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National Western Stock Show
Denver, Colorado

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PREFACE

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ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by Charles McCammon of the NIOSH Denver Field Office and Kenneth Martinez, of the Hazard Evaluations and Technical Assistance Branch, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS). Field assistance was provided by Diane Bullock, Bambi Jones, Jane McCammon, Lyle McKenzie, Michelle Heinzman, Tom Stauch, Ken Douglas, and John Martyny. Desktop publishing by Bambi Jones.

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Health Hazard Evaluation Report 96-0056-2583
National Western Stock Show
Denver, Colorado
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SUMMARY

In response to a request from the City & County of Denver, NIOSH conducted a health hazard evaluation at the National Western Stock Show (NWSS) held January 6-21, 1996 in Denver, Colorado. The request was prompted by reports of health problems repeatedly experienced by City & County employees after working at the NWSS. These health problems included a variety of allergic and flu or cold-like symptoms, such as runny nose, congestion of the nose, throat and lungs; fever, and eye irritation. These symptoms had become so commonplace that workers and visitors to the NWSS had collectively termed them the "Stock Show Crud". The request specified assistance in monitoring exposures to carbon monoxide, carbon dioxide (as an indicator of ventilation efficiency), total and respirable dust, free silica, and bioaerosols.

The National Western Stock Show is one of the top five stock shows and rodeos in the country. Approximately 500,000 visitors attend the NWSS each year. The show is held in a large multi-building complex near downtown Denver. Twenty-two rodeos occur during the two-week period of the NWSS. The stock show also includes daily stock competition for numerous breeds of cows, sheep, and hogs; competition classes for horses; and a wide variety of other activities including sheep shearing contests, wagon-drawn vehicle competitions, a petting zoo, and numerous vendor booths.

Monitoring was conducted on six different days during the two-week duration of the NWSS. On four of these days, fixed location monitoring was conducted in the three large arenas (the Coliseum, Stadium, and Event Center) and at different sites around the NWSS complex. Fixed location monitoring was conducted for carbon monoxide (CO), carbon dioxide (CO_2), temperature, humidity, total and respirable dust, respirable silica, particle counts over several size distributions, ergosterol, spore counts, and endotoxins. Portable monitors were used to sample for CO and CO_2 throughout the complex. One personal sample was collected for CO using a personal data logger.

Levels of CO, total and respirable dust, and respirable silica were all well below established evaluation criteria. Particle counts were significantly greater than those commonly found in office buildings, but less than those found in many industrial settings. Spore counts, ergosterol and endotoxin levels were all significantly elevated over background levels. Spore concentrations throughout the first floor of the Hall of Education building were 1 to 1½ orders of magnitude greater (ranging as high as 1,430,000 spores per cubic meter of air [spores/m^3] in Expo Hall 1) than background concentrations (geometric mean of 30,000 spores/m^3). This difference indicates a significant increase in the exposure potential in areas that house animal populations.

Ergosterol (an indicator for fungi) concentrations in the Hall of Education were an order of magnitude greater (ranging up to 258 nanograms per cubic meter of air [ng/m^3] in Stadium Hall 1) than background concentrations (geometric mean of 7 ng/m^3). This correlates with the spore sampling results, although larger differences were observed with the spore data. This larger disparity between the high concentration areas and background may be due to the increased sensitivity of the sampling and analytical method for fungal spores. Endotoxin concentrations in these same areas were also an order of magnitude greater (ranging up to 97 endotoxin units per cubic meter of air [EU/m^3] in Stadium Hall 1) than background concentrations (geometric mean of 3 EU/m^3). However, all of the endotoxin samples were below the criteria suggested by Rylander of 200 EU/m^3 for an 8-hour TWA.

CO_2 levels throughout the Hall of Education Complex (including the Expo Hall and Beef Palace) ranged from 625 ppm up to 4450 ppm. Levels were consistently above 1000 ppm (a criteria sometimes used to indicate ventilation efficiency) and averaged closer to 2000 ppm. The highest levels (4200-4450 ppm) were measured on a Saturday in the center of the Hall of Education building, second floor, near the vendor's exhibits. The floors were often so crowded it was difficult to move, particularly on weekends. Another area where high levels of CO_2 were consistently observed was in the Beef Palace Auction Arena. During an auction, concentrations of CO_2 averaged between 2500 to 3500 ppm. CO_2 levels in the Coliseum during the rodeos averaged between 1145 to 1490 ppm with peaks up to 2000 ppm. Levels in the Event Center averaged between 860 and 1700 ppm with most levels remaining below 1000 ppm. Average daily CO_2 levels in the Stadium were below 1000 ppm every day with only brief excursions above 1000 ppm.

Additional ventilation is recommended to dilute the levels of CO_2 and airborne biological material in the Hall of Education complex and the promenade area in the Coliseum. Additional work practice recommendations to help reduce exposures to airborne biological material are included in the Recommendation Section of this report.

High levels of carbon dioxide and elevated levels of airborne biological material (as measured by spore concentrations, ergosterol and endotoxin levels) were observed throughout the National Western Stock Show Complex. It is difficult to assess the health hazard associated with the airborne biological material since there are no established evaluation criteria for these compounds. However, the observed levels (for spore and ergosterol concentrations) are consistent with those reported in the literature that are associated with specific adverse health outcomes. Increased ventilation is recommended to reduce carbon dioxide and airborne biological material. Other recommendations are included to help further reduce airborne biological material.

Keywords: SIC 7999 (Amusement and Recreation Services, Not Elsewhere Classified), stock show, carbon dioxide, carbon monoxide, total dust, respirable dust, silica, ergosterol, endotoxin, and spores

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INTRODUCTION

On November 22, 1995 the National Institute for Occupational Safety and Health (NIOSH) received a letter from the City and County of Denver's Occupational Health/ Indoor Air Specialist requesting NIOSH's assistance in determining worker and spectator exposures during the National Western Stock Show held in Denver, Colorado January 6-21, 1996. The exposures of concern were carbon monoxide (CO), carbon dioxide (CO_2) as an indicator of ventilation efficiency, total and respirable dust, free silica, and bioaerosols.

BACKGROUND

The National Western Stock Show (NWSS) is one of the top five stock shows and rodeos in the country. Approximately 500,000 visitors attend the two-week long NWSS each year. A general layout of the NWSS grounds is shown in Figure 1. Twenty-two rodeos occur in the Denver Coliseum during the two-week period. Rodeo and associated stock are housed in the Horse Barn area west of the Coliseum. The stock show also includes daily stock competition for numerous breeds of cows, sheep, and hogs. Most of the halter shows for the cows are held in the Stadium while the sheep and hog classes are held in the Stadium Hall. Animals are housed and groomed in stalls located on the ground floor of the Hall of Education (HOE), north of the Stadium. Once the animal competitions are over, auctions are held to sell the stock. Some of the cattle auctions are held in the Beef Palace auction area, located on the first floor of the HOE on the Northwestern corner. The remaining auctions are held in a specially curtained off area on the western edge of the Stadium. Sheep and hog auctions are generally held in the Stadium Hall, at the western edge of the HOE.

The second floor of the HOE contains a wide variety of vendors selling products related to stock show animals (e.g., farm equipment, veterinary products, cowboy hats, clothing, food, etc.). The small top floor of the HOE contains a petting zoo, various small animals such as chickens, rabbits, and guinea pigs, and more vendors. The various horse shows, both halter and performance, occur in the Events Center. Horses used for these events are stabled in the Event Center Horse Barn with an overflow area on the first floor, in the eastern part of the HOE. During each day of the NWSS, a variety of events occur in each of the locations described. The three main arenas of concern in the request were the Coliseum, Stadium, and Event Center. The Event Center was constructed one year ago, while the Coliseum and Stadium were built over 40 years ago. Dirt used in these arenas is stored in a parking lot west of the Coliseum and reused each year. The dirt, consisting mostly of sand, is spread throughout the arenas prior to the NWSS; a few inches of new sand are added on the top each year. No attempt is made to remove or sterilize the animal feces that are deposited in the soil during the stock show.

Over the years, many of the Denver employees who work at the NWSS complained about feeling ill at the end of the show. This illness, referred to by the workers as the "Stock Show Crud", includes a variety of allergic and flu-or cold-like symptoms, such as runny nose, congestion of the nose, throat and lungs, fever, and eye irritation. During the 1995 NWSS, City and County of Denver employees conducted limited monitoring for CO, CO_2, and particulates. Based on this limited monitoring and the recurrence each year of the Stock Show Crud, the city requested that NIOSH conduct more extensive monitoring to determine what may be causing these symptoms.

METHODS

Carbon Monoxide
Carbon monoxide (CO) was monitored with Biosystems, Inc. Toxilog personal CO monitors equipped with electrochemical sensors. These units were set to record CO levels every 10 seconds and store the results in a data logger. At the end of the day, the data were downloaded to a computer and the results printed. The units were calibrated before the survey and periodically during the two-week NWSS run. Each unit was zeroed on outside air daily.

Carbon Dioxide
Carbon dioxide (CO_2), CO (for one of the two units), temperature and relative humidity were monitored with Metrosonics, Inc. Model AQ501 IAQ Monitors. These units were set in three main event centers (Coliseum, Stadium, and Event Center), to continuously monitor during different events. The data were stored in an internal data logger and later downloaded to a computer and printed. The units were calibrated prior to use and the CO_2 levels were checked against outside levels before use each day.

CO_2 levels were monitored throughout the NWSS complex with portable Gas Tech, Inc. Model RI-411A CO_2 Monitors. These units utilize infrared detectors for CO_2. The units were calibrated daily to 350 parts per million (ppm) of CO_2 using outside air.

Particulates
Two different real-time monitors were used to sample for airborne particulates. The first was the Grimm Model 1105 Dust Monitor (Labortechnik GmbH & CoKG, Ainring, Germany). The Grimm Dust Monitor is a light scattering aerosol spectrometer designed for real-time particulate measurement with particle size discrimination. Eight channels collect count information for particle sizes of 0.75, 1, 2, 3.5, 5, 7.5, 10, and 15 micrometers (µm). Data were collected during four separate rodeo shows to monitor the dust generated by distinct rodeo events. The monitor was mounted on the railing next to the arena floor at an approximate height of five feet. For each rodeo show, data was integrated for 1 minute (min) and stored sequentially on the Grimm data card over the entire show time period. The collected particle count and size information was downloaded to a laptop computer following the completion of the show. Start and stop times for significant rodeo events were recorded during each sample collection period.

The second particle monitor used was the MET One Laser Particle Counter. The Met One Particle counter stores the data in internal data loggers and may also be connected to printers to provide 2.5-minute averages of the particle counts at different particle size distributions. Two different Met One units were used; one provided particle counts at cut points of 0.3 µm and 5.0 µm. The other unit gave cut points of 0.5, 1.0, 2.0, 5.0, and 10.0 µm. These cut points provided counts of particles that were in the air with sizes in the range of 0.5-1.0 µm, 1.0-2.0 µm, etc.

Respirable Dust and Crystalline Silica
Air samples for respirable dust and crystalline silica were collected at 1.7 liters per minute (Lpm) on pre-weighed PVC membrane filters. Prior to collection onto the filters, 10-mm nylon cyclones were used to remove all airborne dust except the respirable fraction. Gilian Model HFS 113D personal sampling pumps were used to collect the samples. Respirable dust levels were quantified by weighing the filters after sampling to determine the amount of airborne dust that was in the respirable range. These same filters were then analyzed for quartz and cristobalite (crystalline silica) content using X-ray diffraction according to NIOSH Analytical Method #7500.[1]

Microbiologic Aerosols

To determine area concentrations of airborne fungi and Gram-negative bacteria at various Coliseum locations, air was drawn through filters, via flexible Tygon® tubing, with Gilian® Model HFS 513A high flow personal sampling pumps. Two distinct methods of sampling and analysis were used for the collection of fungal particles. In the first method, airborne fungal spores were collected on a 37-millimeter (mm) mixed cellulose ester (MCE) filter at a calibrated flow rate of 2 Lpm with subsequent optical microscopic analysis. Each filter sample was analyzed according to a modification of NIOSH Method 7400.[1] One quarter of each filter sample was cleared with acetone vapor and mounted in a phloxine-alcohol-glycerin mounting medium. (Phloxine is a biological dye that stains fungal spores pink.) The prepared slide was allowed to sit over night or was heated gently to enhance staining before reading. Slide samples were scanned (200 fields per sample) at 400x magnification using bright field or phased contrast illumination. Only particles greater than 2 µm in diameter were considered as possible fungal spores. In the second method, samples for ergosterol were collected through a 25-mm, 0.2-µm polytetrafluoroethylene (PTFE) filter at a calibrated flow rate of 1.5 Lpm. (Ergosterol is a component of fungal membranes and has been used as an indicator of biomass.[2,3,4]) The recovery of ergosterol from each filter sample was facilitated with methylene chloride. Filter extracts were analyzed by high performance liquid chromatography with an ultraviolet detector set at 282 mm. In an analytical column of Adsorbosphere C18 (Alltech 28015) with octadecyl silane (C18) chemically bonded to 3 µm silica particles, ergosterol eluted at 3.3 minutes using a flow rate of 1 milliliter per minute (ml/min).

