An Independent Assessment of the February 14, 2014 Underground Radiation Release Event at the Waste Isolation Pilot Plant (WIPP)

December 2014

2014 WIPP Radiation Release Event

Dr. Russell Hardy
Dr. Punam Thakur
Dr. Ila Pillalamarri
Brant Lemons
Sally Ballard

THIS PAGE LEFT INTENTIONALLY BLANK

Acknowledgements

The Carlsbad Environmental Monitoring and Research Center (CEMRC) has been performing environmental monitoring activities and publishing results associated with the WIPP for the past 16 years. During this time, the scientific and technical staff at CEMRC has perfected the ability to gather environmental samples, prepare them for analyses, and analyze them for the presence of both radiological and non-radiological constituents for the benefit of the citizens of Southeast New Mexico and the greater scientific community. This ability was put to the test on February 14, 2014.

As the director of CEMRC, I would like to acknowledge the dedicated members of the CEMRC scientific and technical staff who worked tirelessly during and after the February 14, 2014 underground radiation release event to collect samples, to prepare samples, and to analyze those samples for the presence of radiologic isotopes so that the CEMRC could communicate to its constituents, to the DOE, and to the public at large regarding the severity and the overall impact that the event had on the environment and the general populace. I am very proud of these individuals' efforts, their dedication, and the professionalism they exhibited in terms of working days, nights, and weekends to conduct this important work. In my humble opinion, the CEMRC proved its worth in the days, weeks, and months following the event and I am extremely proud of all of the following members of my team, and specifically those directly involved in the WIPP release activities:

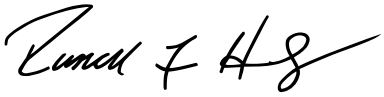
- Radiochemistry Group (RC) – the group responsible for the identification and quantification of radioisotopes in environmental samples including WIPP exhaust air, ambient air, soil, and surface water/sediment.
    - Dr. Punam Thakur, RC Manager and Senior Research Scientist
    - Ms. Sally Ballard, Senior Research Assistant
    - Mr. Brant Lemons, Associate Research Scientist
- Internal Dosimetry Group (ID) aka Whole Body Counting program – the group responsible for the identification and quantification of radioisotopes in human subjects.
    - Dr. Ila Pillalamarri, ID Manager and Associate Research Scientist
    - Ms. Jennifer Lemons, Research Lab Technician
    - Ms. Adrianne Navarrette, Research Engineering Technician
- Field Program Group (FP) – the group responsible for the collection and distribution of environmental samples including WIPP exhaust air, ambient air, soil, and surface water/sediment.
    - Mr. Jim Monk, FP Manager and Radiation Safety Specialist
    - Ms. Adrienne Chancellor, Associate Research Scientist
    - Mr. Leo Hinojos, Research Lab Technician
    - Ms. Adrianne Navarrette, Research Engineering Technician

Acknowledgement: This material is based upon work supported by the Department of Energy Office of Environmental Management under Award Number DE-EM0002423.

Disclaimer: This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Lastly, I want to thank Ms. Melinda Wilson for editing and formatting this report and Dr. Punam Thakur for writing a majority of the content of this report, for preparing and analyzing the environmental samples collected for the presence of radiological constituents, and for assisting me in conveying this analytical information to the general public.

Needless to say, I am proud of all of the CEMRC's employees and am indebted to them all for their service, dedication, and hard work as a result of this event.



Dr. Russell Hardy
Director, CEMRC

Executive Summary

Recent incidents at the nation's only operating deep geologic nuclear waste repository, the Waste Isolation Pilot Plant (WIPP), resulted in a small release of americium and plutonium from one or more defense-related transuranic (TRU) waste containers into the environment on the evening of February 14, 2014. WIPP is a U.S. Department of Energy (DOE) mined geologic repository that has been in operation since March, 1999. Over 85,000 cubic meters of waste in various vented payload containers have been emplaced in the repository. The primary radionuclides within the disposed waste are $^{239+240}$Pu and ^{241}Am, which account for more than 99% of the total TRU radioactivity disposed and/or scheduled for disposal in the repository. For the first time in its fifteen years of operation, there was an airborne radiation release from the WIPP.

In February, 2014, two isolated incidents took place at the WIPP that caused concern for the WIPP workforce and the DOE, as well as with other interested parties such as WIPP regulators and the local populace. On February 5, a truck used to remove salt from an active mining location to the salt hoist caught on fire in the northern part of the underground facility. All workers were safely evacuated and the underground portion of WIPP was shut down. Although several workers were treated for smoke inhalation, no radioactive waste was impacted by this fire, because the fire occurred at a considerable distance from the waste panels. However, nine days later, at approximately 11:30 PM Mountain Standard Time (MST) on Friday, February 14, a second unrelated event occurred, which resulted in the release of americium and plutonium isotopes from at least one TRU waste container into the underground environment. The release was detected by an underground CAM (Continuous Air Monitor) located near panel 7 where waste had most recently been emplaced. As soon as this CAM alarmed on the night of February 14, the WIPP ventilation system automatically switched to filtration mode, reducing the flow of air within the repository, and rerouting the exhaust air stream through a set of surface-mounted HEPA filter banks. Independent analytical results of air filters from sampling stations on and near the WIPP facility were compiled and released by the Carlsbad Environmental Monitoring and Research Center (CEMRC), confirming the presence of trace amounts of ^{241}Am and $^{239+240}$Pu, at ratios reflecting the suspect waste stream, in both WIPP exhaust air and ambient air near the WIPP facility. These concentrations of radiological contaminants in the air samples collected were deemed to be very small, localized, and well below any level of public-health or environmental concern.

In response to this incident, CEMRC began an intensified WIPP underground air sampling campaign and accelerated its radiochemical analyses of samples obtained in and around the WIPP site. Rapid analyses were also performed on ambient air samples and on environmental samples from the vicinity of the WIPP site immediately after the event's occurrence.

This report summarizes the independent monitoring of these two environmental events that occurred at the WIPP in February, 2014. These results were reported to the public by CEMRC as they were obtained through analyses. The data collected following the February fire and radiation release events at the WIPP were compared to the similar data collected during the monitoring phase of the WIPP to assess the radiological and ecological impacts, if any, of radiation on workers and on the general public living and working near the WIPP. Based on the analyses conducted by the CEMRC scientific staff, measured releases were determined to be low and localized, and no negative radiation-related health effects among local workers or the public should be expected.

SECTION 1 | INTRODUCTION

This section describes an overview of the WIPP site and the CEMRC's major environmental programs. The Waste Isolation Pilot Plant (WIPP), is a radioactive waste repository operated by the U.S. Department of Energy (DOE) for the permanent disposal of defense transuranic (TRU) wastes. Located in the Chihuahuan desert of southeastern New Mexico near Carlsbad, the facility is designed to permanently dispose of transuranic (TRU) wastes that were generated from research and the production of nuclear weapons at various DOE sites.

Environmental monitoring is a key component in the development and operation of any nuclear facility. Well after the facility had been sited and constructed, but before repository operations began, the DOE and local community leaders recognized the value of having an independent environmental monitoring program. With the help of the DOE, the New Mexico State University (NMSU) created the CEMRC, which is funded annually by the DOE through a financial assistance grant process that respects its independence in carrying out and reporting the results of environmental monitoring at and near the WIPP site. The CEMRC program maintains capabilities necessary for the rapid detection of radionuclides in the event of accidental releases from the repository or the site during waste handling and/or disposal operations.

SECTION 2 | WIPP UNDERGROUND AIR MONITORING

This section summarizes WIPP's underground air monitoring efforts following the February 14, radiation release event. The WIPP facility operates three effluent air monitoring stations. These are known as Stations A, B, and C respectively. Each station is equipped with at least one fixed air sampler collecting particulates from the effluent air stream on a Versapor filter. Station A is an above ground sampling platform, which collects particulates of unfiltered air exhausted from the repository, that is then either released directly to the environment or is directed into a HEPA filter bank designed to capture up to 99.97% of radioactive material. Activities measured at Station A reflect the level of contamination

present in the exhaust air of the repository prior to being released to the environment. The Station B sampler collects particulates from the underground exhaust air after HEPA filtration and, sometimes, non-filtered air during maintenance-related activities. Therefore, following a radiological event, such as the one that occurred on February 14, 2014, the activities measured at Station B are reflective of the level of contamination that was ultimately released into the environment. The effluent studies at Station A and Station B are a major component of WIPP Environmental Monitoring (WIPP-EM) program. Sampling operations at Station A provide a way to monitor for releases of radionuclides and other substances in the exhaust air from the WIPP. In addition, if radioactive materials were to be released from the facility, we would expect to detect it at Station A and/or Station B before it is observed in the local population or environment. Station A is located where radioactive or hazardous materials would most likely first be detected in the event of a release. The daily monitoring of the air filter samples collected from Station A indicates that the event released moderate levels of radioactivity within the WIPP repository, predominantly consisting of americium and plutonium. While results from Station B indicates that a small, but measurable amount of radioactivity eventually escaped to the surface and was detected beyond the site's inner boundary.

SECTION 3 | AMBIENT AIR MONITORING

A network of continuously operating samplers at three locations across the WIPP site was used to ascertain whether or not there were releases to the ground surface following the radiation release event from the WIPP underground. Air sampling was performed weekly at these three monitoring stations. A total of 56 air particulate filter samples have been obtained since the February 14 event. Except for the brief detection of americium and plutonium in the nearby ambient air samples, there is no increase in radiological contaminants that could be attributed to the recent radiation release from the WIPP in the wider region. CEMRC has been monitoring radionuclide concentrations in ambient since the inception of the WIPP-EM program in 1996. With few exceptions, fallout from atmospheric testing of nuclear weapons is the primary source of plutonium in ambient air. One of the most interesting and important findings from the prior WIPP-EM aerosol studies was that $^{239+240}$Pu in aerosols from all stations exhibited seasonal patterns and that the peak $^{239+240}$Pu activities generally occur in the March to June timeframe, which is when strong and gusty winds in the area frequently give rise to blowing dust.

SECTION 4 | SOIL MONITORING

This section summarizes soil monitoring efforts conducted around the WIPP Site following the February 14, radiation release event. Soil samples were collected and analyzed to monitor the deposition of americium and plutonium, if any, following the underground radiation release event at the WIPP. Samples were analyzed for radionuclides expected to

occur in the areas sampled. The data also show, as expected, that no detectable increases above those typical of previously measured natural variation occurred as a result of the February 14, 2014 underground radiation event.

SECTION 5 | SEDIMENT MONITORING

This section summarizes sediment monitoring conducted at three reservoirs on the Pecos River, which is the major perennial fresh water system closest to the WIPP that has extensive human usage. The three reservoirs are (1) Brantley Lake, located approximately 55 km (34 miles) northwest of the WIPP; (2) Lake Carlsbad, located in Carlsbad and approximately 40 km (25 miles) northwest of the WIPP; and (3) Red Bluff Reservoir, located approximately 48 km (30 miles) southwest of the WIPP. As in the case of soil, levels of radionuclides in sediment samples from the aforementioned three reservoirs in the region following the February 14 radiation release event showed no detectable increases above those typical of previously measured natural variation.

SECTION 6 | SURFACE WATER MONITORING

Samples of surface water in the vicinity of the WIPP site were collected and analyzed to determine the concentrations of radiological contaminants in the aquatic environment attributed to the recent radiation event at the WIPP. The surface water samples were collected in the same general area as the sediment from the three regional reservoirs situated on the Pecos River. As expected, the isotopes of americium and plutonium were not detected in any of the surface water samples. As for the gamma radionuclides, ^{40}K was detected in two of the surface water samples collected from Red Bluff reservoir while concentrations of all other gamma radionuclides were typically less than the minimum detectable concentrations.

