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Yellowstone Winter Use Personal Exposure Monitoring

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I. Executive Summary

In January 2006, the National Park Service contracted with Montana Tech of The University of Montana and Boise State University to evaluate employee exposure to air contaminants and noise associated with snowmobile operations in Yellowstone National Park. The exposure evaluations were performed at the Park's West Entrance during the 2006 President's Day three-day weekend (February 18, 19, and 20). Further noise evaluations were also performed in Mammoth on February 27, 2006.

The employee exposure evaluations were performed during anticipated peak levels of snowmobile use in an attempt to obtain worst-case measurements during winter use work activities. Personal and area air sampling and noise monitoring were performed on Yellowstone National Park's West Entrance personnel and a park ranger. Personal and area air samples were collected for the following contaminants:

- Aldehyde screen
- BETX (benzene, ethyl benzene, toluene, and xylenes)
- Total hydrocarbons
- Volatile organic compounds (VOCs)
- Carbon Monoxide
- Respirable particulate matter (2.5 µm, 4.0 µm, and 10 um)
- Noise

With the exception of VOCs, the results of the current study were compared to established occupational exposure limits. These limits include permissible exposure limits (PELs) established by the Occupational Safety and Health Administration (OSHA), threshold limit values (TLVs) established by the American Conference of Governmental Industrial Hygienists (ACGIH), and recommended exposure limits (RELs) established by the National Institute of Occupational Health (NIOSH). VOC results were compared to Minimal Risk Levels (MRL) established by the Agency for Toxic Substance and Disease Registry (ATSDR). All employee exposures to the above air contaminants and noise were well below established occupational limits and MRLs except two short term benzene samples. The benzene samples were above the intermediate-duration inhalation exposure of 0.006 ppm, but below the acute-duration inhalation exposure of 0.009 ppm. The intermediate- duration is used for exposures from 14-364 days per year and the acute- duration is for exposure of less than 14 days per year.

The results from the current study were also compared with the 2005 study to evaluate trends in Park Service personnel exposure to winter use vehicle emissions. Comparison of the 2005 study results with previous studies showed a general decrease in exposure to aldehydes, BETX, VOCs, and respirable particulate matter.

II. Introduction

In November 2004, The National Park Service published its final rule allowing up to 720 snowmobiles per day to enter Yellowstone National Park. The total daily commercially guided snowmobile entry limits are 400, 220, 40, 30 and 30 for the West Entrance, South Entrance, East Entrance, North Entrance, and Old Faithful, respectively. The final rule also allows only those snowmobiles that meet the National Park Service Best Available Technology (BAT) requirements. [1]

In addition to the snowmobile BAT emission requirements, there are BAT requirements for snowmobile sound emissions. These BAT requirements are 73 dBA or less at idling speed. The Society of Automotive Engineers testing procedures allow for a 2 dB tolerance over the sound level limit to provide for variations in test site, temperature gradients, wind velocity gradients, test equipment, and inherent differences in nominally identical vehicles. It has been observed that under some test site conditions, variability in test results greater than 2 dB can be experienced.

During the Presidents Day Weekend in February, 2006, an industrial hygiene survey was performed in Yellowstone National Park. The major objective of the survey was to evaluate Park Service personnel exposure to particulate matter, air contaminants, and noise emitted by snowmobiles and snow coaches. Personal and area air sampling and noise monitoring were performed on West Entrance personnel and a park ranger over the course of three working days. The employee exposure evaluations were performed during anticipated peak levels of snowmobile use in an attempt to obtain worst-case measurements during winter use work activities. Samples were collected on February 18, 19, and 20, 2006.

III. Material and Methods

Personal and area air samples were collected to determine Park Service employee exposure to noise and specific toxic air contaminants. The area air samples were located at workstations so that estimates of employee exposure could be determined. Personal samples were collected on employees wearing sample media. Personal and area air samples were collected for the following contaminants:

- Aldehyde screen
- BETX (benzene, ethyl benzene, toluene, and xylenes)
- Total petroleum hydrocarbons
- Volatile organic compounds (VOCs)
- Carbon Monoxide
- Respirable particulate matter 2.5, 4.0, and 10 micrometer (μm) aerodynamic diameter
- Noise

The employee exposure monitoring was conducted at the West Entrance kiosks because the majority of the snowmobiles enter the Park by this route. Sampling was also performed on a Park ranger operating a snowmobile. At the Park's West Entrance all samples were collected on a partial shift basis due to fact that Park employees only monitor snowmobiles as they enter the Park and all entries were typically completed by approximately noon each day. In all cases, the sample results were integrated over an 8-hour time period to allow for appropriate comparison with OSHA PELs,[2] ACGIH TLVs,[3] and NIOSH RELs.[4] VOCs were compared to MRLs established by the ATSDR.[5] See Appendix A for a description of these established exposure limits.

A. Snowmobile Entries

In an effort to correlate the level of air and noise emissions with the number of winter recreational vehicles entering through the Park's West Entrance, the number and type of snowmobiles and snow coaches were logged each sampling day by National Park Service staff and the research team. As the bulk of air contaminant and noise exposure is associated with Park employees monitoring traffic as it passes a kiosk, only vehicles entering the park were logged. Table I below summarizes the number of snowmobiles and snow coaches that entered through the West Entrance to Yellowstone National Park during the 2006 Presidents' Day weekend. The entries were logged each day by the Park Service Employees.

Table I. Number of West Entrance Entries by Date

Date	# Snowmobiles	# Snow Coaches
2/18/06	243	25
2/19/06	231	23
2/20/06	174	15

During the corresponding weekend in 2005, similar numbers of snowmobile and snow coach traffic was observed and there were no significant differences in the vehicle traffic between the 2005 and 2006 Presidents Day weekends.

B. Meteorological Data

Over the duration of the contract period, an attempt was made to obtain worst case sampling data. On February 18, 2006, a haze was observed in the town of West Yellowstone, which suggested the presence of an atmospheric inversion and a subsequent lowering of the mixing height. However, ambient air quality data collected from the Montana Department of Environmental Quality's air monitoring station located at the West Entrance to Yellowstone National park did not verify the presence of these conditions during any of the monitoring dates of the current study. In general terms, the temperatures were well below zero at the beginning of each day's sampling and warmed to above zero temperatures during the afternoon. Winds were generally light. Sky conditions were mostly clear on February 18, with more scattered to broken cloud cover appearing on February 19, 2006. The sky conditions were overcast on February 20, 2006. The meteorological data for the three sampling days are provided in Table II below.

Table II. Meteorological Data at the West Entrance During Presidents Day Weekend 2006

Date	Average Temp. ^{0}F	Low Temp. ^{0}F	High Temp ^{0}F	Average Wind Speed (MPH)	Maximum Wind Speed (MPH)	Atm. Pressure (Inches Hg)
February 18, 2006	-19.7	-42	1.0	2.1	5.0	30.61
February 19, 2006	-15.7	-25.2	18	1.4	3.8	30.38
February 20, 2006	-17.3	-26.9	10	2.3	4.6	30.40

C. Aldehydes

Aldehyde samples were collected according to National Institute for Occupational Safety and Health (NIOSH) Manual of Analytical Methods (NMAM) 2539.[6] The sampling media consisted of a solid sorbent tube (10% 2-hydroxymethyl piperidine on XAD-2, 120 mg/60 mg). The samples were collected at a flow rate of 0.01 to 0.05 L/min using SKC low flow sampling pumps. Sampling pumps were calibrated using a Gilian® Gilibrator™ before and after each sampling day. Samples were analyzed by Data Chem Laboratories, an American Industrial Hygiene Association (AIHA) accredited laboratory. Samples were analyzed by gas chromatography/mass spectrometry (GC/MS) for the following compounds: acetaldehyde; acrolein, butyraldehyde, formaldehyde, heptanal, hexanal, iso-valeraledhyde, propionaldehyde, and valeraldehyde. The estimated limit of detection (LOD) for this method is 2 μg of aldehyde per sample. Three blank samples were submitted for analysis for quality control assurance. (NIOSH NMAM 2539 can be viewed in Appendix B).

D. BETX and Total Petroleum Hydrocarbons

BETX ((benzene, ethyl benzene, toluene, and xylenes) and total petroleum hydrocarbon samples were collected according to NIOSH NMAM 1501.[6] The sampling media consisted of a solid sorbent tube (coconut shell charcoal, 100 mg/50 mg). The samples were collected at a flow rate of 0.02 L/min using SKC low flow sampling pumps. Sampling pumps were calibrated using a Gilian® Gilibrator™ before and after each sampling day. Samples were analyzed by Data Chem Laboratories using GC for the following compounds: benzene (LOD 0.5 μg/sample), toluene (LOD 0.7 μg/sample), ethyl benzene (LOD 0.5 μg/sample), xylene (LOD 0.8 μg/sample), and total hydrocarbons (LOD 0.6 μg/sample). Three blank samples were submitted for analysis for quality control assurance. (NIOSH NMAM 1501 can be viewed in Appendix B).

E. Volatile organic compounds (VOCs)

VOC samples were collected according to Environmental Protection Agency (EPA) analytical method TO-15 [7] (Method TO-15 can be viewed in Appendix B). This method documents sampling and analytical procedures for the measurement of subsets of the 97 volatile organic compounds (VOCs) that are included in the 189 hazardous air pollutants (HAPs) listed in Title III of the Clean Air Act Amendments of 1990. VOCs are defined here as organic compounds having a vapor pressure greater than 10 Torr at 25EC -1 C and 760 mm Hg. The sampling media consisted of 400-ml stainless steel mini-canisters used with a sampling regulator to allow for an extended sampling time. The method was used for the determination of volatile organic compounds (VOCs) in air. Samples were analyzed by Data Chem Laboratories through analysis by GC/MS.

F. Carbon Monoxide

Carbon monoxide was measured using an Industrial Scientific iTX® Multi-Gas Monitor™. The Multi-Gas Monitor was equipped with an electrochemical sensor that measures carbon monoxide ranging from 0 to 999 ppm, in 1 ppm increments. The Multi-Gas Monitor was setup to log data every 10 seconds during the monitoring period. Montana Tech received the Multi-Gas monitor from the manufacturer within 1 month of its use in our research, making the instrument in compliance with the manufacturer's recommendations. In addition, the Multi-Gas Monitor was "bump" tested in accordance with Industrial Scientific's recommendations. The data recorded during this research was downloaded and analyzed using Industrial Scientific's software. The instrument was zeroed and calibrated with a certified CO span gas each day prior to use.

G. Respirable particulates

Samples for respirable particulate matter (2.5, 4.0, and 10 micrometer (µm) aerodynamic diameter) were collected using both integrated and real time aerosol samplers. Integrated samples were collected with SKC cyclones and SKC Personal Environmental Monitors (PEM 2.5 and 10 um) according to NIOSH NMAM 0600.[6] SKC cyclones were used to collect both area and personal breathing zone samples with a cut point of 4.0 µm. The cyclone sampling media consisted of a 37-mm polyetrafluoroethylene (PTFE) filter with a 0.45 µm pore size. The cyclone samples were collected at a flow rate of 2.5 L/min using MSA Escort Elf personal sampling pumps.