Samples for endotoxin (a cell wall constituent of Gram-negative bacteria) were collected on a 37-mm polyvinyl chloride (PVC) filter at a calibrated flow rate of 2 liters per minute (Lpm). Each filter sample was analyzed gravimetrically (NIOSH Method 0500[1]) and subsequently placed into 50 ml conical centrifuge tubes. Ten milliliters (ml) of sterile, pyrogen-free water (LAL Reagent Water, BioWhittaker Inc., Walkerville MD) was added to each tube. The filter samples were gently rocked at room temperature for approximately 60 minutes. Each supernate was then decanted in a 15 ml centrifuge tube and centrifuged for 10 min at 2200 revolutions per minute (rpm) at 4˚C. From each tube, 3 ml of the supernatant fluid was recovered, place in a sterile vial, and stored at -85˚C until analyzed. The samples were assayed for endotoxin content using the Kinetic-QCL Assay Kit (BioWhittaker, Walkerville, MD) according to the manufacturer's recommended procedure.

EVALUATION CRITERIA

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for the assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects even though their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or a hypersensitivity (allergy). In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce adverse health effects even if the occupational exposures are controlled at the level set by the criteria. These combined effects are often not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and potentially increasing the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

The primary sources of environmental evaluation criteria for the workplace are: (1) NIOSH Recommended Exposure Limits (RELs)[5] (2) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLVs™)[6] and (3) the U.S. Department of Labor, OSHA Permissible Exposure Limits (PELs)[7]. In July 1992, the 11th Circuit Court of Appeals vacated the 1989 OSHA PEL Air Contaminants Standard. OSHA is currently enforcing the 1971 standards which are listed as transitional values in the current Code of Federal Regulations; however, some states operating their own OSHA approved job safety and health programs continue to enforce the 1989 limits. NIOSH encourages employers to follow the 1989 OSHA limits, the NIOSH RELs, the ACGIH TLVs, or whichever are the more protective criteria. The OSHA PELs reflect the feasibility of controlling exposures in various industries where the agents are used, whereas NIOSH RELs are based primarily on concerns relating to the prevention of occupational disease. It should be noted when reviewing this report that employers are legally required to meet those levels specified by an OSHA standard and that the OSHA PELs included in this report reflect the 1971 values.

A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8-to-10-hour workday. Some substances have recommended short-term exposure limits (STEL) or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from higher exposures over the short-term.

1. Indoor Environmental Quality

Indoor environmental quality (IEQ) is affected by the interaction of a complex set of factors which are constantly changing. Four elements involved in the development of IEQ problems are:

- sources of odors or contaminants,
- problems with the design or operation of the HVAC system,
- pathways between contaminant sources and the location of complaints,
- and the activities of building occupants.

A basic understanding of these factors is critical to preventing, investigating, and resolving IEQ problems.

The symptoms and health complaints reported to NIOSH by non-industrial building occupants have been diverse and usually not suggestive of any particular medical diagnosis or readily associated with a causative agent. A typical spectrum of symptoms has included headaches, unusual fatigue, varying degrees of itching or burning eyes, irritation of the skin, nasal congestion, dry or irritated throats and other respiratory irritations. Usually, the workplace environment has been implicated because workers report that their symptoms lessen or resolve when they leave the building.

A number of published studies have reported a high prevalence of symptoms among occupants of office buildings.[8-12] Scientists investigating indoor environmental problems believe that there are multiple factors contributing to building-related occupant complaints.[13,14] Among these factors are imprecisely defined characteristics of HVAC systems, cumulative effects of exposure to low concentrations of multiple chemical pollutants, odors, elevated concentrations of particulate matter, microbiological contamination, and physical factors such as thermal comfort, lighting, and noise.[15-20] Indoor environmental pollutants can arise from either outdoor sources or indoor sources.

There are also reports describing results which show that occupant perceptions of the indoor environment are more closely related to the occurrence of symptoms than to any measured indoor contaminant or condition.[21-23] Some studies have shown relationships between psychological, social, and organizational factors in the workplace and the occurrence of symptoms and comfort complaints.[23–26]

Less often, an illness may be found to be specifically related to something in the building environment. Some examples of potentially building-related illnesses are allergic rhinitis, allergic asthma, hypersensitivity pneumonitis, Legionnaires' disease, Pontiac fever, carbon monoxide poisoning, and reaction to boiler corrosion inhibitors. The first three conditions can be caused by various microorganisms or other organic material. Legionnaires' disease and Pontiac fever are caused by *Legionella* bacteria. Sources of carbon monoxide include vehicle exhaust and inadequately ventilated kerosene heaters or other fuel-burning appliances. Exposure to boiler additives can occur if boiler steam is used for humidification or is released by accident.

Problems NIOSH investigators have found in the non-industrial indoor environment have included poor air quality due to ventilation system deficiencies, overcrowding, volatile organic chemicals from furnishings, machines, structural components of the building and contents, tobacco smoke, microbiological contamination, and outside air pollutants; comfort problems due to improper temperature and relative humidity (RH) conditions, poor lighting, and unacceptable noise levels; adverse ergonomic conditions; and job-related psychosocial stressors. In most cases, however, these problems could not be directly linked to the reported health effects.

Standards specifically for the non-industrial indoor environment do not exist. NIOSH, the Occupational Safety and Health Administration (OSHA), and the American Conference of Governmental Industrial Hygienists (ACGIH) have published regulatory standards or recommended limits for occupational exposures.[4-6] With few exceptions, pollutant concentrations observed in non-industrial indoor environments fall well below these published occupational standards or recommended exposure limits. The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) has published recommended building ventilation design criteria and thermal comfort guidelines.[27,28] The ACGIH has also developed a manual of guidelines for approaching investigations of building-related complaints that might be caused by airborne living organisms or their effluents.[29]

Measurement of indoor environmental contaminants has rarely been helpful in determining the cause of symptoms and complaints except where there are strong or unusual sources, or a proven relationship between contaminants and specific building-related illnesses. The low-level concentrations of particles and mixtures of organic materials commonly found are difficult to interpret and usually impossible to causally link to observed and reported health symptoms. However, measuring ventilation and comfort indicators such as CO_2, temperature, and RH, has proven useful during the early stages of an investigation in providing information relative to the proper functioning and control of HVAC systems. The basis for measurements made during this evaluation are listed below.

Carbon Dioxide

Carbon dioxide (CO_2) is a normal constituent of exhaled breath and, if monitored, may be useful as a screening technique to evaluate whether adequate quantities of fresh air are being introduced into an occupied space. The ASHRAE Standard 62-1989, Ventilation for Acceptable Indoor Air Quality, recommends outdoor air supply rates of 20 cubic feet per minute per person (cfm/person) for

office spaces and conference rooms, and 15 cfm/person for reception areas, and provides estimated maximum occupancy figures for each area.[27]

Indoor CO_2 concentrations are normally higher than the generally constant ambient CO_2 concentration (range 300-350 ppm). When indoor CO_2 concentrations exceed 1000 ppm in areas where the only known source is exhaled breath, inadequate ventilation is suspected. Elevated CO_2 concentrations suggest that other indoor contaminants may also be increased.

Temperature and Relative Humidity

The perception of comfort is related to one's metabolic heat production, the transfer of heat to the environment, physiological adjustments, and body temperatures. Heat transfer from the body to the environment is influenced by factors such as temperature, humidity, air movement, personal activities, and clothing. ANSI/ASHRAE Standard 55-1981 specifies conditions in which 80% or more of the occupants would be expected to find the environment thermally comfortable.[28]

2. Carbon Monoxide

Carbon monoxide (CO) is a colorless, odorless, tasteless gas produced by incomplete burning of carbon-containing materials; e.g., natural gas. The initial symptoms of CO poisoning may include headache, dizziness, drowsiness, and nausea. These initial symptoms may advance to vomiting, loss of consciousness, and collapse if prolonged or high exposures are encountered. Coma or death may occur if high exposures continue.[30,31]

The NIOSH REL for CO is 35 ppm for an 8-hour TWA exposure, with a ceiling limit of 200 ppm which should not been exceeded.[5] The NIOSH REL of 35 ppm is designed to protect workers from health effects associated with carboxy-hemoglobin (COHb) levels in excess of 5%.[5] The ACGIH recommends an eight-hour TWA TLV of 50 ppm, with a ceiling level of 400 ppm. Currently, the ACGIH has published a notice of an intent to change the TLV to 25 ppm as an eight-hour TWA.[6] The OSHA PEL for CO is 50 ppm for an 8-hour TWA exposure. In addition to these standards, the National Research Council has developed a CO exposure standard of 15 ppm, based on a 24 hours per day, 90-day TWA exposure.[32]

3. Microbial Contaminants

Microorganisms (including fungi and bacteria) are normal inhabitants of the environment. The saprophytic varieties (those utilizing non-living organic matter as a food source) inhabit soil, vegetation, water, or any reservoir that can provide an ample supply of a nutrient substrate. Under the appropriate conditions (optimum temperature, pH, and with sufficient moisture and available nutrients) saprophytic microorganism populations can be amplified. Through various mechanisms, these organisms can then be disseminated as individual cells or in association with soil/dust or water particles. In the outdoor environment, the levels of microbial aerosols will vary according to the geographic location, climatic conditions, and surrounding activity. In a "normal" indoor environment, the level of microorganisms may vary somewhat as a function of the cleanliness of the HVAC system and the numbers and activity level of the occupants. Generally, the indoor levels are expected to be below the outdoor levels (depending on HVAC system filter efficiency) with consistently similar ranking among the microbial species.[34,35]

Some individuals manifest increased immunologic responses to antigenic agents encountered in the environment. These responses and the subsequent expression of allergic disease is based, partly, on a genetic predisposition.[36] Allergic diseases typically associated with exposures in indoor environments include allergic rhinitis (nasal allergy), allergic asthma, allergic bronchopulmonary aspergillosis (ABPA), and extrinsic allergic alveolitis (hypersensitivity pneumonitis).[33] Allergic respiratory diseases resulting from exposures to microbial agents have been documented in agricultural, biotechnology, office, and home environments.[37-44]

Individual symptomatology varies with the disease. Allergic rhinitis is characterized by paroxysms of sneezing; itching of the nose, eyes, palate, or pharynx; nasal stuffiness with partial or total airflow obstruction; and rhinorrhea (runny nose) with postnasal drainage. Allergic asthma is characterized by episodic or prolonged wheezing and shortness of breath in response to bronchial (airways) narrowing. Allergic bronchopulmonary aspergillosis is characterized by cough, lassitude, low-grade fever, and wheezing.[33,45] Heavy exposures to airborne microorganisms can cause an acute form of extrinsic allergic alveolitis which is characterized by chills, fever, malaise, cough, and dyspnea (shortness of breath) appearing four to eight hours after exposure. In the chronic form, thought to be induced by continuous low-level exposure, onset occurs without chills, fever, or malaise and is characterized by progressive shortness of breath with weight loss.[46]

Acceptable levels of airborne microorganisms have not been established, primarily because allergic reactions can occur even with relatively low air concentrations of allergens, and individuals differ with respect to immunogenic susceptibilities. The current strategy for on-site evaluation of environmental microbial contamination involves an inspection to identify sources (reservoirs) of microbial growth and potential routes of dissemination. In those locations where contamination is visibly evident or suspected, bulk samples may be collected to identify the predominant species (fungi, bacteria, and thermoactinomycetes). In limited situations, air samples may be collected to document the presence of a suspected microbial contaminant. Air sample results can be evaluated epidemiologically by comparing those from the "complaint areas" to those from non-complaint areas, or by relating exposure to immunologic findings.