SECTION 7 | WHOLE BODY COUNTING

In addition to the monitoring of environmental media (air, soil, drinking water, and surface water/sediment), the CEMRC also operates a Lung and Whole Body Counting (LWBC) lab that performs *in vivo* measurements of the internally deposited radionuclides in humans and has been performing such measurements since 1997 for public volunteers living within a 100-mile radius of the WIPP facility as well as for WIPP radiation workers and other nuclear-related entities in the surrounding area. Prior to the WIPP becoming operational, the CEMRC LWBC lab performed *in vivo* measurements, also referred to as counts, on 366 public volunteers in order to establish a baseline of radiological activities in the inhabitants within the local population. The WIPP became operational in March 1999, accepting its first waste shipment from Los Alamos National Labs on March 27, 1999. During the WIPP operational phase but prior to the February 14, 2014 event, the CEMRC LWBC lab performed counts on 991 public volunteers. Following the February 14, 2014 event, the CEMRC LWBC lab

performed *in vivo* measurements on 40 public volunteers. By comparing the results of the 40 individuals counted after the underground radiation event to the measurements compiled during the previous 16 years, we can conclude that there is no negative health effect on the public citizens living in the surrounding areas of the WIPP facility as a result of the February 14, 2014 underground radiation event.

SECTION 8 | QUALITY ASSURANCE

This section summarizes the comprehensive quality assurance programs, which include various quality control practices and methods employed to ensure data quality. The programs are implemented through quality assurance plans designed to meet requirements of the American National Standards Institute. Quality assurance plans are maintained for all activities and certified auditors verify conformance. Samples are collected and analyzed according to documented standard procedures. Analytical data quality was verified by a continuing program of internal laboratory quality control, replicate sampling and analysis are often done to assure data quality.

Table of Contents

List of Tables

List of Figures

Acronyms and Abbreviations

µBq	MicroBecquerel
µm	Micrometer
Am	Americium
ANSI	American National Standards Institute
ASTM	American Society for Testing and Materials
Ba	Barium
Bq	Becquerel
C	Centigrade
Ca	Calcium
CAM	Continuous Air Monitor
Ce	Cerium
CEMRC	Carlsbad Environmental Monitoring & Research Center
CEMRP	Carlsbad Environmental Monitoring & Research Program
Cf	Californium
CFR	Code of Federal Regulations
CH	Contact-handled
Ci	Curie
cm	Centimeter
Cm	Curium
Co	Cobalt
Cr	Chromium
Cs	Cesium
DL	Detection Limit
DOE	U.S. Department of Energy
DOE/CBFO	U.S. Department of Energy/Carlsbad Field Office
EEG	Environmental Evaluation Group
EPA	U.S. Environmental Protection Agency
Eu	Europium
FAS	Fixed Air Samples
Fe	Iron
FP	Field Programs
g	Gram
HCl	Hydrochloric acid
$HClO_4$	Perchloric acid
HEPA	High Efficiency Particulate Air
HF	Hydrofluoric acid
HNO_3	Nitric acid
H_2O_2	Hydrogen Peroxide
HPGe	High Purity Germanium
I	Iodine
ID	Internal Dosimetry
Ir	Iridium
K	Potassium
km	Kilometer
L	Liter
LANL	Los Alamos National Labs
LDBC	"Lie Down and Be Counted"

m	Meter
MAPEP	Mixed-Analyte Performance Evaluation Program
mBq	MilliBecquerel
MDC	Minimum Detectable Concentration
MDL	Method Detection Limit
min	Minute
mL	Milliliter
Mn	Manganese
MTL	Minimum Testing Level
MTRU	Mixed Transuranic
Na	Sodium
NaOH	Sodium Hydroxide
Nd	Neodymium
NIST	National Institute of Standards and Technology
NMED	New Mexico Environment Department
NMSU	New Mexico State University
Np	Neptunium
NRIP	National Radiochemistry Intercomparison Program
NWP	Nuclear Waste Partnership
Pb	Lead
Pu	Plutonium
QA	Quality Assurance
QAP	Quality Assurance Program
QAPD	Quality Assurance Program Document
QC	Quality Control
Ra	Radium
RC	Radiochemistry
RH	Remote-Handled
Ru	Ruthenium
Sb	Antimony
SNL	Sandia National Labs
Sr	Strontium
Th	Thorium
TRU	Transuranic
Unc.	Uncertainty
U	Uranium
WHB	Waste Handling Building
WIPP	Waste Isolation Pilot Plant
WIPP-EM	Waste Isolation Pilot Plant Environmental Monitoring
Y	Yttrium
Zn	Zinc
Zr	Zirconium

SECTION 1

Introduction

The Waste Isolation Pilot Plant also known as WIPP is a transuranic (TRU) waste repository operated by the U.S. Department of Energy (DOE). The purpose of the repository is to emplace defense-related TRU wastes in the Salado Formation, a bedded salt formation approximately 655 m (2150 ft.) below the surface of the Earth. Located near Carlsbad, New Mexico, an area with less than 30,000 people, the WIPP facility is the world's first underground repository permitted to safely and permanently dispose of TRU waste generated through defense activities and programs **(see Figure 1.1)**. TRU waste is defined in the WIPP LWA (Public Law 102-579) as radioactive waste containing more than 100 nanocuries (3,700 becquerels [Bq]) of alpha-emitting TRU isotopes per gram of waste, with half-lives greater than 20 years. Most TRU waste consists of contaminated industrial trash, such as rags and tools, sludges from solidified liquids, glass, metal, and other materials. The upper waste acceptance criteria are <0.85 TBq/liter (<23 Ci/liter) of total activity, and <10 Sv/hr dose rate on contact with unshielded waste containers. Since the start of its operation in March 1999, more than 81,000 cubic meters of Cold-War legacy TRU waste have been removed from temporary locations around the nation and shipped to WIPP for permanent disposal. The WIPP is about half full in terms of its legally defined capacity.

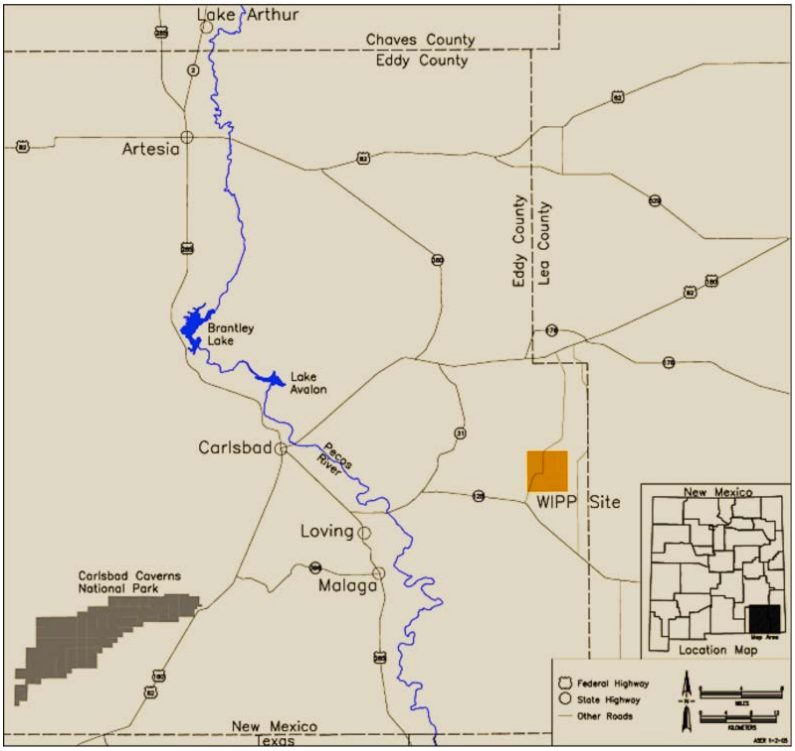


Figure 1.1 Location of the WIPP site

Two types of TRU wastes are currently stored in the WIPP repository: (1) mixed transuranic waste (MTRU), meaning there is also hazardous waste components present, and (2) non-mixed waste that contains only radioactive elements, mostly plutonium. The TRU waste is subdivided into contact-handled (CH) and remote-handled (RH) waste on the basis of the dose equivalent rate at the surface of the waste container. According to the legal definition, the term "contact-handled transuranic waste" means transuranic waste with a surface dose rate not greater than 200 millirem per hour. The term 'remote-handled transuranic waste' means transuranic waste with a surface dose rate of 200 millirem per hour or greater" (Congress, 1992). Contact-handled TRU waste typically emits relatively little gamma radiation; therefore, it can be handled directly by workers. Remote-handled TRU waste emits higher levels of gamma (penetrating) radiation; therefore, gamma rays represent the main radiological health hazard for workers handling RH-TRU waste. The WIPP became operational in March 26, 1999 for the disposal of TRU waste, and the WIPP first received mixed waste shipments on September 9, 2000. The WIPP mission is to dispose of 176,000 m^3 (6.2 million cubic feet) of contact-handled waste and 7,080 m^3 (250,000 cubic feet) of remote-handled waste which is equivalent to about 810,000 fifty-five gallon drums. Approximately 90,451 m^3 (319,000 cubic feet) of CH waste and 356 m^3 (12,572 cubic feet) of RH waste have been disposed of at the WIPP facility as of January, 2014. At least 66,200 m^3 of transuranic waste sit at several DOE sites, awaiting shipment to WIPP.

As shown in Figure 1.2, the WIPP repository layout currently has eight panels planned, each consisting of seven waste disposal rooms approximately 300 feet (91 meters) long and 33 feet (10 meters) wide. Seven of the panels have been excavated; and the first five have been closed and sealed from ventilation air. Panel 6 is full and is awaiting closure. Waste disposal is in progress in the seventh panel. Two additional panels are being planned.

The facility also consists of common drifts for access and ventilation to the disposal panels, four shafts connecting surface operations to underground emplacement activities and above ground waste receipt and handling facilities. The repository is ventilated by drawing in a large amount of outside air, unfiltered. Since the air in the repository exits to the surface through its exhaust shaft, this shaft is the sole potential pathway for airborne radioactivity release from the WIPP during normal operations. The potential for release is mitigated by HEPA (High Efficiency Particulate Air) filters which are located at the surface. Continuous air monitors in the underground are used to control whether or not the ventilation air returning to the surface is passed through these large HEPA filter systems before being released to the atmosphere.

