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Case Study
Air Contaminant Exposures Among Transportation Security Administration (TSA) "Checked Baggage" Screeners at Four International Airports

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INTRODUCTION

In January 2004, the National Institute for Occupational Safety and Health (NIOSH) received several requests from the Transportation Security Administration (TSA) to conduct health hazard evaluations (HHEs) at four international airports: Palm Beach, Florida (PBI): Miami, Florida (MIA); Washington-Dulles, Dulles, Virginia (IAD); and Baltimore-Washington (BWI), Linthicum, Maryland. The requests expressed concern that contaminants found in the emissions of tug engines operating near "checked baggage" screening areas were related to health problems reported by some TSA employees, including respiratory distress, dizziness, and headaches. After conducting initial site visits in early 2004, NIOSH investigators returned to each airport and between April 2004 and July 2004, conducted general area and personal breathing zone (PBZ) air sampling for diesel exhaust (measured as elemental carbon [EC]), nitrogen dioxide (NO_2), nitric oxide (NO), carbon monoxide (CO), and volatile organic compounds (VOCs).

BAGGAGE SCREENING/BAGGAGE TRANSFER

At these airports, passengers check their bags at the ticket counter and a series of conveyor belts deliver bags to screening areas. TSA screeners manually load the bags onto another conveyor belt that transfers the baggage to an explosive detection system (EDS) machine. After examination, bags are loaded onto a carousel that routes each bag to the appropriate terminal where airline personnel transfer the bags to carts attached to tugs for transport to the aircraft. Our surveys were scheduled to coincide with "push" periods when the highest number of flights depart the airport within a narrow timeframe. It was assumed that during those time periods, tug traffic and the potential for exposure to combustion products would be the greatest.

At each airport, individual airlines maintain and operate their own tugs. The tugs' fuel source varies by airline and included diesel, gasoline, propane, and electricity. Large, pedestal-mounted fans were typically located near EDS machines to increase air movement and provide comfort to workers in the bag screening areas. General dilution ventilation was provided in each of the baggage screening areas surveyed. A unique dilution ventilation system that is automatically controlled via CO sensors was used at IAD. Additional information regarding the number of TSA workers at each airport, tug fuel types, and the number of bags screened during each sampling effort appear in Table I.

TABLE I. Transportation Security Administration Worker, Airport, Fuel Source, and Baggage Information

Airport	Number of TSA Workers	Tug Fuel Source	Number of Bags Screened During 2 Days of Sampling	Comments
PBI	85	Gasoline, diesel	23,158	Screening area open to tarmac
MIA	171	Gasoline, diesel, propane	64,123	Semi-enclosed screening areas, Damaged ventilation systems
IAD	120	Gasoline, diesel, electric	50,096	Enclosed screening areas, unique ventilation system; operates based on CO sensors
BWI	241	Gasoline, diesel	41,276	Enclosed screening areas

Notes: PBI = Palm Beach International Airport; MIA = Miami International Airport; IAD = Washington-Dulles International Airport; BWI = Baltimore-Washington International Airport.

AIR CONTAMINANTS/HEALTH EFFECTS

Diesel engine emissions consist of a complex mixture that includes both gaseous and particulate fractions. This mixture varies greatly with fuel and engine type, load cycle, maintenance, tuning, and exhaust gas treatment. The gaseous constituents include carbon dioxide, sulfur dioxide (SO_2),CO, NO, NO_2, and VOCs.[1–6] The particulate fraction (soot) is composed of solid carbon cores that tend to combine to form chains of particles or aggregates of which 95% are less than 1 μm in size.[7] Estimates indicate that as many as 18,000 different substances resulting from the combustion process may be adsorbed onto these particles.[8] The adsorbed material accounts for 15%–65% of the total particulate mass and includes compounds such as polynuclear aromatic hydrocarbons, a number of which are known mutagens and carcinogens.[3,4,9,10]

Many of the individual components of diesel exhaust are known to have toxic effects, including: (1) pulmonary irritation from oxides of nitrogen; (2) eye and mucous membrane irritation from SO_2, phenol, sulfuric acid, sulfate aerosols, and acrolein; and (3) cancer in animals from polynuclear aromatic hydrocarbons. Limited epidemiologic evidence suggests an association between occupational exposure to diesel exhaust emissions and lung cancer in humans and led NIOSH in 1988 to recommend regarding whole diesel exhaust (both gaseous and particulate fractions) as a potential occupational carcinogen.[4] Although the Occupational Safety and Health Administration (OSHA) and the American Conference of Governmental Industrial Hygienists (ACGIH®) have exposure limits for some of the individual components of diesel exhaust (i.e., NO_2, xylene, and CO), no exposure limits have been established for whole diesel exhaust. The California Department of Health Services (CDHS) Hazard Evaluation System and Information Service (HESIS) recommends keeping exposures to diesel exhaust particles (measured as elemental carbon [EC], a surrogate indicator of exposure) below 20 $\mu g/m^3$.[10] Occupational exposure limits for the other compounds evaluated (NO_2, NO, CO, VOCs) appear in Table II.