4. Bacterial Endotoxin

A bacterial endotoxin is a lipopolysaccharide compound from the outer cell wall of gram-negative bacteria, which occur abundantly in organic dusts.[47] It has been shown that the biological properties of endotoxin vary depending upon the bacterial species from which they are derived, as well as upon the state of the growth cycle of the bacteria.[48] Endotoxins have a wide range of biological activities involving inflammatory, hemodynamic, and immunological responses. Of most importance to occupational exposures are the activities of endotoxin in the lung.[49] The primary target cell for endotoxin-induced damage by inhalation is the pulmonary macrophage. Human macrophages in particular have been shown to be extremely sensitive to the effects of endotoxin in vitro.[50] Endotoxin, either soluble or associated with particulate matter, will activate the macrophage, causing the cell to produce a host of mediators.[49]

Clinically, little is known about the response to inhaled endotoxins. Exposure of previously unexposed persons to airborne endotoxin can result in acute fever, dyspnea, coughing, and small reductions in forced expiratory volume in one second (FEV_1), although some investigators have not been able to demonstrate acute changes in FEV_1.[49] The effects of repeated exposure to aerosols of endotoxins in humans are not known. Some animal studies have demonstrated a chronic inflammatory

response characterized by goblet cell hyperplasia and increased mucous production. This suggests that repeated exposure may cause a syndrome similar, if not identical, to chronic bronchitis.[49]

Occupational exposure criteria have not been established for bacterial endotoxin by either OSHA, NIOSH, or ACGIH. However, Jacobs has reported that a sufficient toxicological data base is believed to exist for establishing an occupational limit for endotoxin based on acute changes in pulmonary function.[49] Eight-hour (8-hr) TWA concentrations have been suggested for over-shift decline in FEV_1 (100 - 200 ng/m^3), for chest tightness (300 - 500 g/m^3), and for fever (500 - 1,000 ng/m^3).[48]

An 8-hr TWA threshold for airborne endotoxin of 10 ng/m^3 has also been suggested based on a decline in FEV_1 for individuals sensitized to cotton dust.[51] The exposure system for the study from which this recommendation was made consisted of a commercial carding machine in a cardroom, an exposure room, and connecting duct work. Airborne dust concentrations were determined in the exposure room using four vertical elutriators.[51] The vertical elutriator has traditionally been the instrument of choice for cotton dust sampling because it will not collect cotton fly lint fibers and dust particles with an aerodynamic mass medial diameter larger than 15 µm.[52]

5. Silica (Quartz, Cristobalite)

Crystalline silica (quartz) and cristobalite have been associated with silicosis, a fibrotic disease of the lung caused by the deposition of fine particles of crystalline silica in the lungs. Symptoms usually develop insidiously, with cough, shortness of breath, chest pain, weakness, wheezing, and non-specific chest illnesses. Silicosis usually occurs after years of exposure, but may appear in a shorter period of time if exposure concentrations are very high.[53] The NIOSH RELs for respirable quartz and cristobalite, published in 1974, are 50 µg/m^3, as TWAs, for up to 10 hours per day during a 40-hour work week.[54] These RELs are intended to prevent silicosis. However, evidence indicates that crystalline silica is a potential occupational carcinogen and NIOSH is currently reviewing the data on carcinogenicity.[55-57] The OSHA PELs and the ACGIH TLVs™ for respirable quartz and cristobalite are 100 and 50 µg/m^3, as 8-hour TWAs, respectively.[5,6]

RESULTS

1. Respirable and Total Dust; Free Silica

Air samples collected in the Stadium, Coliseum, and Event Center for respirable and total dust were all very low, with over fifty percent of the samples below the limit of detection (0.02 milligrams/sample). The highest level measured for respirable dust was 0.27 mg/m^3. All samples were well below the OSHA PEL of 5 mg/m^3 as a TWA for respirable dust. All but one of the samples for total dust were below 1 mg/m^3. One sample, collected in the Hall of Education 1 East, was 1.5 mg/m^3. All samples were well below the ACGIH TLV of 10 mg/m^3 and the OSHA PEL of 15 mg/m^3 for total dust.

Air samples for respirable free silica were all below the limit of detection for quartz (0.01 mg/sample) and cristobalite (0.02 mg/sample). In fact, 70% of the air samples did not have enough collected mass to conduct the analysis. Bulk analysis of sand from the various arenas had previously been analyzed and found to contain 49% (Coliseum), 45% (Stadium), and 61% (Event Center) crystalline quartz.

2. Carbon Dioxide (CO_2)

Tables I-IV contain summaries of CO_2 levels measured throughout the NWSS grounds. Table I contains a summary of levels in the Hall of Education building; Table II summarizes CO_2 levels in the Event Center; Table III in the Stadium; and Table IV the Coliseum. Additional CO_2 data are summarized in Figures 2-4 which contain selected printouts of the Metrosonic datalogger results of fixed point sampling during specific events. Table V contains a summary of these fixed point CO_2 measurements.

CO_2 levels throughout the Hall of Education Complex (including the Expo Hall and Beef Palace) ranged from 575 ppm up to 4450 ppm (Table I). Levels were consistently above 1000 ppm and averaged closer to 2000 ppm. The highest levels (4200-4450 ppm) were measured on a Saturday in the center of the Hall of Education building, second floor, near the vendor's exhibits. The floors were often so crowded that it was difficult to move. This was particularly true on weekends. Another area where high levels of CO_2 were consistently observed was in the Beef Palace Auction Arena. Levels of CO_2 during an auction averaged 2500 to 3500 ppm.

The fixed point monitoring data (Table V and Figures 2-4) shows that CO_2 levels in the different arenas were lower than those found throughout the Hall of Education building. CO_2 levels during the rodeos averaged between 1145 to 1490 ppm with peaks up to 2000 ppm. Levels in the Event Center averaged between 860 and 1700 ppm. For most days, levels remained below 1000 ppm with the exception of 1-19-96 (see Figure 4). On this day, the weather was mild and there was little demand for heating or cooling. Around noon on this day, the ventilation system came on and the CO_2 levels quickly dropped below 1000 ppm. CO_2 levels in the Stadium averaged below 1000 ppm every day with only brief excursions above 1000 ppm.

3. Carbon Monoxide (CO)

In general, CO levels were very low, with most areas recording 1-3 ppm of CO at the most. Occasionally, gas-powered vehicles were encountered and brief CO spikes would be recorded. For example, during the rodeo and after events in the other arenas, trucks or tractors would be driven into the arena to drag the grounds or to bring in or remove equipment. Some of the tractors were diesel powered and had very little or no CO emissions. If the vehicles were gas-powered, a brief CO spike was recorded. The highest level was a peak of 125 ppm which lasted for only a minute. The peak was noted when the person carrying the monitor walked behind an operating gas powered car in the food area between the Stadium and the Coliseum.

Table V contains summaries of CO monitoring data collected at fixed sampling locations in the Coliseum, Stadium, and Event Center. During most of the events, short-term peak concentrations of CO up to 33 ppm were measured. However, the average levels over the entire performance were all below 8 ppm. The brief peaks were all related to gas-powered vehicles entering the arenas. The STEL values are the highest 15-minute average over the monitoring period. The STELs ranged from 0 to 12 ppm.

Figure 5 shows a graph of CO levels measured in the breathing zone of a worker who drove a propane-powered sweeper during the evenings throughout the Hall of Education. The average CO reading for the entire evening period (4:30 pm to 9:30 am) was 5 ppm with a peak of 75 ppm. This was the only personal sample collected for CO.

All of the TWA, STEL and Ceiling levels of CO measured were below the applicable OSHA, NIOSH and ACGIH limits.

4. Bioaerosols

Graphical summaries of the sampling results for spores, ergosterol, and endotoxins are presented in Figures 6-8. Sampling results are presented as geometric means calculated over four survey days with I-bars indicating minimum and maximum values. Observed trends for each analyte appear consistent across sample locations. The lowest concentrations for spores, ergosterol, and endotoxins were found in the Hall of Education (3rd Floor), the Horse Event Center, and the Security Office in the Coliseum. (The Security Office was selected as a control location with which to compare to other sampled areas.) The highest concentrations for all three analytes were found in Expo Hall 1, Hall of Education 1 West, and Stadium Hall 1. Expo Hall 1 served as a horse paddock area; the Hall of Education 1 West stabled cattle; and Stadium Hall 1 was used for various competitions for small animals such as hog shows, sheep shearing, and miniature horse shows. The relative concentrations were consistent with factors such as level of activity, quantity of animals per area, and level and type of ventilation.

5. Particle Counts

Graphical summaries of the sampling results from real-time particulate measurements from the Grimm monitors are presented in Figures 9-12. Graphical summaries from the MetOne particle counters are presented in Figures 13-19 and are very similar to the data in Figures 9 and 10. Particle counts varied considerably during a specific event. Overall counts were higher than those reported in indoor studies but still low when compared with industrial exposures.

DISCUSSION

Respirable and total dust and silica exposures were below the established criteria levels. Particle counts reflected a wide range of particle levels at different size distributions, mostly correlating with specific events in the arenas. For example, elevated particle counts at all size distributions were measured when the Westernaire performance group had 30-40 horses galloping around the arena. During the bull riding or horse (bareback and saddle) riding, levels spiked considerably whenever the animals came close to the measurement area on the fence. However, the overall dust levels remained below established criteria.

CO levels were consistently below the most stringent evaluation criteria (25 ppm as a TWA). Occasional high levels of CO were measured when gas-powered vehicles were driven into one of the arenas. Prior to the start of the NWSS, while walking through the Stadium area, consistent levels of 40 ppm CO with spikes over 150 ppm were measured while two trucks were preparing the sand. During the NWSS, gas-powered vehicles were not driven inside the arenas for long periods of time. Consequently, high levels of CO were not observed. The only sustained exposure to CO was to the worker who drove a propane-powered sweeper throughout the Hall of Education every evening (Figure 5). However, this worker's average full-shift exposure was only 5 ppm of CO.

The spore concentrations observed in Expo Hall 1, Hall of Education 1 West, and Stadium Hall 1 were 1-1½ orders of magnitude greater (ranging as high as 1,430,000 spores per cubic meter of air [spores/m^3] in Expo Hall 1) than those observed in the Security Office (geometric mean of 30,000 spores/m^3). This difference

indicates a significant increase in the exposure potential in areas that house animal populations. These values are consistent with a Swedish study of farm workers in 28 swine confinement houses that reported a mean concentration of 20,000 spores/m^3.[58] In another study of Finnish farmers (diagnosed with farmer's lung) handling hay, straw, or grain, mean spore concentrations ranging from 50,000 to 2,700,000 spores/m^3 were reported.[59]

Ergosterol (an indicator of fungi) concentrations in these areas were an order of magnitude greater (ranging up to 258 nanograms per cubic meter of air [ng/m^3] in Stadium Hall 1) than the levels in the Security Office (geometric mean of 7 ng/m^3). This correlates with the spore sampling results, although larger differences were observed with the spore data. The greater disparity for spores between the high concentration areas and the Security Office may in large part be due to the increased sensitivity of the sampling and analytical method for fungal spores. Endotoxin concentrations in these areas were also an order of magnitude greater (ranging up to 97 endotoxin units per cubic meter of air [EU/m^3] in Stadium Hall 1) than the levels measured in the Security Office (geometric mean of 3 EU/m^3). However, all of the endotoxin samples were below the criteria suggested by Rylander of 200 EU/m^3 for an 8-hour TWA.[48] The activities that contributed to these elevated levels included washing and blow drying the animals in preparation for being shown; using large fans throughout the first floor of the Hall of Education to keep the animals cool; large numbers of people moving through the area disturbing the highly biologically active dust on the floor; and constant cleaning of old straw and animal feces from the area. The Expo Hall 1 area is on the first floor of the Hall of Education (HOE) building and was used to stable horses. This area had some of the highest spore counts, ergosterol and endotoxin levels. The level of activity was less in this area as compared to the HOE 1 East and West, yet the measures of biological activity were higher. This may be due to the presence of a concrete floor in this area as compared to a dirt floor in the rest of the building. The hard surface of the concrete floors and the high volume of foot traffic across the surface could result in more dust being caused to be airborne than in the dirt floor areas. The dirt floors were also kept moist in order to reduce dust. Another point of concern regarding the very high levels of biological agents in the Hall of Education complex is that most of the area samples were collected high off the ground (6-7 feet) for sample security reasons. These samples were well above the breathing zone of people in these areas. Therefore, the actual exposures may be even higher than the samples indicate.

