Evaluation of Radiation Exposure to TSA Baggage Screeners

Chandran Achutan, PhD
Charles Mueller, MS

Health Hazard Evaluation Report
HETA #2003-0206-3067
Transportation Security Administration
Washington, DC
September 2008

DEPARTMENT OF HEALTH AND HUMAN SERVICES
Centers for Disease Control and Prevention

National Institute for Occupational Safety and Health

The employer shall post a copy of this report for a period of 30 calendar days at or near the workplace(s) of affected employees. The employer shall take steps to insure that the posted determinations are not altered, defaced, or covered by other material during such period. [37 FR 23640, November 7, 1972, as amended at 45 FR 2653, January 14, 1980].

CONTENTS

REPORT

ACKNOWLEDGMENTS

HIGHLIGHTS OF THE NIOSH HEALTH HAZARD EVALUATION

The National Institute for Occupational Safety and Health (NIOSH) received requests from management and employees at the Transportation Security Administration (TSA) to determine the levels of radiation emissions from explosive detection systems (EDS) and to evaluate employee exposure to radiation at airports during baggage screening. NIOSH researchers began an investigation in August 2003.

What NIOSH Did

- We observed checked and carry on baggage screening practices at 12 airports.
- We took radiation measurements at EDS machines.
- We talked to baggage screeners regarding health and safety concerns.
- We conducted personal radiation dosimetry on baggage screeners at six airports.

What NIOSH Found

- We measured low doses of radiation among baggage screeners in most airports. Doses for some of the baggage screeners exceeded the maximum dose for the public.
- We observed unsafe work practices such as reaching into EDS machines to clear bag jams.
- Some EDS machines were not well maintained (i.e., they had bent curtain rods and missing curtain flaps).
- Most EDS machines emitted low levels of radiation; a few exceeded regulatory limits.

What TSA Managers Can Do

- Develop a radiation safety program in accordance with the Occupational Safety and Health Administration standard.
- Provide regular radiation training to baggage screeners.
- Provide regular training on safe work practices to baggage screeners.
- Improve equipment maintenance.
- Periodically check radiation levels from EDS machines, and post these results on each surveyed EDS machine.
- Conduct limited dosimetry on employees to evaluate dose differences between baggage screeners working at selected airports.
- Improve health and safety communication between employees and management at each airport.
- Work with EDS manufacturers to improve design of machines.

What TSA Employees Can Do

- Use an appropriate pole to clear bag jams. Do not reach or crawl into EDS machines to clear bag jams.
- Inform supervisor if equipment is malfunctioning.

What To Do For More Information

We encourage you to read the full report. If you would like a copy, either ask your health and safety representative to make you a copy or call 1-513-841-4252 and ask for HETA Report #2003-0206-3067.

SUMMARY

NIOSH investigators determined that at the time of this evaluation, TSA baggage screeners at the 12 surveyed airports received insufficient radiation safety training and that EDS equipment was being inadequately or inconsistently maintained. The insufficient training and inadequate equipment maintenance could contribute to unnecessary occupational radiation exposures for TSA baggage screeners. This report provides recommendations for protecting all TSA baggage screeners from occupational radiation exposure by improved training on radiation issues and proper work practices, improved EDS equipment maintenance, and more frequent monitoring of EDS equipment for radiation leaks. We also recommend that TSA conduct additional personal dosimetry on baggage screeners to evaluate the radiation dose differences observed between airports and the possibility of occupational high doses.

Between November 2002 and March 2003, the National Institute for Occupational Safety and Health (NIOSH) received three health hazard evaluation (HHE) requests from Transportation Security Administration (TSA) employees at the Cincinnati, Honolulu, and Baltimore airports. The employees expressed concerns about a variety of potential exposures including diesel exhaust, dirt, dust, noise, and hazardous items found in baggage. In addition, a concern common to all three requests was exposure to x-rays from carry-on baggage and checked baggage screening machines. On March 26, 2003, TSA management submitted a separate request for NIOSH "to perform an independent study to determine the levels of radiation emissions from the various TSA screening equipment, and whether routine use of dosimetry is warranted." In May 2003, the following 12 airports were selected for study: Logan International (BOS); Baltimore-Washington International (BWI); Cincinnati/Northern Kentucky International (CVG); Los Angeles International (LAX); T.F. Green Municipal (PVD); Palm Beach International (PBI); Chicago O'Hare International (ORD); Harrisburg International (MDT); Honolulu International (HNL); McCarren International (LAS); Miami International (MIA); and Philadelphia International (PHL). The objectives of the NIOSH HHE were as follows: (1) assess the work practices, procedures, and training provided to TSA baggage screeners who operated machines that generate x-rays and (2) characterize TSA baggage screeners' radiation exposures and determine if routine monitoring with radiation dosimeters is warranted.

Basic characterizations of work practices, spot measurements for radiation, and employee interviews were completed between August 2003 and February 2004. Monthly radiation measurements were obtained from personal dosimeters issued to TSA baggage screeners between March and August 2004.

During the basic characterization phase, we observed poor work practices such as employees reaching into the Explosive Detection System (EDS) machines to clear bag jams and employees covering up the emergency stop buttons. We inspected and measured radiation exposure rates for 281 EDS machines. We observed that EDS machines at several airports exhibited a flaw that could be a source of unnecessary radiation exposure to TSA baggage screeners operating these machines. Radiation could leak out of the main gantry housing the computer-aided tomography (CAT) scanner through gaps between the entrance and exit baggage conveyors that appeared because the conveyor belt tunnels on most standalone units were not bolted to the gantry. Workers who frequently have to push odd-sized baggage up the entrance conveyor of the standalone machines are potentially exposed to the radiation present in the gap between the gantry and conveyor belt tunnel. We recommended taking six machines offline because the potential exposures to workers from these machines were equal to or greater than 500 microRoentgen per hour (µR/hour), the Food and Drug Administration's Performance Standard for cabinet x-ray systems.

Occupational radiation measurements over a 6-month period from 854 TSA employees included 4024 results from dosimeters worn on the chest (as an estimate of exposure received by the whole body) and 3944 results from dosimeters worn on the wrist. Approximately 89% of the occupational whole body exposures and 88% of the occupational exposures to the wrist were below 1 millirem (mrem).

None of the participants' doses in this evaluation exceeded the Occupational Safety and Health Administration (OSHA) permissible exposure limit of 1250 mrem per calendar quarter for individuals present in a restricted area (an area where access is controlled by the employer for purposes of protecting individuals from exposure to radiation or radioactive materials). Furthermore, no doses exceeded 25% of the OSHA quarterly limit which would require employee monitoring.

The median estimated 12-month cumulative occupational whole body dose during the period of observation was zero at four of six airports. The highest median estimated 12-month cumulative occupational doses (whole body and wrist) occurred at LAX (14.7 and 15.5 mrem); the other airport with a non-zero median estimated 12-month cumulative dose was BOS (0.4 mrem each for whole body and wrist). Doses for only two out of 854 individuals exceeded the 500 mrem/year estimated cumulative occupational dose, which is the monitoring threshold of the Nuclear Regulatory Commission, and only 13 exceeded an estimated cumulative whole body or wrist dose of 100 mrem/year, which is the monitoring threshold of the Department of Energy. However, because the sample of airports may not be representative, and the study participants were volunteers, these results may not generalize to the entire TSA workforce.

Given the strengths and weaknesses of this study, the need for a routine radiation dosimetry program for TSA screeners can neither be justified nor refuted at this time. Approximately 90% of the doses that screeners received were below 1 mrem, but some doses were at levels that warrant further action. Therefore, additional monthly or quarterly dosimetry targeted at specific airports for at least a year may be useful to evaluate the high doses reported in this evaluation. The number of airports and the specific airports for this targeted monitoring are left to the discretion of the TSA. Selection criteria could include airport size, machine type, and orientation of machines (in-line versus standalone). It is recommended that the dosimetry program be managed by a health or medical physicist. To address weaknesses of this study, we also recommend that TSA make participation in the dosimetry program mandatory.

Keywords: NAICS 488119 (Other Airport Operations), x-rays, ionizing radiation, low-level radiation exposure, airport screeners, explosive detection systems

INTRODUCTION

Between November 2002 and March 2003, the National Institute for Occupational Safety and Health (NIOSH) received three health hazard evaluation (HHE) requests from Transportation Security Administration (TSA) employees at the Cincinnati, Honolulu, and Baltimore airports. The employees expressed concerns about a variety of potential exposures including diesel exhaust, dirt, dust, noise, and hazardous items found in baggage. In addition, a concern common to all three requests was exposure to x-rays from screening machines for carry-on baggage and checked baggage. On March 26, 2003, TSA management submitted a separate request for NIOSH "to perform an independent study to determine the levels of radiation emissions from the various TSA screening equipment." NIOSH researchers addressed the exposure concerns, other than x-rays, in six separate documents; those in final report format can be found on the NIOSH Web site at www.cdc.gov/niosh/hhe (report ID: 2004-0100-2946; 2004-0146-2947; 2004-0101-2953). Final letter reports may be obtained from the HETAB Records Office at 513-458-7124 (report ID: 2003-0199; 2003-0212; 2003-0316).

In response to the requests concerning x-rays and baggage screening equipment, NIOSH investigated radiation concerns at several airports. On May 21, 2003, NIOSH researchers held an opening conference with TSA management and screener representatives at the TSA headquarters in Arlington, Virginia, to provide an overview of the HHE program, obtain input about work practices and airports from TSA baggage screeners and management, and select the airports to be included in the evaluation.

To perform the HHE, NIOSH entered into an Interagency Agreement with TSA. Under this agreement, TSA provided NIOSH with a portion of the costs, including those associated with radiation dosimetry, travel, instrumentation, and database development.

The objectives of the NIOSH HHE were as follows:

1. To assess the work practices, procedures, and training provided to TSA baggage screeners who operated machines that generate x-rays

2. To characterize baggage screeners' radiation exposures and determine if routine monitoring with radiation dosimeters is warranted

Transportation Security Administration

On November 19, 2001, because of the need for increased air transportation security, Congress enacted the Aviation and Transportation Security Act (ATSA). Under ATSA, the responsibility for inspecting persons and property carried by aircraft operators and foreign air carriers was transferred to a newly formed agency, the TSA. This rulemaking transferred the Federal Aviation Administration (FAA) rules governing civil aviation security to TSA. Prior to TSA, carry-on baggage and checked baggage screening at airports had been privately contracted. With the creation of TSA, these jobs were placed within the federal civil service system (at most airports), and baggage screeners were required to have additional background security evaluation, training, and testing. Since its establishment, TSA has federalized security employees at over 400 commercial service airports throughout the U.S. and its territories to screen carry-on and checked baggage. "Baggage screener" is a job title that describes workers who are responsible for screening carry-on baggage, checked baggage, or both. The responsibilities of TSA baggage screeners relative to carry-on or checked baggage may vary between airports; their major responsibility includes inspecting checked and carry-on baggage for explosives and incendiaries before loading.

Carry-On Baggage Screening

Currently, carry-on baggage of airport travelers is examined by TSA baggage screeners using Threat Image Protection Ready X-ray (TRX) systems located at passenger check points. While a small airport might need only one unit, larger airports such as JFK International in New York or Los Angeles International might install as many as 40. As of 2007, more than 700 TRX systems were installed at U.S. airports, with more than half located at 15 of the largest U.S. airports. The technology involves dual energy x-ray imaging that provides automatic color coding of materials with different atomic numbers so that screeners can easily identify objects within the baggage.

Checked Baggage Screening

TSA baggage screeners use Explosive Detection System (EDS) equipment to x-ray checked passenger baggage. The Aviation Security Improvement Act of 1990 required the FAA to establish criteria for certification of EDS equipment, to develop test protocols, and to have an independent means of testing for certification.[1] In 1994, the FAA approved the use of computer-aided tomography (CAT) scans as the first certified EDS device and began installing these x-ray screening machines in the fall of 1995.[2] Also at this time, the White House Commission on Aviation Safety and Security recommended screening checked baggage for domestic flights and provided funding for checked baggage screening equipment. The EDS machines have the potential for producing higher radiation outputs than the TRX machines.

Beginning in 1999, the FAA evaluated and then began purchasing EDS systems for deployment at Category X and Category I airports (i.e., the largest U.S. airports with the highest security risk). The original plan was to incorporate EDS technology in the airports over a 10- to 15-year period. However, following the attacks on September 11, 2001, the U.S. Congress enacted ATSA because of the need for enhanced air transportation security. The enactment of ATSA effectively led to the installation of EDS equipment in airports in approximately 2 years. Some of the more important consequences from this rapid deployment of EDS machines from the perspective of worker health and safety were inconsistent health and safety training for checked baggage screeners, inconsistent maintenance of the EDS machines, and the inability to address ergonomic problems before EDS machines were installed in some airports. As a result, the TSA and its new workforce had to learn how to use this new technology and adjust to the changing environments while maintaining Homeland Security initiatives.

To accommodate the size and weight of these large machines, most airport terminals required significant modification prior to their installation. In this HHE the location and operation of EDS machines is grouped into either of two categories: standalone or in-line. The standalones are individual units typically located in an airport lobby, though they may also be located in airport basements. TSA baggage screeners manually load and unload baggage into the EDS machine. The in-line EDS machines are integrated into the airport baggage handling conveyor system and are typically located out of the public view. These EDS machines require less manual loading and unloading of baggage by TSA baggage screeners.

