled graphs of the morning and afternoon Route 708 runs (the highest averaged route for PM 2.5 during the study) were provided on the following page and as part of Appendix A. In general, the graphs demonstrated that during stationary, stopped, or idling bus activity PM 2.5 levels increased. Conversely, the PM 2.5 levels decreased when the bus was in motion and when windows were opened. This indicated that particulate was most readily entrained during idle bus activity and that fresh air was entrained and served to dilute concentrations when the bus was in motion. The increase in particulate matter may be due to the fact that large amounts of particulate accumulate on Alaskan roads. A combination of grit, sand, and salt, intentionally added for traction in ice and snow, and the mechanical action of studded tires, which grind down road surfaces and break down particulate into finer dusts, results in significant particulate build-up associated with the road system. Most bus stops occur along the sides of roads, where these dusts and particulate tend to accumulate. The starting and stopping actions of the buses may have caused dust and debris to become airborne and resulted in elevated particulate concentrations.

The PM 2.5 sampling results indicated that Route 708's morning and afternoon runs averaged above and that Routes 11 and 33 averaged below the EPA NAAQS 24-hour average of 0.065 mg/m^3. Assuming PM 2.5 levels were lower while students were in school and at home, an integrated (averaged) 24-hour exposure to PM 2.5 was probably below the NAAQS guideline aimed at protecting the public from health hazards associated with PM 2.5 exposure.

Route 708 AM Chugiak, Gruening, Ravenwood 2/20/2002
2001 Bus #735
Time Vs Particulate Matter (PM) 2.5 microns or less
Average = 0.083 mg/m^3 / Range = 0.003 - 0.327 mg/m^3



Route 708 PM Chugiak, Gruening, Ravenwood 2/20/2002
2002 Bus #767
Time Vs PM 2.5
Average = 0.149 mg/m^3 / Range = 0.000 - 0.461 mg/m^3

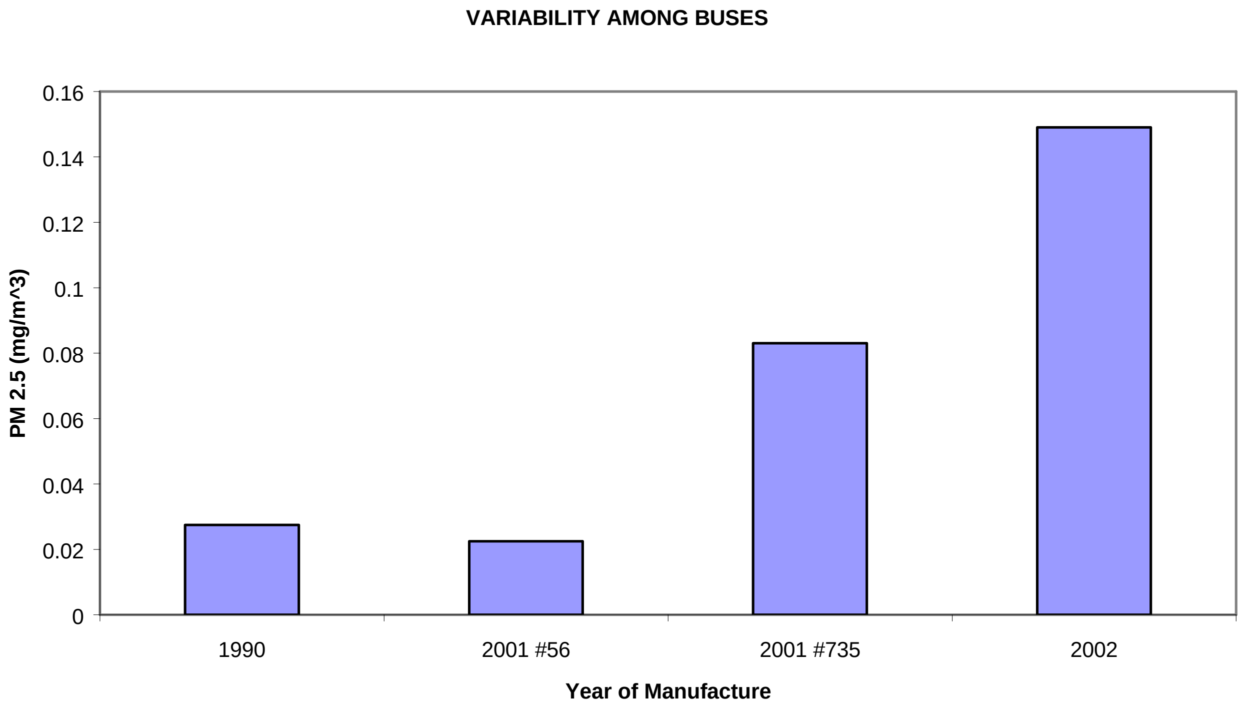


4.0 CONCLUSIONS & RECOMMENDATIONS

The parameters sampled in this study were indicative of diesel exhaust. When a parameter increased or decreased significantly a corresponding dependant effect on the other parameters was expected. We did not find consistent correlations among the parameters. For example, the highest averaged SO_2 concentration occurred during the lowest averaged PM 2.5 level.