SKC PEM samplers with 2.5 and 10 µm cut points were used to collect area samples. The PEM sampling media consisted of a 37-mm PTFE filter with a 0.2 µm pore size. The PEM samples were collected at a flow rate of 2.0 L/min using MSA Escort Elf personal sampling pumps. Sampling pumps were calibrated using a Gilian® Gilibrator™ before and after each sampling shift. Samples were analyzed by Data Chem Laboratories using gravimetric analysis. The estimated limit of detection (LOD) for this method is 0.03 mg per sample. Three blank samples were submitted for analysis for quality control assurance. (NIOSH NMAM 0600 can be viewed in Appendix B).

Real time respirable particulate samples were collected with the following direct reading instrumentation:

Thermo-Electron® (MIE) DataRAM™

The DataRAM is a light-scattering photometer (i.e., nephelometer) that incorporates a pulsed, high output, near-infrared light emitting diode source, a silicon detector/hybrid preamplifier, collimating optics, and a source reference feedback PIN silicon detector. The intensity of the light scattered over the forward angle of 45^o to 90^o by the airborne particles passing through the sensing chamber is linearly proportional to their concentration. The DataRAM's optical configuration produces optimal volume response to particles in the size range of 0.1 to 10µm., achieving high correlation with standard gravimetric measurements of the respirable and thoracic fractions. The DataRAM was configured using a sampling head that selectively measures particulate mass at a 50% cut point of 2.5 µm ($PM_{2.5}$).

TSI® DustTrak™ model 2080 particle analyzer

The TSI® Dustrak™ is a portable, battery operated, laser photometer that measures and records airborne dust concentrations. The DustTrak was used in conjunction with a 9mm nylon cyclone to fractionate particulate aerosols and allow for the collection of 4 micron sized particles at 50% efficiency (PM_4).

H. Noise Dosimetry

Quest Q400 and Quest NoisePro type 2 personal dosimeters were used to evaluate noise exposure to Park Service personnel as they monitored snowmobiles and snow coaches entering the West Entrance to Yellowstone National Park. The internal settings of each dosimeter matched OSHA criteria for evaluating noise exposure and are summarized in Table III. For all sampling events, pre- and post-calibrations were performed on each

Table III. Dosimeter Internal Settings

Instrument Type	Quest Q-400	Quest NoisePro
Weighting	A	A
Threshold	80dB	80dB
Criterion	90dB	90dB
Time Constant	Slow	Slow
Exchange Rate	5dB	5dB
A-weighted Filter Range	70-140dB	70-140dB

dosimeter using either a Quest Model CA-12B or a Quest Model QC-10 acoustical calibrator. All calibrations were made at a sound pressure level of 114dB at 1000 Hz. Both area and personal samples were collected to evaluate compliance with the OSHA noise standard (29 CFR 1910.95). Personal noise samples were collected in the hearing zone of affected personnel and each instrument was configured so that it did not interfere with an employee’s normal job activities. Area samples were collected in the vehicle lane adjacent to the entrance kiosk and directly inside the entrance kiosk in a location where the gate attendant spends the majority of his/her time monitoring snowmobile or snow coach traffic. Figures 1, 2, and 3 provide a visual depiction of the location of both personal and area dosimetry samples.

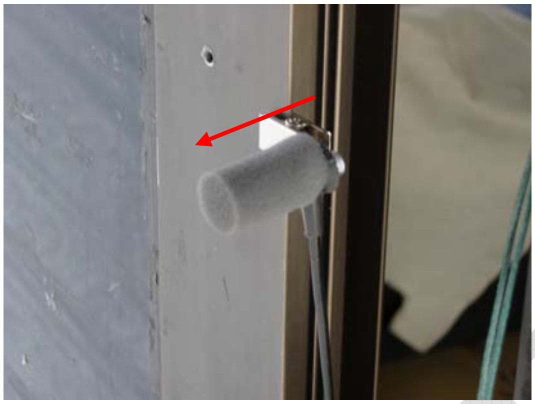

Figure 1. Area sample showing microphone adhered to the window of kiosk A pointing towards the vehicle lane (arrow)

Figure 2. Personal sample placed in the hearing zone of kiosk A gate attendant (arrow)

Figure 3. Area sample showing a dosimeter microphone placed at hearing zone level of a gate attendant inside kiosk A (arrow)

Both types of dosimeters used in this study report results based on a variety of monitoring parameters. The following definitions clarify the meaning of the monitoring parameters used to evaluate compliance with the OSHA noise standard.

Peak dB:	An absolute unweighted peak in dBs characterizing the highest instantaneous sound pressure occurring during the sampling period.
Max dBA:	The highest A-weighted sound pressure level occurring during the sampling period.
Min dBA:	The lowest A-weighted sound pressure level occurring during the sampling period.
SPL_{ave} (dBA):	The average A-weighted sound pressure referenced to 20µPa for the sampling period.
8-hr TWA (dBA):	The average A-weighted sound pressure referenced to 20µPa extrapolated over an 8-hour time period. If the sampling period is less than 8-hours, this parameter assumes silence for the remainder of time not sampled.
8-hr Dose:	The percentage of the maximum allowable dose extrapolated over an 8-hour time period. If the sampling period is less than 8-hours,

this parameter assumes silence for the remainder of time not sampled.

I. Sound Frequency Analyses

Sound frequency analyses were performed with a Quest Sound Pro DXL type 1 real time analyzer and a Quest Model 2700 type 2 sound level meter fitted with a Quest Model OB-50 octave filter. Frequency analyses were performed both inside and outside the West Entrance kiosk stations to characterize noise sources. These surveys were taken with a researcher holding the instrumentation at the hearing zone relative to the kiosk operator.

Frequency analyses of two Park Service 4-stroke snowmobiles were also performed. A researcher rode as a passenger on the machines and conducted frequency spectrum surveys while the machine was idling and while the machine was moving at various speeds up to 45 miles per hour (mph), the Yellowstone National Park snowmobile speed limit.

Pre–and-post calibrations for all sampling events were performed. The Quest Sound Pro DXL instrument was calibrated with a Quest Model QC-10 calibrator at a sound pressure level of 114 dB at 1000 Hz. The Quest 2700 instrument was calibrated with a Quest Model CA-12B calibrator at a sound pressure level of 110 dB at 1000 Hz.

IV. Results and Discussion

The integrated monitoring data for aldehydes, BETX and total hydrocarbons, and respirable particulate are presented in Tables 1C, 2C, and 3C respectively in Appendix C. OSHA PELs, American Conference of Governmental Industrial Hygienists Threshold Limit Values (ACGIH-TLVs), and NIOSH Recommended Exposure Limits (RELs) are also shown in the tables for comparison with exposure measurements. See Appendix D for copies of Data Chem Laboratories analytical reports for all integrated sample analysis, with the exception of the VOCs analytical reports. The VOCs analytical reports are shown in Appendix E.

A. Aldehyde Results

A total of six samples for employee exposure to aldehydes were collected over the Presidents Day weekend in February 2006. One area and one personal sample were collected at the West Entrance kiosks each day on February 18, 19, and 20, 2006. Personal samples were collected on the kiosk attendants near their breathing zone. All area samples for aldehydes were located at workstations so that estimates of employee exposure could be determined. Samples were analyzed by GC/MS for the following compounds: acetaldehyde; acrolein, butyraldehyde, formaldehyde, heptanal, hexanal, iso-valeraledhyde, propionaldehyde, and valeraldehyde. The estimated limit of detection (LOD) for this method is 2 μg of aldehyde per sample. All samples were reported as less than the LOD for the analytical method and thus were below established occupational exposure limits (see Appendix C Table 1C).

B. BETX and Total Hydrocarbon Results

A total of six samples for employee exposure to BETX and total hydrocarbons were collected at the West Entrance kiosks during President's Day weekend on February 18, 19, and 20, 2006. Four samples were personal samples and two samples were area samples located in employee workstations. Samples were analyzed using GC for benzene, toluene, ethyl benzene, xylene, and total hydrocarbons. All samples were reported as less than the LOD for the analytical method and thus were below established occupational exposure limits (see Appendix C Table 2C).
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C. Volatile Organic Compound (VOC) Results

A total of 13 mini-can samples for VOCs were collected over the Presidents Day weekend in February 2006. Two 2-hour area samples and one 5-hour area sample were collected in the West Entrance kiosk A each day on February 18, 19, and 20, 2006. One 2-hour mini-can sample and the 5-hour sample were started at approximately 7:30 AM each morning. The second mini-can sample was started at approximately 9:30 AM each morning when the first mini-can sample was stopped. This sampling strategy was designed to identify peak emission concentrations associated with intermittent vehicle traffic. Additional mini-can samples were collected on February 20, 2006. Figure 4 below shows the location of the mini-can area samples collected in kiosk A and the ventilation duct providing air to the kiosk. The ventilation system maintains a positive pressure in the kiosks. The area samples were positioned to approximate the breathing zone of the kiosk attendant. Two 2-hour area samples were collected approximately 30 feet in front of the entrance to kiosks A and B where snowmobiles stop before passing through the entrance to the Park (see Figure 5). One 2-hour personal sample was collected on a Park Ranger while he performed his ranger duties operating a BAT Arctic Cat 600 Touring snowmobile, and one 5-hour area sample was collected at the air intake to the ventilation system for the kiosks at the West Entrance (see Figure 6 below). The ventilation intake is located 115 feet east of the ventilation section where the arrow is pointing in Figure 6. The control mini-can sample was taken 10 feet from the intake, approximately 105 feet from location where the arrow is pointing. The ventilation intake consists of a 24 inch diameter plastic pipe. The end of the intake is the shape of a horsehead and is covered with a wire mesh grid to preventing large objects from entering.

The following describes the sample type and location of the mini-can samples.

MC 218-21 --- 2-hour area sample in kiosk A at the West Entrance.
MC 218-22 --- 2-hour area sample in kiosk A at the West Entrance.
MC 218-51 --- 5-hour area sample in kiosk A at the West Entrance.
MC 219-21 --- 2-hour area sample in kiosk A at the West Entrance.
MC 219-22 --- 2-hour area sample in kiosk A at the West Entrance.
MC 219-5 ---- 5-hour area sample in kiosk A at the West Entrance.

MC 220-21 --- 2-hour area sample in kiosk A at the West Entrance.
MC 220-22 --- 2-hour area sample in kiosk A at the West Entrance.
MC 220-51 --- 5-hour area sample in kiosk A at the West Entrance.
MC 220-E21 - 2-hour area sample before entrance to kiosks A & B at the West Entrance.
MC 220 E22 - 2-hour area sample before entrance to kiosks A & B at the West Entrance.
MC 220-PR5- 2-hour area sample on park ranger operating BAT 2003 Polaris Frontier Touring snowmobile.
MC 220-B5 -- 5 hour area sample at the air intake to the ventilation system for the kiosks at the West Entrance.