METHODS

Diesel Exhaust (Elemental Carbon)

Full-shift PBZ air samples for EC were collected on 37-millimeter quartz fiber filters (closed face) using AirChek 2000 (SKC, Eighty Four, Pa.) sampling pumps operating at approximately 2.5 L/min. A total of 72 screeners were monitored among the four airports. The filters were placed in the workers' breathing zone and connected via Tygon tubing to the sampling pump. The samples were analyzed by NIOSH Method 5040.[11]

Nitrogen Dioxide (NO_2) and Nitric Oxide (NO)

Full-shift PBZ air samples for NO_2 and NO were collected on sorbent tubes containing oxidizer plus a triethanolamine-treated molecular sieve. A total of 40 screeners were monitored among the four airports. In addition to the PBZ samples, 21 general area air samples were collected. Flow rates of approximately 0.050 L/min and 0.20 L/min were used to collect the PBZ and general area air samples, respectively. After collection, the samples were analyzed according to NIOSH Method 6014.[11]

TABLE II. Occupational Exposure Limits

Contaminant	OSHA PEL	NIOSH REL	ACGIH TLV
Diesel Exhaust	N/A	N/A	20 $\mu g/m^3$[A]
NO_2	5 ppm[B]	1 ppm[C]	3 ppm[D]
NO	25 ppm (TWA)	25 ppm (TWA)	25 ppm (TWA)
CO	50 ppm (TWA)	35 ppm (TWA)	25 ppm (TWA)
Isopropanol	400 ppm (TWA)	400 ppm (TWA)	200 ppm (TWA)
Toluene	200 ppm (TWA)	100 ppm (TWA)	50 ppm (TWA)

Notes: PEL = permissible exposure limit; REL = recommended exposure limit; TLV = threshold limit value; N/A = not available; TWA = time-weighted average.

[A] Exposure limit is currently under review by ACGIH®. California Department of Health Services recommends keeping exposure below 20 $\mu g/m^3$ as an 8-hour time-weighted average.

[B] Ceiling concentration.

[C] 15-min short-term exposure limit (STEL).

[D] 8-hour TWA.

In addition to sorbent tube sampling, NO_2 concentrations were measured using Toxilog Ultra (Biosystems, Middletown, Conn.) direct-reading instruments equipped with electrochemical sensors operated in a passive diffusion mode. Average personal exposures, maximum 15-min short-term exposures, and maximum peak exposures were recorded by attaching these instruments to the belt of 23 screeners and worn for the entire work shift. Stored data were downloaded to a laptop computer after sampling.

Volatile Organic Compounds (VOCs)

To screen for VOCs, a total of 20 general area air samples within the baggage screening areas were collected at all four airports using thermal desorption (TD) tubes attached by Tygon tubing to SKC Pocket Pumps calibrated at a flow rate of 0.05 L/min. Each TD tube consists of three beds of sorbent material (SKC) (a front layer of Carbopack Y, a middle layer of Carbopack B, and a back section of Carboxen 1003). Qualitative analysis was performed with an ATD 400 automatic thermal desorption system (PerkinElmer, Wellesley, Mass.) interfaced with an HP5890A gas chromatograph with an HP5970 mass selective detector (Hewlett-Packard, Palo Alto, Calif.) according to NIOSH Method 2549.[11]

To analyze specific VOCs, (based on the results of the TD samples), full-shift general area air samples were collected simultaneously on charcoal tubes attached by Tygon tubing to SKC Pocket Pumps calibrated at a flow rate of 0.2 L/min. Quantitative analysis for isopropanol, benzene, toluene, xylenes, and trimethylbenzenes was performed using a Hewlett-Packard model 5890A gas chromatograph equipped with a flame ionization detector according to NIOSH Methods 1300, 1400, 1501, and 1550.[11] All sampling pumps used during these surveys were calibrated before and after each sampling event against a primary standard (BIOS Dry-Cal; Bios International, Pompton Plains, N.J.) to verify flow rate.