During the time this HHE was conducted, two licensed EDS manufacturers operated in the United States (L3 Communications [New York, New York] and InVision® Technologies, Inc. [San Rafael, California]) with only four EDS models produced by these companies. L3 Communications produces the eXaminer 3DX™ 6000, while InVision Technologies manufactures the CTX 2500™, CTX 5500 DS™, and CTX 9000 DSi™. All models use CAT scan technology to create a three-dimensional scanned image of the object. The density of the scanned object is then compared to that of known explosives.[3]

Explosive trace detectors (ETDs) were present at all of the surveyed airports and are used as an additional security check for carry-on baggage. However, ETD devices are not discussed in this report for the following reasons: (1) they do not produce x-rays (they use a natural radioactive source) and (2) the shielded devices analyze swabs instead of baggage, further minimizing any potential radiation exposure to the TSA operator.

L3 eXaminer 3DX™ 6000

The L3 Communications eXaminer 3DX 6000 EDS uses a helical-cone beam to provide a three-dimensional CAT image of an object as it passes along the baggage conveyor. The system includes a high efficiency, wide dynamic range, solid state x-ray detector system that rotates to present both projection and axial images of the moving object for analysis by the baggage screener.[4] This system can be configured as a standalone unit or built in-line with the conveyor system, and can screen up to 500 bags per hour. Once powered, the 3DX 6000 x-ray detector is designed to continuously scan, regardless of whether a bag is in the machine.

InVision CTX 2500, 5500, and 9000

While InVision CTX models vary in size and intended airport application, all use a single rotating x-ray source to acquire positioning images and CAT-slice images. The smallest models, the CTX 2500 and 5500, are intended for standalone in-lobby installations at airports where space is at a premium. After scanning, the bag can be ejected from either the front or rear of the machine. The largest model, the CTX 9000, is intended solely for in-line baggage scanning installations. Unlike the 3DX 6000 made by L3, the InVision CTX machines only power the x-ray detector if a bag is within the gantry scanning area.

Carry-on and Checked Baggage Screener Activities

The main responsibilities of carry-on baggage screeners are to direct the public to place their luggage in the TRX machines and to examine the x-ray image of the scanned item. Sometimes they may physically inspect passengers, or analyze swabs taken on the surface of passengers' personal items using an ETD. Although they work around the TRX machines, little to no opportunity for radiation exposure exists.

The checked baggage screeners perform their jobs either in airport lobbies in plain sight of the public or in the airport basement. Their main functions include loading and unloading bags onto the EDS machine. Regardless of the location, the main responsibilities of the baggage screeners are to load and unload checked bags into the EDS machine by means of a belt conveyor, then check the x-ray image of the scanned bag for explosives, weapons, or other banned material. If the x-ray image indicates the presence of suspicious material, the bag is removed from the EDS machine and inspected by hand. During this survey, NIOSH investigators observed screeners loading and unloading bags both at the beginning (or foot) of the conveyor and at the EDS tunnel entrance. In the latter instance, baggage screeners were occasionally observed loading or unloading baggage as it passed through the lead strip curtains separating the conveyor from the gantry scanning area, a work practice that places them close to the EDS machine where they may be subject to unnecessary radiation exposure.

Radiation Monitoring of TSA Workers

In 1975, FAA rules included a requirement that operators of the x-ray generating equipment wear personal radiation dosimeters.[5] In August 1997, the FAA proposed omitting the requirement that air carriers monitor their employees for radiation exposure; this rule became final in July 2001.[6] The FAA justified this decision based on the lack of any incident in which a person received excessive radiation from x-ray machines used for screening with "today's technology." The "today's technology" statement referred to the use of improved x-ray tubes and lower radiation output of the current generation of carry-on baggage x-ray screening equipment compared to equipment of the 1970s.[6] The FAA rule eliminated the radiation dosimeter requirement, although it still required aircraft operators to comply with requirements of other federal agencies or state governments (as applicable) regarding the use of radiation dosimeters. The decision not to monitor became final before widespread use of EDS machines.

After ATSA was enacted in 2001, the state radiation programs lost their oversight of radiation programs for airport baggage screeners. TSA employees are subject to the federal Occupational Safety and Health Administration (OSHA) workplace health and safety regulations.

BACKGROUND (CONTINUED)

Radiation Units

Radiation exposure is typically expressed in units of roentgen (R), which represent the amount of electromagnetic (i.e., gamma or x-ray) radiation exposure to a radiation detector. Radiation dose is reported in units of "roentgen equivalent man" (rem). For the purposes of this study, an exposure of 1 R is considered biologically equivalent to a dose of 1 rem. Also, the exposures and doses in this report are expressed as a millionth of a roentgen (μR), a thousandth of a roentgen (mR), or a millionth of a rem (mrem). The real-time radiation measurements using the ionization chamber can measure the radiation rate in μR/hour. The effective radiation dose in mrem can be compared to occupational or public dose limits. The radiation dosimeters worn by the TSA employees in this evaluation measure directly in mrem.

METHODS

To achieve the objectives of this evaluation, airport selection criteria and an exposure assessment strategy were established that included (1) characterization of TSA baggage screeners' exposure to x-rays at the selected airports, (2) characterization of the radiation leakage profiles on selected units representing the various types of EDS equipment, and (3) a 6-month personal and environmental radiation monitoring period in a subset of the selected airports. This evaluation assessed work practices and personal radiation exposures to carry-on baggage screeners operating the TRX machines, and the checked baggage screeners operating the EDS equipment. However, we focused on the EDS machines because they were not addressed in the 1997 FAA decision to remove radiation dosimetry requirements and because EDS machines could potentially produce high radiation outputs if not properly used and maintained.

The airports included in this study were selected during the NIOSH opening conference at the TSA headquarters in Washington, DC, in May 2003. As a start to the process of airport selection, TSA employee and management representatives suggested 30 airports for consideration. The selection criteria for these 30 airports included the number of TSA baggage screeners, anecdotal information from TSA management on employee complaints in some airports, geographic location, airport type (servicing, originating, connecting, and/or international travelers), and the time of year (some selected airports experienced seasonal peaks for passenger and baggage handling). TSA management and employee representatives mutually decided that the airports represented in the original three employee-initiated HHE requests (Cincinnati, Honolulu, and Baltimore) should be included in the 30 airports identified as potential candidates for this evaluation. These initial 30 airports were reduced to 12 after considering the survey costs and the time to complete the surveys, with six of the final 12 selections identified for personal dosimetry (Table 1). The final airports chosen for this HHE included small and large airports, airports that had L3 and CTX EDS machines, airports that had in-line and standalone EDS machines, and airports where the EDS machines were clustered next to each other or placed far apart.

Table 1. Airports Selected for Study

Airport Name	Location	Date of Basic Characterization	Dosimeter Survey?
Logan International [BOS]	Boston, Massachusetts	August 2004	Yes
Baltimore/Washington International [BWI]	Baltimore, Maryland	December 2003	Yes
Cincinnati/N. Kentucky International [CVG]	Erlanger, Kentucky	November 2003	Yes
Honolulu International [HNL]	Honolulu, Hawaii	November 2003	No
McCarran International [LAS]	Las Vegas, Nevada	January 2004	No
Los Angeles International [LAX]	Los Angeles, California	November 2003	Yes
Harrisburg International [MDT]	Harrisburg, Pennsylvania	December 2003	No
Miami International [MIA]	Miami, Florida	January 2004	No
Chicago O'Hare [ORD]	Chicago, Illinois	January 2004	No
Palm Beach International [PBI]	Palm Beach, Florida	January 2004	Yes
Philadelphia International [PHL]	Philadelphia, Pennsylvania	December 2003	No
T.F. Green International [PVD]	Providence, Rhode Island	August 2004	Yes

Phase 1: Basic Characterization

All 12 airports received a basic characterization that consisted of an observational survey, a review of airport-specific screening operations, and an inspection of x-ray generating equipment. During these site visits, NIOSH researchers met with TSA workers and management to learn about work practices, baggage screening procedures, exposure controls, maintenance activities, and radiation training. We conducted group or private interviews with baggage screeners to discuss any occupational health and safety concerns. Maintenance records were reviewed, but because many of the EDS machines were recently installed (within one year), the records often provided little information. Information was also obtained on the number of TSA workers, the number and orientation of EDS and TRX machines, and monthly baggage throughput of EDS machines for the past 6 months. Video tapes and digital photos were taken to illustrate common work practices and examples of faulty equipment. Some of these photos are provided at the end of this report.

NIOSH researchers visited the two EDS manufacturers to discuss problems found with their respective baggage scanning equipment and make recommendations to improve their product before it was deployed to TSA or other customers.

Employee Interviews

In Phase 1, employee interviews were usually done informally in the work area, either one-on-one or with an EDS crew (typically six to eight baggage screeners). Baggage screeners were briefed on the NIOSH study and were invited to discuss any radiation or non-radiation health and safety concerns regarding their work environment. Radiation questions were addressed in the field, while non-radiation concerns were noted and addressed during the closing conferences, which were held at each airport at the end of the initial visit and included management and employee representatives.

Real-Time Radiation Measurements

During the Phase 1 surveys, real-time radiation measurements were taken around the EDS and TRX machines. This technique, referred to as the "spot-check" method throughout the rest of the report, allowed NIOSH researchers to quickly assess the performance of engineering controls (e.g., shielding) designed to prevent workers' exposure to radiation and to determine if any EDS or TRX equipment had excessive radiation leakage. Radiation exposure levels were typically measured at the EDS and TRX entrance (where bags are loaded) and at the exit (where bags are unloaded). They were also measured along the seams of the machines where there is a potential for radiation leakages and at locations where employees stand. Employees usually stood 1–8 feet from the entrance and exit tunnels of the machines, depending on their activity. These spot checks often allowed NIOSH researchers to engage TSA baggage screeners in discussions about their radiation concerns and to demonstrate when, where, and why radiation exposures might occur during their screening operations.

NIOSH researchers used two Fluke Biomedical 451P ionization chamber instruments (InVision, Cleveland, Ohio) to measure the real-time radiation exposure rates in units of µR/hour. The Fluke Biomedical 451P was chosen because it provides an integrated mode, data logging capability, and a freeze mode used to identify peak measurements. Both Fluke meters were calibrated with a cesium (Cs)-137 source with an energy level of 662 kilo electron volts. Because the Cs-137 source has a higher energy level than the x-rays generated by the EDS machines, an energy response was determined for each meter to derive an appropriate correction factor. We determined that the two meters may underestimate the EDS x-ray energy by either 20% or 30%. To take a conservative approach, we used a correction factor of 1.3 (30%).

The Fluke Biomedical 451P does not comply with all Food and Drug Administration (FDA) regulations that define the type of instrument and procedures for measuring radiation leakage because it underestimates the exposure rate when the radiation beam is smaller than the volume of its ionization chamber. In addition, the instrument is not radio frequency-shielded. Currently, the only commercially available instrument that complies with these regulations is the Victoreen 440 RF/D or C (InVision, Cleveland, Ohio). However, this instrument lacks the ability to integrate and provide a measure of total exposure.

Prior to beginning this survey, NIOSH researchers discussed the instrumentation issue with FDA officials including the fact that the NIOSH measurements were for screening purposes and not to assess compliance with FDA regulations. All agreed that the Fluke Biomedical 451P ion chamber would be appropriate for NIOSH to use during the TSA radiation surveys.[7]

Photos

Digital photos were taken to capture the work locations of the baggage screeners, including the EDS operator and the baggage loader and unloader stations. These photos were also used to document information regarding the baggage spacing relative to volume throughput and the baggage type (oversized luggage versus small bags), to identify damage to the EDS entrance and exit tunnels, and to identify the condition of the lead strip curtains. In addition, photos were taken to demonstrate work practices such as clearing bag jams, reaching into or through the lead curtains at the entrance and exit, and loading and unloading bags.

Phase 2: Radiation Dosimetry

Phase 2 involved monitoring the radiation exposure received by TSA baggage screeners at six airports (BOS, BWI, CVG, LAX, PBI, and PVD) over a 6-month period. Carry-on baggage screeners and checked baggage screeners were eligible for the study. Baggage screeners who were interested in having their personal radiation exposure monitored were asked to complete a questionnaire during Phase 1 of the study. The completed questionnaire was returned to NIOSH researchers during the site visit or mailed in pre-stamped and addressed envelopes. Volunteers were asked to wear two dosimetry badges, one on their chest (to approximate their whole body dose) and another on the wrist of their dominant hand (to measure the dose that would be received if the hand, wrist, or fingers were exposed during operation of the machine). Volunteers wore these badges for one month, after which the badge was sent to a NIOSH contract laboratory (Landauer Inc., Glenwood, Illinois) for analysis; the laboratory sent a replacement badge to the participant at the beginning of each month. The procedure continued for 6 months. Every study participant was assigned a unique 4-digit identification number that, in addition to use by NIOSH investigators to calculate summary statistics, also allowed the study participants to access their monthly dosimetry results from a secure website.

The badges used the Optically Stimulated Luminescence (OSL) technology, which uses aluminum oxide crystals (Al_2O_3) as the detector material. The amount of radiation exposure (in mrem) is measured by stimulating the Al_2O_3 material with green light from either a laser or light emitting diode source. The resulting blue light emitted from the Al_2O_3 is proportional to the amount of radiation exposure. Both high and low-energy photons are measured with this technique.

Area Dosimeters

Area dosimetry data were collected at each of the six airports that participated in the personal dosimetry study. The purpose of the area monitoring was to characterize potential radiation exposures in the general work areas around the EDS machines. The area badges were placed near the EDS machines, and in locations near the EDS accessed by the public. The number of badges provided to each airport depended upon the number, layout, and orientation of EDS machines in the airports. We provided 125 badges to the airports for area dosimetry as follows: BOS (15), CVG (15), LAX (20), PVD (20), PBI (25), and BWI (30).