Figure 4. Location of mini-can area samples in kiosk A at the West Entrance

Figure 5. Location of mini-can samples MC 220-E21 and MC 220-E22

Figure 6. Ventilation duct to West Entrance kiosks

The results of the mini-can samples for VOCs that were above the limit of detection for the analytical method are shown in Table IV. The results for the various compounds identified in the samples are expressed in part per million (ppm). The compound 1,2-

Dichlorobenzene was detected at a concentration of 0.00074 ppm in sample MC-219-22 collected at the West Entrance kiosk on February 19, 2006, and is not shown in Table IV.

The results in Table IV are best interpreted by comparison with MRLs established by ATSDR.[5] ATSDR MRLs that have been established for compounds detected during the current study (Table IV) are shown in Table V. An MRL is an estimate of the daily human exposure to a hazardous substance that is likely to be without appreciable risk of adverse non-cancer health effects over a specified duration of exposure. These substance specific estimates, which are intended to serve as screening levels, are used by ATSDR health assessors and other responders to identify contaminants and potential health effects that may be of concern at hazardous waste sites. With the exception of two benzene samples, all of the compounds reported above the limit of detection in Table IV are below all established recommended MRL (acute, intermediate, and chronic) levels shown in Table V. The benzene samples with concentrations of 0.0072 ppm and 0.0086 ppm are above the intermediate-duration inhalation exposure of 0.006 ppm, but below the acute-duration inhalation exposure of 0.009 ppm. However, both of these were short term samples taken to minimize dilution effects and thereby obtain a better idea of potential worst case exposures.

The VOC results in Table IV were also interpreted by comparison with sample MC220-B5. This sample was collected near the air intake to the ventilation system for the kiosks at the West Entrance on February 20, 2006, to serve as a control sample. Although the overall total VOC concentrations and number of contaminants detected in the control sample MC220-B5 were less than the other samples, the following compounds were detected in this sample: Propene, Dichlorodifluoromethane, Chloromethane, Freon 11, Acetone, Methylene Chloride, Benzene, Toluene, m,p-Xylene, and 1,2,4-Trimethylbenzene. Statistical analysis using a two-sample t-test was performed to determine if there were statistically significant differences between the control sample and the other 11 samples collected (sample MC220-PR5 was excluded from the analysis because this sample was collected on a Park ranger operating a snowmobile). The t-test results indicated that the background sample VOC concentrations were significantly less statistically than VOC concentrations for samples MC 218-21, MC218-22, MC 219-21, and MC 220-22 ($p < .05$). Only sample MC 220-22 was collected on the same day as the background sample. The difference found between the background sample collected on 2-20-06 and the other three samples collected on different days may be due to differences in snowmobile traffic, meteorological conditions, or other factors.

A comparison was also made between the VOC concentrations obtained in the current study and the 2005 study. Concentrations of fourteen compounds (shown in Table VI) that were detected in the majority of samples during each year were compared using a one-way analysis of variance (ANOVA). The results of the ANOVA showed that only benzene concentrations were significantly higher in the current survey when compared to the 2005 survey ($p < .05$). The mean benzene concentration during the current survey was 0.0032 compared to a mean concentration of 0.0011 during the 2005 survey. Both mean concentrations are well below the MRL for benzene.

A final analysis was performed to determine if a correlation existed between VOC concentrations and number of vehicles (snowmobiles and snow coaches) entering the West Entrance. A correlation analysis was performed using VOC concentrations found during both the 2005 and 2006 surveys and the number of vehicles entering the West Entrance on the days sampling was performed. No correlation was found between VOC concentrations and number of vehicles entering. See Appendix E for copies of Data Chem Laboratories analytical reports for VOCs analysis.

Table IV. Volatile Organic Compounds Identified by Method TO-15

*ND – None Detected	2/18/2006	2/18/2006	2/18/2006	2/19/2006	2/19/2006	2/19/2006	2/20/2006	2/20/2006	2/20/2006	2/20/2006	2/20/2006	2/20/2006	2/20/2006
	MC218-21	MC218-22	MC218-51	MC219-21	MC219-22	MC219-5	MC220-21	MC220-22	MC220-51	MC220-E21	MC220-E22	MC220-PR5	MC220-B5
Analyte	**PPM**	**PPM**	**PPM**	**PPM**	**PPM**	**PPM**	**PPM**	**PPM**	**PPM**	**PPM**	**PPM**	**PPM**	**PPM**
Propene	0.0073	0.00018	0.0042	0.021	0.0042	0.0056	0.0059	0.024	0.0025	0.015	0.011	0.0085	0.0023
Dichlorodifluoromethane	0.00058	0.0067	0.00046	0.00061	0.00053	0.00055	0.00060	0.00058	0.00058	0.00062	0.00058	0.00049	0.00059
Chloromethane	0.0073	0.00025	0.0006	0.00086	0.00077	0.00082	0.00085	0.00079	0.00052	0.00098	0.0013	0.0009	0.0009
1,3-Butadiene	0.008	0.0018	ND	0.0035	ND	0.00041	0.00052	0.0032	ND	0.0018	0.0012	ND	ND
Freon 11	0.0027	0.00025	0.00019	0.00025	0.00023	ND	0.00025	0.00024	0.0002	0.00025	ND	0.00023	0.00022
Acetone	0.0041	0.0042	0.0076	0.0049	0.250	0.010	0.006	0.0071	0.016	0.003	0.023	0.0037	0.0082
Methylene Chloride	0.0004	0.00092	0.00039	0.0012	0.0027	0.00054	0.00038	0.00028	0.00033	0.00035	0.00027	0.00044	0.0003
2-Butanone	ND	ND	0.00023	ND	0.013	ND	0.00039	0.00039	ND	0.00099	ND	ND	ND
Ethyl Acetate	ND	0.002	ND	ND	0.0019	ND	ND	ND	ND	ND	ND	ND	ND
Hexane	0.0024	0.0038	0.0016	0.0063	0.0019	0.0023	0.0048	0.0073	ND	0.0037	0.0021	0.0014	ND
Chloroform	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.00052	ND
Benzene	0.0023	0.004	0.00082	0.0072	0.0017	0.0015	0.003	0.0086	0.00049	0.0049	0.0025	0.002	0.00031
1,2-Dichloroethane	ND	ND	ND	ND	0.00074	ND	ND	ND	ND	ND	ND	ND	ND
Cyclohexane	0.00062	0.00091	ND	0.0012	ND	ND	0.0011	0.0014	ND	0.00079	ND	ND	ND
Trichloroethene	ND	ND	ND	ND	0.00029	ND	ND	ND	ND	ND	ND	0.00034	ND
Heptane	0.00048	0.0013	0.00032	ND	0.00065	0.00033	0.001	0.0019	ND	0.00099	0.00066	ND	ND
Toluene	0.0043	0.0083	0.003	0.014	0.016	0.0054	0.0069	0.016	0.0022	0.0084	0.0044	0.0036	0.00077
Tetrachloroethene	ND	ND	ND	ND	0.00017	0.00021	ND	ND	0.00031	ND	ND	0.00066	ND
Ethylbenzene	0.00047	0.0012	0.00024	0.0019	0.0029	0.00044	0.00087	0.0021	0.00025	0.0011	0.00061	0.00037	ND
m,p-Xylene	0.0017	0.005	0.00083	0.0074	0.013	0.0017	0.0031	0.0081	0.001	0.0046	0.0027	0.0014	0.00029
o-Xylene	0.00058	0.0018	0.00032	0.0026	0.0041	0.00065	0.0011	0.0029	0.00039	0.0017	0.00094	0.00052	ND
Styrene	0.00011	0.00025	ND	0.00041	0.0048	0.00012	ND	0.0004	ND	0.0003	0.00014	0.00018	ND
4-Ethyl toluene	0.00015	0.00046	ND	0.00059	0.00054	0.00013	0.00029	0.00074	ND	0.0003	0.00026	0.00012	ND
1,3,5-Trimethylbenzene	0.00015	0.00051	ND	0.00068	0.00055	0.00013	0.00022	0.00066	ND	0.00043	0.00026	0.00012	ND
1,2,4-Trimethylbenzene	0.00045	0.0019	0.00036	0.0024	0.00021	0.00057	0.0009	0.0026	0.00041	0.001	0.00089	0.00052	0.00015

Table V. ATSDR Minimal Risk Levels (MRLs) December 2005

Analyte	ATSDR Minimal Risk Levels (MRLs) December 2005
Propene	No MRL available. Listed by ACGIH as a simple asphyxiant.
Dichlorodifluoromethane	No MRL available
Chloromethane	**Inh.** Acute-0.5ppm, Int-0.2ppm, Chr-.05ppm
1,3-Butadiene*	No MRL available. Environmental Protection Agency Screening Level 5.75 ppm
Freon 11	No MRL available
Acetone	**Inh.** Acute-26ppm, Int-13ppm, Chr-13ppm, **Oral** Int-2 mg/kg/day
Methylene Chloride	**Inh.** Acute-0.6ppm, Int-0.3ppm, Chr-0.3ppm, **Oral** Acute-0.2 mg/kg/day, Chr-0.06 mg/kg/day
2-Butanone	1.0 ppm ATSDR chronic inhalation RMEG/RFC
Ethyl Acetate	No MRL available. OSHA PEL and ACGIH TLV 400 ppm
Hexane	**Inh.** Chr.- 0.6 ppm,
Chloroform	**Inh.** Acute-0.1ppm, Int-0.05ppm, Chr-0.02ppm, **Oral** Acute-0.3mg/kg/day, Int-0.1mg/kg/day, Chr-0.01mg/kg/day
Benzene	**Inh.** Acute-0.009 ppm, Int-0.006 ppm, Chr.-0.003 ppm
1,2-Dichloroethane	**Inh.** Chr-0.6ppm, **Oral** Int-0.2mg/kg/day
Cyclohexane	No MRL available
Trichloroethene	**Inh.** Acute-2ppm, Int-0.1ppm, **Oral** Acute-0.002mg/kg/day
Heptane	No MRL available. OSHA PEL 500 ppm. ACGIH TLV 400 ppm
Toluene	**Inh.** Acute-1ppm, Chr-0.08ppm, **Oral** Acute-0.8mg/kg/day, Int-0.02mg/kg/day
Tetrachloroethene	**Inh.** Acute-0.2ppm, Chr-0.04ppm, **Oral** Acute-0.05mg/kg/day
Ethylbenzene	**Inh.** Int-1.0ppm
m,p-Xylene	**Inh.** Acute-2.0ppm, Int-0.6ppm, Chr.-0.05ppm **Oral** Acute-1.0 mg/kg/day, Int-1.0 mg/kg/day, Chr.-0.6 mg/kg/day
o-Xylene	**Inh.** Acute-2.0ppm, Int-0.6ppm, Chr.-0.05ppm **Oral** Acute-1.0 mg/kg/day, Int-1.0 mg/kg/day, Chr.-0.6 mg/kg/day
Styrene	**Inh.** Chr-0.06ppm, **Oral** Int-0.2mg/kg/day
4-Ethyl toluene*	No MRL available. Registry of Toxic Effects of Chemical Substances database;inhalation TCLo (similar to an inhalation LOAEL) of 5,000 mg/m^3 or 1,017 ppm in rats and rabbits treated to 4ethyltoluene 6 hours a day for 100 days.
1,3,5-Trimethylbenzene*	**NIOSH, ACGIH** 25 ppm TWA; 5 ppm ceiling
1,2,4-Trimethylbenzene*	**NIOSH, ACGIH** 25 ppm TWA; 5 ppm ceiling
1,2-Dichlorobenzene	**Oral** Acute-0.8mg/kg/day, Int-0.4mg/kg/day, Chr.-0.4mg/kg/day