Carbon Monoxide

Carbon monoxide (CO) exposures were evaluated using the Toxilog Ultra and the Q-TRAK Plus indoor air quality (IAQ) monitor model 8554 (TSI Inc., Shoreview, Minn.), operated in a passive diffusion mode. A total of 61 full-shift personal samples were collected using the Toxilog Ultras. The Q-TRAK measures CO in real-time, and spot measurements of CO were taken throughout the baggage areas during the work shift. All passive diffusion monitors were calibrated before and after sampling according to the manufacturer's specifications.

Tailpipe Emissions

Grab sampling of tailpipe emissions from gasoline-powered tugs operating at MIA and IAD was performed using a GasLink LT Emissions analyzer (Ferret Instruments, Cheboygan, Mich.) that measures hydrocarbons (HC), CO, CO_2, and oxides of nitrogen (NO_x) in real time. As they operated gasoline-powered tugs in the traffic lanes of the various screening areas, drivers were asked to stop momentarily while emissions from the idling tug were measured and recorded.

TABLE III. Personal Breathing Zone Diesel Exhaust Particulate (Elemental Carbon)

Location	Number of Samples ($\mu g/m^3$)	Mean ($\mu g/m^3$)	Std. Dev. ($\mu g/m^3$)	Minimum ($\mu g/m^3$)	Maximum ($\mu g/m^3$)
PBI	16	5.9	2.5	1.0	11
MIA	13	12	3.9	5.9	19
IAD	24	14	5.6	3.2	26
BWI	19	11	4.7	4.0	24
All Airports	72	11	5.4	1	26

Notes: PBI = Palm Beach International Airport; MIA = Miami International Airport; IAD = Washington-Dulles International Airport; BWI = Baltimore-Washington International Airport.

RESULTS

As shown in Table III, a total of 72 PBZ air samples were collected for diesel exhaust (EC) in baggage screening areas at the four airports. Concentrations ranged from 1 $\mu g/m^3$ to 26 $\mu g/m^3$, with an average concentration for all airports of 11 $\mu g/m^3$. Four samples exceeded 20 $\mu g/m^3$ (three at IAD [22, 25, 26 $\mu g/m^3$] and one at BWI [24 $\mu g/m^3$]). The range of average air concentrations was relatively narrow (6 $\mu g/m^3$ to 14 $\mu g/m^3$). The highest average EC concentration occurred at IAD, whereas the lowest occurred at PBI.

A total of 61 full-shift TWA exposures to CO were collected using the Toxilog Ultra device. The average TWA concentration across all airports was 3 ppm, with a range of 0.6 ppm (BWI) to 5.3 ppm (MIA). Instantaneous peak concentrations ranged from 37 ppm to 106 ppm.

A total of 61 air samples were collected for NO and NO_2 (40 PBZ and 21 General Area). All results were reported as either "none detected" (ND) or "Trace." Samples collected for NO were considered ND if the analytical result was less 0.03 ppm, and Trace if the result was less than 0.7 ppm but greater than 0.03 ppm. For NO_2, ND was defined as less than 0.02 ppm and Trace if the value was less than 0.8 ppm but greater than 0.02 ppm. None of the samples collected approached their respective 8-hour TWA occupational exposure limit (Table II). Air samples for NO_2 were also collected using the Toxilog Ultra device equipped with a sensor specific for NO_2. Average TWA and peak concentrations followed the same trend as the other NO/NO_2 air samples (all were very low). Instantaneous peak concentrations ranged from 0.4 ppm to 1.7 ppm.

The dominant VOCs identified were isopropanol and toluene. Of the 20 air samples collected at the four airports, isopropanol ranged from less than 0.04 ppm to 0.31 ppm, whereas toluene ranged from less than 0.005 ppm to 0.04 ppm. None of the samples approached any applicable occupational exposure limit.

Tug Emissions

A total of 13 tugs were evaluated at two of the airports (5 at MIA; 8 at IAD). Tailpipe HC concentrations ranged from 20 ppm to 1700 ppm. CO concentrations ranged from

400 ppm to 87,000 ppm, whereas NO_x concentrations ranged from zero ppm to 52 ppm. For comparison, the highest ambient air concentrations for HC at MIA and IAD were 90 ppm and 70 ppm. The ambient air concentrations of CO and NO were zero at both airports. The majority of the tugs ran roughly and had an unstable idle. One particular tug operating at IAD emitted black soot that deposited on the emission analyzer's probe. This tug also emitted a strong odor that was irritating to the eyes, nose, and throat of the emission analyzer operator. Diesel-powered tug emissions were not evaluated during this survey because the instrument can only operate accurately with a single sensor designed to detect emissions from a specific type of engine (i.e., gasoline only, diesel only). Sensors specific to diesel engines were not used because they must be installed and calibrated by the manufacturer. Data collected during the gasoline-powered tug grab measurements appear in Table IV.