Direct Irradiation of Dosimeters

Sixty-seven dosimeters were intentionally irradiated in groups of three from one to ten times in EDS (L3 and CTX) and TRX machines to characterize the response of the dosimeters when directly exposed to the beam. Results from these intentionally exposed badges were used as a benchmark to help identify and explain unusual radiation dosimetry results and provide a realistic estimate of the maximum exposure that would be delivered to a dosimeter if it were purposefully or inadvertently irradiated.

Adjusting for Background Radiation

Control dosimeter badges were provided to the airport managers to store in an area away from radiation sources to provide a background radiation level. The number of control badges provided to each airport was approximately 5% of the number of study participants enrolled in Phase 2. The managers were asked to return these environmental dosimeters to the laboratory along with the employee and area dosimeters. In instances where a control badge was not returned with an employee badge, the background level was estimated by the laboratory or by NIOSH researchers using the equation that follows.[8]

$$\text{Background} = 0.2X + 2.6033, \text{ where}$$

X = days between when the badge was factory shipped and when it was read by the lab, and the constant (2.6033) represents an average background radiation level. This equation was derived by the laboratory based on a year-long study of background radiation throughout the U.S.[9] The measured or estimated background was then subtracted from the employees' whole body and wrist measures to create measures that were adjusted for background radiation. In instances when employees' whole body or wrist measures were non-detectable, or when employees' measures were less than or equal to the measure for background, their adjusted whole body or wrist result would be at most zero. In such cases the adjusted result was given the value zero. The adjusted measures were used for all statistics and analyses involving personal dosimetry.

Validation of Data

Generally, any background-adjusted dosimeter result in excess of 15 mrem (whole-body) and 30 mrem (wrist) for any given month was investigated. Study participants with such results were interviewed via telephone about possibilities of a high exposure (working longer hours than normal, undergoing nuclear medicine procedures or treatments, or self or coworker inadvertently/purposefully passing the badge through the EDS machine). In addition, if a background-adjusted dose exceeded 100 mrem, the badge was reanalyzed to determine if the exposure was static (exposure profile would denote that only one portion of the badge was hit by radiation) or dynamic (exposure profile would denote random hits from radiation source), and if the effective energy of the badge was consistent with the energy from the EDS sources. Askelrod et al. described a procedure to distinguish between static and dynamic exposures in OSL dosimeters.[10] According to the NIOSH contract laboratory, it was not technically feasible to determine exposure profiles for badges with doses less than 100 mrem because the signals were too faint to obtain a reliable reading. Doses were classified as "non-occupational" only under the following circumstances: (1) if the study participant acknowledged the possibility that the badge(s) may have been passed through the EDS, (2) if the participant was undergoing nuclear medicine procedures or treatments that would interfere with the badges, or (3) if the exposure profile was static. If a study participant with a background-adjusted dosimeter result in excess of 15 mrem (whole-body) and 30 mrem (wrist) could not be reached by telephone, that person's dose was deemed occupational and was included in all analyses of occupational doses.

Statistical Analysis

SAS Version 9.1.3 (Cary, North Carolina) was used for all statistical analyses. The Genmod procedure was used to compare the prevalence of doses greater than or equal to 1 mrem for various groups. This program can account for correlation of multiple measures for the same subject. Results with a probability (p) value less than or equal to 0.05 were considered statistically significant.

EVALUATION CRITERIA

In evaluating the hazards posed by workplace exposures, NIOSH investigators use both mandatory (legally enforceable) and recommended occupational exposure levels (OELs) for physical agents as a guide for making recommendations. OELs have been developed by Federal agencies and safety and health organizations to prevent the occurrence of adverse health effects from workplace exposures. Radiation safety professionals rely on the principle of "as low as reasonably achievable" (ALARA) with respect to protecting workers from exposure to ionizing radiation. ALARA is based on the principle that any amount of radiation exposure, no matter how small, can increase the chance of negative biological effects and that the probability of negative effects of radiation exposure increases with cumulative lifetime dose. These ideas are combined to form the linear no-threshold model endorsed by the National Academy of Sciences.[11] The ALARA principle also recognizes, however, that practices that involve use of radiation bring benefits to the general population, so reducing radiation exposure to zero mrem can have a negative societal impact. The economic cost of adding a barrier against radiation must also be considered when applying the ALARA principle.

The TSA workforce is subject to the OSHA regulations for ionizing radiation (29 CFR 1910.1096).[12] However, many additional occupational and public radiation standards have been established by various government and scientific organizations as shown in Table 2. For information on pregnant workers, please refer to documents published by National Council on Radiation Protection (NCRP 116)[13], Nuclear Regulatory Commission (NRC)[14], and International Commission on Radiological Protection (ICRP).[15] These standards are primarily meant to protect workers from long-term, low-level exposure to ionizing radiation. TSA workers are not likely to experience acute health effects because the radiation output from the EDS machines will not result in a dose high enough to cause these effects. Consistent with current practice among radiation safety professionals, TSA is encouraged to apply the ALARA principle in protecting its workers from excessive radiation exposure.

Table 2. Occupational and Public Radiation Dose Limits[a]

	DOE[b]	NRC[c]	OSHA[d]	NCRP[e] (1993)	ICRP (1991)
			Occupational		
Whole body (deterministic)[f]	5,000 mrem per year	5,000 mrem per year	1,250 mrem per quarter for the whole body (head and trunk; active blood-forming organs or gonads)	5,000 mrem per year	2,000 mrem per year average over 5 years (10,000 mrem in 5 years), not to exceed 5,000 mrem in any single year
Lens of eye	15,000 mrem per year	15,000 mrem per year	1,250 mrem per quarter	15,000 mrem per year	15,000 mrem per year
Hands, forearms; feet and ankles	50,000 mrem per year	50,000 mrem per year	18,750 mrem per quarter	50,000 mrem per year	50,000 mrem per year
Skin	50,000 mrem per year	50,000 mrem per year	7,500 mrem per quarter	50,000 mrem per year	50,000 mrem per year
Embryo-fetus of pregnant worker[g]	500 mrem per gestation period	500 mrem per gestation period	No limit established	50 mrem per month over gestation period	200 mrem per gestation period
Cumulative	No limit established	No limit established	5,000 (N-18) mrem N=age (y)	1000 mrem x age (y)	No limit established
			Public		
Whole body (deterministic)	100 mrem per year for members of the public entering a controlled area	100 mrem per year from licensed operation; *or* 2 mrem per hour from any unrestricted area	No limit established	100 mrem for continuous exposure *and* 500 mrem for infrequent exposure	Annual average over 5 years not to exceed 100 mrem
Lens of eye, skin, and extremities[h]	No limit established	No limit established	No limit established	5000 mrem	1,500 mrem to lens of eye *and* 5,000 mrem to skin, hands, and feet
Negligible Individual Dose	No limit established	No limit established	No limit established	1 mrem annual effective dose per source of practice	No limit established

[a] The dose limits are reported in the conventional units (mrem) to be consistent with the U.S. regulations.

[b] The Department of Energy

[c] NRC states that if members of the public are continuously present in an unrestricted area, the dose from external sources cannot exceed 0.002 rem in an hour and 0.05 rem in a year.

[d] OSHA occupational dose limits are reported in terms of dose equivalent per calendar quarter and apply only to individuals who work in a restricted area. Restricted area means any area that is controlled by the employer for purposes of protecting individuals from exposure to radiation or radioactive materials. Minors are restricted to 10% of the limits shown.

[e] NCRP 116 also states, "new facilities and the introduction of new practices should be designed to limit annual effective doses to workers to a fraction of the 1,000 mrem/year implied by the lifetime dose limit."

[f] Occupational and public deterministic dose limits (except OSHA) are reported in terms of annual effective dose (E); the cumulative dose limit is a cumulative effective dose limit. The effective dose ($E=w_R H_T$) is intended to provide a means for handling nonuniform irradiation situations. The tissue-weighting factor (w_R) takes into account the relative detriment to each organ and tissue including the different mortality and morbidity risks from cancer. In other words, the risks for all stochastic effects will be the same whether the whole body is irradiated uniformly or not.

[g] Embryo-fetus dose limit is an equivalent dose (H_T) limit in a month once pregnancy is known. The equivalent dose limit is based on an average absorbed dose in the tissue or organ (D_T) and weighted by the radiation weighting factor (w_R) for radiation impinging on the body ($H_T=w_R D_T$).

[h] Lens of eye, skin, and extremity dose limit is an annual equivalent dose limit.

Radiation Leakage Limits for Equipment

In addition to personal protective dose limits, radiation leakage limits apply to the EDS equipment. The FDA regulation that applies to security systems that use x-rays can be found at http://www.fda.gov/opacom/laws/fdcact/fdcact5c.htm.[16] This regulation states, "Radiation emitted from the cabinet x-ray systems (such as an EDS machine) shall not exceed an exposure of 500 µR in one hour at any point 5 centimeters (approximately 2 inches) outside the external surface." The FDA limit is for radiation leakage, and not the whole-body dose that an individual may receive.

Phase 1: Basic Characterization

We requested employee demographic data at the airports as part of our effort to describe the workforce. In some airports, this information was presented by employment status (full-time versus part-time workers), by gender, by job titles (checked baggage screener, carry-on baggage screener, lead screener, supervisor, etc.), or a combination of all these formats. NIOSH investigators summarized the information in a consistent manner. Most airports also provided us with written or oral information on the number and type of EDS and TRX machines. The employee demographic and machine information are presented in Table 3.

Table 3. Characteristics of Airports that Participated in the NIOSH Evaluation

		EDS				TRX
Airport	No. TSA Employees	No. L3	Orientation	No. CTX	Orientation	No. TRX
BOS	259	37	In-line[a]	None	Not applicable	Not available
BWI	Approx. 600[b]	16[c]	Standalone/in-line	None	Not applicable	26
CVG	350	5	Standalone/in-line	4	Standalone	10
HNL	Not available[d]	6	Standalone/in-line	6	Standalone/in-line	Not available
LAS	814	14	Standalone	None	Not applicable	Not available
LAX	Not available[e]	13	Standalone/in-line	45	Standalone/in-line	Not available
MDT	52	None	Not applicable	2	Standalone	3
MIA	1421	18	Standalone	23	Standalone	38
ORD	Approx. 1800	28	Standalone	12	Standalone	Not available
PBI	Not available[d]	9	Standalone	None	Not applicable	Not available
PHL	825	15[f]	Standalone	25[g]	Standalone/in-line	26
PVD	Approx. 100	None	Not applicable	12	Standalone	Not available

a. BOS baggage screeners were located in a control booth, so their potential for radiation exposure is very low.
b. About 160 employees are checked baggage screeners.
c. Includes two that were not operational during the NIOSH evaluation.
d. Information not received from airport.
e. Only employees at the international terminal were included in the study.
f. Includes four that were not operational during the NIOSH evaluation.
g. Includes 15 CTX 9000, of which 11 were operational during the NIOSH evaluation.

The TRX systems appeared to be sufficiently shielded, although on a few of machines some of the lead strip curtain flaps were missing. We measured no readings exceeding the FDA regulation (>500 µR/hour) from these machines. The entrance and exit locations had radiation measurements ranging from 20–60 µR/hour. On some TRX and EDS machines, the lights denoting that the x-rays were "on" were inoperable or blocked from view by items placed in front of them (Photos 26–27).

EDS units located outdoors in semi-protected environments (overhead roof, but no exterior walls) or in basements were vulnerable to flooding. In two airports, employees said that the equipment had failed because of water incursion. This is supported by equipment maintenance records from one of the airports that found computer work stations were not functioning after they got wet. Employees were also concerned about electrical safety following flooding.

We observed that L3 EDS machines at several airports exhibited a flaw that could result in unnecessary radiation exposure to TSA baggage screeners operating these machines. Radiation could leak out of the main gantry housing the CAT scanner through gaps between the entrance and exit baggage conveyors that appeared because the conveyor belt tunnels on most L3 standalone units were not bolted to the gantry (Photo 22). Although workers do not typically stand along the side of the L3 where these gaps are found, a potential for exposure exists if workers stand along the side during lull periods, or if the gaps align with workers operating nearby EDS equipment. Employees at one airport reported that tug drivers who transport baggage from the EDS machines to the airplanes sometimes crash into the L3 machines, causing the gantry to separate from the conveyor belt tunnels. To prevent this, the airport placed concrete barriers in front of the L3 machines. It is also our understanding that TSA authorities at this airport raised this concern with airline representatives, who oversee tug operations. The gaps between the gantry and the tunnel are due to poor machine design and wear and tear from regular use.

During this evaluation, NIOSH researchers observed inactivated, removed, or inadequately maintained engineering controls that were modified by employees to make the screening process quicker. At some airports, the safety interlock switches on L3 access panels were intentionally bypassed with duct tape, paper towels, or other materials (Photos 24–25). This bypass allowed the screeners to open the access panels and quickly clear bag jams while the EDS machine remained active, thus avoiding a delay in restarting the EDS. However, bypassing the safety interlocks invalidates the FDA approval for the cabinet x-ray system and may result in an unnecessary radiation dose to the screener. In other instances, worn grommets and poor maintenance on the L3 access panels required screeners to come up with ways to keep the safety interlocks activated. This problem was reported to the manufacturer, who then installed adjustable interlock switches. At one airport, the emergency shut-off switch on an L3 machine had been intentionally blocked to avoid accidental deactivation if hit by nearby stacked baggage (Photo 28). This machine deactivation would have resulted in a lengthy restart period and disruption of the checked baggage screening process.