Table VI. Comparison of VOC Concentrations in the 2005 and 2006 Surveys

Contaminant by Year	Sample No.	Mean ppm	Maximum ppm	Minimum ppm	Standard Deviation
Benzene (2006)	13	0.0032	0.0086	0.00049	0.0024
C_6H_6 (2005)	11	0.0011	0.0024	0.00007	0.00085
Dichlorodifluoromethane (2006)	13	0.0015	0.0067	0.00046	0.0022
Dichlorodifluoromethane (2005)	11	0.00075	0.0032	0.00005	0.00093
Chloromethane (2006)	13	0.0013	0.0073	0.00025	0.00182
Chloromethane (2005)	11	0.00098	0.0028	0.00017	0.00081
Freon 11 (2006)	13	0.00039	0.0027	0.00006	0.0007
Freon 11 (2005)	11	0.00034	0.00097	0.00006	0.0003
Acetone (2006)	13	0.027	0.25	0.003	0.067
Acetone (2005)	11	0.035	0.27	0.0001	0.0787
Methylene Chloride (2006)	13	0.00066	0.0027	0.00027	0.00067
Methylene Chloride (2005)	11	0.00099	0.0044	0.00012	0.00124
Toluene (2006)	13	0.0072	0.016	0.0007	0.00517
Toluene (2005)	11	0.0123	0.069	0.00008	0.01994
Ethylbenzene (2006)	13	0.00097	0.0029	0.0001	0.00086
Ethylbenzene (2005)	11	0.00749	0.045	0.00012	0.0134
m,p-Xylene (2006)	13	0.0039	0.013	0.00029	0.00369
m,p-Xylene (2005)	11	0.0335	0.22	0.0001	0.0654
o-Xylene (2006)	13	0.00136	0.0041	0.00008	0.00121
o-Xylene (2005)	11	0.01596	0.11	0.00008	0.03293
1,2,4-Trimethylbenzene (2006)	13	0.00077	0.0024	0.00015	0.00068
1,2,4-Trimethylbenzene (2005)	11	0.0276	0.22	0.0001	0.0665
1,3,5-Trimethylbenzene (2006)	13	0.0003	0.00068	0.00008	0.00023
1,3,5-Trimethylbenzene (2005)	11	0.00657	0.051	0.00008	0.01538
Styrene (2006)	13	0.00053	0.0048	0.00005	0.00129
Styrene (2005)	11	0.00095	0.0057	0.00005	0.00162
4-Ethyl toluene (2006)	13	0.00029	0.00074	0.00007	0.00022
4-Ethyl toluene (2005)	11	0.0036	0.034	0.00007	0.01011

D. Carbon Monoxide Results

Carbon monoxide (CO) was measured using an Industrial Scientific iTX® Multi-Gas Monitor™. The results of the CO monitoring are shown in Table VII. The OSHA PEL for CO is 50 ppm and the ACGIH TLV is 25 ppm. The NIOSH REL for CO is 35 ppm with a 200 ppm ceiling. None of the CO levels observed in this study exceeded the established occupational exposure limits.

Table VII. Real Time Carbon Monoxide Concentrations

Date	Location	Start	Stop	CO Avg (ppm)	CO 8 Hour TWA	CO Peak (STEL)
2/18/2006	Kiosk A	8:19 AM	11:38 AM	0.36	0.29	26 ppm @ 10:26 AM
2/19/2006	Kiosk A	7:39 AM	12:57 PM	2.10	0.94	49 ppm @ 9:12 AM
2/20/2006	Kiosk A	8:20 AM	11:24 AM	1.11	0.61	91.0 ppm @ 9:04 AM

E. Respirable Particulate Results

A total of 12 integrated samples for respirable particulate ($PM_{4.0}$, $PM_{2.5}$, PM_{10}) were collected during the Presidents Day weekend on February 18, 19, and 20, 2006. One personal and one area sample for respirable particulate $PM_{4.0}$ was collected on each of the three days at the West Entrance kiosk A. One area sample for respirable particulate $PM_{2.5}$ and PM_{10} was collected on each of the three days in the West Entrance kiosk A. Samples were analyzed by gravimetric analysis and all results, with the exception of one sample, were below the limit of detection for the analytical method. Sample ZF A06-11 for respirable particulate $PM_{4.0}$ showed a concentration of 0.1 mg/m^3. All samples for respirable particulate were below established occupational exposure limits (see Appendix C Table 3C).

Samples for respirable particulate were also collected using real time aerosol monitors and these results are outlined below.

F. Real Time Respirable Aerosol Sampling Results; PM_4 and $PM_{2.5}$

i. TSI® DustTrak model 2080 PM_4 Results

On all three of the aforementioned sampling days area samples were taken to characterize occupational exposure to the respirable fraction of particulate aerosols. A TSI DustTrak® model 2080 was used in conjunction with a 9mm nylon cyclone to fractionate particulate aerosols and allow for the collection of 4 micron sized particles at 50% efficiency (PM_4). The location of each sampling device relative to the West entrance to Yellowstone National Park is summarized in the following bullet list.

- Location A: TSI DustTrak® placed inside kiosk A entrance gate window with 9mm cyclone place inside the traffic lane

- Location B: TSI DustTrak® place inside and against the north wall of kiosk A with 9mm cyclone elevated to breathing zone height

Figures 7 and 8 provide a visual depiction of the location of each TSI DustTrak® sampler.

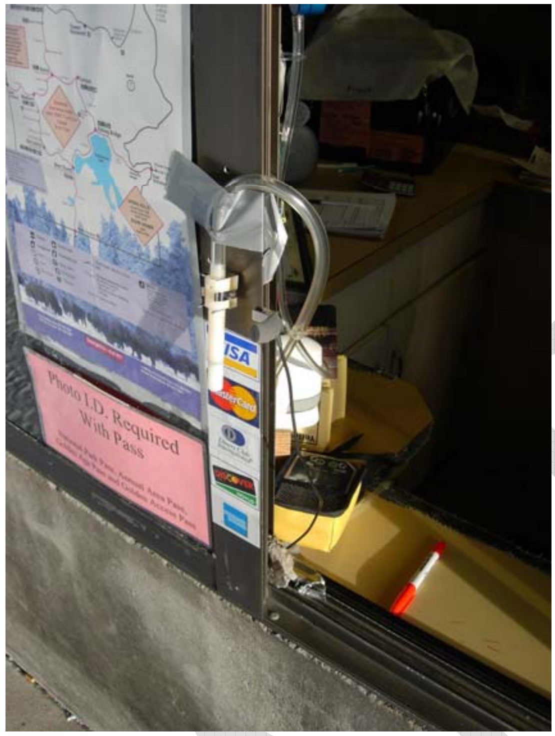


Figure 7. 9mm cyclone in traffic lane of kiosk A

Figure 8. DustTrak with 9mm cyclone against north wall of kiosk A

Table VIII summarizes the results of respirable aerosol sampling taken on February 18, 19, and 20, 2006.

Table VIII. Respirable Dust (PM_4) Results for February 18, 19, and 20, 2006

Date	**Monitoring Parameters**						
	Location	**Start Time**	**Stop Time**	**Avg. (mg/m^3)**	**8-hr TWA (mg/m^3)**	**Max (mg/m^3)**	**Min (mg/m^3)**
2-18-06	A	07:59:05	11:42:25	0.018	0.008	0.188	0.002
2-18-06	B	08:00:20	11:43:42	0.018	0.008	0.154	0.002
2-19-06	A	07:19:32	11:02:42	0.016	0.008	0.081	0.001
2-19-06	B	07:19:18	11:02:28	0.009	0.004	0.026	0.002
2-20-06	A	07:46:45	11:17:45	0.013	0.006	0.135	0.004
2-20-06	B	07:46:30	11:17:30	0.007	0.003	0.014	0.002

The results provided in Table VIII suggest that 8-hr TWA respirable aerosol concentrations are well below the OSHA Permissible Exposure Limit for Particulates Not Otherwise Regulated (respirable fraction) of 5 mg/m^3. Of note is the lower average respirable concentrations seen on February 19 and 20, 2006 when compared to February 18, 2006. This is likely due to a behavior change observed among snowmobile operators who would stop their vehicles at a given distance away from the entrance and walk up to the kiosk to check in prior entering the park. It was also observed that on these two days some operators would turn off their vehicles while conversing with the gate attendant, which may have also contributed to the lower respirable concentration averages.

Figures 9, 10, and 11 below provide real time PM_4 concentrations over the duration of the sampling period on each day sampled.