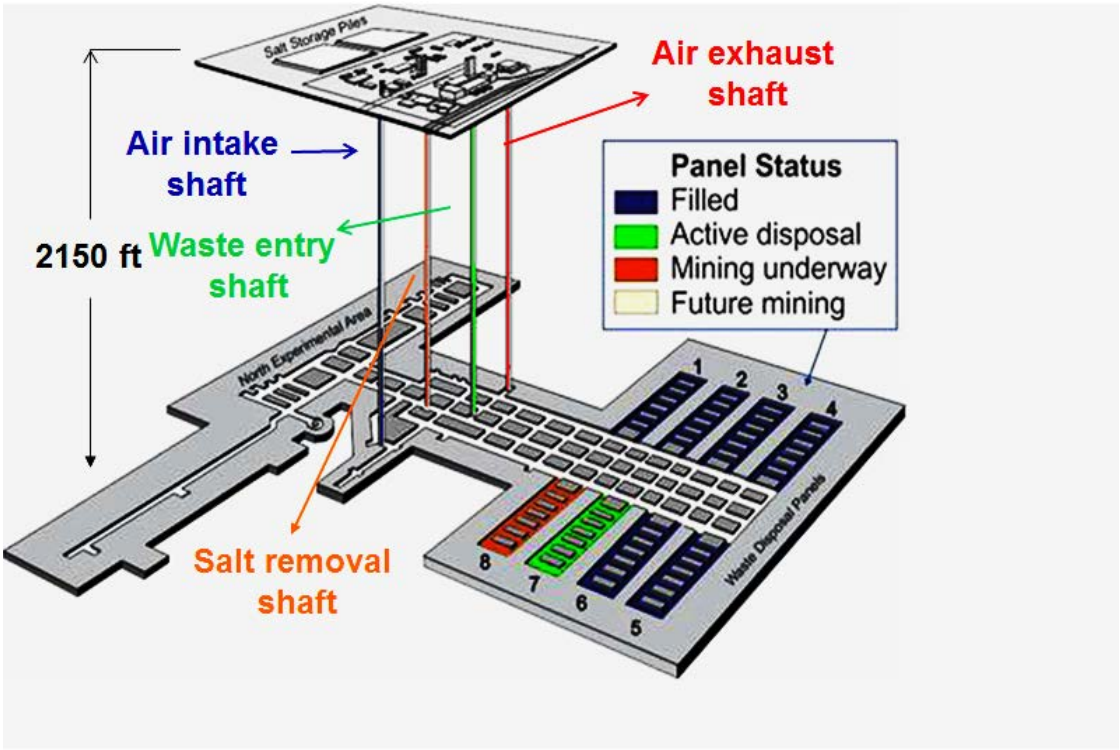


Figure 1.2 WIPP layout

In terms of exhaust air monitoring, the WIPP facility operates three effluent air monitoring stations. These are known as Stations A, B, and C respectively. Each station is equipped with at least one fixed air sampler that collects particulates from the effluent air stream on a Versapore filter. Representative sampling is assured by system design. Under normal operating conditions (such as those encountered prior to the February 14, 2014 underground radiation event), unfiltered air is drawn through the repository and exhausted from the repository directly to the environment after passing through the Station A sampling port. Therefore, during normal operating conditions, the activities measured at Station A would represent the radiological activities present in the air within the repository and would be reflective of the level of contamination released directly to the environment. However, once contamination is detected in the underground by a continuous air monitor (such as what occurred during the radiological event on February 14, 2014), the system shifts into "filtration mode" thereby significantly lowering the quantity of air being drawn through the repository and directing this exhaust air through the bank of HEPA filters before being released into the environment.

The Station B fixed air sampler collects the air downstream of the bank of HEPA filters and is representative of the level of contamination ultimately released into the environment while operating in filtration mode. It is important to note that the WIPP exhaust air ventilation system has been operating in filtration mode since the underground event

occurred on February 14, 2014. Station C is used to sample the exhaust from the Waste Handling Building (WHB) where air exhausted from the WHB passes through double HEPA filters before being vented to the environment. The waste container is the primary confinement barrier in the WHB; while negative building pressure and HEPA filtration provide secondary confinement to potential radiological contamination. CEMRC, like the New Mexico Environment Department (NMED) and the WIPP contractor (NWP), has its own collection ports at Station A and Station B on which it collects exhaust air samples in order to perform its independent analyses. Prior to the underground release event, CEMRC did not sample Stations B or C unless there was an indication of a release-detection by a CAM located in the underground or in the WHB. Since the release event, CEMRC has been performing expedited sampling and analysis of Station A and B filters respectively.

WIPP History

The WIPP site is an essential effort in support of cleaning up the nation's TRU waste which is currently stored at several federal facilities around the country. The history of the WIPP goes back to 1957, when the National Academy of Science recommended bedded salt formations as the optimal geologic formation for the underground disposal of radioactive waste. Salt deposits were selected as the host for the disposal of nuclear waste for the following reasons: 1) Most deposits of salt are found in stable geological areas with very little earthquake activity, assuring the stability of a waste repository. 2) Salt deposits also demonstrate the absence of water that could move waste to the surface. If water had been present in the past or was currently present, it would have dissolved the salt beds. 3) Salt is relatively easy to mine in comparison to many other geologic formations. 4) Finally, rock salt heals its own fractures because it behaves plastically under lithostatic pressure. The impetus to go forward with the project developed in 1969-1970 when a series of fires at the DOE Rocky-flats facility near Denver, Colorado caused an airborne release of plutonium. At that time, DOE agreed to stop storing plutonium wastes at Rocky Flats and began shipping TRU wastes to Idaho National Engineering and Environmental Laboratory in southeastern Idaho. Idaho was promised that the wastes would only be stored for ten years in Idaho while the search began for a site where these wastes could be permanently disposed. DOE had previously evaluated a site near Lyon, Kansas, in an abandoned salt mine, but strong political opposition by state officials and a combination of numerous borehole and large volumes of water "lost" in fractures in the salt forced them to look elsewhere. They considered several New Mexico sites, eventually settling on the site near Carlsbad. The encouragement of local politicians and businesses, the depressed economic conditions in that part of the state at the time, and a ready labor force already trained in what was needed to construct the repository, were all important factors in bringing WIPP to this area. In 1979, Congress authorized the construction of the WIPP facility, and the DOE constructed the facility during the 1980s. In late 1993, the DOE created the Carlsbad Area Office (CAO), subsequently re-designated as the

Carlsbad Field Office (CBFO), to lead the TRU waste disposal effort. The CBFO coordinates the TRU program throughout the DOE complex.

On March 26, 1999, the WIPP facility received its first waste shipment from the Los Alamos National Laboratory in Los Alamos, New Mexico.

Background Radiation

There are several sources of naturally occurring radiation: cosmic and cosmogenic radiation (from outer space and the earth's atmosphere), terrestrial radiation (from the earth's crust), and internal radiation (naturally occurring radioactive material in our bodies, such as potassium or ^{40}K). The most common sources of terrestrial radiation are uranium, and thorium, and their decay products. Radon gas, a decay product of uranium, is a widely known naturally occurring terrestrial radionuclide. Another source of terrestrial radiation is ^{40}K. While not a major radiation source, the presence of ^{40}K in the southeastern New Mexico environment may be due to the deposition of tailings from local potash mining. In addition to natural radioactivity, small amounts of radioactivity from aboveground nuclear weapons tests that occurred from 1945 through 1980, and the 1986 Chernobyl and 2011 Fukushima nuclear accidents are also present in the environment. Together, these sources of radiation are called "background" radiation **(see Figure 1.3)**.

Naturally occurring radiation in the environment can deliver both internal and external doses. An internal dose is received as a result of the intake of radionuclides through ingestion (consuming food or drink containing radionuclides) and inhalation (breathing radioactive particulates). An external dose can occur from immersion in contaminated air or deposition of contaminants on surfaces. The worldwide average natural dose to humans is about 2.4 millisievert (mSv) per year, which is four times more than the worldwide average artificial radiation exposure. Site-specific background gamma measurements on the surface, conducted by Sandia National Laboratories (SNL), showed an average dose rate of 7.65 microrem per hour (Minnema and Brewer, 1983), which would equate to the background gamma radiation dose of 0.67 millisieverts (mSv) (67.0 mrem) per year. A comprehensive radiological baseline study before WIPP facility disposal operations began was also documented in *Statistical Summary of the Radiological Baseline for the Waste Isolation Pilot Plant* (DOE/WIPP-92-037), which provides the basis for environmental background comparison after WIPP facility disposal operations commenced.

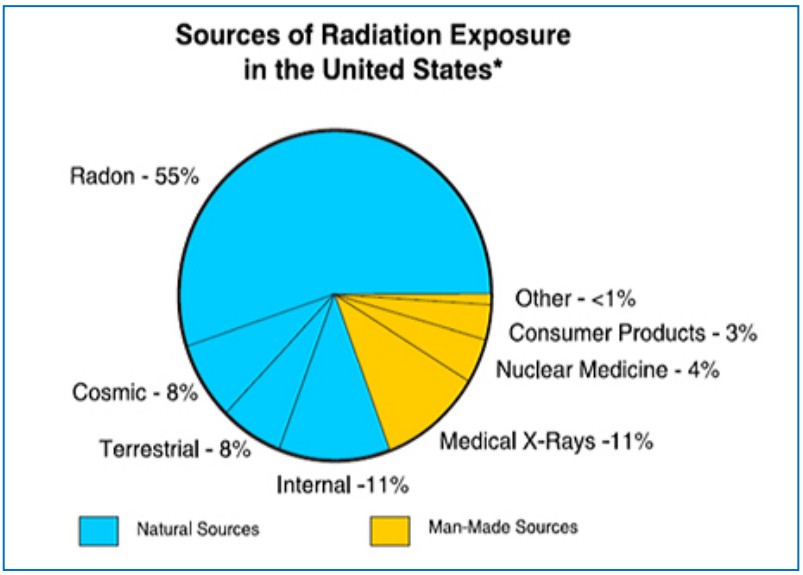


Figure 1.3 Source of Radiation Exposure
(Source: National Council on Radiation Protection (ICRP)

In the Carlsbad area, where the WIPP is located, there is an additional potential local source of anthropogenic radioactivity that resulted from an underground nuclear test conducted during the Plowshare project. This particular test occurred at the Gnome site, about 8.8 km (5.5 miles) southwest of the WIPP site, in 1961 when an underground test of a 3.3-kiloton ^{239}Pu device vented radioactive materials to the surface. Clean-up efforts at this site have been carried out in several campaigns since that time, and the surface contamination is now well below the risk-based action levels. However, ^{137}Cs and plutonium have been detected by the CEMRC in some samples of surface soils collected at the Gnome site. While the transport of these contaminants from the Gnome site to the WIPP remains a possibility during high wind seasons (Stout and Arimoto, 2010); more than fifteen years of monitoring data and the activity levels detected, as well as their atomic ratio measurements, suggest that pre-release-event plutonium and americium in aerosol and soil samples taken near the WIPP facility mainly represent redistributed global fallout.

Independent Environmental Monitoring Program –An Overview

The success of any routinely misperceived project such as a nuclear facility is strongly tied to the degree of public participation, acceptance and understanding. The WIPP is an example where public engagement has constantly been at a high level. From the standpoint of addressing the operational and environmental risks, as well as allaying public concerns, the WIPP has endured extensive human health and environmental monitoring. In addition to the regulatory compliance monitoring required by the repository licensee, and also conducted by the State of New Mexico and previous entities, the local community demanded the implementation of a sophisticated environmental monitoring program carried out by an

independent academic institution that would emphasize a science-based program, rather than one focused on compliance.

Many factors contributed to the success of this project during its first almost 15 years of operations. An important factor is the local acceptance engendered by an independent environmental monitoring program in the vicinity of the WIPP that began before and continues after the WIPP began receiving nuclear waste. This independent monitoring is being conducted by the Carlsbad Environmental Monitoring and Research Center (CEMRC), which is associated with the New Mexico State University system. The CEMRC is funded by the DOE through a financial assistance grant process that respects its independence in carrying out and reporting the results of environmental monitoring activities conducted at and near the WIPP site. Unlike most environmental programs which only monitor down to compliance or action levels, the mission of the CEMRC is to monitor to below background levels, as the public needs to know what is truly happening in the environment and what effect WIPP operations may have on their lives and health. As a result, some approaches the CEMRC has undertaken is to increase counting times on alpha and gamma spectroscopy in order to routinely achieve the lower detection limits for alpha and gamma-emitting radionuclides or by adopting a 12-detector array for *in vivo* bioassay in order to observe the 17.5 keV spectrum indicating the presence of Pu in the lung.

Radionuclides present in the environment, whether naturally occurring or anthropogenic (human-made), may contribute to radiation doses to humans. Therefore, environmental monitoring around nuclear facilities is imperative to characterize radiological baseline conditions, identify any releases, and to determine their effects, should they occur. The purpose of the radiological environmental monitoring program is to measure radionuclides in the ambient environmental media. These data allow for a comparison of sample data to results from previous years and to baseline data, to determine what impact, if any, the WIPP is having on the surrounding environment. Radiological monitoring at the WIPP site includes sampling and analysis of air (both WIPP underground exhaust and ambient air), drinking water, surface water, sediment and soil.

The primary focus of the CEMRC monitoring is on airborne radioactive particulates; however, other pathways are also monitored. The collected pre-disposal baseline data of various anthropogenic radionuclides present in the WIPP environment, either from global fallout as a result of nuclear weapons testing or Chernobyl-type accidents, is essential for the proper evaluation of the WIPP's integrity. These data can be compared against disposal phase data to assess the radiological and ecological impacts, if any, of radiation on workers, and on the general public living and working near the WIPP. The CEMRC program has capabilities to detect radionuclides rapidly in case of accidental releases from the repository or the site during operations.