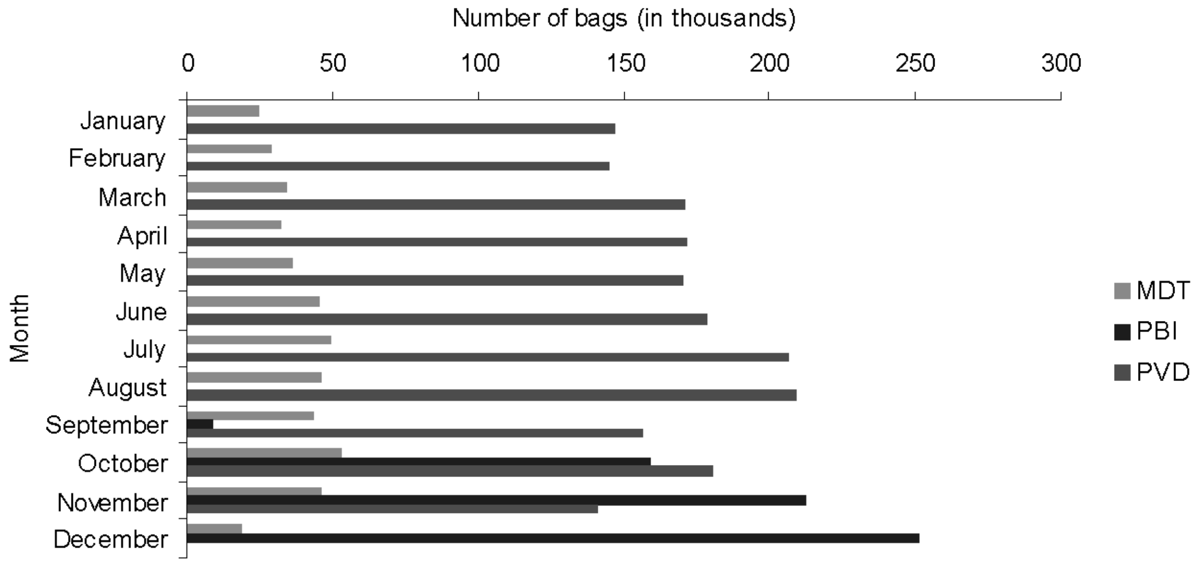
NIOSH researchers observed examples of improper work practices in some instances. For example, some TSA baggage screeners were placing their hands beyond the lead strip curtains on EDS machines to adjust or remove baggage. In one airport, employees used a hollow tube made of polyvinyl chloride (PVC) to push bags through the EDS machine. In that instance, NIOSH researchers informed employees and management that a hollow PVC tube can transmit radiation from the point source (the machine) to the worker's body if the tube was perfectly aligned with the radiation source and the worker's body. We recommended capping the PVC tube, covering it with lead tape, or using a solid wooden pole instead.

Instances of appropriate work practices were also observed. In one airport, the L3 entrance tunnel dislodged after a baggage strap became caught on the machinery. TSA employees generated an FDA report, and an L3 technician reattached the entrance tunnel and rechecked the unit. In addition, all of the baggage screeners were advised by the airport management to complete an injury report. At another airport, when a bag jam occurred, the baggage screeners notified the supervisor who had the keys to open the access door to clear the jam. This procedure safeguarded the screeners from opening the access panels themselves and potentially being exposed to radiation. This key control procedure should identify the authorized individuals who have access to the keys, and these individuals should be able to respond quickly to minimize downtime of the EDS machine.

At one airport we measured a radiation rate of >1,500 µR/hour about 6.5 inches from the exit lead strip curtain on several CTX units. Although not a direct hazard to TSA baggage screeners (since no workers would typically be standing at this location), this radiation rate did not comply with design criteria of the EDS equipment. We demonstrated that this radiation rate could be eliminated by simply reducing the distance between the lead strip curtains and the conveyor belt. At another airport, a CTX machine had an electric-eye control system feature that stopped the conveyor belt. This allowed screeners to attach security stickers to the scanned baggage as it exited the machine. The placement of the electric-eye was too close to the exit and would not allow a long piece of baggage to completely exit the machine prior to scanning the next piece. As a result, the EDS would activate the x-ray source and radiation would scatter through the displaced exit lead strip curtains, resulting in unnecessary radiation exposures to the screener attaching stickers to the baggage. The radiation intensity varied by the size of the opening from the displaced lead curtains, the contents of the baggage being screened, and the size of the baggage exiting the machine. This unnecessary radiation exposure problem was eliminated by relocating the electric eye further from the CTX exit curtain.

Three airports (MDT, PBI, and PVD) provided records showing the monthly throughput of bags for their EDS machines. The data presentation differed between airports: MDT provided monthly (January–December 2003) baggage output for both of its CTX machines; PBI provided monthly data from September through December 2003; and PVD provided daily data for 12 CTX machines from late December 2002 to November 2003. The data for calendar year 2003 is summarized in a consistent manner by month and presented in Figure 1.

Figure 1: Bags/month passed through EDS machines at 3 airports in 2003



The rationale for examining baggage throughput was to determine if heavy demand on the EDS systems during certain times of the year may result in more bag jams and thus greater radiation dose to the baggage screeners. Anecdotally, the number of bag jams increased as the number of bags passed through an EDS machine increased. We do not have systematic data on the number of bag jams by machine type, airport, or individual machines. Only one airport provided data on bag jams: it reported 158 bag jams on four L3 machines over a 6-month period. When asked by NIOSH investigators, baggage screeners described the frequency of bag jams as a function of shift, hour, and total number of bags screened; these descriptions varied within and between airports (Table 4)

Table 4: Spot-check Measurements at a Sample of Machines where Screeners Reported Bag Jams

Airport	Machine	Bag Jams	Measurement (µR/hr)	Comment
BWI	L3	130–520/day/machine	1300 at entrance	Curtain, railing inside machine bent
LAX	CTX 2500	2/shift/machine	52 at exit	Employees enter machine to get bag
	CTX 5500	2–3/day/machine	229 entrance; 131 exit	None
	CTX 5500	5/week/machine	286 at entrance	None
	L3	10/shift/machine	390 at exit	Employees enter machine to get bag
PHL	L3	1/shift/machine	130–156 at entrance	None
	L3	1–2/week/machine	52–104 at entrance	None

Employee Interviews

Baggage screeners were concerned that their exposures had not been routinely monitored via personal dosimetry. They reported that employers prior to TSA had provided them with monthly dosimetry badges. Some also feared that radiation from the machines may harm fetuses. Many baggage screeners were concerned about contracting communicable diseases (such as pink eye and influenza) from the public. These latter concerns were outside the scope of the present evaluation, and employees were referred to the TSA Occupational Safety and Health Office.

Real-Time Radiation Measurements

NIOSH investigators examined approximately 100 TRX machines; none of these machines registered readings in excess of the FDA regulation of 500 µR/hour, although a few of the machines had missing lead curtains. Of the 281 EDS machines inspected by

NIOSH researchers, 123 were CTX machines and 158 were L3 machines. Most of the machines registered low radiation levels (less than 500 µR/hour at distances more than 5 cm from the external surface of the machines). At the start of the survey, NIOSH investigators obtained readings from machines that appeared well shielded and well maintained. Table 5 summarizes radiation levels from well-shielded EDS and TRX machines. However, as the surveys continued, we focused on machines that were problematic, and only reported these numbers.

Table 5. Summary of Radiation Levels (µR/hour) from Well-Shielded EDS and TRX Machines

Baggage Screening Machines	Entrance Lead Curtain			Exit Lead Curtain		
	Still	Moving	Inside	Still	Moving	Inside
L3	52–104	104–468	5850	52–130	52–1820	2080–5590
CTX 2500	NA	NA	61100	NA	52	42900
CTX 5500	33–52	130	NA	33	79–195	NA
TRX	NA	20–80	2080	NA	26–82	3250

CTX 9000: 104–182 µR/hour along the seam
NA: Not available

Six of the L3 machines registered radiation levels that exceeded 500 µR/hour. Three of the units had gaps between the gantry and the entrance tunnel; on two machines, the interior lead curtains were damaged, and on one, employees had bypassed the machine's interlock system. NIOSH researchers recommended that TSA take the six machines off-line to reduce radiation exposure to baggage screeners. TSA subsequently took the machines off-line until repairs were made on the machines.

Radiation Profiles

Figure 2 compares the radiation levels taken at the entrance of an EDS machine and the entrance of a TRX machine. The average exposure rate of the EDS machine was 0.16 mR/hour, while the average exposure rate of the TRX machine was 0.022 mR/hour.

Figure 2: Comparison of radiation output between an EDS and TRX machine

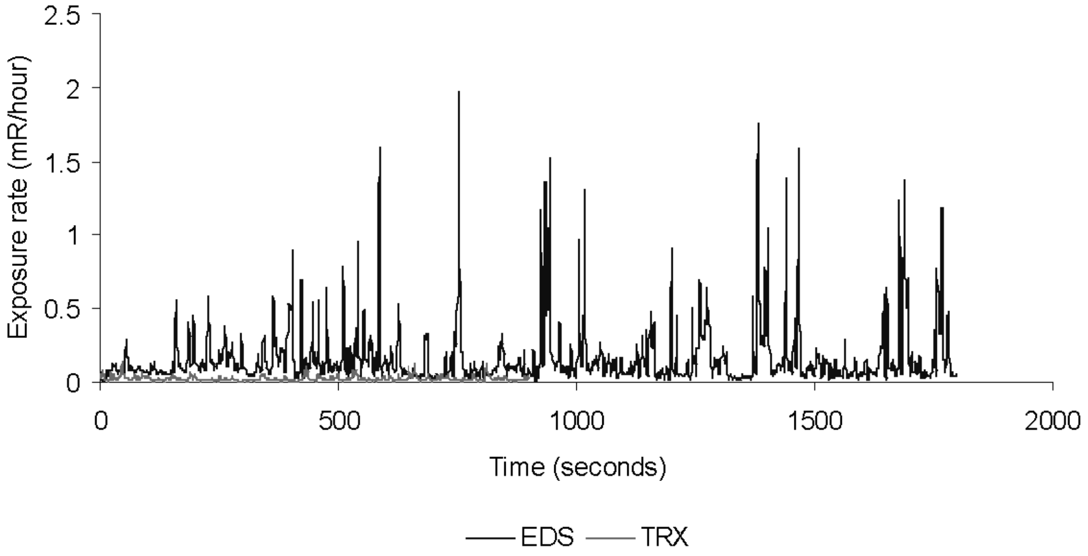


Figure 3 compares the entry and exit ports of an L3 EDS machine at PBI. Both sets of measurements were collected for 15 minutes. The number of bags during this slow period was 39. The average exposure rate at the entry was 0.13 mR/hour and 0.10 mR/hour at the exit. The peaks correspond to the lead curtains being displaced as the baggage enters or exits the L3 machine. The maximum readings at the entry port were 3.5 mR/hour and 10.5 mR/hour at the exit port. The maximum peaks corresponding to these measures are truncated in Figure 3 so as not to obscure the lower measures.

Figure 3: Radiation profiles at the entry and exit of an EDS machine during a slow period

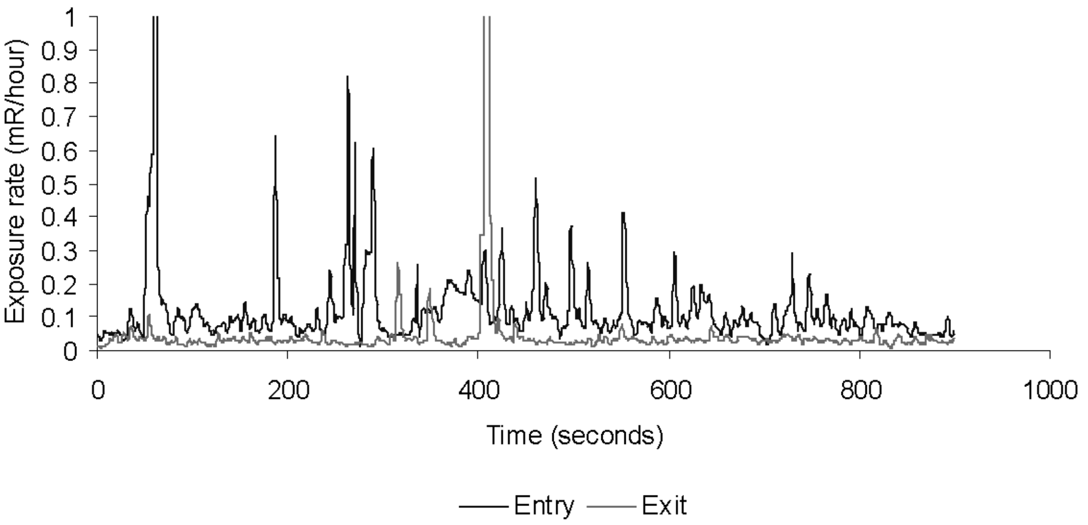


Figure 4 shows a profile of radiation levels from an L3 EDS machine at LAS during a 30-minute busy period. The measurements compare radiation levels at the exit location of the EDS (average = 0.057 mR/hour) and at the location where the employee was sitting (average = 0.032 mR/hour). Although many peaks occurred in the 200 to 600 µR/hour range, the operator's exposure was low because he was sitting away from the baggage exit location. Employee exposures dropped by 50% as they moved 1–2 feet away from the EDS machine, supporting the idea that administrative measures (such as locating the employee away from the baggage exit location) can help to reduce the employee's exposure to radiation.