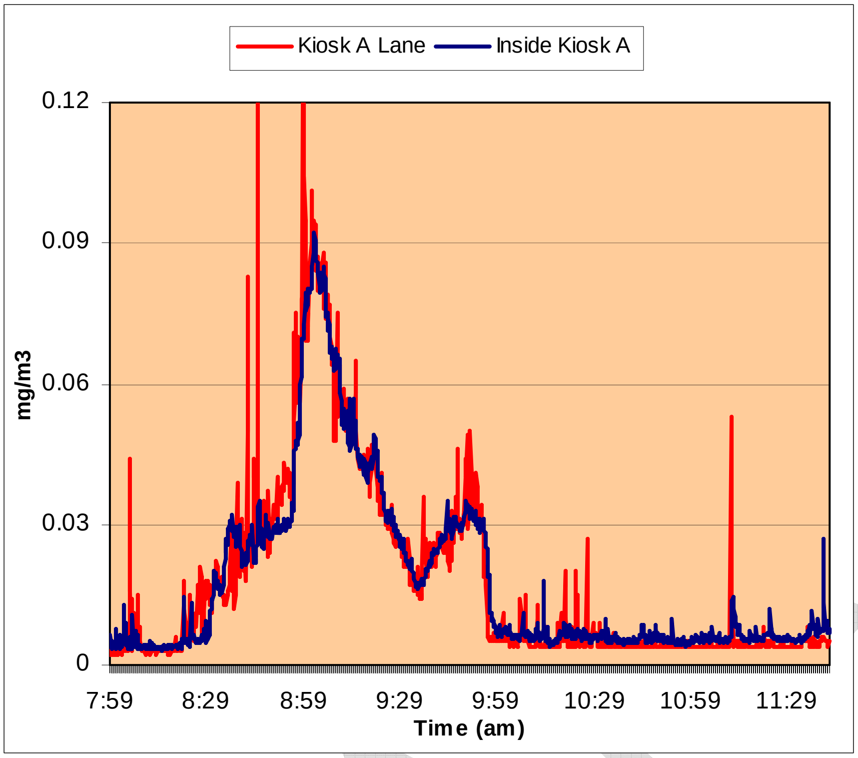


Figure 9. Real time PM_4 concentrations – 2/18/06

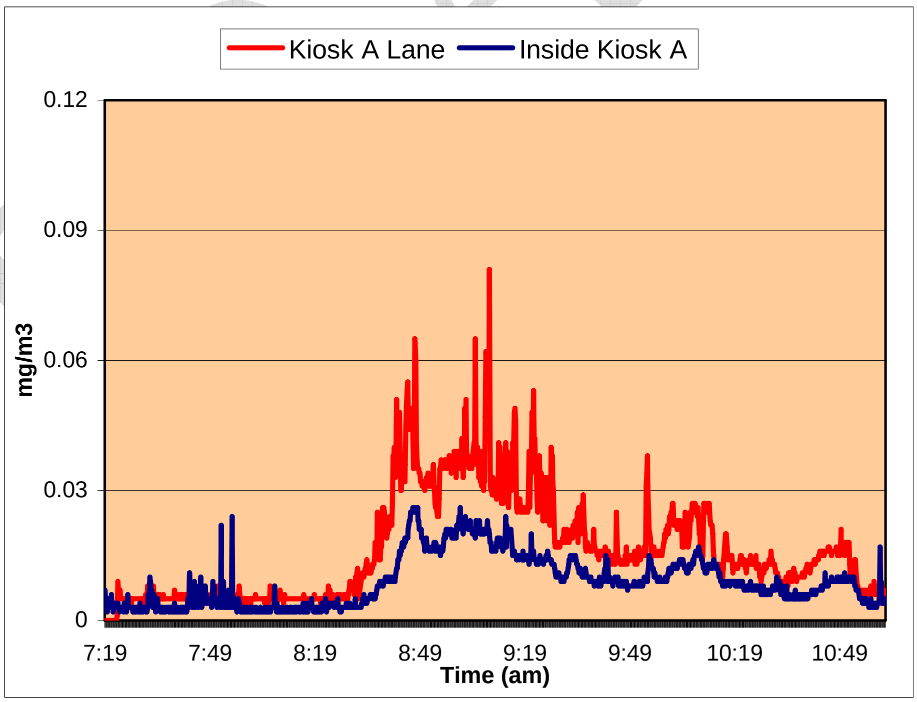


Figure 10. Real time PM_4 concentrations – 2/19/06

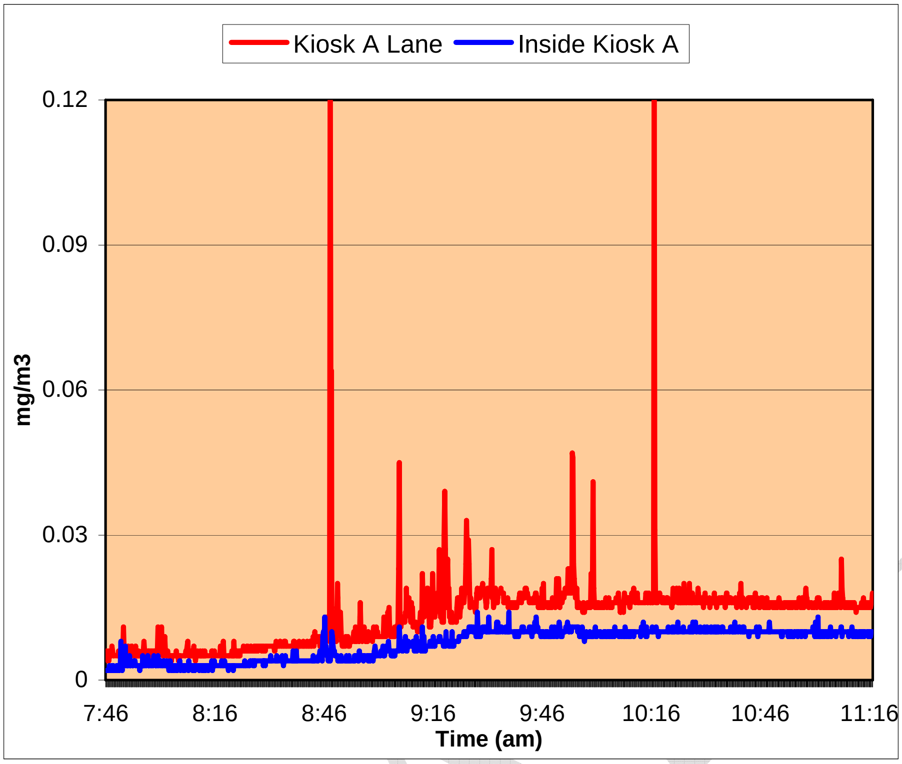


Figure 11. Real time PM4 concentrations – 2/20/06

Figures 9, 10, and 11 reveal relatively consistent respirable aerosol concentrations when comparing those obtained inside the lane of kiosk A to those obtained inside the ambient environment of kiosk A on a given day (particularly on February 18, 2006). It is possible that this is a function of the kiosk A window remaining open for the majority of each of the sampling periods in an effort to accommodate visitors to the park. Also striking is the PM_4 concentration patterns (signature) reflecting pre- and post-rush hours in terms of motorized traffic passing kiosk A.

ii. Thermo-Electron® (MIE) DataRAM™ Results

A Thermo-Electron® (MIE) DataRAM™ was used to obtain real time particle mass concentration data. Previous studies have shown that $PM_{2.5}$ measurements from real time instruments are well correlated and highly predictive of measurements from the gravimetric sampling method for aerosols in workplace environments.[8] Real time $PM_{2.5}$ samples were collected in kiosk A at the West Entrance on February18, 19, and 20, 2006. The results of the real time particle concentration sampling are shown in Table IX. The data are represented graphically in Figures 12, 13 and 14.

Table IX. Real Time Particle Mass Concentration Data $PM_{2.5}$

Date	Location	Cut Point	Start Time	Stop Time	Avg. Conc (ug/m^3)	Max (ug/m^3)	Time of Max
2/18/2006	Kiosk A	$PM_{2.5}$	7:52 AM	12:05 PM	5.3	60.0	7:59 AM
2/19/2006	Kiosk A	$PM_{2.5}$	7:49 AM	11:09 AM	4.4	32.1	8:53 AM
2/20/2006	Kiosk A	$PM_{2.5}$	7:54 AM	12:20 PM	4.3	13.9	8:06 AM

As can be seen in Figures 12, 13, and 14 below, the highest ambient particle concentrations monitored at the entrance station kiosks appear to correspond with the periods of peak snowmobile and snow coach traffic entering the park (midmorning). On February 19 and 20, 2006 ambient $PM_{2.5}$ particle concentrations were consistently lower at the entrance kiosks. This is probably due to fewer machines entering through the West Entrance kiosks on these days (see Table I). As during the 2005 survey, it was observed on February 19 and 20, 2006, that the some snowmobile guides would stop their vehicles approximately 20 to 30 feet in front of the kiosk window and walk to the window with their paperwork. In terms of occupational exposure, no particle size selective exposure limits exist to exclusively evaluate $PM_{2.5}$. In terms of public health, while the real time monitors employed in this study are not EPA reference sampling methods, all average concentrations are well below the EPA's 24-hour National Ambient Air Quality Standards for these agents.

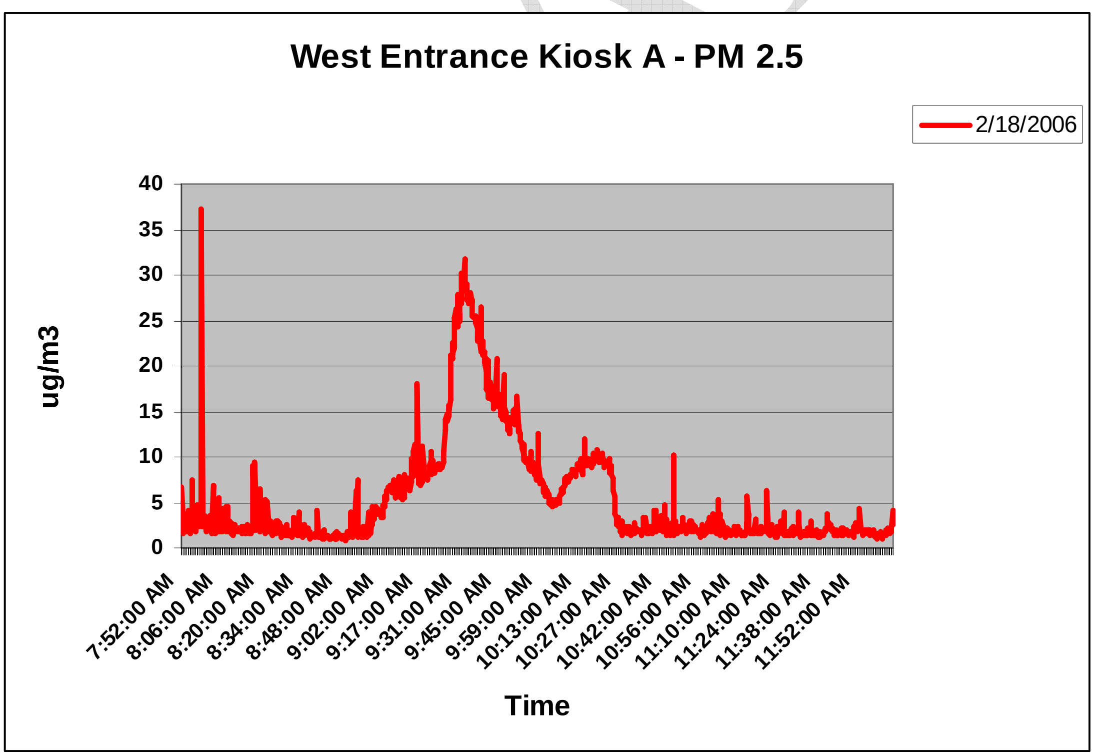


Figure 12. Real time $PM_{2.5}$ particle concentrations – West Entrance kiosk A (2/18/2006)