CEMRC's environmental monitoring activities generally fall into three categories: collecting environmental samples and analyzing them for a variety of contaminants, evaluating whether WIPP activities cause any environmental impacts, and taking corrective action when an adverse effect on the environment is identified. The current CEMRC operational environmental sampling and analytical plan is detailed in previous CEMRC annual reports. The four major elements of the program are WIPP exhaust air, ambient air, drinking water and human monitoring. At present, soil, sediment and surface water samples are not routinely acquired and analyzed.

The CEMRC operates three ambient air samplers in and around the WIPP site. The sites are located in the most prevalent wind directions from the facility. The primary purpose is to obtain baseline data and to determine whether the nuclear waste handling and storage operations at the WIPP have released radionuclides into the environment around the WIPP.

Public drinking water samples are also routinely sampled from six drinking water sources in the region of the WIPP. These sampling locations are not likely to be affected by any WIPP radioactivity releases; however, because water is a primary vector in the food chain, the samples are collected and analyzed regularly. As with community air sampling, the absence of WIPP radionuclides in drinking water samples provides additional public assurance.

As mentioned previously, WIPP exhaust air is the most likely pathway for accidental radioactivity releases from the WIPP. Accident release scenarios are postulated in the WIPP Safety Analysis Report (USDOE WIPP 1997a). If an underground operations accident were to occur, air samples would be collected from Stations A and B, the final release points of the underground repository exhaust ventilation system. Consequently, the CEMRC collects filter(s) from Station A and B each day, screening the filters for radioactivity, and then performs the more sensitive radiochemical analyses on the composited monthly filters. The daily sampling allows a careful study of the variability of radioactivity background and trends.

From time to time, soil, sediment and surface water samples are also collected and analyzed to verify radionuclides concentrations and to establish the variability of background radioactivity. In addition, soil samples were previously collected from selected areas and control locations outside the Gnome site and were analyzed for the presence of radionuclides thereby creating the ability to identify localized surface contamination. The results of this study are presented in the 2005/2006 CEMRC Annual Report.

CEMRC has been monitoring the concentration of plutonium (Pu) and americium (Am) in the area around the WIPP sites for many years, as isotopes of these elements are the major radioactive constituents in the TRU waste. Additionally, uranium isotopes (^{238}U, ^{235}U, ^{234}U), prominent alpha-emitting radionuclides in the natural environment, and cesium (^{137}Cs), a

potentially important beta and gamma-emitting constituent of the TRU waste disposed at WIPP, have been the subject of background studies conducted by the CEMRC at WIPP prior to 1999 and continue to be monitored. Cobalt (^{60}Co) and other gamma-emitters, though not major constituents of the TRU waste, are also monitored. Lastly, potassium (^{40}K), a natural gamma-emitting radionuclide, which is ubiquitous in the earth's crust, is also monitored because of its possible enhancement in southeastern New Mexico due to potash mining.

In addition to the monitoring of environmental media (air, soil, drinking water, and surface water/sediment) in the vicinity of the WIPP site, the CEMRC also performs routine monitoring of adult residents living within a 100-mile radius of the WIPP facility for the presence of gamma-emitting radioisotopes through its *Lie Down and Be Counted* (LDBC) program. The LDBC project serves as a component of the WIPP Environmental Monitoring program that directly addresses the general concern about personal exposure to contaminants shared by residents who live near DOE sites. As in other aspects of the WIPP-EM program, *in vivo* bioassay testing was used to establish a baseline profile of internally-deposited radionuclides in a sample of local residents before disposal phase operations began, and has continued into the disposal phase to the present. The sampling design includes the solicitation of adult volunteers from all segments of the community, with sample sizes sufficient to meet or exceed a 15% range in margin of error for comparisons between major population ethnicity and gender categories as identified in the 1990 U.S. census. Radiobioassays of the original volunteer cohort have been ongoing since July 1999. New volunteers continue to be recruited each year to establish new study cohorts and to replace volunteer attrition. While the passage of time and the overall success of the WIPP have historically made it difficult to attract new volunteers to the LDBC program, the February 14, 2014 event appears to have renewed interest on behalf of resident volunteers. Results of the LDBC, both historically and with respect to the February 14, 2014 underground radiation event are reported herein.

The Fire and Radiological Release Events at the Waste Isolation Pilot Plant

Two isolated incidents took place at WIPP in February, 2014. On February 5, a truck used to remove mined salt from the underground facility caught on fire in the northern part of the underground facility (**Figure 1.4**). Workers were evacuated and the underground portion of WIPP was shut down. Several workers were treated for smoke inhalation, but no injuries occurred. No radioactive waste was impacted by this fire because the fire occurred at a considerable distance from the waste.

Figure 1.4 EIMCO Haul Truck 74-U-006B after Fire

In response to this incident, the CEMRC conducted an emergency analysis of the air filter collected from the WIPP underground (Station A) which collects particulates from unfiltered air used to ventilate the repository that is ultimately discharged to the environment. Analysis of the air-filter samples from the WIPP underground showed no additional radiation beyond normal background levels. This indicates that the fire-incident did not result in any release of radioactivity; hence there is no health risk of radiation releases caused by the fire. Nine days later, at approximately 11:30 PM on Friday, February 14, a second unrelated event occurred, which resulted in the release of americium and plutonium isotopes from at least one TRU waste container into the underground environment. The release was detected by an underground continuous air monitor (CAM) located near panel 7 where waste was being emplaced (**Figure 1.5**). As soon as the CAMs alarmed on the night of February 14, the WIPP ventilation system automatically switched to filtration mode, reducing the flow of air within the repository, and directing the exhaust air stream through HEPA filter banks.

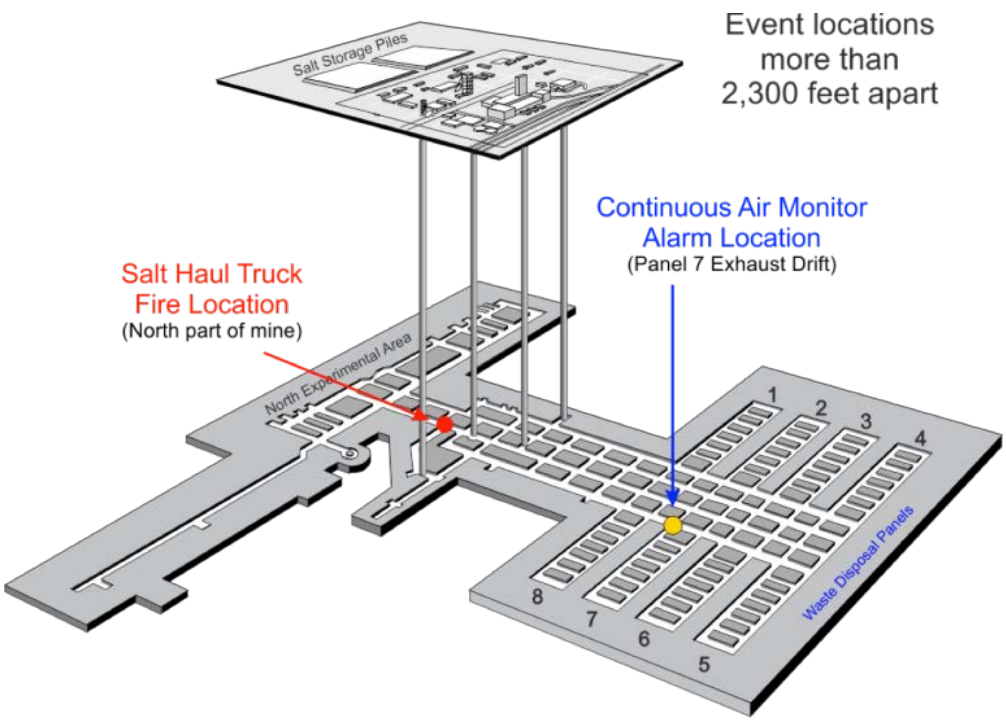


Figure 1.5 Locations of Fire and Radiological Release Event

A measurable, but small, portion of the contaminated air bypassed the HEPA filters via leakage through two imperfectly sealing ventilation system dampers and was discharged directly to the environment from an exhaust duct. Since this incident occurred during the night, only a few employees were at the WIPP site and no employees were in the underground. Personnel were frisked and none were reported to have external contamination; however, a total of 21 personnel were later found to have positive bioassay results for ^{241}Am. Follow-up testing results were below the detectable limits of the laboratory analysis, indicating that the radioactive isotopes were excreted from the body. Additionally, on February 19, 2014, the CEMRC reported that trace amounts of americium and plutonium were detected at an ambient air sampler located approximately one-half mile northwest of the WIPP site.

Whether the radiation leak and the truck fire inside WIPP were connected remains an unanswered question. Among other possible causes of the leak, an energetic release from a waste drum in room 7 of panel 7 is now under consideration. In a recent news release, DOE announced that photos taken of the waste underground showed evidence of heat and gas pressure resulting in a deformed lid, in material expelled through that deformation, and in melted plastic and rubber and polyethylene in the vicinity of that drum. Recent entries into underground Panel 7 have confirmed that at least one waste drum containing a nitrate salt bearing waste stream from Los Alamos National Laboratory was breached underground and

was the most likely source of the release (**Figure 1.6).** Further investigation is underway to determine if other containers contributed to the release.

Figure 1.6 Photo of ruptured drum in room 7, panel 7 at WIPP

In response to this incident, the CEMRC conducted accelerated analyses of the underground filters collected from Stations A and B as soon as site access was allowed. Rapid analyses were also performed on ambient air samples and on environmental samples from the vicinity of the WIPP site. This report summarizes the data collected following the radiation release event at the WIPP.

SECTION 2

WIPP Underground Air Monitoring

The WIPP repository is ventilated by drawing ambient air down three widely spaced access shafts (air intake shaft, salt shaft, and waste handling shaft) to the underground and exhausting it out a single fourth shaft (exhaust shaft). Sampling the exhaust shaft air, at a point named Station A, allows an evaluation of the frequency and amount of any radioactivity released from or through the repository. The effluent studies at Station A are a major component of the WIPP Environmental Monitoring (WIPP-EM) program. Sampling operations at Station A provide a way to monitor for releases of radionuclides and other substances in the exhaust air from the WIPP. In addition, if radioactive materials were to be released from the facility, detection at Station A would precede observation in the local population or environment.

Station A is an above ground sampling platform that collects particulates from unfiltered air exhausted from the repository and directs air either to the environment or into a HEPA filter bank (**Figure 2.1**). Station B samples the underground exhaust air after HEPA filtration and, sometimes, non-filtered air during maintenance activities (**Figure 2.2**). While in filtration mode, Station B becomes a post-filtration sampler analyzed by the CEMRC and other entities. When not in filtration mode Station B is not sampling WIPP exhaust air, hence the CEMRC does not perform analyses on Station B filters unless the system is operating in filtration mode. The Overview of the WIPP ventilation system and normal underground air flow are depicted in **Figure 2.3**.

Sample Collection

Unfiltered exhaust air from the underground repository is sampled at station A. The Station A air samples are collected on 47 mm diameter membrane filters (Versapor ® membrane filter, PALL Corporation) with the use of a shrouded probe, commonly referred to as a fixed air sampler or FAS. As shown in **Figures 2.4 and 2.5**, it has a transfer line running to each of three sampling legs; thus a total of three concurrent samples can be collected from the FAS, one each for the CEMRC, the site contractor (Nuclear Waste Partnership, NWP) and the New Mexico Environment Department (NMED). A previous test of the probes confirmed that this configuration allows for the collection of representative air samples (Rodger, 1997). Under normal (non-filtration) operating conditions, each day approximately 81 m^3 (2,875 ft^3) of air is filtered through each of the Versapor filters at Station A. Typically, CEMRC Field Program technicians collect samples at Station A daily; however, occasionally more than one sample per day is collected if the flow rate on any of the sampler legs drops

below 0.06 m^3. When this occurs, a low-flow alarm on the sampler is activated and the filters are changed as needed by WIPP radiological control technicians.