We found the parameters varied randomly during certain types of bus activity. For example, we did not find a consistent correlation among uphill versus downhill or slow versus fast bus activity. Instead, variability may have been route/location and ambient condition specific rather than bus exhaust specific. For example, the lowest PM 2.5 averaged concentrations occurred during the “Upper Hillside” Route 11. This route was the most snow covered and least traveled, which may have resulted in reduced particulate concentrations. Furthermore, afternoon particulate levels were approximately 2-3 times greater than morning, which may be attributed to increased vehicular and human activity.

We did not find correlations among the buses and their date of manufacture. As the following bar graph indicated, two buses of the same date of manufacture varied widely in PM 2.5 concentrations and the newest bus indicated the highest concentration. This variability was most likely dependent upon changes in route location and ambient conditions rather than differences in bus exhaust entrainment.



Based upon the sampling results, EHS-Alaska, Inc. concluded:

(1) CO_2 and PM 2.5 concentrations increased when buses were stopped or idling and decreased when buses were in motion.

(2) PM 2.5 concentrations were approximately 2 to 3 times higher during afternoon sampling periods when compared to morning levels.

(3) With the exception of PM 2.5 concentrations during Route 708, all parameters averaged concentrations inside the school buses were below regulatory or recommended guidelines.

(4) The four sampled parameters did not consistently correlate with each other. This may indicate that contaminants, such as PM 2.5, were a result of other sources and were not specific to diesel exhaust.

(5) The buses PM 2.5 concentrations varied widely among dates of manufacture and did not vary with date of manufacture as expected, i.e. the newest bus (2002) had the highest level and the oldest bus (1990) had one of the lowest levels.

EHS-Alaska, Inc. recommends:

(1) Bus drivers keep bus idling episodes to a minimum.

(2) Students and bus drivers open windows as often as practical to dilute potential CO_2 and PM 2.5 concentrations.

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APPENDIX A

CO_2, CO, SO_2, & PM 2.5 Graphs

APPENDIX B

CO_2, CO, SO_2, & PM 2.5 Data

APPENDIX C

Instrument Specifications and Calibration Certificates

INTERSCAN Model 1240SP Dual Range Toxic Gas (SO_2) Analyzer

SO2 Range	0 to 2 ppm, 0 to 20 ppm
SO2 Accuracy:	±2% of full scale
SO2 LLD*:	1% of full scale
SO2 Power:	Ni-Cd batteries
Sensor Type:	2- Electrode Electrochemical Voltametric
Flow Rate:	1 liter per minute ± 0.2
Output	0 - 100 mV

* LLD = Lower Limit of Detection

Metrosonics dl-3200 Data logger used for INTERSCAN SO2 Analyzer

Input Range:	±100 mV
Accuracy:	0.1 % of full scale
Resolution:	0.01 % of full scale
Sampling Rate:	1/second
Period Length:	1-minute
Operating Temp:	-20 to + 60°C
Battery Type:	9V alkaline

TSI Model 8520 DustTrak Aerosol Monitor

Measurement range:	0.001 to 100 mg/m^3
Resolution:	1% or reading or 0.001 mg/ m^3 whichever is greater
Particle size range:	0.1μ to 10μ (1μ = one-millionth of a meter)
Sensor Type:	90° light scattering
Flow Rate:	1.7 liters per minute
Operating Temp.	0 - 50°C
Sampling Rate	1/second
Period Length	1-minute
Power:	4 "C" alkaline batteries

The Model 8520 DustTrak Aerosol Monitor assesses airborne particle concentrations corresponding to PM-10, PM-2.5, PM-1.0 and respirable (PM 4.0) fractions. The PM-2.5 setting was used for this study.

TSI Model 8762 IAQ-Calc Indoor Air Quality Meter

CO measurement range:	0 to 500 ppm
CO accuracy:	±3% of reading or ±3 ppm, whichever is greater
CO resolution:	0.1 ppm
CO sensor:	Electrochemical
CO2 measurement range:	0 to 5000 ppm
CO2 accuracy:	±3% of reading or ±50 ppm, whichever is greater
CO2 resolution:	1 ppm
CO2 sensor:	Dual Wavelength NDIR (Non-dispersive infrared)

APPENDIX D

Field Notation Sheets

APPENDIX E

Bus Route Maps