Workplace Observations

All four airports used pedestal-type fans in the screening areas to provide worker comfort during periods of elevated temperatures. Additional environmental control for all baggage screening areas was accomplished mainly by mechanical, general dilution ventilation systems (via duct-mounted fans and discharge vents), although two airports (PBI, MIA) also relied on natural ventilation via prevailing winds. The baggage screening area at PBI is enclosed on three sides and opens to the tarmac. The ventilation system at PBI consisted of a series of ducts containing internal fans that drew air from ground level near the screening areas and discharged it outside. The baggage screening areas at MIA are mostly enclosed and located beneath the various terminals. The ventilation systems used at the screening areas at MIA consisted of numerous overhead ducts with internal fans to move the air and exhaust it outside. Visual inspection of the systems at MIA, however, revealed crushed ducts and inoperable fans that varied in severity from terminal to terminal (some ducts were slightly dented, whereas others were severely crushed, collapsed, or separated from adjacent ducts). Since some of the ventilation systems within the baggage screening areas at MIA were damaged, their effectiveness remains unknown. At BWI, each baggage screening area was mostly enclosed, with openings to the outside via garage-type doors, and the ventilation system was similar to those at PBI and MIA in that it used general dilution ventilation that was controlled thermostatically. In addition, depending on weather, the garage doors could be opened to provide additional natural ventilation.

IAD facilities management installed a unique ventilation system that was remotely controlled by a computerized CO sensor system that used 100% outside makeup air to ventilate one of the baggage screening areas. According to design, as CO concentrations increase, supply air fans run at increasing speeds until the CO concentrations reach 15 ppm. At that time the fans run at 100% of their maximum volumetric flow rate (approximately 27,000 cubic feet per minute [CFM]). This fan/duct configuration was also designed to keep the screening areas under negative pressure relative to ambient pressure outdoors. On a quarterly basis, airport maintenance staff use a direct-reading CO monitor to check CO sensors and calibrate them for accuracy.

In another baggage screening area, the ventilation system consisted of intake vents mounted flush in the floor, covered with grating, and connected to duct work routed to an outside wall for discharge. However, many of the intake grates were obscured with debris, potentially reducing the efficiency and effectiveness of this system. In addition, some of the condensate discharge lines from the EDS machines drained into these floor-mounted intake vents, creating an ideal environment for mold or fungal growth, which could possibly contribute to contamination of the entire ventilation system.

TABLE IV. Gasoline-Powered Tug Tailpipe Emissions

Airport Code	Time	HC (ppm)	CO (ppm)	NO_x (ppm)	Comments
MIA	6:40 a.m.	95	0	0	
MIA	6:30 a.m.	90	0	0	Ambient air
MIA	2:00 p.m.	26	400	52	
MIA	2:40 p.m.	140	1300	20	
MIA	6:40 p.m.	70	0	0	Ambient air
IAD	9:25 a.m.	1600	87,000	0	Heavy black soot on probe, tug running poorly, strong odor, burning sensation in nose, throat, and eyes
IAD	9:35 a.m.	77	20,000	3	
IAD	10:00 a.m.	570	6200	1	
IAD	10:07 a.m.	20	1100	9	
IAD	4:55 p.m.	442	900	7	Engine has audible "miss," runs rough at idle
IAD	4:57 p.m.	640	500	0	Engine has audible "miss," runs rough at idle
IAD	5:00 p.m.	1700	400	0	Runs poorly, vacillating idle
IAD	5:04 p.m.	645	6800	0	

The remaining three baggage screening areas at IAD used an outdoor air makeup inlet connected to a series of ceiling-mounted ducts with numerous discharge ports (vents) positioned along their length. No automatic CO sensors were noted for these systems, and the operational efficiency and effectiveness of the mechanical ventilation systems were not evaluated.

Across airports and airlines, a variety of tugs and fuels are used (gasoline, diesel, propane, electricity). TSA employees reported that during cold weather, some tugs were started inside the baggage screening areas and allowed to run for extended periods of time while warming up. Additionally, TSA employees reported that airline employees were more likely than usual to turn off tugs during our surveys. Housekeeping in the baggage screening areas was poor across all the airports we surveyed, with some areas cluttered with debris that partially obscured the floor-mounted intake vents (IAD). Cracks in floors, uneven walking surfaces, and oil leaking from tugs could increase the possibility of a worker slipping and falling.