Figure 2.1 Location of Station A

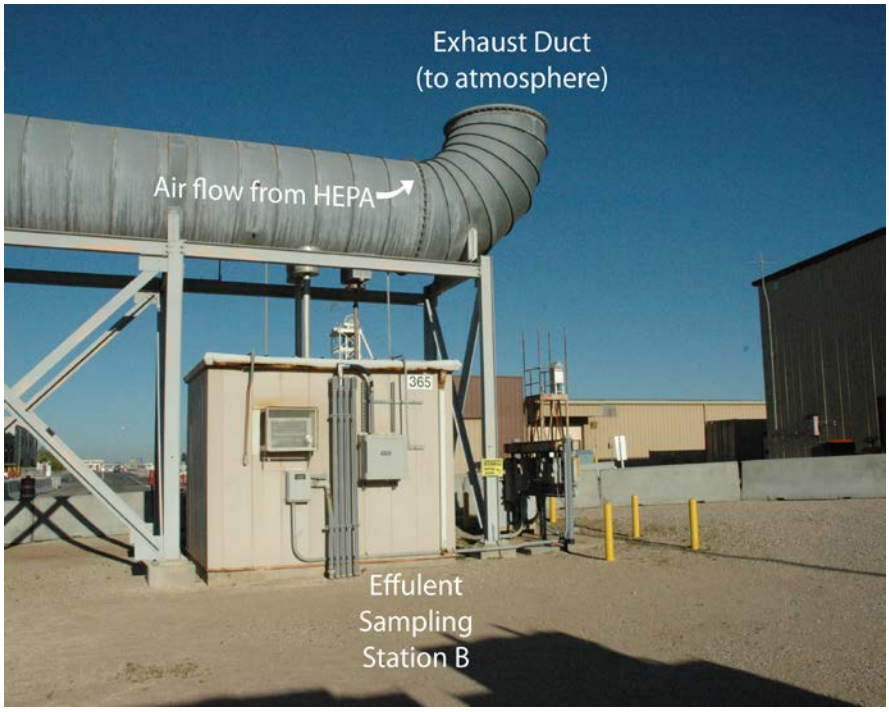


Figure 2.2 Location of Station B

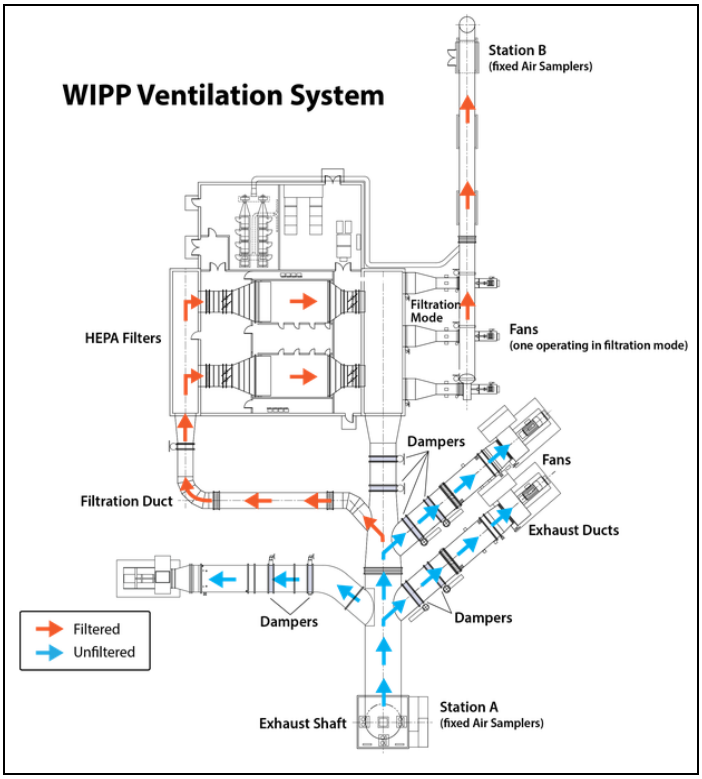


Figure 2.3 Overview of WIPP Ventilation System

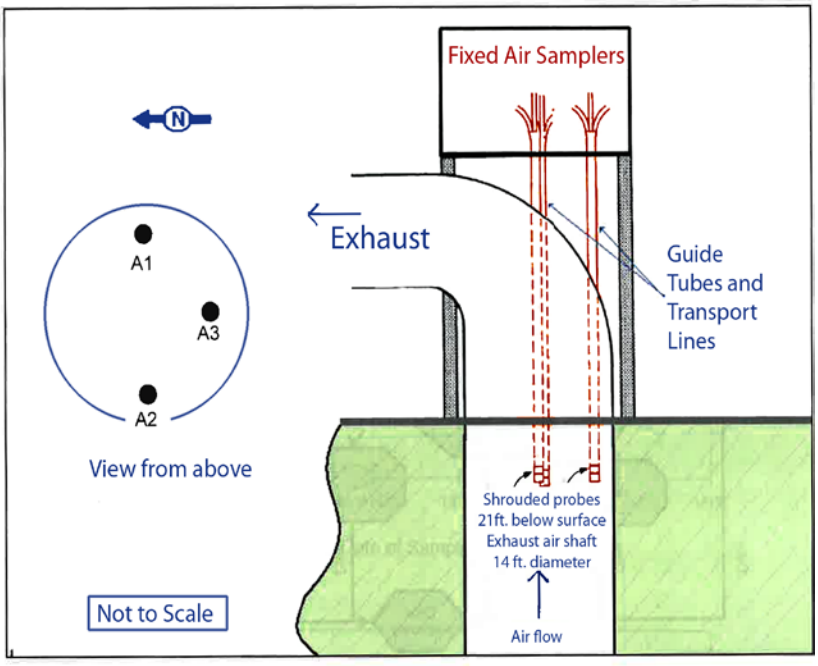


Figure 2.4 Overview of Station A

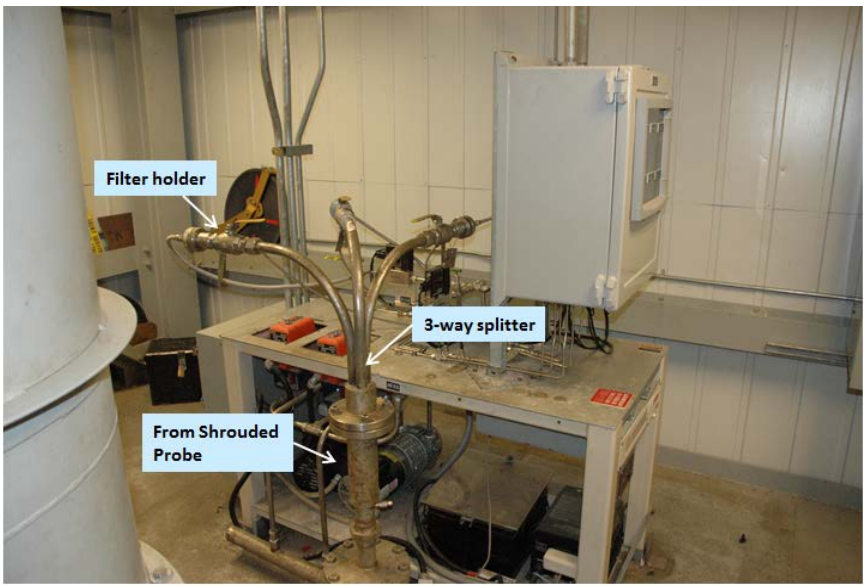


Figure 2.5 Fixed Air Samplers at Station A

Prior to the underground radiation event, weekly filter samples are typically collected at station B. Each week at Station B, approximately 583 m^3 (20,603 ft^3) of air is filtered through each of the Versapor filters. Prior to the release event, filter samples were combined monthly for Station A for analysis by CEMRC and NWP, and quarterly for Station B for analysis by NWP. For some time following the radiation release event, filters at station A and B were changed every 8 hours and measurements were performed on each individual filter initially and later on daily combined filters, by the CEMRC, depending on the levels of contamination found. As airborne concentrations receded toward pre-event ambient levels, the filter sampling and analysis program reverted back to the pre-incident schedule; however it is important to note that since the repository continues to operate in filtration mode, CEMRC technicians continue to collect Station B samples daily rather than weekly.

Sample Preparation and Analysis

Under normal operation, once the samples are collected from the site and returned to the laboratory, individual filters are desiccated for two to three days to ensure that any moisture on the filters is evaporated and to ensure complete decay of the immediate daughter products of ^{222}Rn and ^{220}Rn. Once dried, the filters are then weighed to determine mass loadings. Following the desiccating and weighing process, the Station A filters are counted for gross alpha and beta activities on a Protean MPC 9604 low background gas proportional counter for 1200 minutes. After gross alpha beta measurements, individual

filters are digested and the filter solutions are then combined into monthly composites. The monthly composite samples are used for the determination of actinide activities. Only one half of the sample is used for the determination of the actinide activities. The remaining aliquot is archived.

Following the release event, gross alpha and beta screening was not being performed routinely; instead, an emergency actinide separation was carried out on individual or daily filters collected from Station A and Station B. Later, beginning March 2014, gross alpha and beta analysis were being performed routinely. In preparation for gross alpha/beta counting, the filter is centered on a stainless steel planchet. The standard planchets for the alpha and beta were prepared from certified solutions of ^{239}Pu and ^{90}Sr/^{90}Y obtained from Analytics, Inc. (Atlanta, GA, USA). The planchet is counted on a low-background gas proportional counter for 180-300 minutes. The sample detectors are gas flow window type counters with an ultra-thin window. The counting gas consisted of P-10, which is a mixture of 90% argon and 10% methane. The operating voltage on the detector was selected as 1,450V.

Filter samples for radiochemical analysis were prepared by wet digestion with HNO_3, HCl and perchloric acid until the filter is totally dissolved. This mixture is heated to dryness and then re-dissolved in 20 mL of 1 M HCl. Generally, half of the sample is used for the determination of the actinide activities and other half for the gamma analysis. However, for the filters collected immediately after the incident when the potential for high-levels of contaminant was significant, appropriate dilutions of filter solutions were made prior to actinide separations. The actinides are concentrated in an iron hydroxide precipitate as $Fe(OH)_3$. After decantation and centrifugation, the precipitate is dissolved in 10 ml of conc. HNO_3 and diluted to 20 ml to make the solution 8 M in HNO_3. The oxidation state of plutonium as Pu(IV) was adjusted by adding 1 ml of 1 M NH_4I with a 10 min wait step, followed by 2 ml of 2 M $NaNO_2$. Plutonium is separated from americium and uranium using an anion exchange column. The fraction containing americium and uranium is separated using a TRU extraction chromatography column in 2 M HNO_3 as described in previous CEMRC reports. The individual actinides are then micro-co-precipitated with a Nd-carrier and counted using alpha spectrometry. The sample for both alpha and gamma analysis were counted for 24 hours. A simplified scheme of the radiochemical separation process is shown in Figure. 2.6.

Data Reporting

The activities of the actinides and gamma radionuclides in the WIPP underground air samples are reported as *activity concentration in* Bq/m^3. *Activity concentration* is calculated as the activity of radionuclides detected in Becquerel's (Bq) divided by the volume of air in cubic meters.