The areas with the highest levels of biological agents contained much stronger odors. While the odors themselves may not cause health problems, they are indicators of a lack of good general ventilation. One high odor area that was frequently mentioned by city workers was near the Clydesdale area in the Coliseum. The Budweiser Clydesdale team was stabled on the ground floor on the northeast portion of the Coliseum at the foot of a stairway. Ammonia odors were quite strong in the stairway area approaching the Clydesdale stables where public viewing was allowed. There was little air movement in this area. Air flow in general in this area came from the Coliseum horse barn into the paddock area and then into the Coliseum itself. On windy days, when the western most doors into the horse barn were left open, air flow was quite gusty from the horse barn into the Coliseum. The horse barn area contained relatively high levels of biological agents (see samples labeled Coliseum Horse Paddock in Figures 6-8) and strong odors and air from this area was blown into the Coliseum itself. An odor control system had been installed in the bay door area between the horse barn and the paddock. The odor control agent was called Get the Odor Out and was automatically misted into the air. The only hazardous ingredient listed in the MSDS was a stabilized chlorine peroxide. No health problems were reported from the use of this material. Workers who had been in the areas prior to the odor control system being installed (prior to the 95-96 show) thought the system helped.

Employees in the First Aid station in the Coliseum were interviewed to determine what types of health problems were being reported during the NWSS. Most of the reports were for allergy problems (eye irritation and redness or watering of the eyes, runny nose, sneezing, etc.) or asthma. Fourteen people with asthma

reported to the First Aid station on one Saturday. These were individuals with pre-existing asthma conditions who had an attack during the stock show. Many of these people reported allergies to animals. The high biological activity documented with the spore counts, ergosterol, and endotoxin may have contributed to these problems.

The CO_2 levels in many places in the NWSS complex indicate the need for additional ventilation to handle the large numbers of people and animals. This is especially true in the Hall of Education complex. The areas with the highest levels of CO_2 were the Beef Palace Auction Arena and most of the Expo Hall during weekend crowding. At any area where large numbers of people gathered, such as the main second floor entrance to the Expo Hall from the Stadium, high levels of CO_2 (>2000 ppm) were consistently measured. Areas where high levels of ergosterol, spore counts, and endotoxin were found were also areas where elevated CO_2 levels were measured. On most days during the NWSS, the outside bay doors were open into the first floor of the Hall of Education (where cattle are stabled). However, if the outside doors could not be opened due to weather, which often occurs in January, the air quality conditions would worsened appreciably. Another area that consistently had high levels of CO_2 was in the promenade area of the Coliseum. This area was crowded with vendors and people most of the time. Most of the ventilation in the Coliseum was concentrated on the arena itself, not the promenade.

The effectiveness of ventilation in reducing CO_2 levels, and concurrently lowering temperature, relative humidity, particulate levels and CO, is illustrated in Figures 4 and 16. These data were collected in the Event Center on Jan 19. Levels of CO_2, CO and particle counts (see Figure 16) rose slowly throughout the morning. At approximately 11:00 am, the ventilation system started operating (as reported by the person watching the equipment in the Event Center), and levels of all these contaminants dropped. CO_2 levels decreased from a high of 2800 ppm to below 1000 ppm in about 2 hours. Similar trends were observed for the other contaminants such as particle counts (Figure 12). This was also observed on January 12 in the Event Center (Figure 3) when CO_2 levels reached a high of 1500 ppm at 11:00 am and dropped to a level of approximately 850 ppm where it remained for the rest of the day.

CONCLUSIONS

Respirable and total dust levels, silica levels and CO concentrations were observed to be below the recommended criteria levels. Biological activity, as measured by ergosterol, spore counts and endotoxin levels, was elevated on the first floor of the Hall of Education and in the Stadium Hall. These are areas where high numbers of animals were housed and cleaned for show. Strong odors of animals, molds, etc. were associated with these areas. It is difficult to draw specific conclusions about the health implications of elevated levels of the ergosterol, spore counts, and endotoxin. There are no specific evaluation criteria against which to measure these levels other than the research studies quoted. However, the observed levels of spore counts and ergosterol were significantly above background levels and were at levels that are consistent with those seen in other studies where adverse health effects were observed.

CO_2 levels throughout the Hall of Education complex were well above 1000 ppm (a criteria sometimes used to indicate ventilation efficiency), averaging above 2000 ppm and ranging up to 4300 ppm. These levels of CO_2 indicate the need for additional outside air ventilation throughout the complex to help lower the levels of airborne bioaerosols and control odors. CO_2 levels in the promenade area around the Coliseum were also consistently high. Additional outside air ventilation is therefore indicated around the promenade. The

ventilation system in the Event Center should be adjusted to introduce outside air (outside air dampers set at a minimum setting of 20%) for dilution prior to a certain preset time.

RECOMMENDATIONS

1. Although elevated CO levels were not documented *during* the NWSS, levels monitored *prior* to the show were high. Likewise, it is anticipated that CO levels during the dismantling of the show will also be high. Therefore, electric or natural gas-powered vehicles are recommended when such vehicles are required to be inside any of the buildings, particularly the Hall of Education building. Propane-powered vehicles can emit significant CO levels if they are not properly maintained, so they are not generally recommended for use inside buildings.

2. Increased outside air ventilation is recommended for the Hall of Education complex, which includes the Expo Hall, the Beef Palace, and the Stadium Hall. Evaporative coolers, equipped with fans, exist throughout the Hall of Education and could be used (without the cooling cycle on) to bring outside air into the building. This may not be sufficient to provide the amount of air needed to correct the problem. It is recommended that the buildings be engineered to meet the ASHRAE Guidelines 62-1989.[27]

3. The ventilation system in the Event Center should be adjusted to also meet the ASHRAE Guidelines. The system is relatively new and has demonstrated that it can effectively control contaminants if working properly.

4. The high levels of spore counts, ergosterol and endotoxin are of concern but represent an unknown health hazard. Increased dilution ventilation should lower the exposure potential. Steps should be taken to reduce the source of these contaminants. Frequent cleaning of animal stalls and contaminated bedding is recommended. Most areas on the first floor of the Hall of Education were kept fairly clean to keep the animals clean for show. However, animal stalls in the horse barn in the Coliseum appeared to be cleaned less frequently. Light application of moisture, particularly in areas with concrete floors, should help reduce the dust in these areas. This would be especially effective if performed just before the floors are swept. If drains are present, rinsing these areas with water would be a preferred method of floor cleaning. The promenade area of the Coliseum had been cleaned in the past with an oil-treated cleaning compound (usually sawdust). This practice had been discontinued and only dry sweeping was done. Use of the sweeping compound would help reduce dust during cleaning.

5. The effectiveness of any ventilation changes and the general air quality in the various buildings, should be monitored periodically with CO^2 meters.

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Table I

Summary of Carbon Dioxide Levels

National Western Stock Show

HALL OF EDUCATION COMPLEX

HETA 96-0052

DATE	LOCATION	TIME	CONCENTRATION (ppm)
Jan. 10	EH2-Entry	1200	1300
Jan. 10	EH2-Center	1205	1875
Jan. 10	EH1-Aisle 12	1210	850
Jan. 10	EH1-Aisle 8	1240	1000
Jan. 10	EH1-Aisle 5	1245	1100
Jan. 10	EH1-BP-Entry	1250	2400
Jan. 10	BP-NW Entry	1300	1500
Jan. 10	BPAA-NE Entry	1305	2800
Jan. 10	BPAA-SE Entry	1315	2650
Jan. 10	EH2-Food Area	1420	1425
Jan. 10	EH2-Aisle 1900	1422	1400
Jan. 10	EH2-Restaurant West Door	1430	2000
Jan. 10	EH2-Restroom	1435	1750
Jan. 10	EH2-Southside Aisle 1000	1445	1875
Jan. 10	EH1-West	1512	2150
Jan. 10	EH-BP-top	1515	3350
Jan. 10	EH-BP-top	1517	3475
Jan. 10	EH3-Aisle 700	1528	1425

DATE	LOCATION	TIME	CONCENTRATION (ppm)
Jan. 10	EH2-Aisle 1000	1700	1763
Jan. 10	EH3-NE	1710	2325
Jan. 10	EH1	1710-1725	2250
Jan. 10	EH3-center	1712	2000
Jan. 10	EH3-South	1715	1675
Jan. 10	EH2-East	1750	2175
Jan. 10	EH3-Rabbits	1755	2350
Jan. 10	EH2-Aisle 1300	1800	2450
Jan.10	HE2- Walkway	1800-1820	2500
Jan. 10	EH1-West	1810	2850
Jan. 10	EH2-various	1820-1835	2500
Jan. 11	HE2-Entry from Stadium	1230	1575
Jan. 11	EH3-SE Corner-Petting Zoo	1235	1575
Jan. 11	EH3-NE Corner-Rabbits	1237	2050
Jan. 11	EH3-NE Top Stairs	1240	2500
Jan. 11	EH2-NE Bottom Stairs	1245	1575
Jan. 11	EH2- restroom, N. Center	1247	2100
Jan. 11	EH2-NW Corner Near EXIT	1250	2100
Jan. 11	HE1-BP	1300	2400
Jan. 11	HE2-Entry from Stadium	1310	1750
Jan. 12	HE2-Aisle 500 South	1340	2650
Jan. 12	HE-East	1341	2625
Jan. 13	HE1-NE Entry	-	2850
Jan. 13	HE2-Aisle 600 North	-	2100

DATE	LOCATION	TIME	CONCENTRATION (ppm)
Jan. 13	HE2-Aisle 700 Center	-	2850
Jan. 13	HE2-Aisle 900 North	-	3350
Jan. 13	HE2-Aisle 1200 Center	-	4200
Jan. 13	EH2-Aisle 1400-N	-	4450
Jan. 13	EH1-North	-	1075
Jan. 13	EH1-Center	-	2000
Jan. 13	EH1- S. Center	-	2100
Jan. 13	EH1-Horse area	-	1250
Jan. 16	EH1-South	1058	650
Jan. 16	EH1-SE Corner	1101	925
Jan. 16	EH1-Eastside	1102	875
Jan. 16	EH1-North doors	1104	650
Jan. 16	EH1-Men's Restroom	1105	625
Jan. 16	EH1-Aisle 12	1110	750
Jan. 16	EH1-Aisle 10	1112	1075
Jan. 16	EH1-Aisle 8	1115	1500
Jan. 16	EH1-Aisle 6	1117	1750
Jan. 16	EH1-Aisle 4	1120	2150
Jan. 16	EH1-Aisle 2	1123	1500
Jan. 16	EH1-South Aisle 2	1125	2575
Jan. 16	EH1-South Aisle 4	1127	2825
Jan. 16	EH1-South Aisle 6	1130	1875
Jan. 16	EH1-South Aisle 8	1133	1500
Jan. 16	EH1-South Aisle 10	1135	800