DISCUSSION

Of the 72 EC samples collected on TSA screeners, only four PBZ samples exceeded the California Department of Health Services Hazard Evaluation System and Information Service exposure limit recommendation of 20 $\mu g/m^3$ (IAD = 22, 25, 26 $\mu g/m^3$; BWI = 24 $\mu g/m^3$). Based on other diesel exhaust studies, these EC levels are not unusually high.[5,12] Exposure to diesel exhaust can vary depending on the presence or absence of diesel-powered tugs in the area and how the airlines operate and maintain their own tugs.

Regardless of the sampling methods, NO and NO_2 concentrations across the four airports were either ND or Trace and were well below their respective occupational exposure limits. Of the 61 full-shift CO samples, no TWA concentration exceeded any occupational exposure limit. Peak concentrations ranged from 2 ppm to 1150 ppm with an average of 65 ppm. The peak concentration of 1150 ppm was considered suspect because the exposure occurred during the worker's lunch break, and results from other screeners in close proximity to this worker never exceeded 33 ppm. When the suspect value was removed from the data analysis, the average peak concentration was reduced to 27 ppm. None of the other measurements exceeded the OSHA ceiling limit of 200 ppm or approached the IDLH value of 1200 ppm.

Isopropanol was the only chemical used by TSA employees. Its purpose was to periodically clean the table tops where manual bag inspection and ETD processing occurs. Thermal desorption sampling for a variety of VOCs did not identify any unusual compounds, and concentrations of isopropanol and toluene were well below any applicable occupational exposure limits.

The tug exhaust emissions data from two airports (IAD and MIA) (Table IV) showed that most tugs ran poorly. Tugs at IAD emitted more HC and CO than MIA's tugs, while NO_x concentrations were higher at MIA (although personal air sampling data for NO and NO_2 at MIA did not show an inhalational hazard in the baggage screening areas). In general, the potential exists for exposure to CO and NO_x if the tugs are not properly maintained or if they do not operate under the same conditions encountered during the NIOSH survey (i.e., shut off tugs while loading/unloading). During the surveys, we noticed that airline employees often turned off tug engines when loading/unloading baggage. This is important because TSA employees reported that airline employees often left the tugs idling while loading/unloading bags or when leaving the tug for short durations, potentially contributing to increased emissions.

CONCLUSION

Overall, an inhalational hazard from tug exhaust emissions did not exist at the time of the surveys. However, air contaminant concentrations may vary due to a number of factors, such as dilution ventilation, natural ventilation, and the use of pedestal-type fans. Also, contaminant concentrations could increase if tugs are not properly maintained, sit in idle mode for extended periods of time, ventilation systems are rendered inoperable or ineffective due to damage and/or lack of maintenance, or if tug traffic increases. Weather conditions such as stagnant outdoor air may also cause contaminant concentrations to increase. Thus, even though the contaminant concentrations were below relevant occupational exposure limits at the time of these surveys, it is important to ensure that tug emissions are kept as low as possible by performing routine mechanical services, including engine tune-ups, air filter changes, and oil/oil filter changes. Ideally, electric powered tugs should be used when replacing unusable gasoline, propane, or diesel powered tugs. The "on-demand" ventilation system that operates based on CO concentrations could potentially control CO and other tug emissions if that type of system is installed and maintained in other airports where the baggage screening areas are mostly enclosed. The large pedestal-type fans in each screening area appeared to provide some cooling relief to the workers when the ambient temperature and humidity increased. However, the effectiveness of the pedestal-type fans in controlling airborne contaminants was not evaluated in this study.

RECOMMENDATIONS

As a result of these surveys, a number of recommendations were made to the TSA management:

- Develop a procedure for employees to report changes in their work environment to TSA management. The report should trigger an appropriate response to the perceived hazard and then communicate back to the employees the results of all actions taken.
- Improve housekeeping in all screening areas.
- Place signs in tug driving lanes to remind operators to shut off the engine when loading/unloading baggage.

- Keep tugs properly tuned.
- Prevent debris from blocking ventilation openings, especially in the East baggage screening area at IAD.
- Redirect ETD condensate drain lines away from ventilation intake vents at IAD. This practice encourages mold/fungi growth that could contaminate the entire ventilation system.
- Ensure that ventilation systems are maintained and operate according to design specifications.

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