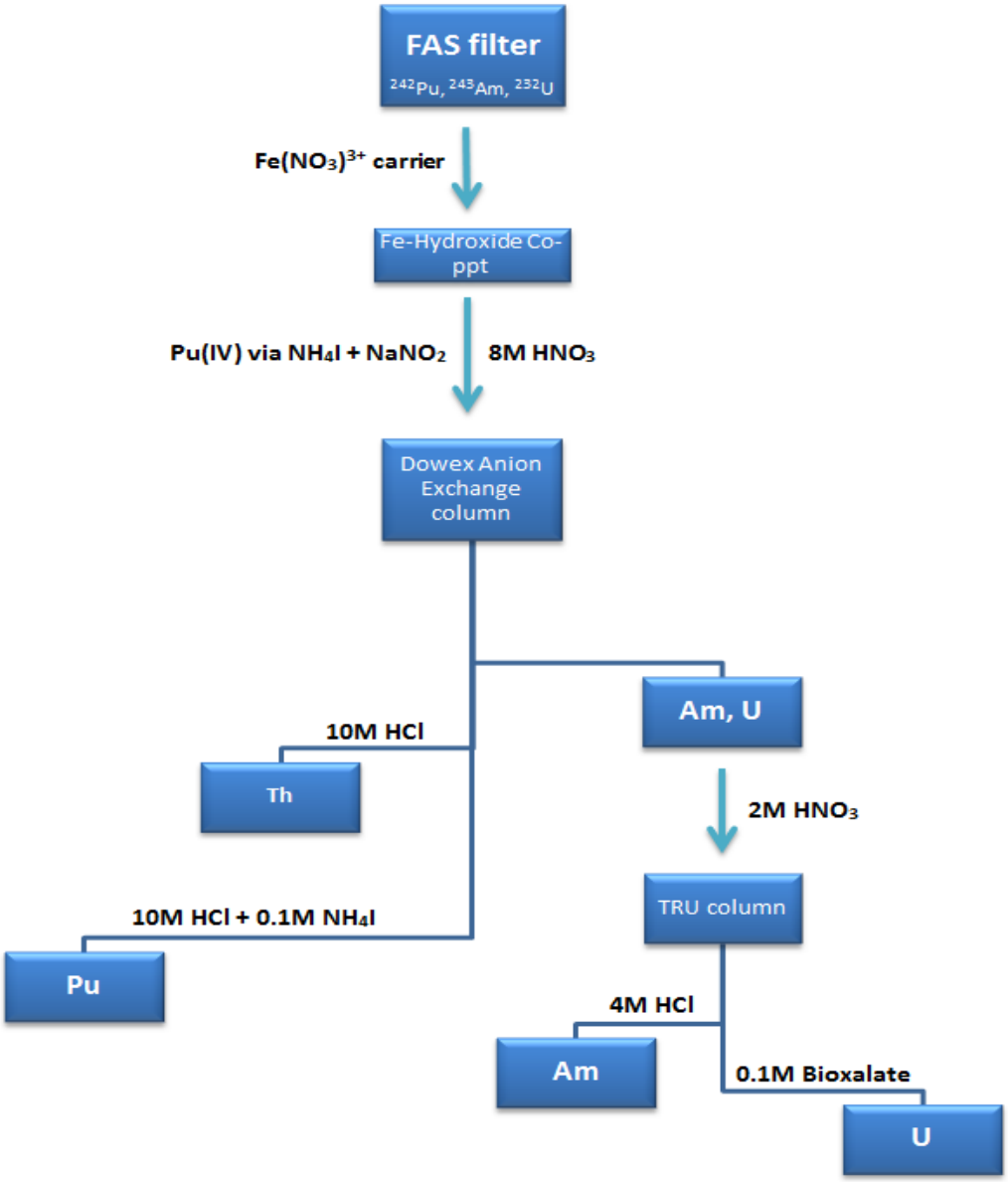


Figure 2.6 Flow Diagram Showing the Analysis of Stations A and B Filters

Results and Discussion

The analysis results of the filter collected from Station A following the fire accident are listed in **Tables 2.1A** (24 hour counting results) **and 2.1B** (5-days counting results). The ^{241}Am, $^{239+240}Pu$ and ^{238}Pu were all below the detection limits. No detection of these radionuclides indicates no nuclear waste was compromised as a result of the underground fire.

The daily gross alpha and beta concentrations in the WIPP exhaust air samples collected between March and June, 2014 are shown in **Figures 2.7 and 2.8**. A significantly higher gross alpha and beta values were detected in filter samples collected in March, 2014 and an overall slightly increasing trend can be seen through early June, 2014. The activities appear to have close to pre-operational levels during last week of June, 2014. Similar seasonal trends in gross beta data can also be seen. The gross alpha and beta concentrations measured in Station A filters following the release event is shown in **Table 2.2**. The pre-release gross alpha and beta concentrations measured at station A are also plotted in **Figures 2.7 and 2.8** for trend analysis. The minimum detectable activity concentrations for the gross alpha emitters is $\approx 1 \times 10^{-7}$ Bq/m^3, while for gross beta emitters the corresponding value is $\approx 2 \times 10^{-7}$ Bq/m^3. The bulk of the activity in those samples results from naturally occurring radioactive materials, specifically radon daughters. The gross alpha and beta concentrations exhibit clear seasonal variability with peaks occurring in the winter. The two samples with elevated gross beta activity concentrations ca. 0.058 Bq/m^3 observed in early 2001(**Figure 2.8)** are because of contamination by material released from an underground fire extinguisher. Follow-up measurements verified that the fire retardant containing ^{40}K was the cause of the elevated results and that WIPP waste had not been released.

The time series of the activity concentrations of transuranic radionuclides $^{239+240}$Pu, ^{238}Pu, and ^{241}Am measured at Station A (Pre- HEPA filtration) and Station B (Post-HEPA filtration) after the release-event are shown in **Figures 2.9 and 2.10.** The values detected at Station A and Station B are considerably higher than those historically measured for these Stations. The daily concentrations of ^{241}Am, $^{239+240}$Pu, and ^{238}Pu measured at Station A filter are presented in **Tables 2.3-2.5.** The maximum air concentrations of plutonium and americium detected at Station A were 4337 Bq/m^3 for ^{241}Am, 672 Bq/m^3 for $^{239+240}$Pu and 30.3 Bq/m^3 for ^{238}Pu. These results were measured on February 15, 2014. The filter that had highest activity was installed in the morning of February, 14, the day of the underground radiation release event, and was removed on February 15, 2014. The high concentration levels were generally detected for about a week. After that, the activity levels decreased significantly to about 0.65 Bq/m^3 for ^{241}Am and 0.06 Bq/m^3 for $^{239+240}$Pu. It is important to note that these high activity values are reflective of what was detected in the unfiltered underground air prior to going through HEPA filtration systems and do not represent the activity levels that ultimately escaped to the environment.

Table 2.1A Activity concentrations of ^{241}Am, $^{239+240}$Pu, ^{238}Pu, and uranium isotopes (Bq/m^3), in Station A filter collected soon after the fire incident at WIPP (24 hours counting)

Radionuclide	Conc. Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
^{241}Am	2.53E-06	7.04E-06	1.21E-05	No detection
$^{239+240}$Pu	1.05E-06	5.88E-06	1.29E-05	No detection
^{238}Pu	-2.92E-07	6.85E-06	1.56E-05	No detection
^{234}U	1.05E-04	3.23E-05	1.58E-05	Detection
^{235}U	1.63E-05	1.35E-05	1.58E-05	No detection
^{238}U	6.22E-05	2.50E-05	2.40E-05	Detection

Table 2.1B Activity concentrations of actinides and gamma radionuclides (Bq/m^3), in Station A filter collected soon after the fire incident at WIPP (5–days counting)

Radionuclide	Conc. Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
^{241}Am	-2.18E-06	1.79E-06	4.39E-06	No detection
$^{239+240}$Pu	3.37E-06	3.31E-06	5.06E-06	No detection
^{238}Pu	-4.21E-07	2.48E-06	5.53E-06	No detection
^{234}U	1.13E-04	1.92E-05	7.71E-06	Detection
^{235}U	1.08E-05	5.74E-06	7.19E-06	No detection
^{238}U	7.58E-05	1.54E-05	1.28E-05	Detection
^{137}Cs	9.58E-04	1.46E-02	2.48E-02	No detection
^{60}Co	-6.54E-04	1.25E-03	2.14E-03	No detection
^{40}K	8.22E-04	1.19E-03	2.01E-03	No detection

*counted for 48 hours for gamma emitters.

In order to determine the amount and type of radionuclides that were ultimately released into the environment, the accelerated analyses of Station B filters were carried out as these filters sampled the underground exhaust air after HEPA filtration. Analysis of the Station B filter that was installed in the morning of February 14, 2014 and removed from Station B in the afternoon of February 18, 2014 showed 2.28 Bq/m^3 of ^{241}Am and 0.22 Bq/m^3 of $^{239+240}$Pu, and 0.032 Bq/m^3 of ^{238}Pu (**Figure 2.10**) . Given that this particular filter remained in the sampler from the time of the underground radiation detection event until four days after the event, this filter was representative of the total amount of ^{241}Am and $^{239+240}$Pu, and ^{238}Pu that may have been released into the environment. The daily concentrations of ^{241}Am, $^{239+240}$Pu, and ^{238}Pu measured at Station B filter are summarized in **Tables 2.6-2.8.**

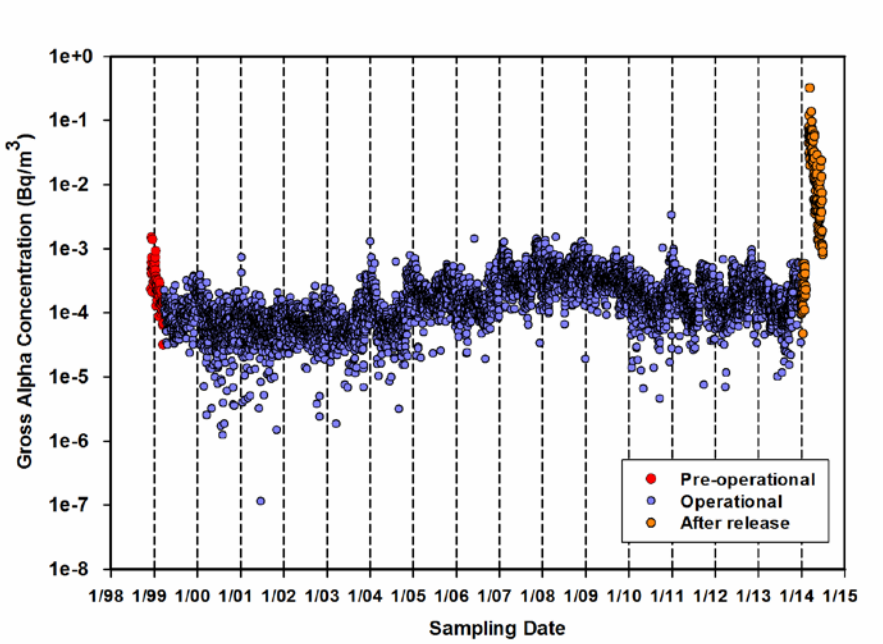


Figure 2.7 Pre and Post release Gross Alpha concentration in Station A (Pre-HEPA) filter