Figure 4: Comparison of radiation profiles of an operator's location relative to the exit of an EDS machine during a busy period

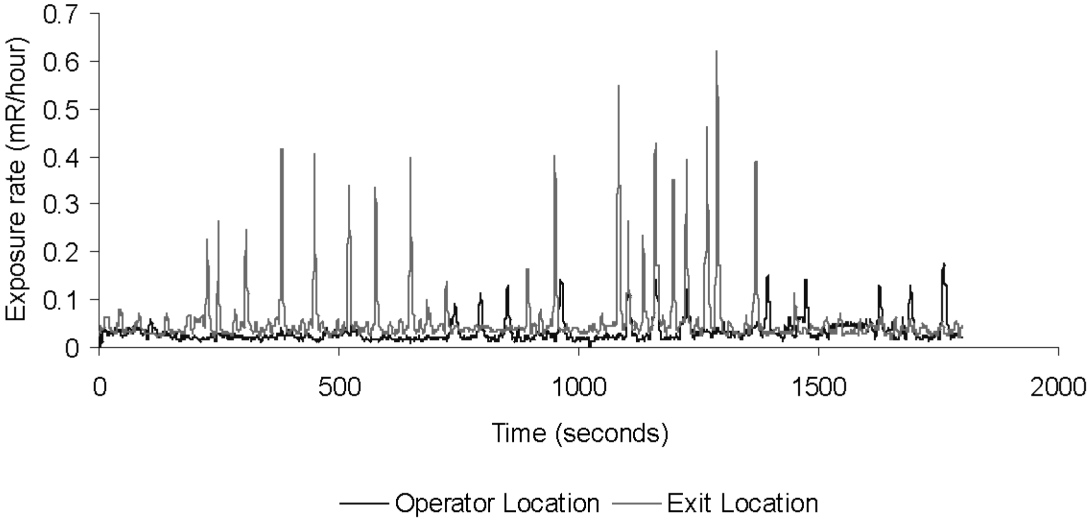
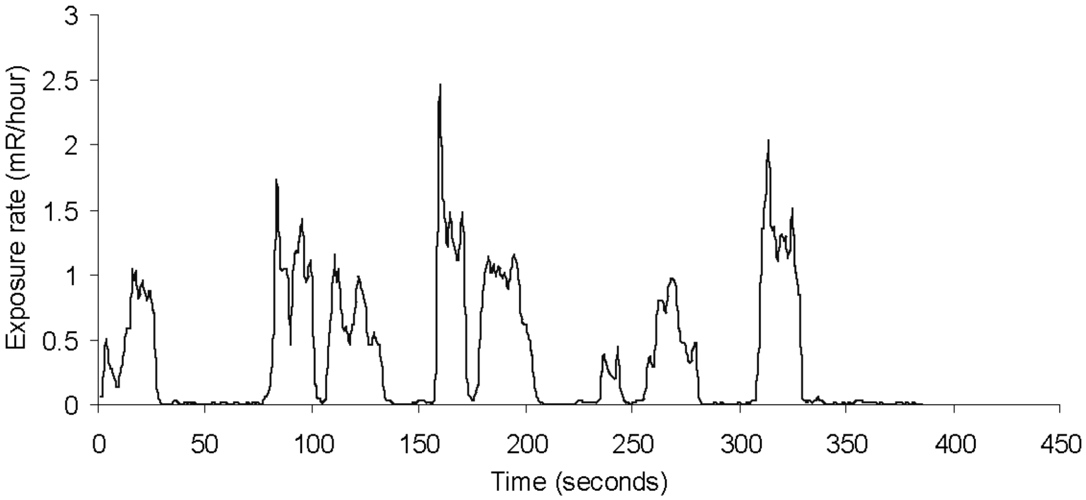


Figure 5 shows a radiation profile from a CTX machine taken at PVD. The x-ray system in the CTX machine is only activated when a bag is in the gantry. Therefore, when no baggage goes through, the readings are zero.

Figure 5: Radiation profile from a CTX machine



Phase 2: Personal Dosimetry

Area Dosimeters

The area dosimeters were often damaged, tampered with, or missing when it came time to exchange them. As a result, these data could not be used to characterize potential radiation exposures in the general work areas from EDS machines, and are not further discussed in this report.

Direct Irradiation of Dosimeters

Data from dosimeter badges passed through a TRX carry-on baggage machine showed no to very small amounts of radiation registered on the badges. The highest dose registered on a badge that was passed 36 times through the machine was 4 mrem.

Badges that were passed through an InVision CTX 5500 machine registered high variation in the resultant doses because the CTX machines activate the x-ray source intermittently during the scanning process. The CTX machines obtain multiple "slice" images (about 2–5 mm thick) as the baggage moves through the system. If the dosimeters were near the area randomly selected by the software to activate the x-ray source, a higher dose would be measured. The average dose was 280 mrem (with a percent coefficient of variation [%CV] of 21) when the badge was scanned 10 times. There was minimal variation in recorded doses when badges were passed through an L3 machine (for 1, 3, 5, and 10 times). The average dose of a badge that passed through an L3 machine once was 156 mrem. Table 6 reports the mean and %CV of doses for the CTX 5500 and the L3 machines.

Table 6. Dose for CTX and L3 EDS Machines During Direct Irradiation of Badges

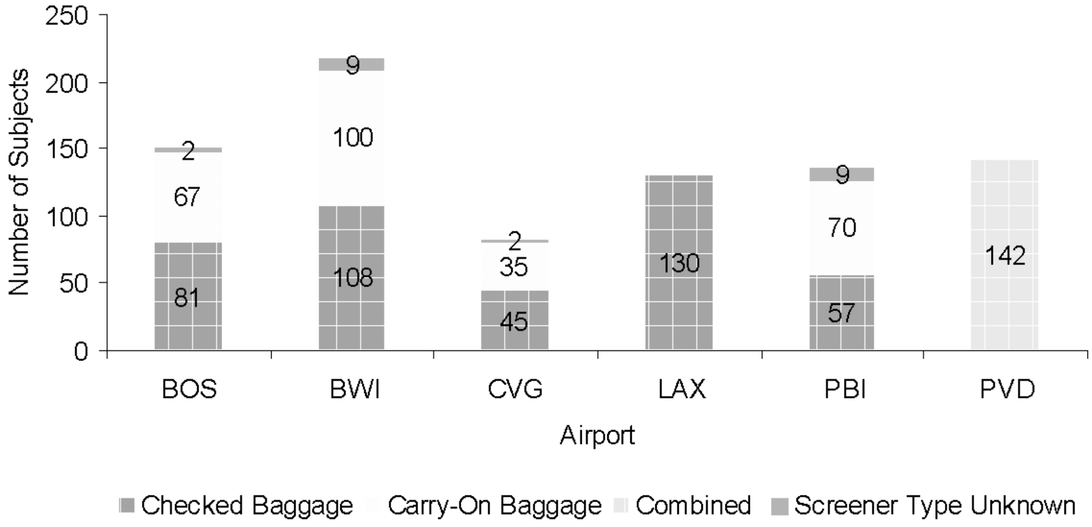
	CTX 5500			L3		
No. of Passes	No. of Badges	Mean (millirem)	% CV	No. of Badges	Mean (millirem)	% CV
1	7	7	98.6	3	156	3.0
3	6	17	88.6	3	494	3.2
5	5	22	155.2	5	976	11.6
10	3	280	20.9	3	2157	6.7

Study Participation

Over 6 months (March through August 2004), 857 TSA baggage screeners working in six airports provided 4051 monthly whole body measures and 3970 monthly wrist measures. The airport with the largest number of participants was BWI (217); the smallest number of participants was at CVG (82). We were not able to calculate participation rates because the denominator data (total number of employees) were only available from four airports. Ninety-one percent of the 857 participants entered the study in March, with the remaining 9% entering from April to July. The number of participants for each of the 6 months was as follows: 781 in March, 760 in April, 741 in May, 684 in June, 628 in July, and 541 in August. This decreasing trend of participation could be due to job turnover or some loss of interest in the study by the participants. Of the 130 participants at LAX, only 52 provided measures through August, giving it the largest percentage of subjects who did not complete the study (60%), followed by CVG and BOS with 50% each, and BWI with 43%. PBI (10%) and PVD (11%) had the smallest percentages of subjects not completing the study.

During the NIOSH evaluation, in four of the six airports (BOS, BWI, CVG, and PBI) each participant worked only as a checked baggage screener or only as a carry-on baggage screener, never working both jobs. At LAX, all of the study participants were checked baggage screeners from the international terminal. At PVD, checked baggage screeners and carry-on baggage screeners were cross-trained and performed both jobs during this study. One hundred forty-two baggage screeners from PVD participated in this study. We were not able to ascertain the screener status of 22 employees. Figure 6 shows the distribution of baggage screeners at BOS, BWI, CVG, LAX, PBI, and PVD.

Figure 6: Number of baggage screeners who participated in the NIOSH evaluation



Adjusting for Background Radiation

Control badges were returned with the employee badges 82% of the time. CVG and PBI returned control badges with employee badges approximately 99% of the time, while BWI only returned these badges 59% of the time. BOS returned control badges 73% of the time, LAX 75% of the time, and PVD 98% of the time.

Analysis of Non-Occupational Data

Based on individual employee interviews and reanalysis of dosimeters, 27 whole body and 26 wrist measures were deemed non-occupational exposures. These doses were excluded from subsequent analyses. The 53 non-occupational measures came from just 28 study subjects, with one subject having eight measures deemed non-occupational. Nineteen individuals contributed a whole body dose and a wrist measure in the same month that were deemed non-occupational. Some study participants reported that they were undergoing nuclear medicine procedures or treatments; others said that coworkers might have tampered with their badges. Both of these circumstances would have overestimated their personal exposures. In addition, 12 badges that exceeded 100 mrem were reanalyzed for static (exposure profile showed that only one portion of the badge was hit) or dynamic (exposure profile showed random hits from a radiation source) exposures; nine badges that were determined to be static were deemed non-occupational exposures. A static exposure profile (Photo 34) is not consistent with the expected occupational exposure profiles of baggage screeners.

The largest number of non-occupational measures (10 whole body; 8 wrist) occurred in March 2004, the first month of the study. By June, the numbers were reduced to three measures each for whole body and wrist. The largest number of non-occupational doses occurred at BWI (15 measures), followed by LAX (13) and PBI (11). BOS had 2 non-occupational measures, PVD had 4, and CVG had 8.

Thirty-three non-occupational doses (18 whole body; 16 wrist) fell between 100 and 1000 mrem. One measure each for whole body and wrist exceeded 1000 mrem. Seventeen doses (8 whole body; 9 wrist) were below 100 mrem.

Analysis of Background-Adjusted Occupational Data

A total of 854 volunteers contributed 4024 monthly whole body and 3944 monthly wrist measures over the 6-month evaluation that were deemed occupational exposures. Approximately 89% of the whole body measures and 88% of the wrist measures were below 1 mrem. The distribution of doses is shown in Table 7.

Table 7. Distribution of Occupational Whole Body and Wrist Doses Over Study Population

	Whole Body Measures		Wrist Measures	
Dose Range (mrem)	Number	Percent	Number	Percent
0 to <1	3594	89	3463	88
1 to <3	252	6	273	7
3 to <5	91	2	112	3
5 to <7	51	1	63	2
7 to <10	23	<1	22	<1
10 to <20	4	<1	7	<1
20 to <30	3	<1	1	<1
30 to <100	3	<1	3	<1
More than or equal to 100	3	<1	0	0

Fourteen of the 24 whole body and wrist measurements that were at or exceeded 10 mrem (an order of magnitude higher than 1 mrem) occurred in LAX (9 whole body; 5 wrist), followed by BOS (2 each for whole body and wrist), BWI (2 for whole body and 1 for wrist), and PBI (3 wrist measures). Twenty individuals contributed the 24 measures that were at or exceeded 10 mrem.

Analysis of Measures by Airport

Due to the skewed distributions, the data are summarized by the median and other percentiles. As shown in Tables 8 and 9, the median whole body and wrist doses for each airport were 0 mrem. In three of the airports, the maximum whole body and wrist doses were an order of magnitude higher than the 99th percentile. These tables also show that the percentage of whole body and wrist doses that exceeded 1 mrem was relatively small (6%–23% for whole body; 6%–26% for wrist). LAX had the highest percentage of whole body and wrist doses at or above 1 mrem, while BWI had the lowest.