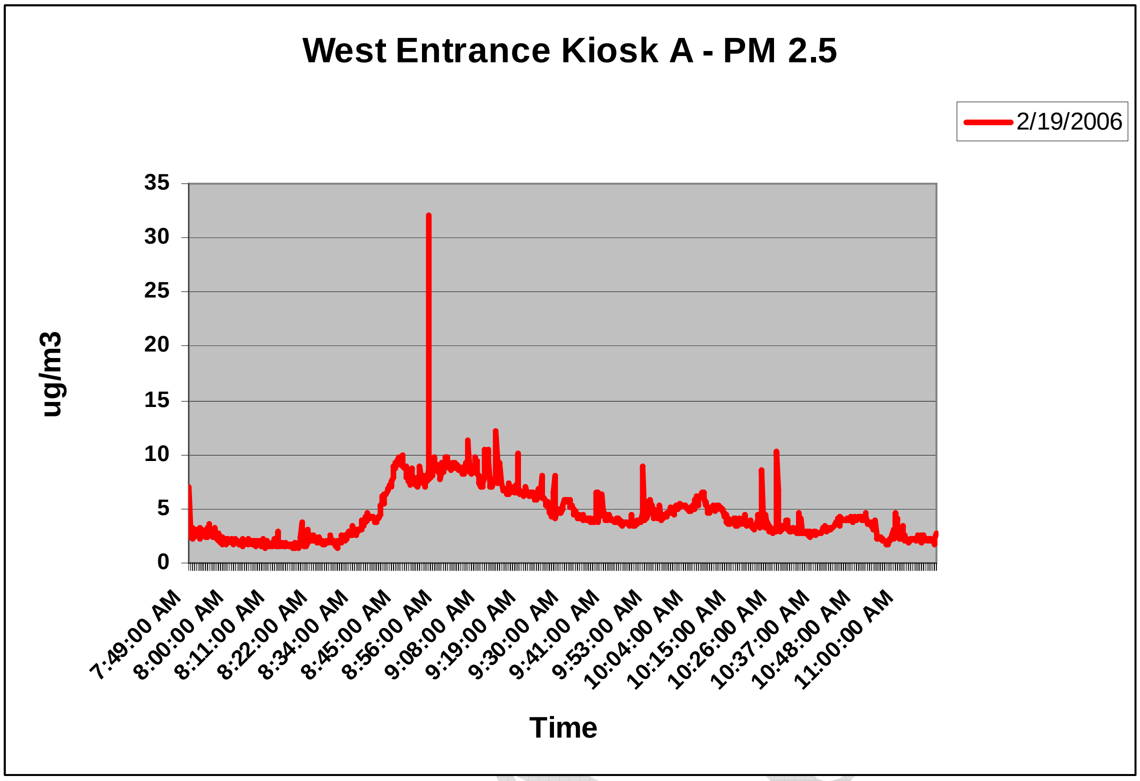


Figure 13. Real time $PM_{2.5}$ particle concentrations – West Entrance kiosk A (2/19/2006)

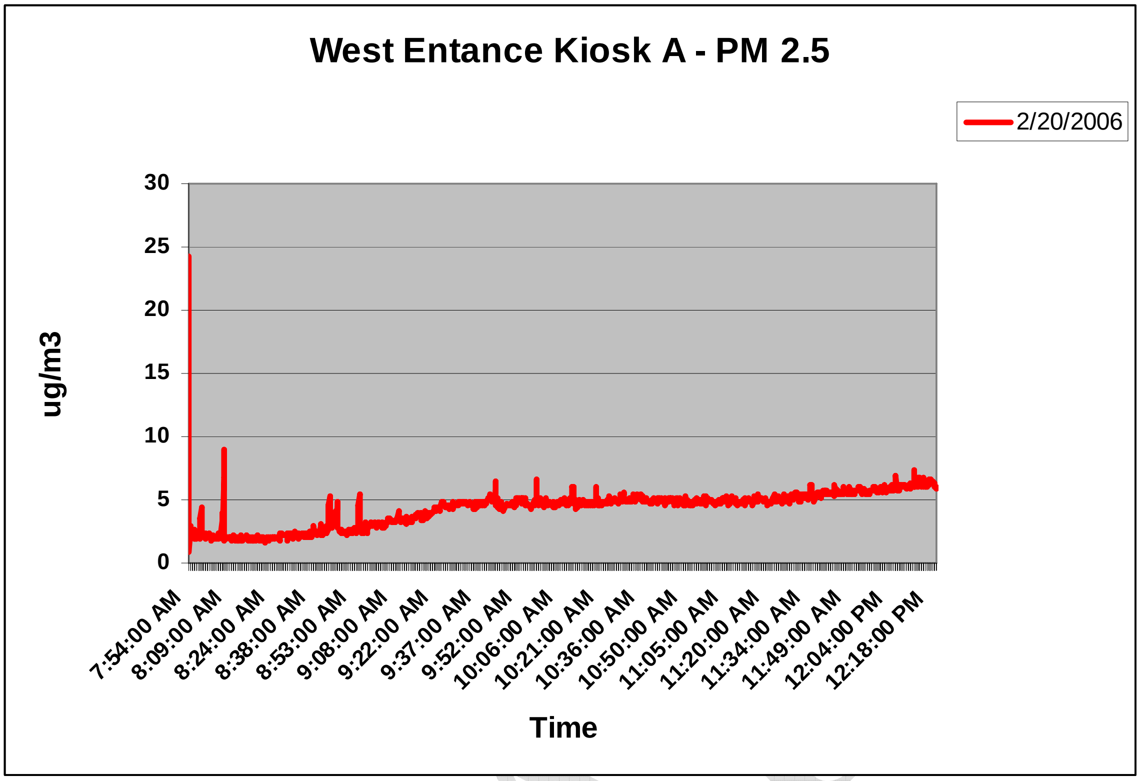


Figure 14. Real time $PM_{2.5}$ particle concentrations – West Entrance kiosk A (2/20/2006)

G. Dosimeter Noise Results

Table X summarizes the results of noise dosimetry performed on February 18, 2006.

Table X. Noise Dosimetry Results for February 18, 2006

Monitoring Identifiers	**Location**		
	Kiosk A Area 1[a]	**Kiosk A Area 2**[b]	**Kiosk A Personal**[c]
Instrument	Quest Q-400	Quest NoisePro	Quest NoisePro
Serial No.	090013	100019	100022
Start Time	0804	0719	0720
Stop Time	1200	1136	1135
Max dBA[d]	96	105	109
Min dBA	<70	<70	<70
SPL_{ave} (dBA)	71	68	85
8-hr TWA	**65**	**64**	**80**
8-hour Dose	**3.2%**	**2.7%**	**26%**

[a]Area sample located in the vehicle lane adjacent to kiosk A; [b]Area sample located inside kiosk A; [c]Personal dosimetry sample located in the hearing zone of kiosk A gate attendant [d] Max dBA is the maximum sound pressure level sampled that allows for A-weighting (accounts for how the human ear hears frequencies

differently) and slow response (an OSHA requirement). OSHA prohibits any exposure to continuous noise exceeding 115 dBA.

The results in Table X above show that area samples taken in the vehicle lane of kiosk A and in the ambient environment of kiosk A are markedly consistent yielding 8-hour dose levels well below the OSHA Hearing Conservation Amendment (8-hour dose of 50%). The results of the personal dosimetry sample acquired from the kiosk A gate attendant, while higher than the area samples, also suggest compliance with the OSHA Hearing Conservation Amendment. From observations made during the sampling period, the higher personal dosimetry sample collected from the gate attendant is reasoned to be a function of the additional noise contribution provided by the volume and frequency of speech delivered by the individual in conjunction with the proximity of the dosimeter microphone to this sound source.

Table XI summarizes the results of noise dosimetry results performed on February 19, 2006.

Table XI. Noise Dosimetry Results for February 19, 2006

Monitoring Identifiers	**Location**					
	Kiosk A Area 1[a]	**Kiosk A Area 2[b]**	**Kiosk A Personal 1[c]**	**Kiosk B Area 1[d]**	**Kiosk B Area 2[e]**	**Kiosk B Personal 2[f]**
Instrument	Quest Q-400	Quest NoisePro	Quest NoisePro	Quest Q-400	Quest NoisePro	Quest NoisePro
Serial No.	090011	100020	100023	090010	100022	100019
Start Time	0730	0714	0735	0740	0736	0720
Stop Time	1100	1100	1053	1116	1055	1052
Max dBA[g]	112	109	114	94	110	113
Min dBA	<70	<70	<70	<70	<70	<70
SPL_{ave} (dBA)	67	67	70	68	83	76
8-hr TWA	**61**	**61**	**64**	**62**	**77**	**70**
8-hr dose	**1.8%**	**1.8%**	**2.9%**	**2.1%**	**16%**	**6.0%**

[a]Area sample located in the vehicle lane adjacent to kiosk A
[b]Area sample located inside kiosk A
[c]Personal sample placed in the hearing zone of the kiosk A attendant
[d]Area sample located in the vehicle lane adjacent to kiosk B
[e]Area sample located inside kiosk B
[f]Personal sample placed in the hearing zone of the kiosk B attendant
[g] Max dBA is the maximum sound pressure level sampled that allows for A-weighting (accounts for how the human ear hears frequencies differently) and slow response (an OSHA requirement). OSHA prohibits any exposure to continuous noise exceeding 115 dBA.

The results in Table XI suggest compliance with the OSHA Hearing Conservation Amendment with all 8-hr dose values well below the action level of 50%. Area samples 1 and 2 (kiosk A) and area sample 1 (kiosk B) are relatively consistent with the area samples taken on February 18, 2006. Area sample 2 (kiosk B) revealed relatively higher noise exposure results for the sampling period when compared to other area samples taken on this or the previous sampling day. While the precise reason for this result is unclear, it is likely that it may be a function of systematic (non-random) error in the sampling method (i.e. noise artifacts due to movements and collisions with the microphone during the sampling period). Concerning the personal dosimetry samples collected in the hearing zone of the gate attendant in kiosks A and B, they are both relatively lower than the personal dosimetry sample collected on the previous day. These lower results may be a function of better placement of the microphone in the hearing zone of the wearers so as not to have anomalous noise contributions related to speech.

Table XII summarizes the results of noise dosimetry results performed on February 20, 2006.

Table XII. Noise Dosimetry Results for February 20, 2006

Monitoring Identifiers	**Location**					
	Kiosk A Area 1[a]	**Kiosk A Area 2[d]**	**Kiosk A Personal [e]**	**Kiosk B Area 1[b]**	**Kiosk B Area 2[c]**	**Kiosk B Personal [f]**
Instrument	Quest Q-400	Quest NoisePro	Quest NoisePro	Quest Q-400	Quest NoisePro	Quest NoisePro
Serial No.	090012	100022	100020	090014	100023	100019
Start Time	0733	0729	0729	0734	0724	0732
Stop Time	1129	1132	1132	1130	1120	1119
Max dBA[g]	104	111	110	96	107	108
Min dBA	<70	<70	<70	<70	<70	<70
SPL_{ave} (dBA)	67	66	75	58	63	77
8-hr TWA	**62**	**60**	**70**	**52**	**58**	**72**
8-hr Dose	**2.1%**	**1.6%**	**6.4%**	**0.54%**	**1.2%**	**7.8%**

[a]Area sample located in the vehicle lane adjacent to kiosk A
[b]Area sample located in the vehicle lane adjacent to kiosk B
[c]Area sample located inside kiosk B
[d]Area sample located inside kiosk A
[e]Personal dosimetry sample placed in the hearing zone of kiosk A attendant
[f]Personal dosimetry sample placed in the hearing zone of the kiosk B attendant
[g] Max dBA is the maximum sound pressure level sampled that allows for A-weighting (accounts for how the human ear hears frequencies differently) and slow response (an OSHA requirement). OSHA prohibits any exposure to continuous noise exceeding 115 dBA.