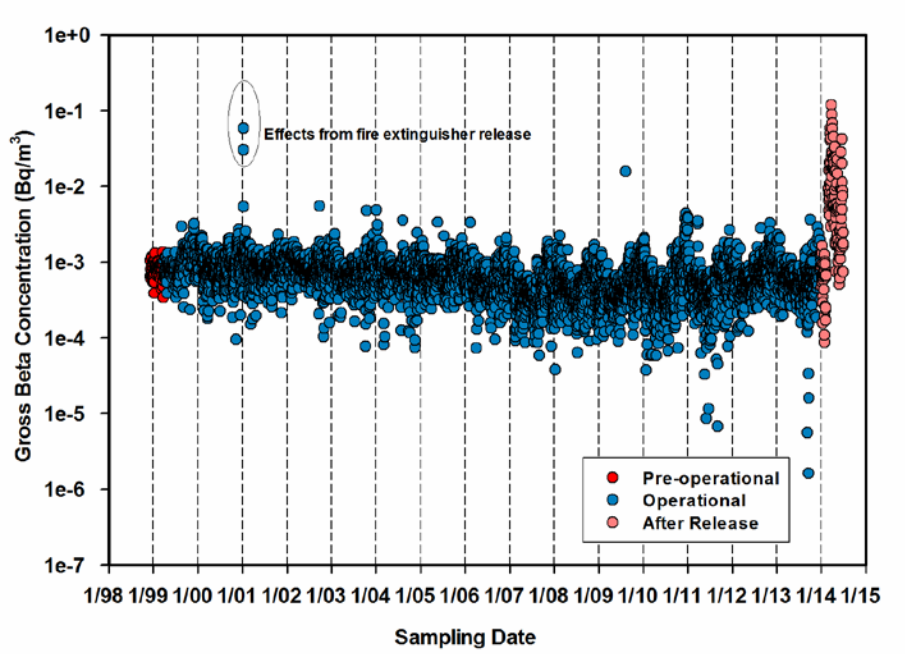


Figure 2.8 Pre and Post release Gross Beta concentration in Station A (Pre-HEPA) filter

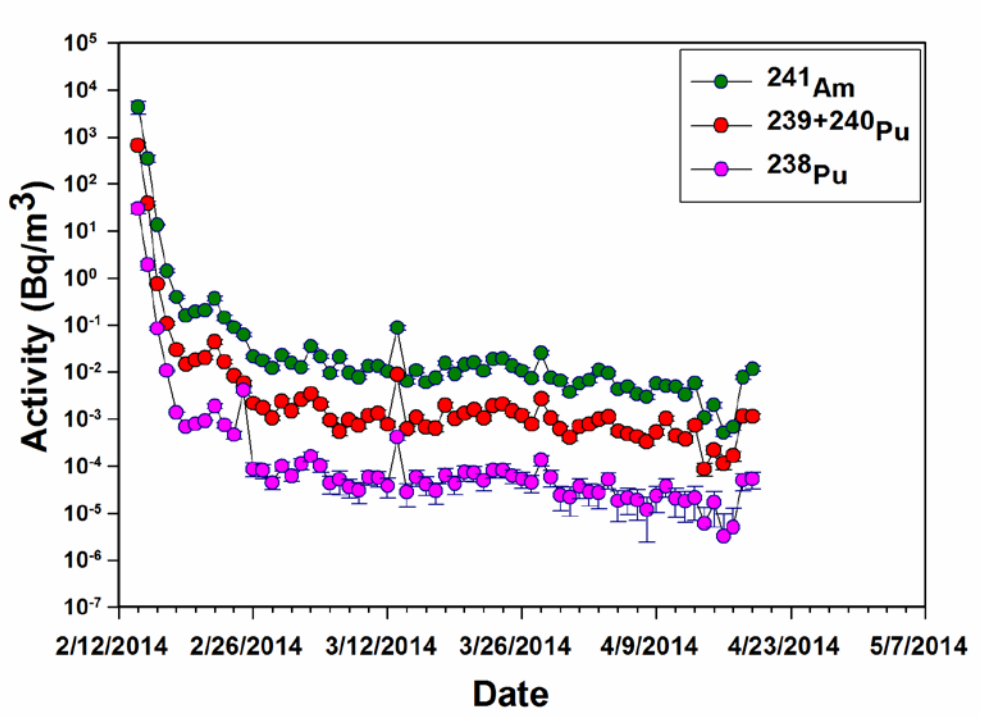


Figure 2.9 The daily ^{241}Am, $^{239+240}$Pu and ^{238}Pu concentrations in Station A (Pre-HEPA) filters following the February 14, radiation release event at the WIPP

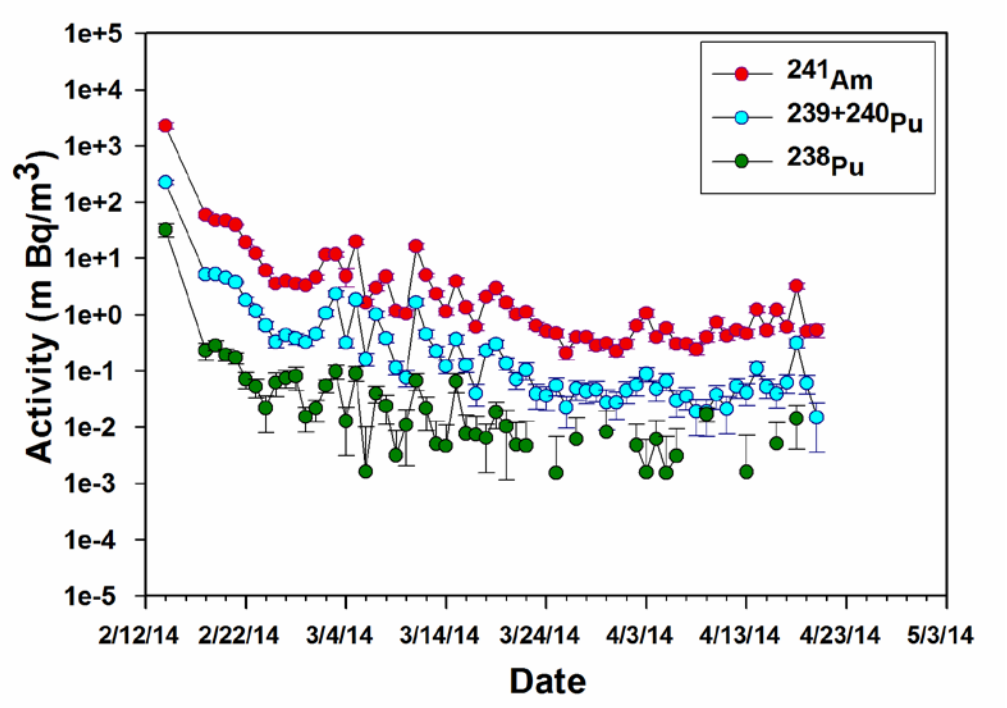


Figure 2.10 The daily ^{241}Am, $^{239+240}$Pu and ^{238}Pu concentrations in Station B (Post-HEPA) filters following the February 14, radiation release event at the WIPP

The flow rate through the HEPA filters is 1699 m^3 (60,000 ft^3) per minute and the station B air sampler draws 0.06 m^3 (2 ft^3) per minute. Thus, the total estimated release based on CEMRC analyses of the station B sample is 2.53×10^7 Bq of ^{241}Am and 2.48×10^6 Bq of $^{239+240}$Pu. The daily analysis of filter samples collected from Station B since February 19, 2014 showed that the activity levels have decreased considerably. By the middle of April, 2014, the concentrations of ^{241}Am and $^{239+240}$Pu measured were in the range 0.11 to 0.53 Bq/m^3 and 0.01 to 0.06 mBq/m^3, respectively, at Station B. The ^{238}Pu level has been below the detection limit in samples from February 19 to the present. As the concentration levels of these radionuclides decreased significantly both at Station A and Station B, beginning April 22, 2014, actinide and gamma analyses are performed on a weekly composite samples. The weekly concentrations of $^{239+240}$Pu, ^{238}Pu, and ^{241}Am detected in Station A and Station B are shown in **Figures 2.11 and 2.12** and the values measured are listed in **Tables 2.3-2.5** (Station A) and **Tables 2.6-2.8** (Station B).

An analysis of historical operational data indicates occasional detections of trace amounts of $^{239+240}$Pu, ^{238}Pu, and ^{241}Am in the exhaust air released from the WIPP (**Figure 2.13**). From 2000 through 2013, only nine Station A measurements can be declared as a certain detection of a radionuclide. Detectable concentrations of Pu isotopes ($^{239+240}$Pu, or ^{238}Pu) and ^{241}Am only occurred in four monthly composite samples from 2003, 2008, 2009 and 2010 (CEMRC Report 2011). As ^{238}Pu concentrations were above detection limits in two of the monthly composite samples (February 2008 and April 2009), these two composite samples were used to calculate the activity ratios between ^{238}Pu and $^{239+240}$Pu. The February 2008 sample ratio was 0.039 and the April 2009 sample ratio was 0.023. A mean ^{238}Pu /$^{239+240}$Pu activity ratio of 0.025±0.004 (0.019-0.039) is compatible with a global fallout origin as reported in different studies (Kelly et al., 1999, Hardy et al., 1973). This compatibility is not proof that there was not a trace of ^{238}Pu released from within the repository; it is only suggestive of a global fallout origin. It is important to note that activities detected in those four composites were extremely low and did not even trigger the underground Continuous Air Monitors (CAM) that are used to detect any release of radioactivity. There was no unambiguous evidence of releases from WIPP operations until the February 14, 2014 event.

With the exception of one detection of ^{137}Cs (which was detected in Station A filter collected on February 14, 2014), no detectable gamma-emitting radionuclides were observed in any of the filter samples collected from Station A or Station B, following the radiation release event at the WIPP. The concentrations of gamma-emitters ^{137}Cs, ^{60}Co and ^{40}K measured in Station A and Station B filter samples are summarized in **Tables 2.9-2.11 (Station A) and Tables 2.12-2.14 (Station B)** and shown in **Figures 2.14-2.19.**

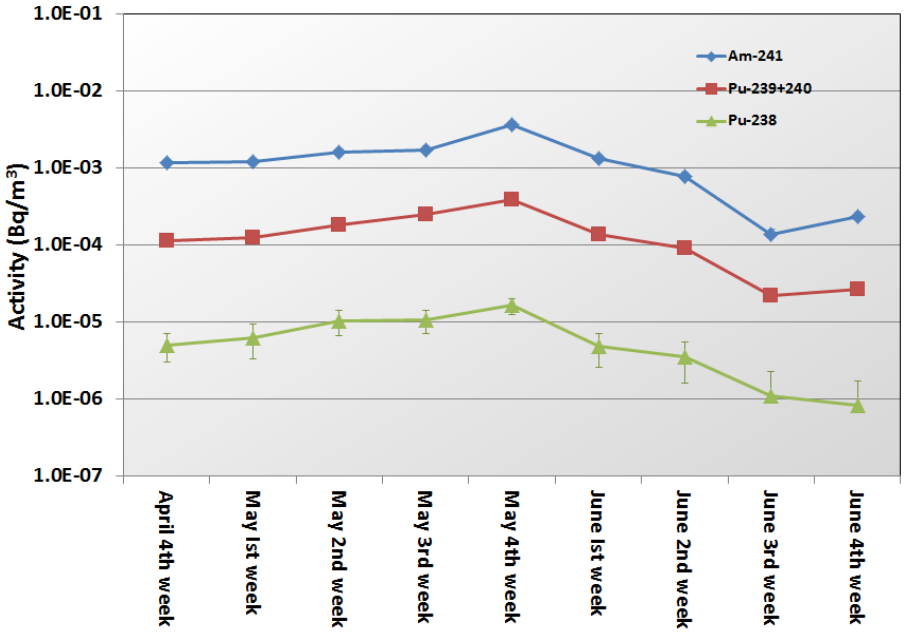


Figure 2.11 The weekly ^{241}Am, $^{239+240}$Pu and ^{238}Pu concentrations in Station A (Pre-HEPA) filters following the February 14, radiation release event at the WIPP