DATE	LOCATION	TIME	CONCENTRATION (ppm)
Jan. 16	EH1-South Aisle 12	1137	575
Jan. 16	EH1-North Aisle 12	1140	575
Jan. 16	EH1-North Aisle 8	1143	1600
Jan. 16	EH1-North Aisle 4	1145	875
Jan. 16	EH1-North Aisle 2	1155	1025
Jan. 18	EH2-Entry from Stadium	-	675
Jan. 18	EH2-Overhead Door Aisle 1400	-	750
Jan. 18	EH2-Restaurant Aisle 1400	-	1050
Jan. 18	EH2-N. Entry Aisle 1300	-	1150
Jan. 18	EH2-N. Entry Aisle 1200	-	1075
Jan. 18	EH2-Middle Aisle 1100	-	1100
Jan. 18	EH2-Middle Aisle 900	-	975
Jan. 18	EH2-Middle Aisle 600	-	1025
Jan. 18	EH2-South Aisle 500	-	975
Jan. 18	EH2-South Aisle 100	-	775
Jan. 18	EH2-Middle Aisle 300	-	875
Jan. 18	EH2-North Aisle 100	-	775
Jan. 18	EH2-North Aisle 400	-	800
Jan. 18	EH2-North Aisle 500	-	875
Jan. 18	EH2-North Aisle 700	-	875
Jan. 18	EH2-North Aisle 800	-	1000
Jan. 18	EH2-North Aisle 1200	-	1225
Jan. 18	EH2-North Aisle 1300	-	1200

DATE	LOCATION	TIME	CONCENTRATION (ppm)
Jan. 19	EH3- Petting Zoo	1100-1330	3200

SA - Stadium Arena
SAA - Stadium Auction Arena
BP - Beef Palace
BPAA - Beef Palace Auction Arena
EC - Events Center
HE - Hall of Education
SH - Stadium Hall
EH1 - Expo Hall (level 1)
EH2 - Expo Hall (level 2)
EH3 - Expo Hall (level 3)

Table II

Summary of Carbon Dioxide Levels

National Western Stock Show

EVENT CENTER

HETA 96-0052

DATE	LOCATION	TIME	CONCENTRATION (ppm)
Jan. 10	Entry	1220	1125
Jan. 10	Entry, Near Shoe Shine	1225	955
Jan. 10	Paddock - center	1230	750
Jan. 10	Paddock - west	1235	550
Jan. 10	SW Entry, Top Stairs	1732	1150
Jan. 10	SW Entry, Top Stairs	1736	1200
Jan. 10	Paddock	1745	775
Jan. 11	Entry	1315	1275
Jan. 11	S. Center, Top Row	1320	1225
Jan. 11	Eastend, Top Row	1330	1300
Jan. 11	Paddock, Westend	1350	1075
Jan. 13	Entry	-	675
Jan. 19	S. Seat.	1100-1330	975

Table III

Summary of Carbon Dioxide Levels

National Western Stock Show

STADIUM ARENA

HETA 96-0052

DATE	LOCATION	TIME	CONCENTRATION (ppm)
Jan. 10	SA	1350	950
Jan. 10	SA-Southside Top Row	1410	950
Jan. 10	SA-Eastside Top Row	1410	875
Jan. 10	SA-Eastside Top Row	1415	775
Jan. 10	SA-Door	1507	1450
Jan. 10	SH-1	1510	1850
Jan. 10	Walk way	1630-1645	1000
Jan. 10	SH	1645-1655	2625
Jan. 10	SA-2nd level East	1647	1050
Jan. 10	SAA	1700-1710	3000
Jan. 10	SH-Aisle 1600	1805	1600
Jan. 12	SH-2 Top Stairs	950	950
Jan. 12	SH-1	955	2200
Jan. 12	SH-North Sheep Shearing	1010	2800
Jan. 12	SH-2 West	1020	1700
Jan. 13	SA-Westend	-	1800
Jan. 13	Livestock Arena	-	2100
Jan.19	SA - S. Center	1100-1330	950

SA - Stadium Arena SAA - Stadium Auction Arena
SH - Stadium Hall

Table IV

Summary of Carbon Dioxide Levels

National Western Stock Show

COLISEUM ARENA

HETA 96-0052

DATE	LOCATION	TIME	CONCENTRATION (ppm)
Jan. 10	West lower	1627	1225
Jan. 10	Portal 10	1820	1100
Jan. 10	West	1827	1625
Jan. 10	Vendor Area	1835-1900	1750
Jan. 11	N. Center (RR1)	1415	1075
Jan. 12	Entry to Ped. Walkway	1350	1350
Jan. 13	Paddock	-	825
Jan. 13	Upper Floor	-	2400
Jan. 19	Center - North	1100-1330	1200

Table V

Summary of Carbon Dioxide and Carbon Monoxide Concentrations for Specific Events
Fixed Location Monitoring
National Western Stock Show
January 10-19, 1996
HETA 96-0052

Date	Time	Carbon Dioxide (ppm)			Carbon Monoxide (ppm)*			
		Average	Minimum	Peak	Average	Minimum	Peak	STEL
Coliseum (Rodeo)								
1-10-96	1930-2230	1160	635	2000	8	3	22	-
1-13-96	1100-1400	1145	870	1510	7	5	33	9
1-16-96	1100-1700	-	-	-	1	0	24	6
1-19-96	1400-1730	1490	1230	1700	7	4	9	-
Event Center								
1-10-96	1300-1600	995	830	1065	-	-	-	-
1-12-96	1000-1500	1050	815	1550	1	0	32	9
1-16-96	1050-1620	860	630	1100	-	-	-	-
1-19-96	0920-1600	1705	860	2830	5	2	19	12
Stadium								
1-10-96	1300-1600	840	655	1250	8	5	8	-
1-12-96	0950	810	585	1390	4	3	17	-
1-16-96	1030-1415	725	555	885	0	0	1	0

*Peak values represent the highest level measured . STEL is the highest 15-minute average CO concentration during the entire sampling period.