The results shown in Table XII above are consistent with results acquired from previous sampling days and suggest compliance with the OSHA Hearing Conservation Amendment.

H. Frequency Analyses

i. Kiosk Station Analyses

On February 18, 2006 frequency analyses were performed to characterize sound sources associated with the West Entrance kiosk stations. Sound measurements were performed in kiosk A with no traffic in the lanes and the main forced air heating system shut off, in kiosk A with no traffic in the lanes and the main forced air heating system operating, and in kiosk A with traffic in lane A and the main forced air heating system operating. The 1/3 octave frequency spectrums under these conditions are presented in Table XIII. Data are presented both in equivalent continuous sound pressure level measurements (Leq) and maximum sound pressure level measurements (Lmax). The Leq and Lmax values at each 1/3 octave frequency are both presented to illustrate fluctuation in the data during the measurement duration. The overall Leq and Lmax sound pressure levels are also included.

The traffic present when the third round of sampling was conducted inside kiosk A consisted of nine Arctic Cat 4-stroke snowmobiles. The snowmobile guide pulled up to the window, let his machine idle and presented passes, etc., to the kiosk attendant. He then slowly progressed through the lane with the other 8 machines following him. The kiosk attendant kept the window open and observed the machines and greeted operators as they passed by. The duration of this survey was 2 minutes 44 seconds. The survey was initiated when the guide pulled up to the kiosk and was terminated when the last machine had cleared the kiosk lane. Because each machine that passed by represented a new source of noise, there was some variation in the acoustic signature if the line of snowmobiles is considered as one noise source.

The dominant octave band center frequencies measured inside kiosk A when snowmobile traffic was present were in the 500 – 2,000 Hz range. Sound pressure levels at these 1/3 octave band center frequencies were plotted in a logged data chart to illustrate the fluctuation in sound pressure level as machines passed by kiosk A (see Figure 15).

On February 18, 2006, sound spectrum analyses were also performed outside of kiosk A approximately 5 feet from lane A. A line of 10 Artic Cat 4-stroke snowmobiles passed through lane A on this sampling event. The guide pulled up to the kiosk A window, shut his machine off and presented passes, etc., to the kiosk attendant. He then started his machine and slowly progressed through the lane with the other 9 machines in tow. The duration of this survey was 1 minute 12 seconds. The survey was initiated when the guide pulled up to the kiosk and was terminated when the last machine cleared the kiosk lane. This frequency analysis data is also presented in Table XIII.

Table XIII. Frequency Spectrum of Sound Sources Associated with Kiosk Operations

	Inside Kiosk A Forced Air Off No Traffic		Inside Kiosk A Forced Air On No Traffic		Inside Kiosk A Forced Air On Traffic		Outside Kiosk A 5 ft from lane A	
1/3 Octave Frequency (Hz)	Leq dBA	Lmax dBA	Leq dBA	Lmax dBA	Leq dBA	Lmax dBA	Leq dBA	Lmax dBA
12.5	-7.5	.4	-4.4	1.8	-4.7	6	-3.3	1.8
16	5.2	16.8	8.6	13.0	5.0	14.1	2.5	11.9
20	8.5	18.1	18.00	23.3	19.4	24.6	19.7	31.5
25	7.9	12.3	18.9	23.1	22.3	27.4	32.7	42.4
31.5	10.3	16.0	14.6	19.7	20.8	30.5	39.1	50.1
40	10.3	13.6	17.7	20.4	20.8	33.6	40.6	52.1
50	17.5	20.8	20.3	24.0	26.1	35.2	47	56.2
63	14.2	24.4	21.3	25.8	28.6	37.6	55.3	64.7
80	21.6	30.1	26.9	31.1	33.9	44.4	56.9	64.4
100	32.9	40.9	39	41.5	42.0	51.6	59.1	65.2
125	47.5	48.9	51.9	54.1	51.5	60.5	60.1	67.8
160	36.7	42.4	43.2	52.2	55.7	67.8	58.1	66
200	40.1	49.1	45.5	50.2	57.6	68.7	60.3	67.5
250	42.7	51.3	49.4	54.4	57.3	65.4	60.5	67.6
315	44.5	52.5	51.1	59.6	58.2	67.8	63	72.5
400	51.1	59.4	53.2	59.7	62.2	75.3	68.9	78.2
500	50.9	57.6	56.4	66.7	66.6	81.3	65.9	75
630	53.2	63.9	55.4	62.1	68.0	85.6	64.7	73.7
800	52.3	57.7	59.0	66.5	65.5	76.5	63.9	72.1
1000	53.3	55.8	60.0	66.2	64.7	76.2	64.8	72.6
1250	55.1	56.6	61.4	68.0	64.3	75.6	64.2	72.4
1600	54.7	58.7	61.3	66.3	64.2	74.4	64.8	73.6
2000	53.9	60.2	60.4	63.6	62.9	73.5	64	73.1
2500	54.3	61.8	58.9	61.5	61.1	70.8	63	71.7
3150	49.5	55.3	56.5	59.3	58.8	68.8	60.7	69.2
4000	46.0	52.4	54.5	59.4	56.4	65.7	59	66.8
5000	45.2	53.3	51.7	55.8	52.8	63.3	57	64.6
6300	43.3	52.9	48.5	53.8	50.1	60.3	54.6	61.6
8000	41.0	47.8	45.5	51.2	47.8	57.7	50.4	58.2
10000	37.2	44.5	41.2	49.0	44.0	55.6	46.4	54.2
12500	32.1	39.2	35.7	42.9	37.7	49.7	41.1	48.4
16000	25.0	31.9	27.9	33.9	29.7	41.0	33	40.3
20000	17.9	20.7	18.5	21.3	19.3	27.9	21	26.7
Overall Sound Pressure Level (dBA)	63.7	68.7	69.6	74.4	75.1	86.9	76.2	83.4

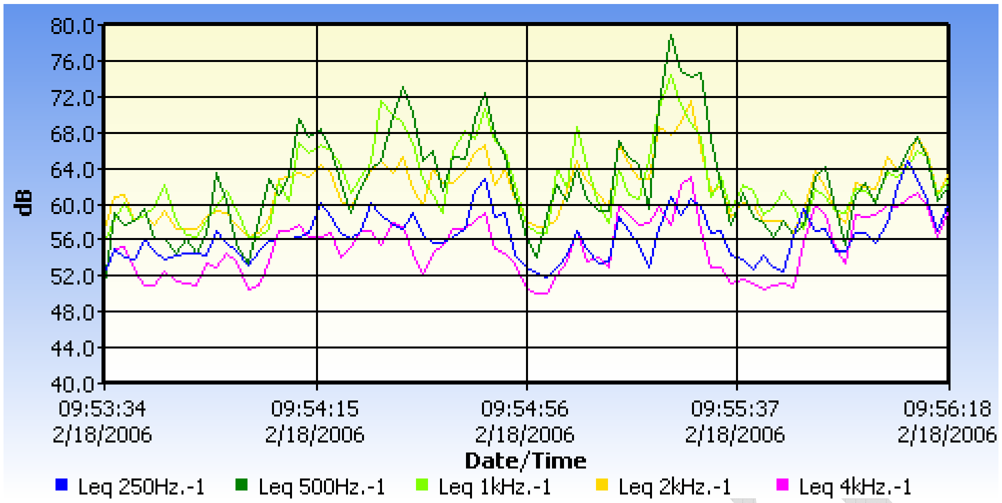


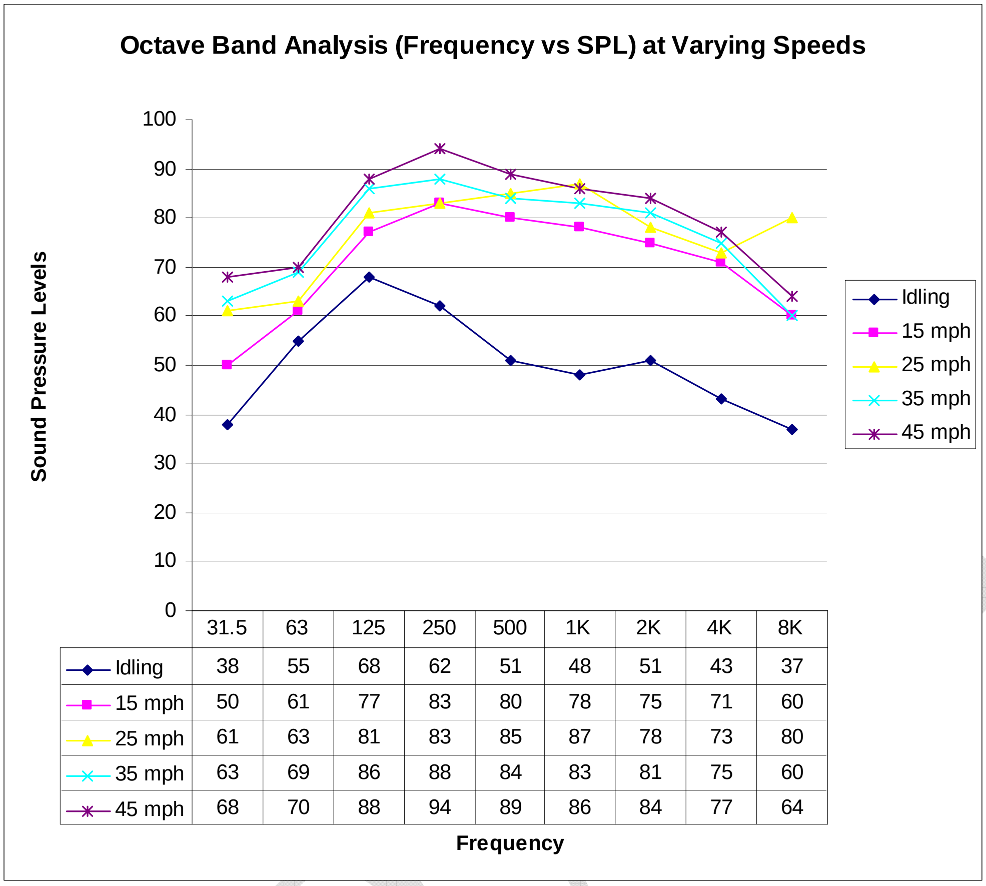
Figure 15. Fluctuation in sound pressure levels at 250 to 4,000 Hz octave band center frequencies inside kiosk A as 9 machines pass by from 9:53:34 to 9:56:18 AM.