Table 8. Summary of Occupational Whole Body Doses (in millirem), by Airport

Airport	No. of Doses	Percent ≥ 1 mrem	Percentiles					Maximum
			50th	75th	90th	95th	99th	
BOS	691	15	0.0	0.0	2.0	3.4	7.2	202
BWI	914	7	0.0	0.0	0.0	1.0	3.0	261
CVG	400	8	0.0	0.0	0.0	2.0	4.0	5.0
LAX	460	23	0.0	0.0	6.0	8.0	23.0	151
PBI	777	9	0.0	0.0	0.0	2.0	4.0	6.0
PVD	782	7	0.0	0.0	0.0	1.0	3.0	7.0

Table 9. Summary of Occupational Wrist Doses (in millirem), by Airport

Airport	No. of Doses	Percent ≥ 1 mrem	Percentiles					Maximum
			50th	75th	90th	95th	99th	
BOS	685	17	0.0	0.0	2.0	3.2	6.2	14.6
BWI	896	6	0.0	0.0	0.0	1.0	4.0	18.2
CVG	389	10	0.0	0.0	1.0	2.0	5.0	7.0
LAX	448	26	0.0	2.0	6.4	7.0	12.0	53.6
PBI	763	11	0.0	0.0	1.0	2.0	6.0	76.0
PVD	763	9	0.0	0.0	0.0	1.0	3.0	8.6

Analysis of Measures by Month

Table 10 shows the distribution of occupational whole body doses, and Table 11 shows occupational wrist doses by month. In March, July, and August, the whole body and wrist doses in the 99th percentile were an order of magnitude smaller than the maximum values. These tables also show that the percentage of whole body and wrist doses that exceeded 1 mrem was relatively small. The highest percentage of measures at or exceeding 1 mrem was in March (26% for whole body; 29% for wrist) and the lowest was in August (5% for whole body dose and 1% for wrist measures).

Table 10. Summary of Occupational Whole Body Doses (in millirem), by Month

Month	No. of Doses	Percent ≥ 1 mrem	Percentiles 50th	75th	90th	95th	99th	Maximum
March	757	26	0.0	1.0	5.0	7.0	13.0	151
April	743	6	0.0	0.0	0.0	1.0	3.4	49.0
May	706	7	0.0	0.0	0.0	1.0	3.0	12.2
June	670	9	0.0	0.0	0.2	1.0	3.0	6.0
July	617	10	0.0	0.0	1.0	3.0	6.1	261
August	531	5	0.0	0.0	0.0	0.4	2.0	202

Table 11. Summary of Occupational Wrist Doses (in millirem), by Month

Month	No. of Doses	Percent ≥ 1 mrem	Percentiles 50th	75th	90th	95th	99th	Maximum
March	759	29	0.0	1.0	4.1	7.0	9.0	53.6
April	734	11	0.0	0.0	1.0	2.0	4.0	39.2
May	696	9	0.0	0.0	0.4	1.4	5.2	14.6
June	650	11	0.0	0.0	1.0	2.0	5.0	26.0
July	598	7	0.0	0.0	0.0	2.0	6.0	76.0
August	507	1	0.0	0.0	0.0	0.0	0.0	7.4

Analysis of Measures by Job Title

At five of the six airports where dosimetry was conducted, the data can be analyzed separately for checked baggage screeners and carry-on baggage screeners. Table 12 reports the distribution of occupational whole body and wrist doses for checked baggage and carry-on baggage screeners. Carry-on baggage screeners had a slightly higher percentage of whole body (91%) and wrist (89%) measures that were below 1 mrem compared to checked baggage screeners (87% for whole body and 86% for wrist). Similarly, fewer individual measures from carry-on baggage screeners for either whole body or wrist were at or above 10 mrem compared to checked baggage screeners.

Table 12. Distribution of Occupational Whole Body and Wrist Doses for Checked Baggage and Carry-On Baggage Screeners at BOS, BWI, CVG, LAX, and PBI

Job	Dose Range (mrem)	Whole Body Doses		Wrist Doses	
		Number	Percent	Number	Percent
Checked Baggage Screeners	0 to <1	1636	87	1562	86
	1 to <3	117	6	118	7
	3 to <5	53	3	71	4
	5 to <7	39	2	48	3
	7 to <10	18	1	19	1
	10 to <20	3	<1	5	<1
	20 to <30	3	<1	1	<1
	30 to <100	3	<1	3	<1
	More than or equal to 100	3	<1	0	0
Carry-On Baggage Screeners	0 to <1	1161	91	1136	89
	1 to <3	79	6	90	7
	3 to <5	28	2	34	3
	5 to <7	9	<1	14	1
	7 to <10	4	<1	1	<1
	10 to <20	1	<1	2	<1
	20 to <30	0	0	0	0
	30 to <100	0	0	0	0
	More than or equal to 100	0	0	0	0

mrem = millirem

Table 13 compares occupational whole body and wrist doses between checked baggage and carry-on baggage screeners by airport. At BOS, the percentage of whole body and wrist measures that were at or above 1 mrem was significantly higher among carry-on baggage screeners compared to checked baggage screeners.

In addition, the percentage of whole body measures at or above 1 mrem was significantly higher for carry-on baggage screeners at CVG. Conversely, at PBI, the percentage of whole body and wrist measures that were at or above 1 mrem was significantly higher among checked baggage screeners than carry-on baggage screeners. The whole body doses and wrist doses at BWI and the wrist doses at CVG did not differ significantly.

Table 13. Comparison of Occupational Whole Body and Wrist Doses Between Checked Baggage and Carry-On Baggage Screeners at or Exceeding 1 Millirem (mrem)*

Airport*	Screeners	Whole Body Doses ≥ 1 mrem Number (%)	P-value†	Wrist Doses ≥ 1 mrem Number (%)	P-value†
BOS	Checked Baggage	42 (11)	< 0.01	44 (12)	< 0.01
	Carry-On Baggage	63 (21)		72 (24)	
BWI	Checked Baggage	35 (7)	0.26	32 (7)	0.57
	Carry-On Baggage	20 (5)		23 (6)	
CVG	Checked Baggage	14 (6)	0.05	28 (13)	0.06
	Carry-On Baggage	18 (11)		11 (7)	
PBI	Checked Baggage	41 (13)	< 0.01	43 (14)	0.05
	Carry-On Baggage	20 (5)		35 (9)	

* No carry-on baggage screeners were evaluated at LAX; PVD screeners did both carry-on baggage and checked baggage screening.

† Statistical comparisons were based upon the proportion of measurements at or above 1 mrem.

Analysis of Measures by Machine Configurations in Airports

Table 14 includes a comparison of checked baggage screeners at PBI (type of EDS installation is standalone) and BOS (type of EDS installation is in-line). The data suggests no statistically significant difference between the standalone EDS units (PBI) and the in-line system in place at BOS (percent ≥1 mrem: 11% whole body; 12% wrist).

The measures for the carry-on baggage screeners show that 21% of the whole body doses and 24% of the wrist doses at BOS attained or exceeded 1 mrem, compared to the 5% of whole body doses and 9% of the wrist doses at PBI. These differences between BOS and PBI were statistically significant.

Table 14. Comparison of Carry-On Baggage and Checked Baggage Screener Occupational Doses at PBI and BOS

Comparison	Airports	Whole Body Doses ≥ 1 mrem Number (%)	P-value*	Wrist Doses ≥ 1 mrem Number (%)	P-value*
Checked Baggage Screener	PBI	41 (13)	0.40	43 (14)	0.38
Checked Baggage Screener	BOS	42 (11)		44 (12)	
Carry-On Baggage Screener	PBI	20 (5)	<0.01	35 (9)	<0.01
Carry-On Baggage Screener	BOS	63 (21)		72 (24)	

mrem = millirem

*Statistical comparisons were based upon the proportion of measurements at or above 1 mrem

Cumulative Data Analysis

Table 15 presents the estimated 12-month cumulative occupational whole body and wrist doses for study participants. The average monthly exposure, based on one, two, three, four, five, or six measurements, was multiplied by 12 to obtain the estimated 12-month cumulative exposure. The median estimated cumulative whole body dose was zero at four of the six airports. The highest median estimated cumulative dose (whole body and wrist) occurred at LAX (approximately 15 mrem), followed by BOS (at 0.4 mrem). To further investigate the high doses for each airport, we calculated the percent of estimated cumulative whole body and wrist doses that reached or exceeded 100 mrem, the monitoring threshold for the DOE. In addition, the table shows the three highest measures at each airport. LAX had the highest percentage of estimated cumulative whole body and wrist doses that reached or exceeded 100 mrem. The three highest estimated cumulative whole body and wrist doses at LAX were above 100 mrem. At two airports (BOS, BWI) the percents of estimated cumulative whole body doses ≥100 mrem were 0.7% and 0.9%, respectively. At BWI and PBI, the percents of estimated cumulative wrist doses ≥100 mrem were 0.5% and 1.5%, respectively.

Table 15. Estimated 12-Month Cumulative Occupational Doses (mrem)

	Airport	No. Subjects	Minimum	Median	Highest Three Measures	Percent ≥ 100 mrem	Quartile Range*
Whole Body	BOS	150	0.0	0.4	423, 43.8, 35.3	0.7	8.8
	BWI	216	0.0	0.0	636, 151, 48.0	0.9	0.8
	CVG	82	0.0	0.0	21.0, 15.0, 12.0	0.0	4.0
	LAX	126	0.0	14.7	906, 230, 169	4.8	22.8
	PBI	136	0.0	0.0	36.0, 24.0, 20.0	0.0	3.2
	PVD	141	0.0	0.0	21.0, 20.0, 13.2	0.0	2.0
Wrist	BOS	150	0.0	0.4	41.3, 34.9, 29.9	0.0	9.0
	BWI	216	0.0	0.0	218, 36.0, 36.0	0.5	0.0
	CVG	82	0.0	0.0	27.0, 24.0, 20.0	0.0	6.0
	LAX	126	0.0	15.5	215, 120, 108	2.4	20.8
	PBI	136	0.0	0.0	154, 130, 52.0	1.5	4.0
	PVD	142	0.0	0.0	24.0, 17.2, 12.0	0.0	2.4

* Difference between 25th and 75th percentile

mrem = millirem

Table 16 shows the estimated 12-month cumulative occupational whole body and wrist doses separately for checked baggage and carry-on baggage screeners by airport. The highest median estimated cumulative doses (whole body and wrist) for the checked baggage screeners occurred at LAX, while the highest median estimated cumulative doses (whole body and wrist) for the carry-on baggage screeners occurred at BOS. The discrepancy in the number of subjects in Tables 15 and 16 occurs because we did not have job title information on 22 baggage screeners (nine each from BWI and PBI; two each from BOS and CVG).

Two employees had estimated occupational exposures that would exceed an estimated 12-month whole-body dose of 500 mrem, which is the monitoring threshold for NRC. The employee with the highest whole body dose (906 mrem) only contributed measures in 2 of 6 months. This employee's whole body dose in March was 151 mrem, and the whole body dose in August was 0 mrem. The cumulative dose is calculated as follows:

$$\text{cumulative dose} = 12 \text{ x } \{(151+0)/2\} = 12 \text{ x } (72.5) = 906 \text{ mrem.}$$

Similarly, the employee with an estimated whole body dose of 636 mrem contributed measures in 5 months, of which three whole body doses were zero. This employee's whole body dose in April was 4 mrem, and in July was 261 mrem. The cumulative dose is calculated as follows:

$$\text{cumulative dose} = 12 \text{ x } \{(4 +261+0+0+0)/5\} =$$
$$12 \text{ x } \{265/5\} = 12 \text{ x } (53) = 636 \text{ mrem.}$$

Thirteen of the 854 individuals (1.5%) who contributed an occupational whole body or wrist dose exceeded the estimated 12-month cumulative occupational whole body and wrist doses of 100 mrem.

Table 16. Estimated 12-Month Cumulative Occupational Doses for Checked Baggage and Carry-On Baggage Screeners (mrem)

Job	Measure	Airport	No. Subjects	Minimum	Median	Percent ≥ 100 mrem	Highest Three Measures
Checked Baggage Screener	Whole Body	BOS	81	0.0	0.0	1.2	423, 22.2, 18.2
		BWI	108	0.0	0.0	1.9	636, 151, 48.0
		CVG	45	0.0	0.0	0.0	21.0, 15.0, 12.0
		LAX	126	0.0	14.7	4.8	906, 230, 169
		PBI	57	0.0	0.0	0.0	36.0, 20.0, 20.0
Checked Baggage Screener	Wrist	BOS	81	0.0	0.0	0.0	21.7, 20.0, 19.9
		BWI	108	0.0	0.0	0.9	218, 36.0, 14.4
		CVG	45	0.0	0.0	0.0	27.0, 24.0, 20.0
		LAX	126	0.0	15.5	2.4	214, 120, 108
		PBI	57	0.0	0.0	3.5	154, 130, 52.0
Carry-on Baggage Screener	Whole Body	BOS	67	0.0	5.3	0.0	35.3, 29.3, 26.6
		BWI	99	0.0	0.0	0.0	24.0, 23.2, 18.0
		CVG	35	0.0	0.0	0.0	12.0, 12.0, 9.6
		PBI	70	0.0	0.0	0.0	12.0, 8.0, 4.0
Carry-on Baggage Screener	Wrist	BOS	67	0.0	4.8	0.0	41.3, 34.9, 29.9
		BWI	99	0.0	0.0	0.0	36.0, 26.4, 20.8
		CVG	35	0.0	0.0	0.0	19.2, 12.0, 7.2
		PBI	70	0.0	0.0	0.0	28.0, 10.0, 10.0

mrem = millirem

DISCUSSION

Radiation Dosimetry

Overall, the radiation doses for TSA baggage screeners were low. Approximately 90% of the whole body and wrist measures were below 1 mrem. This suggests that the shielding on the EDS machines can be effective in limiting worker exposures consistent with the ALARA principle. When the analysis was conducted by month, March had the largest percentage of doses above 1 mrem. March was the first month of the dosimetry study, so a learning curve with respect to how to properly wear and store the badges may explain this high percentage. For example, at the end of the work shift if the badges were left near the EDS machines, it is possible for the badges to register additional radiation dose that is non-occupational.