Figures

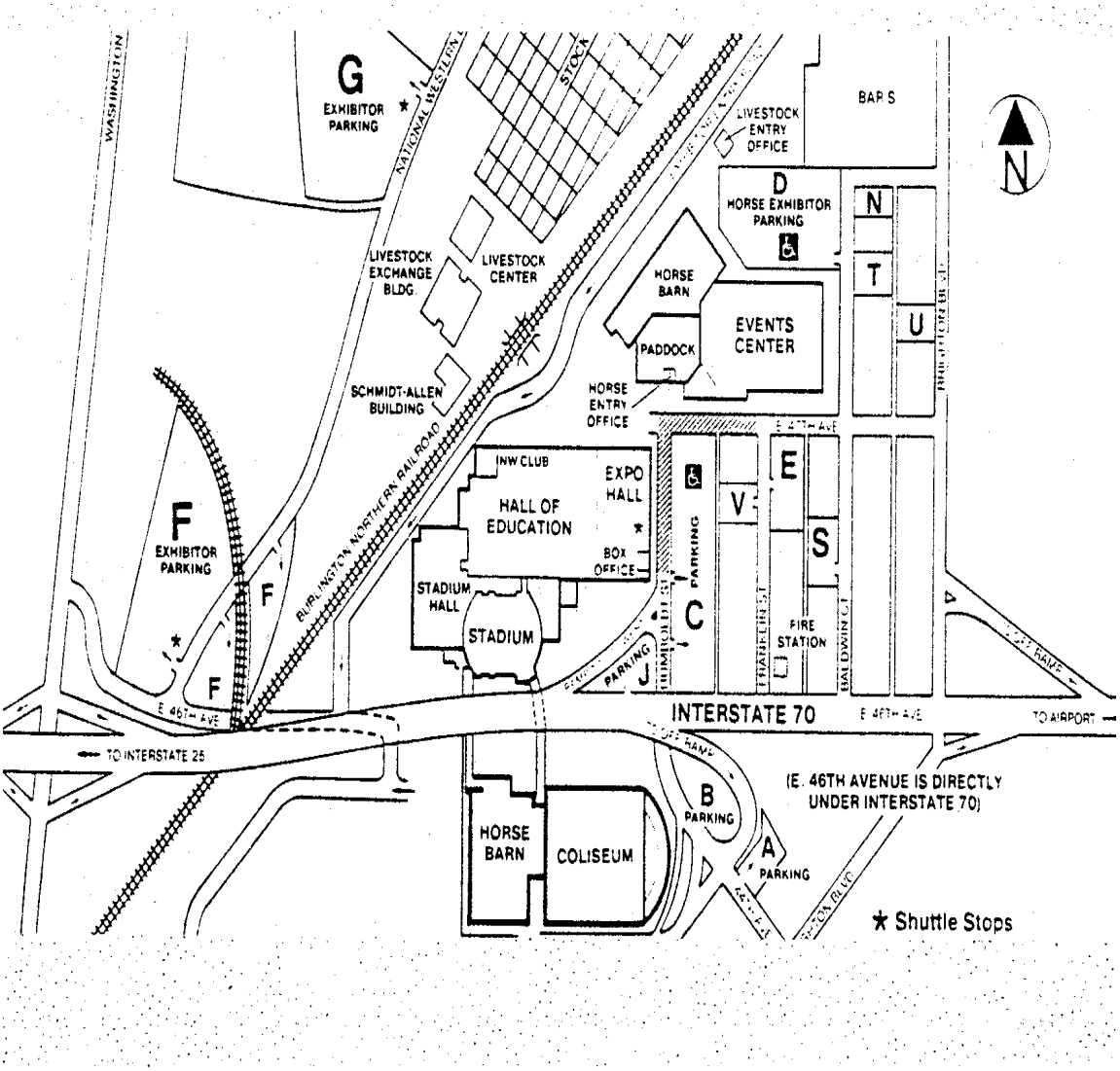

Figure 1. Layout of the National Western Stock Show Grounds

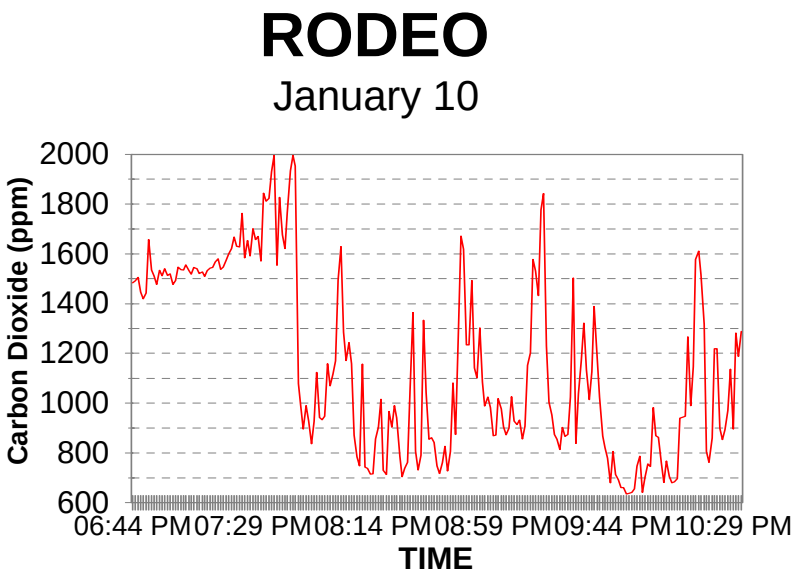

Figure 2. Carbon Dioxide Concentrations During Rodeo, Jan. 10

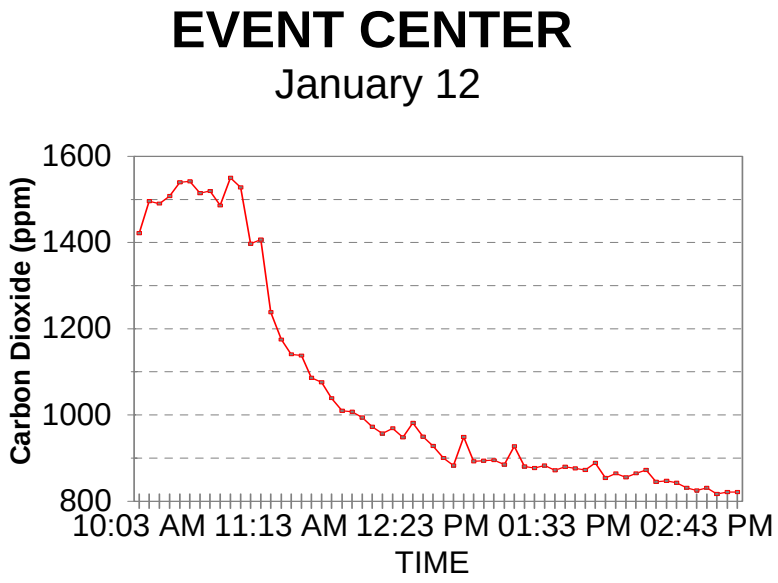

Figure 3. Carbon Dioxide Concentrations in Event Center, Jan 12

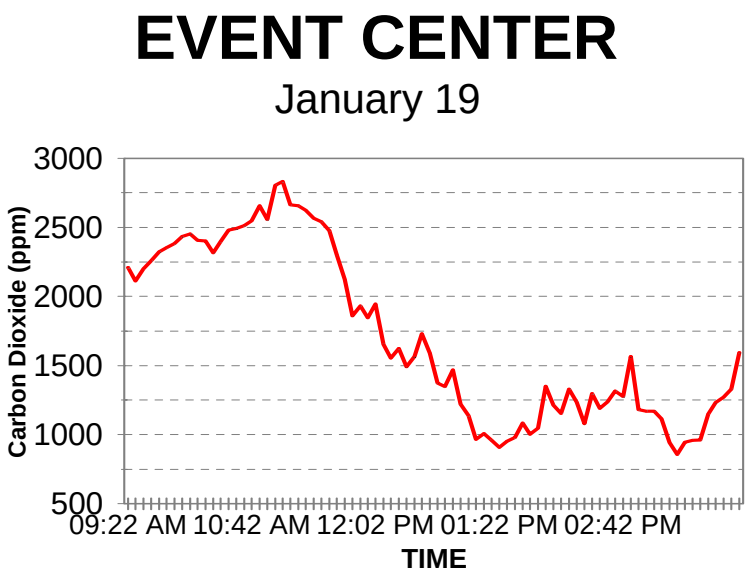

Figure 4. Carbon Dioxide Concentration in Event Center, Jan 19

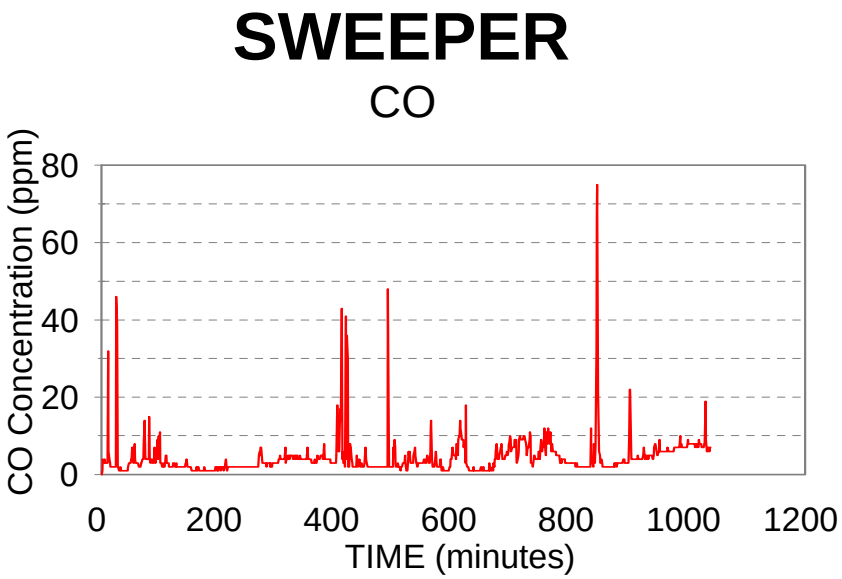

Figure 5. Carbon Monoxide Concentrations on Floor Sweeper in Hall of Education, January 18, 1996

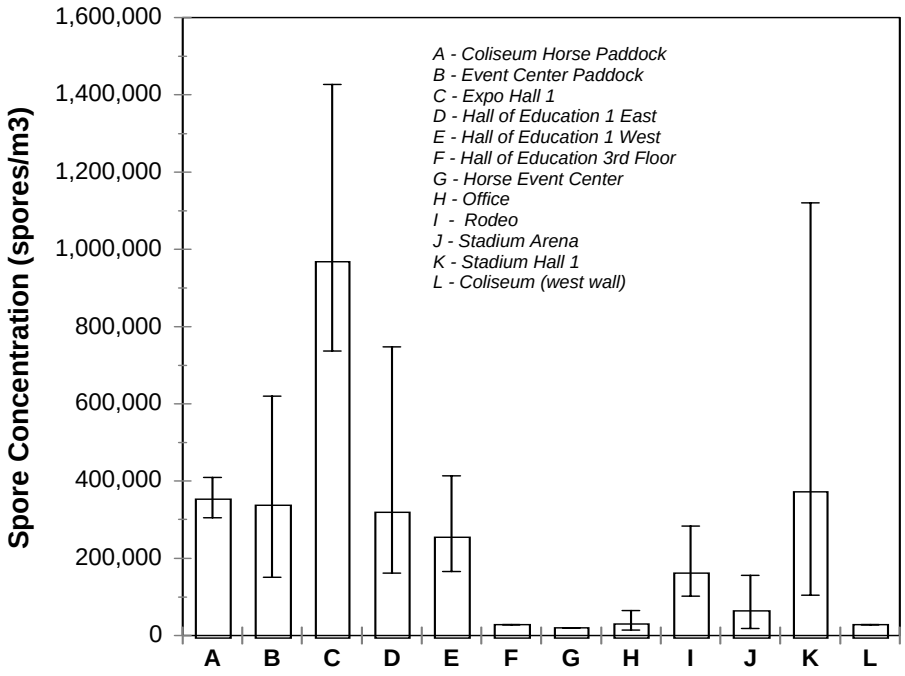

Figure 6. Total Spore Sampling Results, NWSS, January 1996

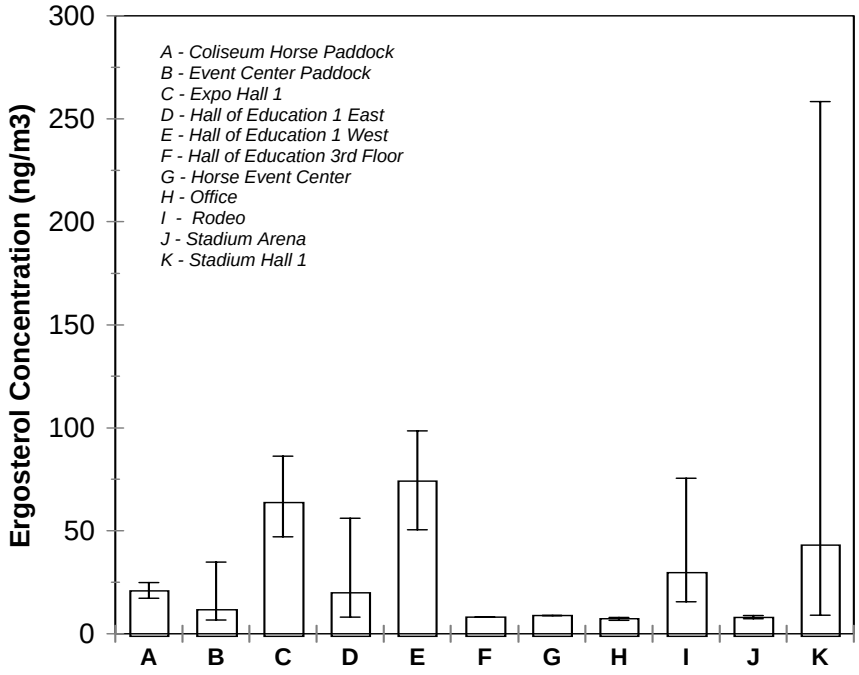

Figure 7. Ergosterol Sampling Results, NWSS January, 1996

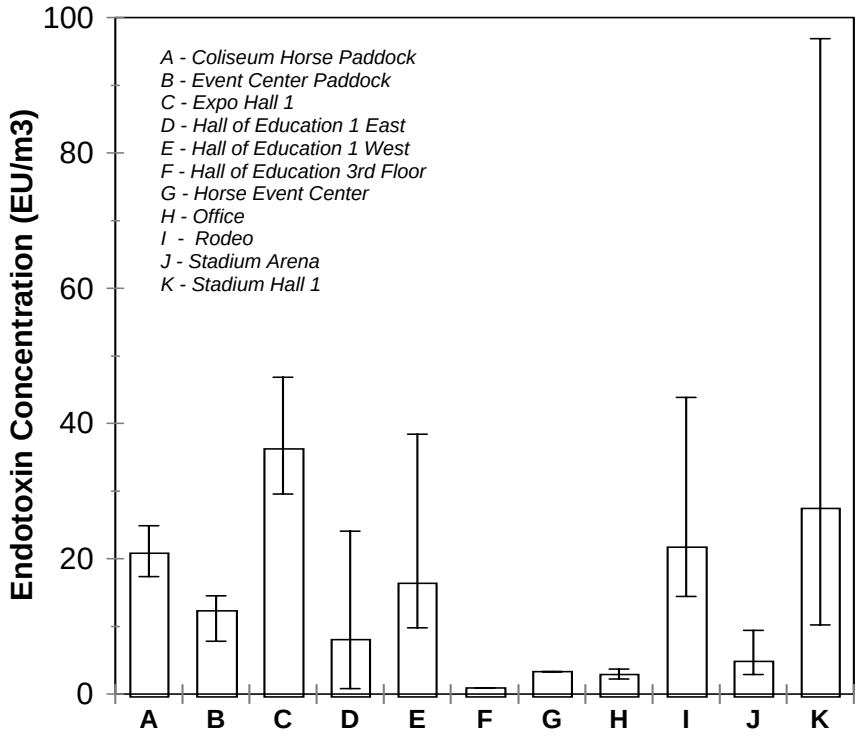

Figure 8. Endotoxin Sampling Results, NWSS, January 1996

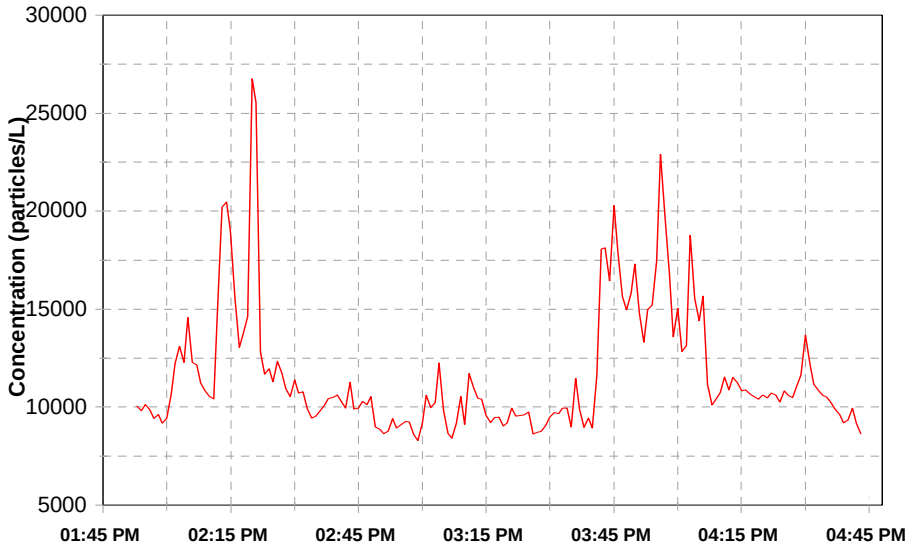

Figure 9. Real-time Particle Concentration (>0.7 um) for Rodeo, January 12, 1996

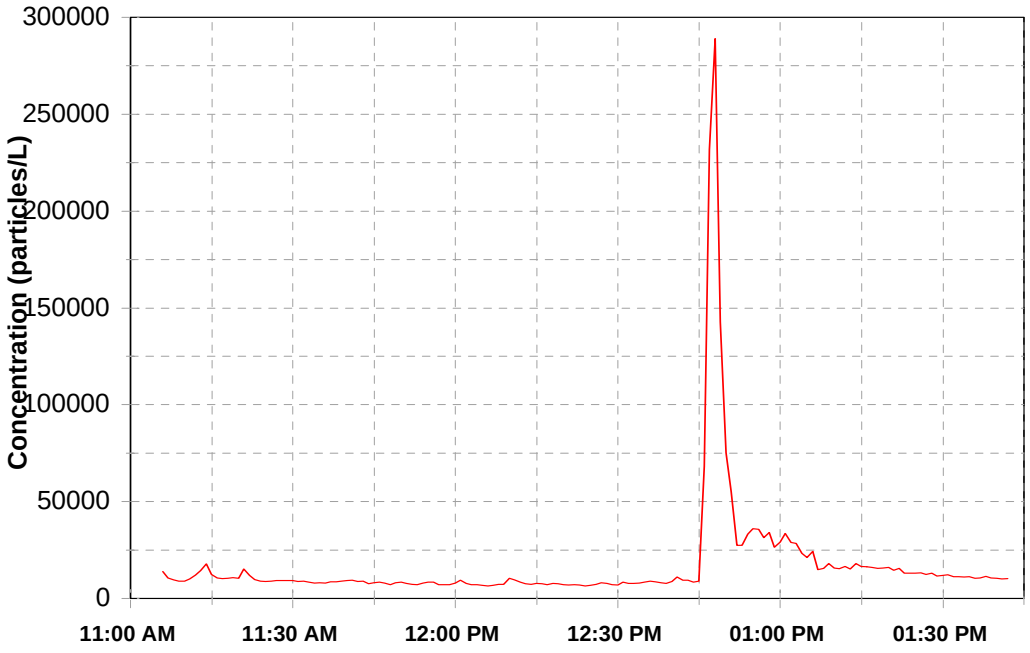

Figure 10. Real-time Particle Concentrations (>0.7 micron) for January 13 Rodeo (early show)