Analysis of the acoustic spectrum data for kiosk sound sources indicates that while there is some background noise in the kiosk associated with the forced air heating system, the dominant sound source is the line of traffic passing through the kiosk lanes. The dominant octave band center frequencies for sounds inside the kiosk when snowmobile traffic passed ranged from 250 to 4,000 Hz. From observations made during the sampling period, it is reasoned that the attendant's voice also contributed to this source as he/she communicated with the snowmobile operators. The overall sound pressure levels recorded from this frequency analysis correlate well with the personal dosimetry values described in the previous section of this document. While the frequency analyses are useful in characterizing individual noise sources, the dosimeter results are crucial in determining the time-weighted dose to the kiosk attendants. The TWA personal dosimetry results should be used to make comparisons to occupational exposure limits.

ii. 4-Stroke Park Service Machine Analyses

On February 20, 2006, frequency analyses of a Park Service snowmobile were performed. A 2006 Arctic Cat 660 4-stroke machine operated by a Park Service employee was selected. The analyses included sound pressure level measurements at each octave band center frequency and were performed while the machine was idling and moving at speeds of 15, 25, 35, and 45 miles per hour (mph). The analyses were conducted on a packed snow trail.

A graph illustrating average sound pressure levels recorded at each octave band for the various speeds is presented in Figure 16. When the machine was idling, the dominant octave band frequency range was 125 Hz. The sound pressure levels measured at each octave band increased as the machine's speed increased. When the machine was moving, the dominant frequency ranges were consistently in the 125 – 500 Hz range. While the change in machine speed resulted in increased sound pressure levels, these increases occurred across the spectrum, leaving the dominant frequencies intact.



	31.5	63	125	250	500	1K	2K	4K	8K
Idling	38	55	68	62	51	48	51	43	37
15 mph	50	61	77	83	80	78	75	71	60
25 mph	61	63	81	83	85	87	78	73	80
35 mph	63	69	86	88	84	83	81	75	60
45 mph	68	70	88	94	89	86	84	77	64

Figure 16. Octave band frequency spectrum graph – 4 stroke Arctic Cat 660 at speeds from 0 – 45 mph.

On February 27, 2006, a Montana Tech graduate student conducted additional frequency analyses of a Park Service machine at Mammoth, MT. An older model (2004) 4-stroke Arctic Cat 660 was selected for these analyses. The analyses included sound pressure level measurements at each 1/3 octave band center frequency and were performed while the machine was idling and moving at speeds of 10, 15, 20, 25, 30, 35, 40, and 45 mph. The analyses were conducted on an unpacked road.

A graph illustrating average sound pressure levels recorded at each 1/3 octave band for the various speeds is presented in Figure 17. While not presented as clearly as the single octave band measurements in Figure 16, a similar pattern exists with this data. With the exception of 10 mph, the sound pressure levels measured at each 1/3 octave band increased as the machine's speed increased. Similarities in dominant frequency ranges were also noted.

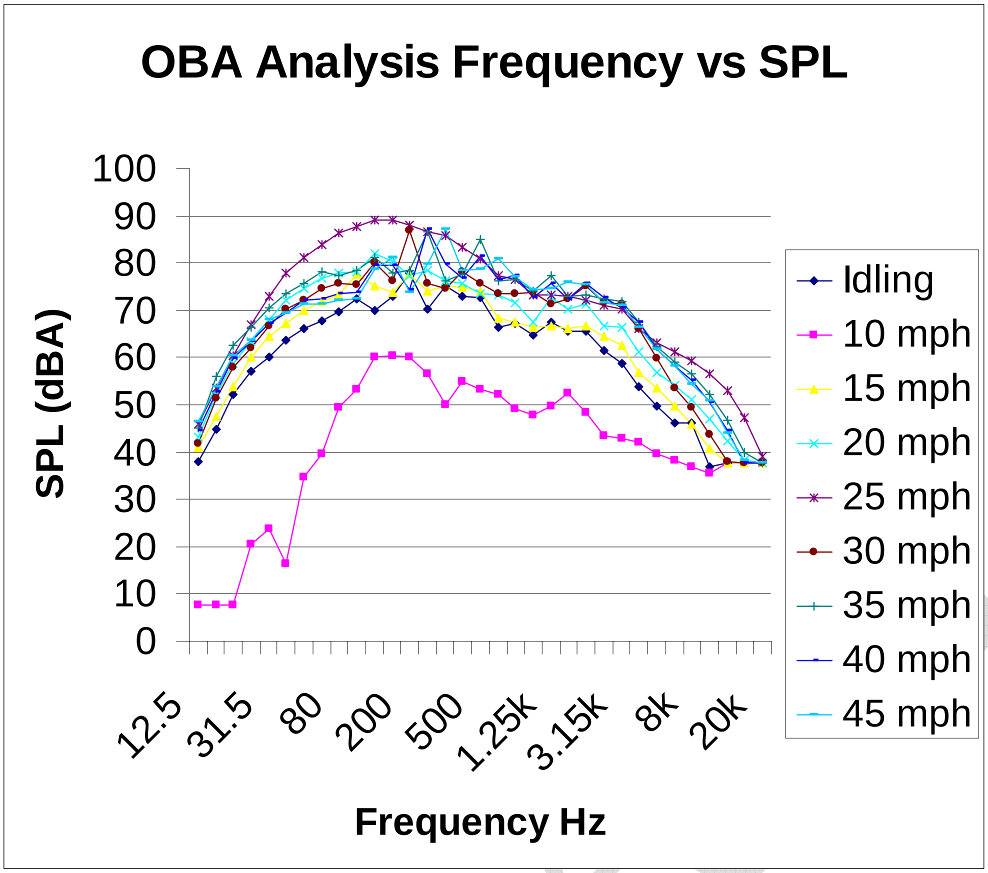


Figure 17. 1/3 octave band frequency spectrum graph – 4 stroke 2003 Arctic Cat at speeds from 0 – 45 mph.

The average overall sound pressure level measured near the operator's ear on the February 20th surveys while the machine was idling was 69 dBA. This is well within the 73 dBA or less BAT requirements for snowmobile sound emissions at idling speed. The average overall sound pressure levels measured at the operator's ear while at speeds of 15, 25, 35, and 45 mph were 87, 91, 92, and 97 dBA respectively. Similar overall sound pressure levels measured near the operator's ear were recorded for the February 27 survey. The average overall sound pressure levels measured at the operator's ear while idling and at speeds of 10, 15, 20, 25, 30, 35, 40 and 45 mph were 67, 84, 85, 89, 97, 90, 92, 91 and 92 dBA respectively. Depending on the duration of exposure and the speed at which the machine is operated, noise exposures to Park Service snowmobile operators may exceed OSHA's Hearing Conservation Amendment and Engineering Standard (29 CFR 1910.95).

Helmets are required to be worn by park employees when operating or riding as a passenger on a snowmobile in Yellowstone; they are not required for park visitors or commercial operators. The primary purpose of the snowmobile helmet is to provide impact protection; there is most likely some thermal protection as well. Helmets may also provide some degree of sound attenuation. The attenuation of two helmet models commonly used by Park Service personnel will be evaluated during the summer of 2006.

This information will be obtained by the real-ear attenuation at threshold (REAT) of hearing protection devices test method as defined by ANSI S3.19-1974,[8] ANSI S12.6-1997,[9] and ISO 4869-1:1990.[10] This forthcoming information will be valuable in further assessing snowmobile operators' noise exposure.

V. Summary of Findings of the Current Study

The focus of the current study was to evaluate occupational exposure to toxic air pollutants and noise emitted by snowmobiles and snow coaches operating in Yellowstone National Park. The sampling strategies employed were designed to assess occupational exposures through a combination of personal and area sampling. The results of the current study indicate that Park Service employee exposure to airborne contaminants associated with winter-use vehicle emissions are significantly less than established occupational exposure limits and MRLs. Integrated sampling results for aldehydes, specific BETX compounds and total hydrocarbons, and $PM_{4.0}$, $PM_{2.5}$, and PM_{10} were less than the limit of detection for the analytical methods employed. For the VOCs detected in the current study, concentrations were in the ppb range and all VOC concentrations were less than established MRLs.

A comparison between the current study and the 2005 study showed no significant differences in winter use vehicle traffic or Park Service employee exposure to aldehydes, BETX and total hydrocarbons, or respirable particulates. A comparison between the VOC concentrations obtained in the current study and the 2005 study showed that only benzene concentrations were significantly higher in the current study when compared to the 2005 study. The mean benzene concentration during the current study was 0.0032 compared to a mean concentration of 0.0011 during the 2005 survey. Both mean concentrations are well below the MRL for benzene.

A final analysis was performed to determine a correlation between VOC concentrations and number of vehicles (snowmobiles and snow coaches) entering the West Entrance. A correlation analysis was performed using VOC concentrations found during both the 2005 and 2006 surveys and the number of vehicles entering the West Entrance on the days sampling was performed. No correlation was found between VOC concentrations and number of vehicles entering the West Entrance.

The results of the current dosimetry study indicate that Park Service employee exposures to noise associated with winter-use vehicle emissions are well below OSHA's Hearing Conservation Amendment and Engineering Standard (29 CFR 1910.95). Area dosimetry samples both inside and outside the kiosks are relatively consistent between sample periods. Personal dosimetry samples were generally slightly higher than the area samples. It is reasoned that this may be a function of the additional noise contribution provided by the kiosk attendant's voice due to the close approximation of the microphone.

Frequency analyses of noise sources at the West Entrance kiosks indicate that while there is some background noise in the kiosks associated with the forced air heating system, the dominant sound source is the line of traffic passing through the kiosk lanes.

Frequency analyses of Park Service 4-stroke machines identified dominance in the 125 – 500 Hz range. Increases in machine speeds resulted in increased sound pressure levels across the spectrum. It is anticipated that helmets may provide some degree of sound attenuation. The attenuation of two helmet models commonly used by Park Service personnel will be quantified during the summer of 2006. This information will be evaluated, along with the frequency spectrum analyses data for the machines, in order to estimate Park Service employee exposures while wearing helmets.

VII. Conclusions and recommendations

A. Worker exposure to toxic air contaminants were below established occupational standards and established recommended exposure limits.

B. Worker exposure to toxic air contaminants were less than Minimal Risk Levels (MRLs) established by ATSDR excluding two short term benzene concentrations that were higher than the intermediate-duration inhalation exposure levels.

C. The results of the current study indicate that, with the exception of benzene, occupational exposures to airborne contaminants were not significantly different than results obtained during the 2005 study.

D. The number of snowmobiles entering the West Entrance during both the 2005 and 2006 studies was less than the allowable limit. An increase in snowmobile traffic to the allowable limit may increase exposures and should be evaluated.

E. Noise exposures received by employees monitoring snowmobile and snow coach traffic as it enters the West Entrance to the Park are well below both the OSHA Engineering Standard for noise exposure (90 dBA 8-hr TWA) and the OSHA Hearing Conservation Amendment (85 dBA 8-hr TWA).

F. The primary source of noise exposure to the kiosk attendants is the snowmobile and snow coach traffic as it passes through the kiosk lanes.

G. Personal exposure monitoring of Park employees for snowmobile emissions should be expanded in both time and job classes to obtain a more representative distribution of exposures.

H. Frequency analyses of Park Service BAT machines identified dominance in the 125 to 500 Hz frequency range. Increases in machine speeds generally resulted in increased sound pressure levels across the spectrum.

I. Sound attenuation provided by snowmobile helmets will be quantified during the summer of 2006. This information should be used to further evaluate snowmobile operator noise exposures.

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