The dosimetry results showed the median estimated 12-month cumulative doses (for either whole body or wrist) for all six participating airports were low, with four of the six airports having a median estimated cumulative whole body and wrist doses of 0 mrem. However, the non-zero estimated 12-month cumulative doses imply that checked baggage screeners at LAX (and to a lesser extent, the carry-on baggage screeners at BOS) receive unnecessary radiation exposures. In addition, two out of 854 individuals had cumulative occupational doses that exceeded the 500 mrem/year cumulative occupational doses, and 13 had estimated cumulative whole body and wrist doses that exceeded the estimated cumulative whole body and wrist doses of 100 mrem/year. Some of these individuals were missing data for most months, and the monthly results were highly variable, suggesting unusual occurrences rather than routine exposures. However, because our sample of airports was not necessarily representative, and the study participants were volunteers, these results may not generalize to the entire TSA workforce.

Given the strengths and weaknesses of this study, the need for a routine radiation dosimetry program for TSA screeners can neither be justified nor refuted at this time. Approximately 90% of the doses that screeners received were below 1 mrem, but some doses were at levels that warrant further action. Therefore, additional dosimetry targeted at specific airports for at least a year (on a monthly or quarterly basis) may be useful to evaluate the high doses found in this evaluation. The number of airports and the specific airports for this targeted monitoring are left to the discretion of the TSA. Selection criteria could include airport size, machine type, and orientation of machines (in-line versus standalone). Management of the dosimetry program by a health or medical physicist is recommended. Mandatory rather than voluntary participation in the dosimetry program would address a weakness of this study.

We are uncertain why the radiation doses were higher in LAX and BOS. Possible reasons include the screeners not following proper safety protocols (reaching into EDS machines, bypassing safety interlocks), poor maintenance of the EDS systems (shifting or missing shielding, incomplete installations, curling lead curtains), engineering controls that were not in place (improperly placed electric eyes, conveyor systems that delay entry on the L3 entrance tunnel while lead curtains are displaced), lack of hazard awareness (not knowing where radiation leaks typically occur and how to avoid unnecessary exposures), badges that were tampered with, or screeners' nuclear medicine procedures or treatment. More research is needed to explain the differences in dose at these airports.

Carry-on baggage screeners at BOS had significantly higher radiation exposures than the checked baggage screeners. In addition, the carry-on baggage screeners at BOS had significantly higher radiation exposures than the carry-on baggage screeners at PBI. One explanation could be that checked baggage screeners (using EDS machines) at BOS were located in a control room away from any radiation source, while the carry-on screeners (using TRX machines) were located next to the EDS systems and were exposed to low-level radiation emissions from these machines. Also, as described below, each airport administered the radiation dosimetry program differently, which may have influenced the results. More research needs to be conducted on the BOS carry-on baggage screeners to verify this finding.

The day-to-day management of the dosimetry study was left to the airport managers. Although NIOSH researchers provided input to the airport managers on carrying out the dosimetry study, implementation and quality control of the dosimetry study varied across airports. For example, at PBI and PVD, a committee was formed to manage the dosimeter program. Management and employee representatives ensured that baggage screeners stored their badges carefully, wore them appropriately, and mailed them in with the controls at the end of the month in a timely manner. These airports had the fewest study drop-outs and the fewest participants with results that required additional evaluation. In contrast, procedures at some airports were less rigorous as evidenced by dosimeters that were returned late or unused. Our experience suggests that both management and employees must actively support and oversee the program to achieve meaningful results.

Unlike hard hats, safety glasses, or respirators, a personal radiation dosimeter provides no protection against radiation exposure for the user. However, routine use of radiation dosimeters, when deemed appropriate, can prevent workers from accumulating exposure that exceeds occupational exposure limits. Conventional practice is to exchange dosimeters monthly or quarterly to identify workers who are approaching pre-established exposure limits.
In the event of an incident, the dosimeter can be processed immediately to determine whether any radiation exposure was received by the worker and whether further steps need to be taken to reduce health risks from such an exposure. The data provided by a routine radiation monitoring program can validate the effectiveness of work procedures, confirm that the radiation-generating devices used for baggage and checkpoint screening are safe, detect changes in exposure conditions, and verify the effectiveness of engineering controls. A technically sound, properly administrated personal dosimeter monitoring program can

provide a level of confidence to workers and management that the potential for exposure from equipment used for baggage or checkpoint screening is acceptably low.

Dosimetry is widely used in health care facilities. The estimated annual average individual effective dose of dental workers is 5 mrem.[17] From 1985 to 1989, the average annual effective dose of ionizing radiation to U.S. medical workers was reported to be about 50 mrem.[18] A recent study from Ireland found the following average doses per worker from 2001–2005 by research sector: medical (32 mrem), industrial (79 mrem), and educational (24 mrem).[19] These doses are higher than the averages found in our study.

Training and Maintenance

This evaluation underscored the need for TSA baggage screeners operating the EDS and TRX machines to be provided safety training related to the potential for exposure to x-rays generated by the machines, the health risks associated with exposure to x-rays, and the practical methods for reducing risk. None of the TSA baggage screeners we encountered had received formal radiation training at the time of our evaluation. This evaluation also demonstrated the need for routine maintenance of the EDS machines to ensure that engineering controls that limit radiation exposure to workers continue to be effective.

Dose Limits for TSA Workers

TSA baggage screeners are covered by the OSHA ionizing radiation standard.[12] However, it is unclear what part of the work area is considered a "restricted area" (defined by OSHA as "any area access to which is controlled by the employer for purposes of protection of individuals from exposure to radiation or radioactive materials"). Therefore, these workers are required to be monitored if they will or are likely to receive a dose in any calendar quarter in excess of 25% of the applicable value (i.e., 1250 mrem for whole body x-ray). This is equivalent to a cumulative whole body dose of approximately 313 mrem over 3 consecutive months. Doses for none of the participants in this evaluation exceeded 313 mrem over 3 consecutive months (the OSHA quarterly limit that requires employee monitoring). Thus far, OSHA has not formally defined "restricted area" as it pertains to TSA workplaces. In reviewing inspection reports, it appears that individual OSHA area offices have considered different criteria for a "restricted area."

At the time of the NIOSH study, TSA baggage screeners had not received adequate training on workplace hazards associated with ionizing radiation. This training is especially needed to keep pace with the implementation of new detection technology with the potential for higher radiation exposures. Also, proper worker training and equipment maintenance will most likely ensure that TSA workers keep their exposures ALARA.

Protecting Workers from Radiation Exposure

The preferred control method for reducing workplace exposures, substituting or replacing x-ray screening technologies with non-radiation screening technologies, is not currently economically feasible. The next best approach to exposure control is the use of engineering controls such as shielding of the source. Although the manufacturer is responsible for supplying and installing x-ray generating equipment that complies with FDA regulations regarding radiation leakage, maintaining all the engineering controls that limit radiation exposure becomes the responsibility of the TSA at the end of the warranty period. TSA workers will be adequately protected from unnecessary radiation exposure by properly *shielding* the source, keeping workers a *minimum* distance away from the x-ray source and reducing the *time* a worker is close to the source (e.g., by placing computer controls away from x-ray source). Training for workers and supervisors on safe work procedures and radiation risk so that unsafe practices can be recognized and avoided is essential. NIOSH investigators also recommended that the L3 manufacturer re-engineer the entrance and exit tunnels of their standalone systems (such as by bolting the tunnels to the scanning gantry) and improve the safety interlocks to reduce the potential for radiation exposure. These recommendations were verbally communicated at a meeting on March 30, 2004, at the L3 Communications Manufacturing Facility in St. Petersburg, Florida.

Ergonomic Issues

Although ergonomic aspects of the job were not a formal part of this evaluation, we observed TSA baggage screeners, especially at airports with standalone EDS installations, encountering physical challenges during the loading and unloading of passenger baggage. Ergonomic problems reported by TSA employees during informal interviews included moving very heavy baggage (>70 pounds/bag), bags ejecting from EDS machines with excessive force following scanning, and lifting bags over obstacles (such as the edge of a conveyor belt) when hand searches were required.

Study Strengths and Limitations

Strengths

This study identified potential health hazards to baggage screening personnel, some of which are related to a lack of sufficient training on radiation safety issues. Flaws in the EDS baggage screening equipment were also identified and brought to the attention of the manufacturers at the March 30, 2004, meeting, and the equipment manufacturers have already taken corrective action. This is also the first study to describe radiation exposure levels to baggage screening personnel working with EDS machines and to address the issue of personal dosimetry for these workers.

Limitations

A limitation of this study is that we were not able to evaluate all airports, and of those selected, not all had personal dosimetry. High costs and logistical issues were reasons why we could not study more airports. In our opinion, the number of airports in this study was sufficiently large to capture the variety of TSA work environments. However, because the airports included in this HHE were not necessarily a representative sample, and employee participation was voluntary, the results may not generalize to the entire TSA workforce. Another limitation of the study is that we were not able to correlate employees' personal dosimetry data to their work practices or exposures from faulty equipment. Therefore, we were only able to suggest possible reasons for the high doses based on our initial observations. With respect to personal dosimetry, NIOSH investigators had no control over how the dosimetry program was managed. Sometimes the badges were not stored properly, were tampered with, or were not returned with the control badges for adjusting doses for background. We were also unable to obtain the total number of TSA baggage screeners at participating airports, making it impossible to calculate participation rates.

CONCLUSIONS

At the time of the NIOSH evaluation, TSA baggage screeners were not formally trained on radiation issues. Also, some of the EDS machines that we inspected were not in proper working order. Overall, the personal exposures in this study were low: only 11% of the whole body and 12% of the wrist data measured doses were above 1 mrem. Only two of 854 individuals exceeded an estimated annual cumulative dose of 500 mrem, and only 13 (1.5%) exceeded an estimated annual cumulative whole body and wrist doses of 100 mrem. However, because the airports may not be representative, and the study participants were volunteers, these results may not generalize to the entire TSA workforce. Given the strengths and weaknesses of this study, the need for a routine radiation dosimetry program for TSA screeners can neither be justified nor refuted at this time. Approximately 90% of the doses received by screeners were below 1 mrem, but some doses were at levels that warrant further action. Therefore, additional dosimetry may be useful to evaluate further the high doses found in this evaluation. Radiation dosimetry may also be useful to evaluate the effectiveness of the TSA radiation training program that was initiated in 2005 and the introduction of newer EDS screening technologies, such as backscatter imaging. While NIOSH researchers used a Fluke Biomedical 451P ion chamber to conduct radiation surveys of EDS equipment, more research is needed to select the most appropriate monitoring equipment for routine assessments. In the TSA work environment, radiation exposures were not the only potential hazard. Potential ergonomic hazards associated with lifting heavy passenger baggage existed at nearly all of the airports involved in this evaluation.

RECOMMENDATIONS

Based on the observations during the walk-through surveys and results from the 6-month dosimetry monitoring, NIOSH researchers offer the following recommendations for ensuring the health and safety of TSA baggage screeners. It is our understanding that TSA has already taken some steps to address health and safety issues such as developing radiation training modules for employees.

1. TSA is encouraged to apply the ALARA principle in protecting its workers from excessive radiation exposure by including training, periodic surveys, and an operations and maintenance plan in its radiation safety program.

a) Training

1) Provide annual training on safe work practices for all TSA baggage screeners. Develop a system of documenting good and bad work practices, and communicating them to all airports.

2) Now that applicability of the OSHA ionizing radiation standard[12] has been clarified to cover TSA, the requirements of the standard should be implemented. These requirements include providing training on radiation issues for all TSA baggage screeners. Ensure that baggage screeners understand the harmful effects of radiation and the engineering controls built into the EDS systems to protect them. Particular attention should be given to guarding against intentional and inadvertent alterations of engineering controls. In addition to following the requirements of the OSHA ionizing radiation standard, develop a policy to communicate ionizing radiation hazards to, and address the workplace needs of, pregnant workers.

b) Periodic Surveys

1) Conduct additional radiation dosimetry for at least a year (on a monthly or quarterly basis) to evaluate further the dose differences between selected airports, and any large deployments of new machine designs. The program should be administered by qualified persons (medical or health physicists) knowledgeable in radiation protection principles and should incorporate joint management and employee participation in design and implementation. After sufficient data have been collected to ensure statistically valid results, the need for continued or expanded dosimetry should be evaluated by a health and safety committee comprised of TSA management and employee representatives and outside experts.

2) Define standards to keep exposures ALARA and below statutory limits.

3) Provide both a portable radiation detection instrument (i.e., ionization chamber) at each airport where

TSA baggage screeners are assigned and personnel training to measure radiation intensities around EDS equipment. This will allow TSA management and screeners to independently assess the quality of the EDS maintenance program and ensure that no radiation leaks have developed because of use, abuse, or poor maintenance activities. Ensure that the instrument is maintained and calibrated regularly, and employees are trained on how to use it. The instrument must be calibrated at energies consistent with the EDS machines. As an alternative to purchasing additional radiation detection instrumentation, the EDS maintenance agreements, which already exist at airports covered by the TSA, could be modified to require monthly spot checks of EDS equipment.

4) Post "Survey Stickers" on every EDS machine that explain in easy to understand language when that machine last received a radiation survey (including both spot checks and required FDA surveys).

5) We recommend that TSA management request from OSHA an interpretation of "restricted area" as it applies to TSA workplaces. This may have implications for the application of requirements in the OSHA ionizing radiation standard, including monitoring. NIOSH representatives would be available to discuss this issue further, particularly as related to HHE findings.

c) Operations and Maintenance Plan

1) Develop a comprehensive maintenance program for the EDS machines and make that information available to TSA baggage screeners.