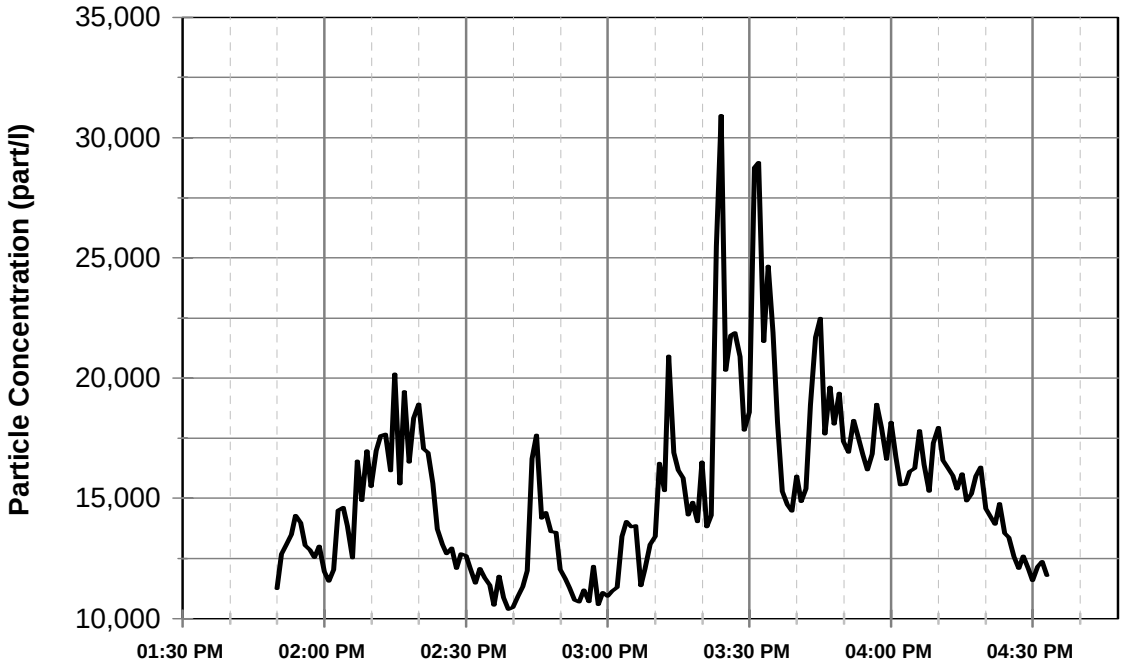

Figure 11. Real-time Particulate Measurement Results for January 16 Rodeo (late show)

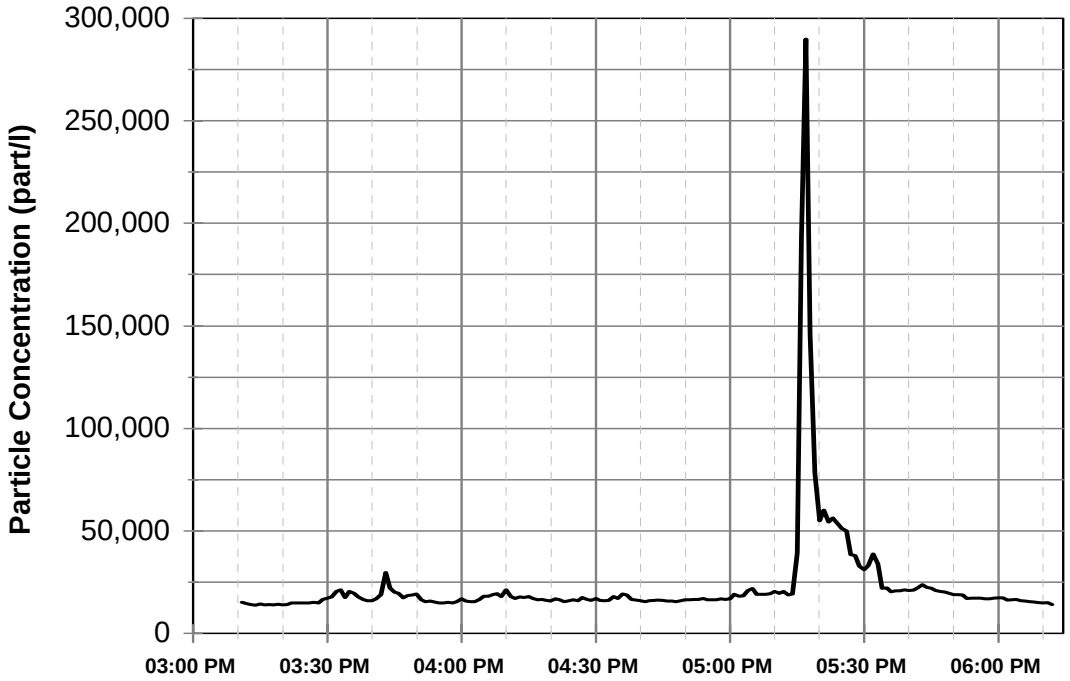

Figure 12. Real-time Particle Concentration Results for Rodeo (early show), January 16

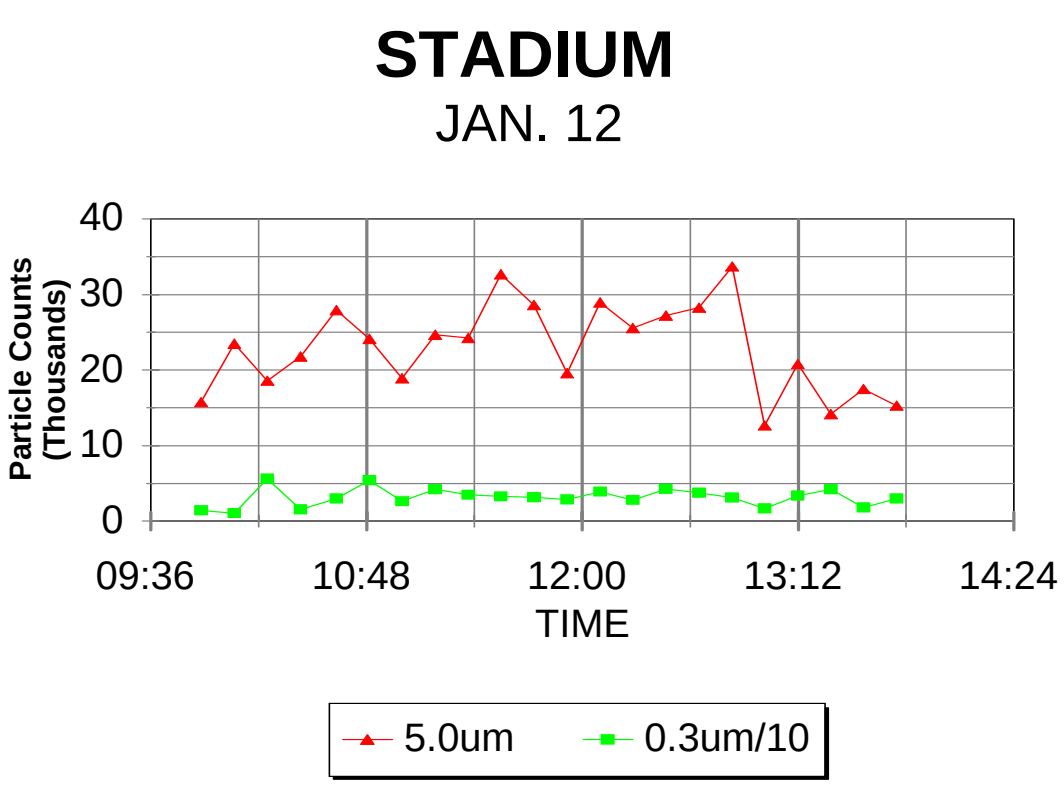

Figure 13: **Real-time Particle Counts Over Time, at Two Size Distributions (>0.3µ and >0.5µ) in the Stadium, January 12, 1996**

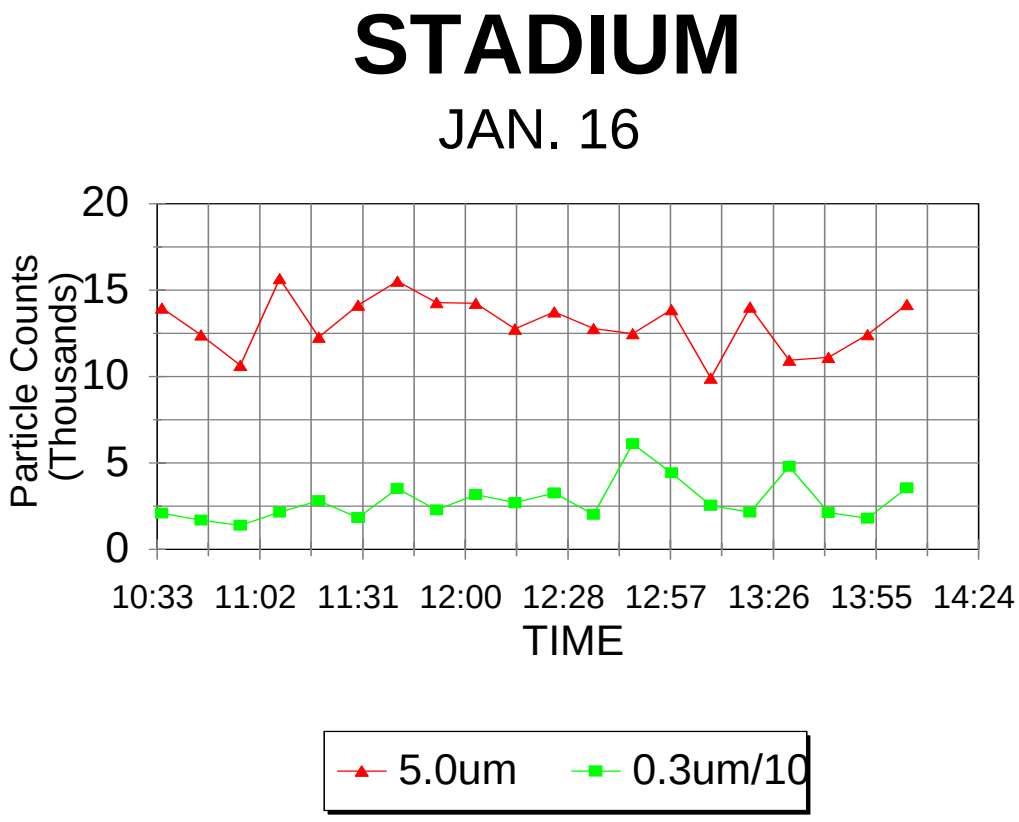

Figure 14: **Real-time Particle Measurements at two Size Distributions (>0.3µ and >0.5 µ), at Stadium, January 16**