2) Require that the same training and operating and maintenance procedures applied to federal workers are applied to private security screeners if an airport chooses to use private security screeners.

3) Work with manufacturers of EDS machines to minimize failure of engineering controls due to wear and tear, and to design better machines that discourage intentional bypassing of interlocks.

RECOMMENDATIONS (CONTINUED)

2. Although this evaluation only focused on radiation exposure, TSA workers raised other issues of concern. TSA management is encouraged to address these concerns.

a) Communicable Diseases

1) Encourage baggage screeners who are concerned about communicable diseases to report their concerns to their immediate supervisor and to the TSA Occupational Safety and Health Office. If not currently in place, procedures for handling concerns should be developed and communicated to employees.

b) Ergonomics

1) Evaluate potential ergonomic hazards associated with lifting heavy passenger baggage.

REFERENCES

1. Aviation Security Information Act [1990]. Public Law 101-604.
2. FAA [1996]. Annual Report to Congress on Civil Aviation Security: January 1, 1996 – December 31, 1996. Report of the Administrator of the Federal Aviation Administration to the United States Congress.
3. TSA [2002]. TSA fact sheet: explosive trace detectors (ETD) and explosive detection systems (EDS). Transportation Security Administration, Office of Communication and Public Information. Washington, DC.
4. L3 Communications [2004]. eXaminer 3DX™ 6000 Explosive detection system. [http://findarticles.com/p/articles/mi_m0EIN/is_1998_Nov_24/ai_53258773]. Date accessed: June 18, 2007.
5. 40 Fed. Reg. 29114 [1975]. Federal Aviation Administration: occupational safety and health issues for airline employees.
6. 40 Fed. Reg. 37330 [2001]. Federal Aviation Administration: aircraft operator security, final rule.
7. Kassiday D [2006]. Telephone conversation on July 12, 2006, between D. Kassiday of the Food and Drug Administration and C. Achutan of the Division of Surveillance, Hazard Evaluations and Field Studies, National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention, Public Health Service, U.S. Department of Health and Human Services.

8. Salasky M (msalasky@landauerinc.com) [2005]. Private e-mail message to John Cardarelli, April 7, 2005.

9. Quirke E [2007]. Telephone conversation on June 14, 2007, between E. Quirke of Landauer® and C. Achutan of the Division of Surveillance, Hazard Evaluations and Field Studies, National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention, Public Health Service, U.S. Department of Health and Human Services.

10. Askelrod MS, Agersnap-Larsen N, McKeever SWS [2000]. A procedure for the distinction between static and dynamic radiation exposures of personal radiation badges using pulsed optically stimulated luminescence. Radiat Meas 32:215–225.

11. National Academy of Sciences [2006]. Health risks from exposure to low levels of ionizing radiation. [http://www.nap.edu/catalog.php?record_id=11340]. Date accessed: October 2, 2007.

12. CFR [1996]. 29 CFR 1910.1096. Code of Federal Regulations. Washington, DC: U.S. Government Printing Office, Office of the Federal Register.

13. NCRP [1993]. NCRP Report No. 116, Limitation of exposure to ionizing radiation. Bethesda, Maryland.

14. NRC [2007]. Regulatory Guide 8.13 - Instruction Concerning Prenatal Radiation Exposure. [http://www.nrc.gov/reading-rm/doc-collections/reg-guides/occupational-health/active/8-13/]. Date accessed: November 29, 2007.

15. ICRP [2000]. ICRP publication 84: pregnancy and medical radiation. Published by Elsevier.

16. CFR [1974]. 21 CFR 1020.40. Code of Federal Regulations. Washington, DC: U.S. Government Printing Office, Office of the Federal Register.

17. Sabol J, Weng PS [1995]. Introduction to radiation protection dosimetry. Published by World Scientific.

18. UNSCEAR [1993]. Sources and effects of ionizing radiation. 1993 Report to the General Assembly. New York: United Nations Scientific Committee on the Effects of Atomic Radiation.

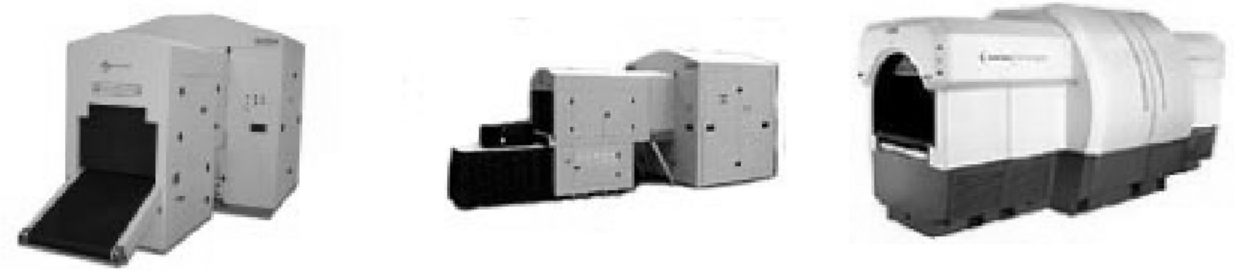
19. Colgan PA, Currivan L, Fenton D [2007]. An assessment of annual whole-body occupational radiation exposure in Ireland (1996–2005). Radiation Protection Dosimetry. Advance access, published June 11. [http://rpd.oxfordjournals.org/cgi/reprint/ncm235v1]. Date accessed: November 30, 2007.

Photos

The photos below illustrate work practices of TSA baggage screeners and equipment problems that were observed by NIOSH researchers.

Photos 1–3: TRX machines

Photos 4–6: EDS machines



Photos 7–10: NIOSH researchers measuring radiation levels from TRX and EDS machines:

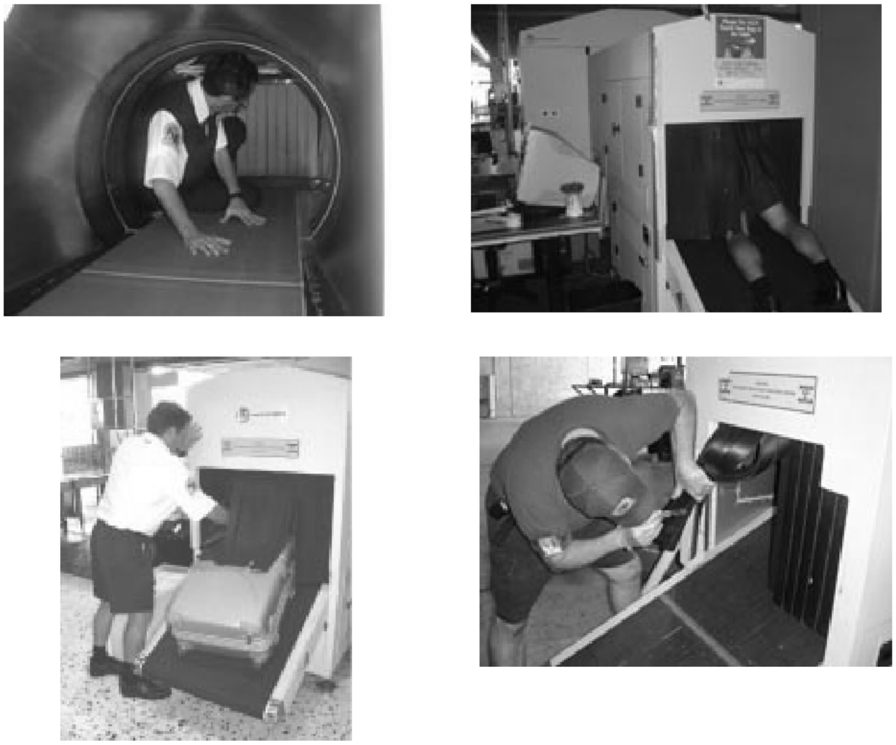
PHOTOS (CONTINUED)

Photos 11–13: Employees checking for radiation leakage

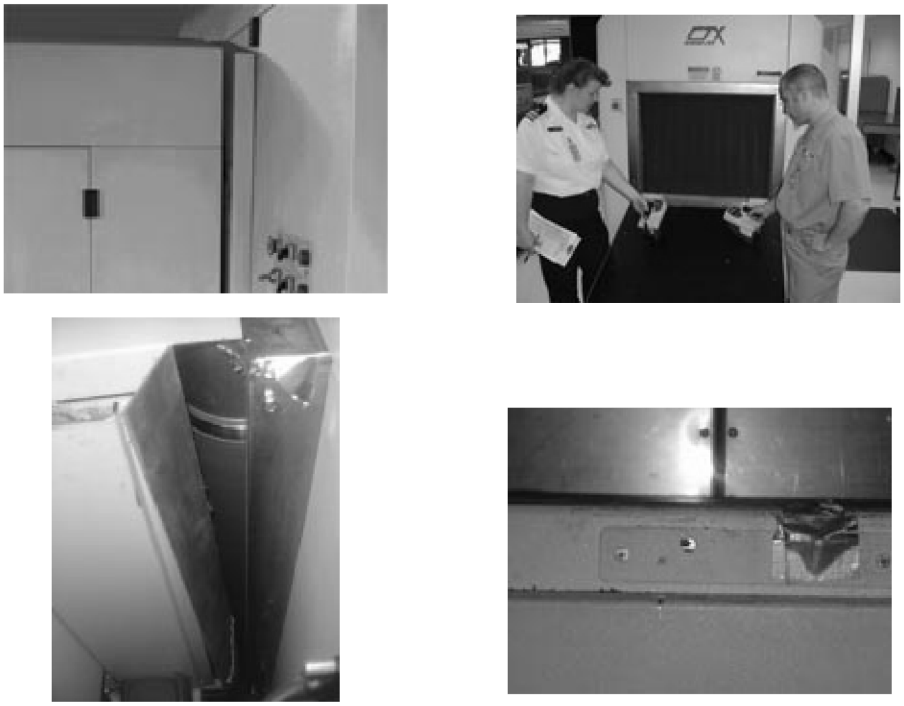
Photos 14–17: Location of workers in relation to EDS machines

PHOTOS (CONTINUED)

Photos 18–21: Poor work practices



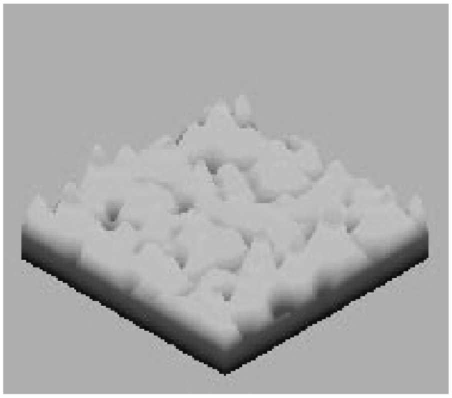
Photos 22–25: Safety violations/poor machine design (including location of “unnecessary radiation leakage” in photo 23)

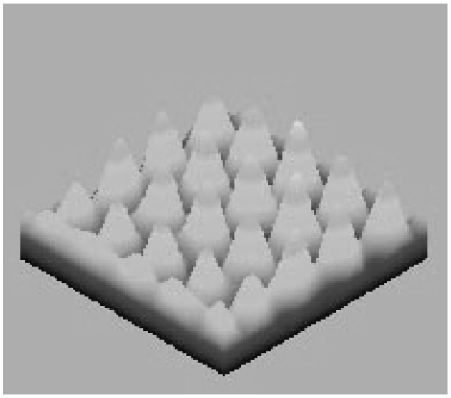


Photos 26–29: Examples of blocked emergency buttons

Photos 30–33: Curtain and curtain bars in good and damaged condition

Photos 34–35: Radiation badges denoting static and dynamic exposures, respectively





ACKNOWLEDGEMENTS AND AVALIBILITY OF REPORT

The Hazard Evaluations and Technical Assistance Branch (HETAB) of the National Institute for Occupational Safety and Health (NIOSH) conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health (OSHA) Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employers or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

HETAB also provides, upon request, technical and consultative assistance to federal, state, and local agencies; labor; industry; and other groups or individuals to control occupational health hazards and to prevent related trauma and disease. Mention of company names or products does not constitute endorsement by NIOSH.

This report was prepared by Chandran Achutan and Charles Mueller of HETAB, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS). The study design and initial data analyses was conducted by John Cardarelli, formerly with DSHEFS. Field assistance was provided by Donnie Booher, Gregory Burr, Chad Dowell, Kevin Dunn, Melissa Finley, Ronald Hall, Ann Krake, Dino Mattorano, Mark Methner, Ron Sollberger, and David Sylvain. Radiation dosimeters were provided and analyzed by Landauer®, Glenwood, Illinois. Technical consultation was provided by Henry Spitz and Robert D. Daniels of the Industrywide Studies Branch, DSHEFS. Desktop publishing was performed by Donna Pfirman. Editorial assistance was provided by Gregory Burr, Ellen Galloway, and Donna Pfirman.

Copies of this report have been sent to employee and management representatives at the Transportation Security Administration and the OSHA Regional Offices. This report is not copyrighted and may be freely reproduced. The report may be viewed and printed from the following Internet address: http://www.cdc.gov/niosh/hhe. Copies may be purchased from the National Technical Information Service (NTIS) at 5825 Port Royal Road, Springfield, Virginia 22161.

Page intentionally blank.

Below is a recommended citation for this report:
NIOSH [2008]. Health Hazard Evaluation Report: Radiation Exposure to TSA Baggage Screeners, Washington, DC. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, NIOSH HETA No. 2003-0206-3067.

National Institute for Occupational Safety and Health

Delivering on the Nation's promise: Safety and health at work for all people through research and prevention.