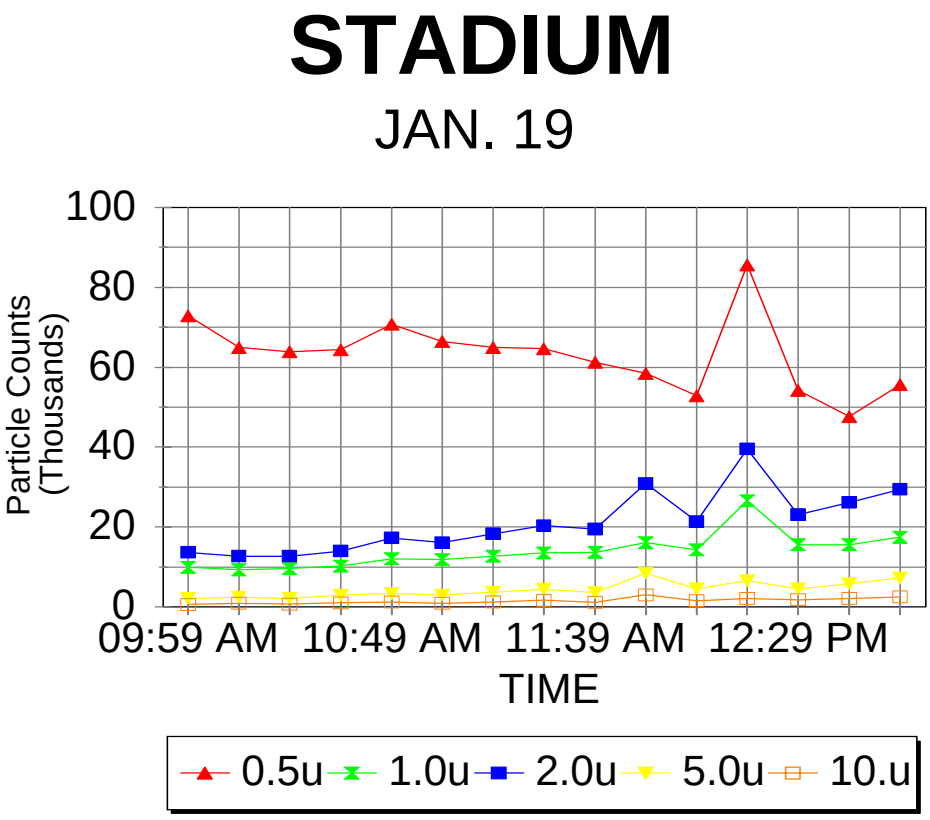

Figure 15: **Real-time Particulate Measurements in the Stadium, Jan 19**

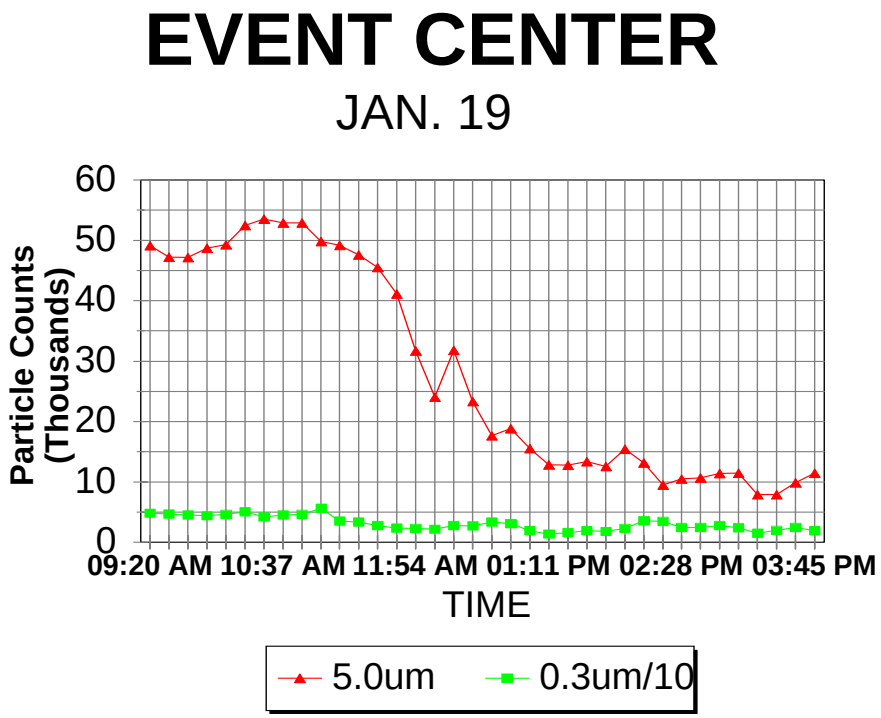

Figure 16: **Real-time Particle Measurement in Event Center, Jan 19**

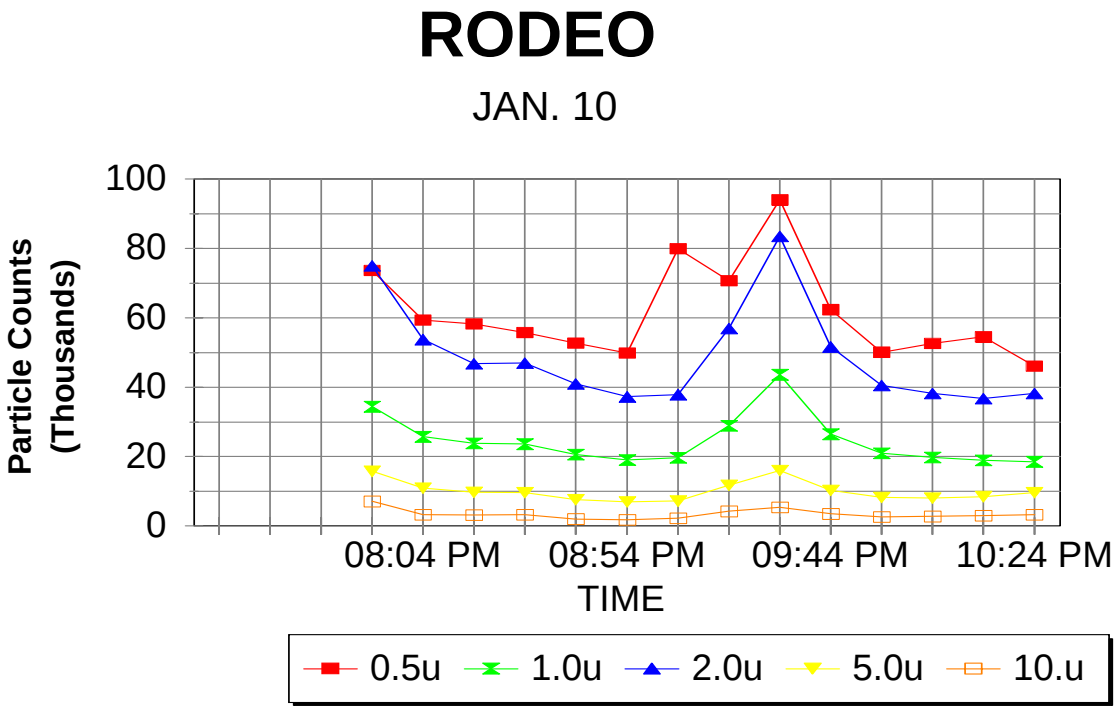

Figure 17: **Real-time Particle Measurement during Rodeo, Jan 10**

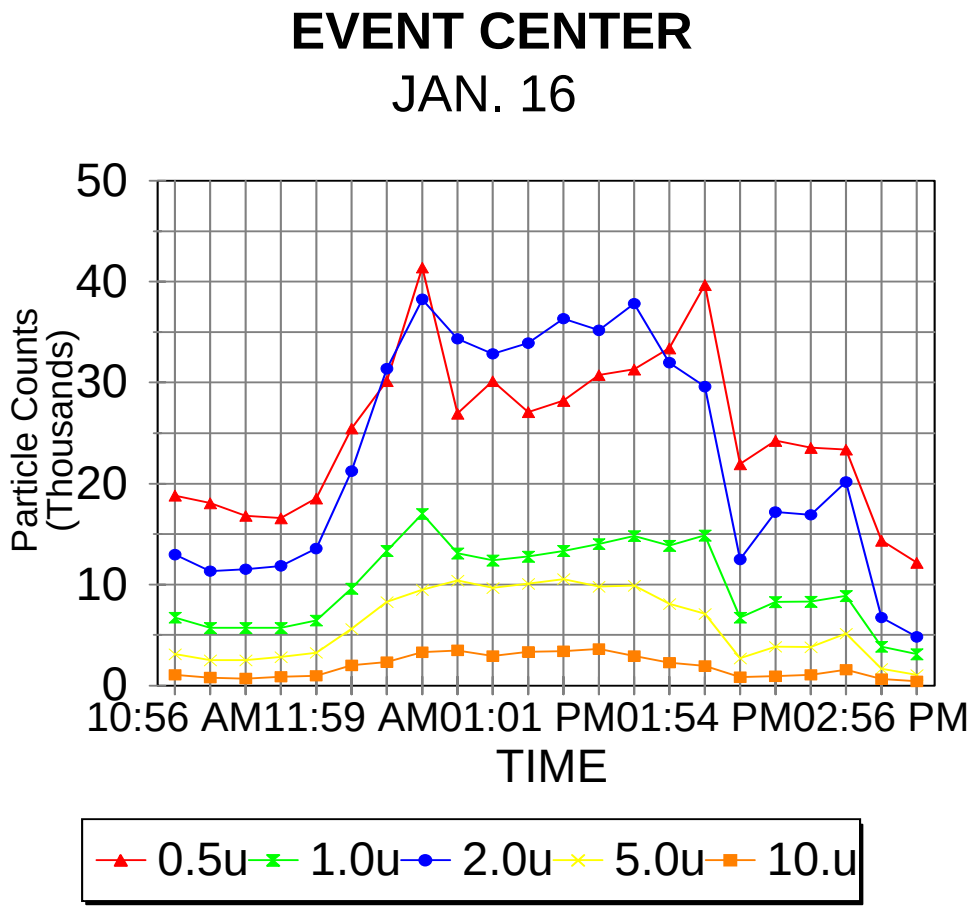

Figure 18: Real-time Particle Measurement, Event Center Jan 16

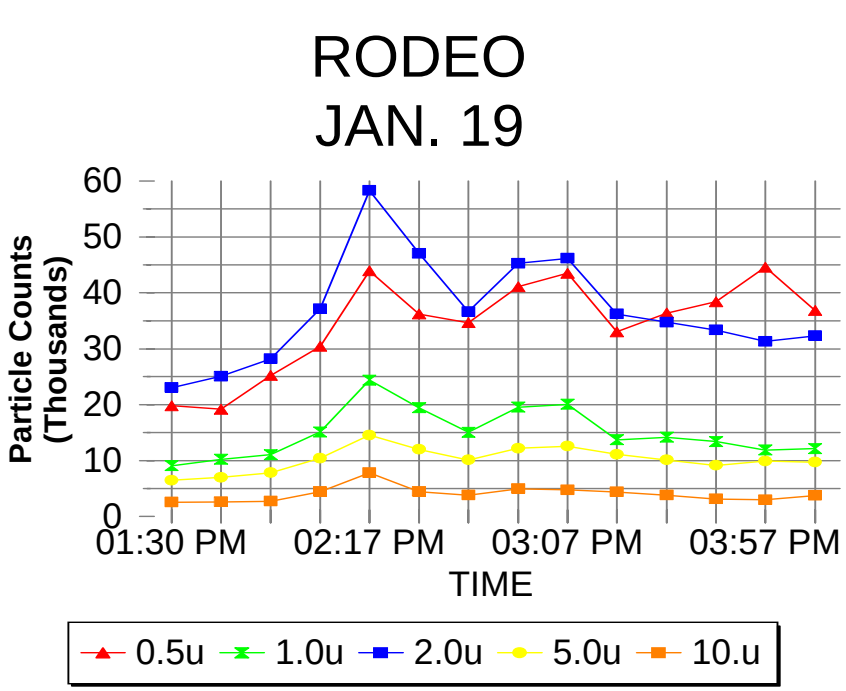

Figure 19: Real-time Particle Measurement, Rodeo on Jan. 19, 1996