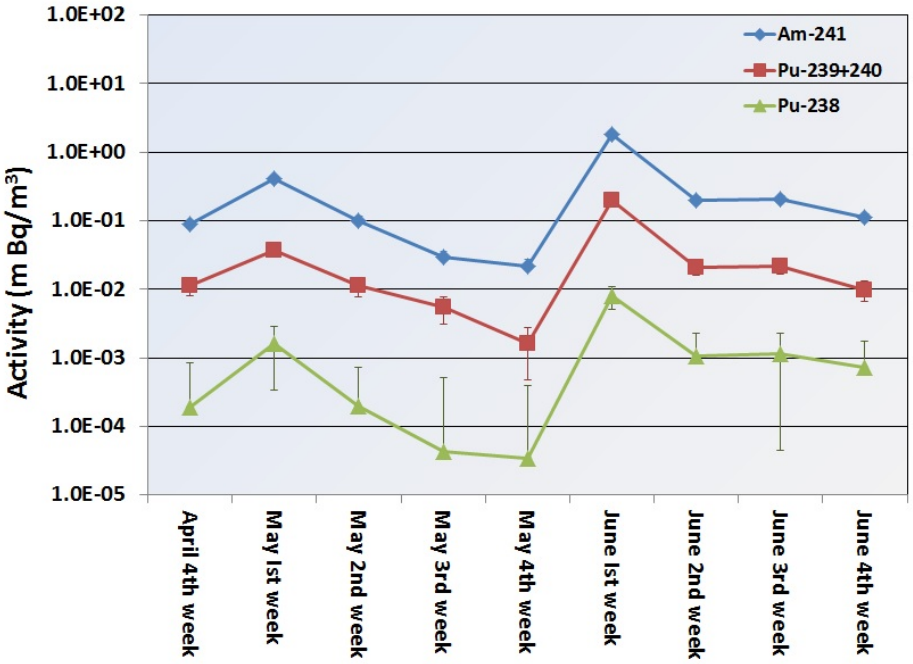


Figure 2.12 The weekly ^{241}Am, $^{239+240}$Pu and ^{238}Pu concentrations in Station B (Post-HEPA) filters following the February 14, radiation release event at the WIPP

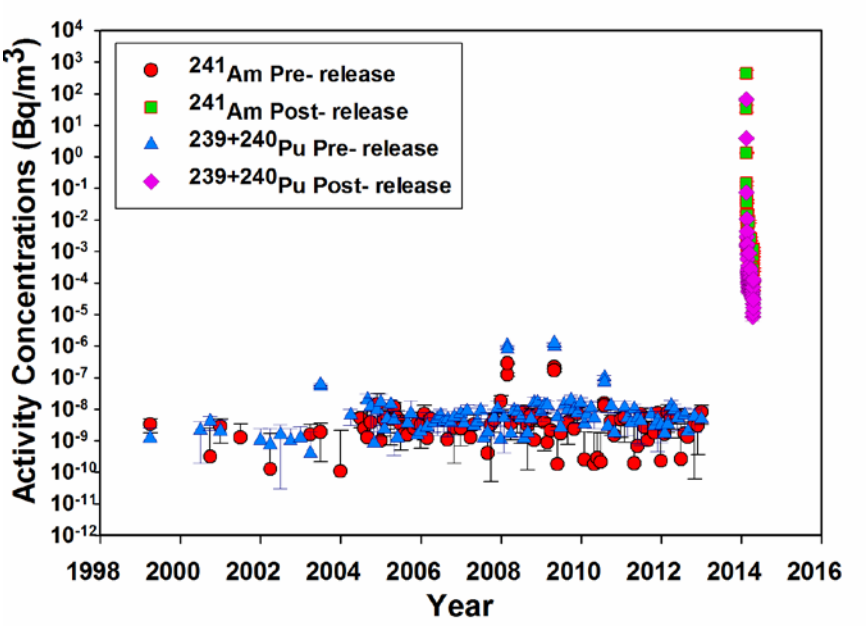


Figure 2.13 Pre- and Post- release event $^{239+240}$Pu and ^{241}Am concentrations in the WIPP exhaust air (Station A, Pre-HEPA)

An analysis of historical operational data indicates with the exception of occasional detections from ^{40}K, no detectable gamma-emitting radionuclides were observed during the last fifteen years of monitoring. Since these isotopes were not detected, no comparisons between years or among locations were performed.

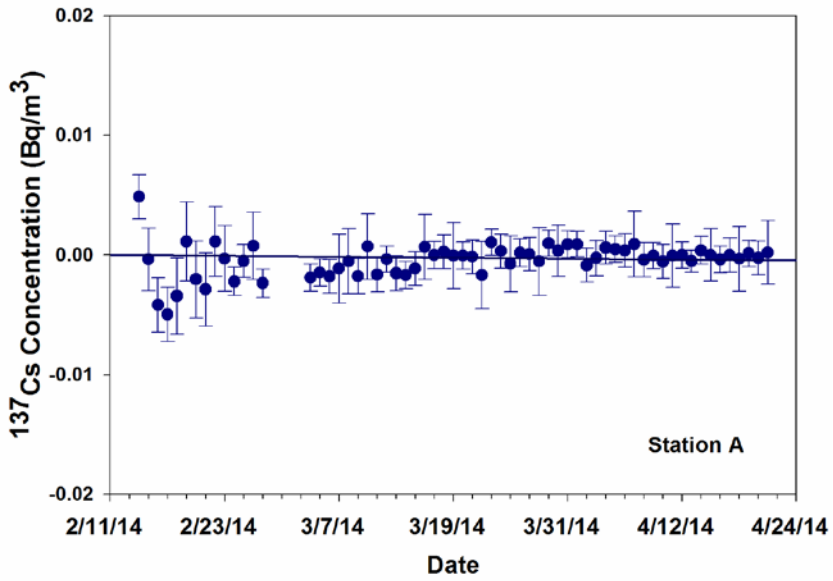


Figure 2.14 The ^{137}Cs concentrations in the WIPP exhaust air (Station A, Pre-HEPA)

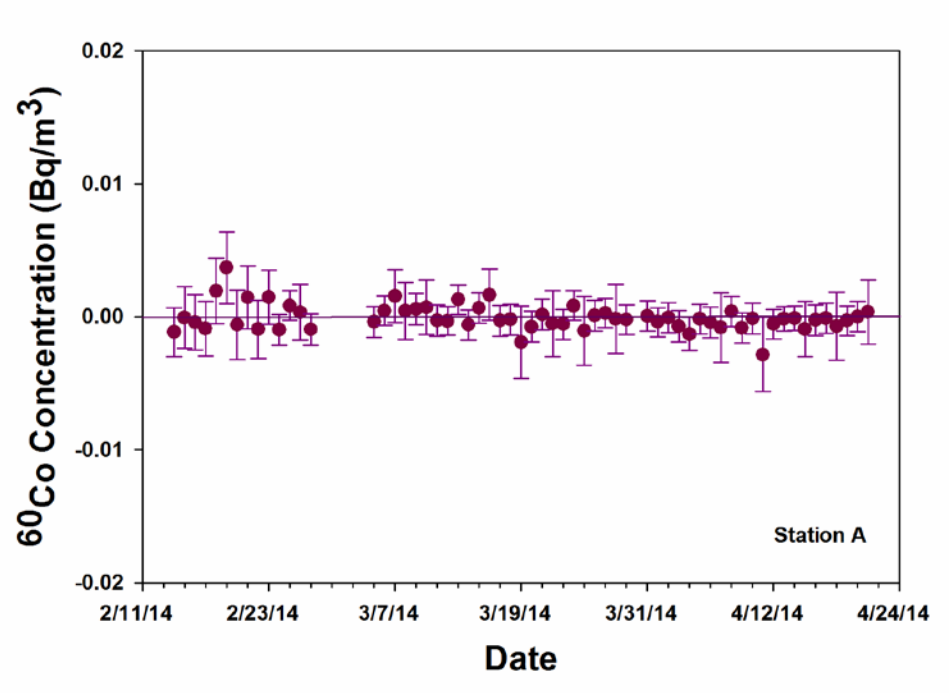


Figure 2.15 The ^{60}Co concentrations in the WIPP exhaust air (Station A, Pre-HEPA)

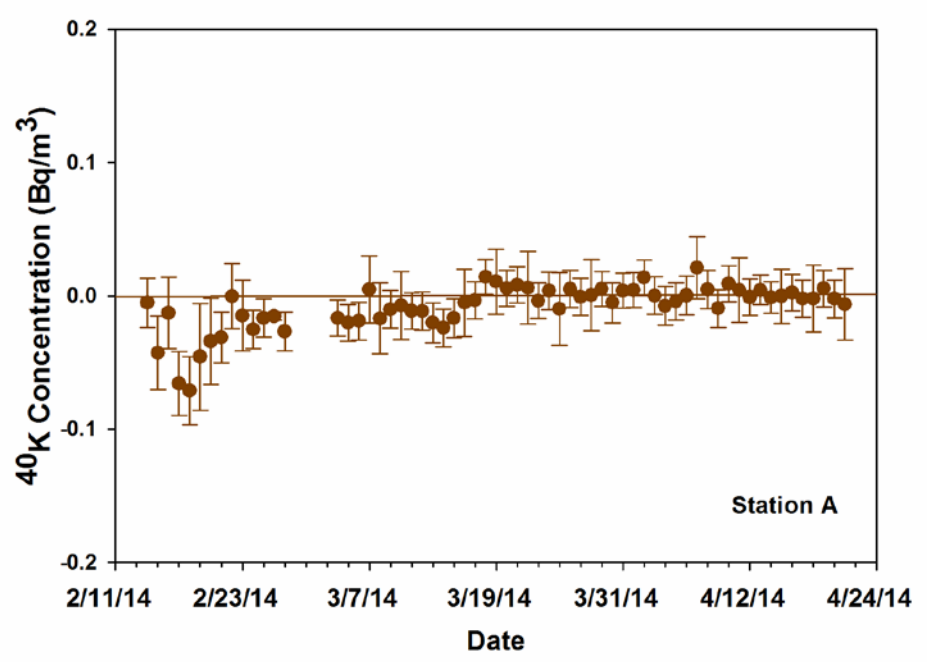


Figure 2.16 The ^{40}K concentrations in the WIPP exhaust air (Station A, Pre-HEPA)

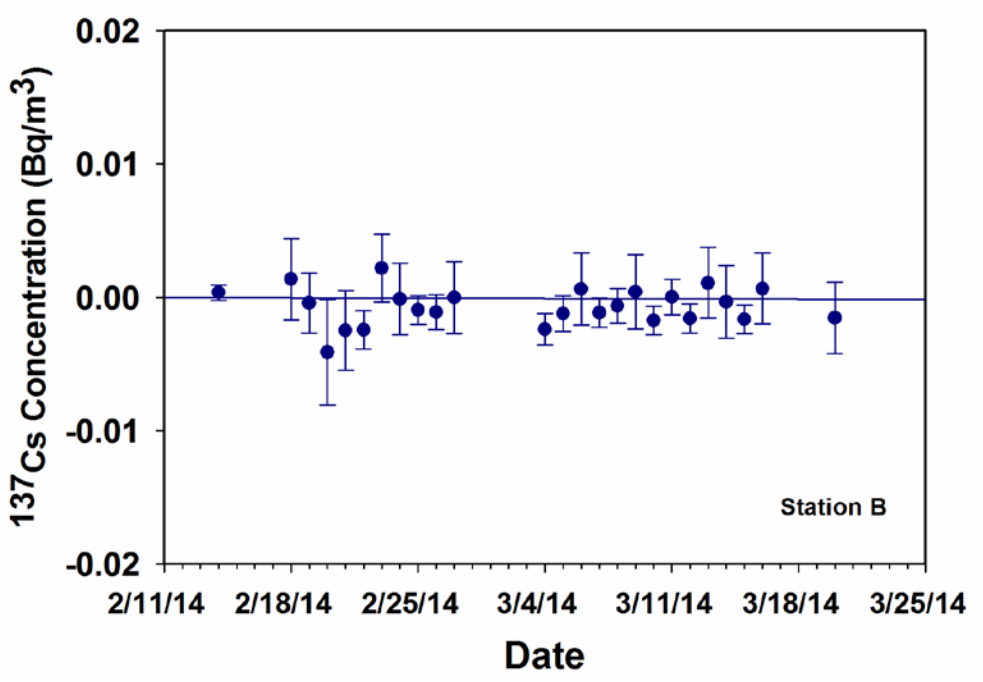


Figure 2.17 The ^{137}Cs concentrations in the WIPP exhaust air (Station B, Post-HEPA)

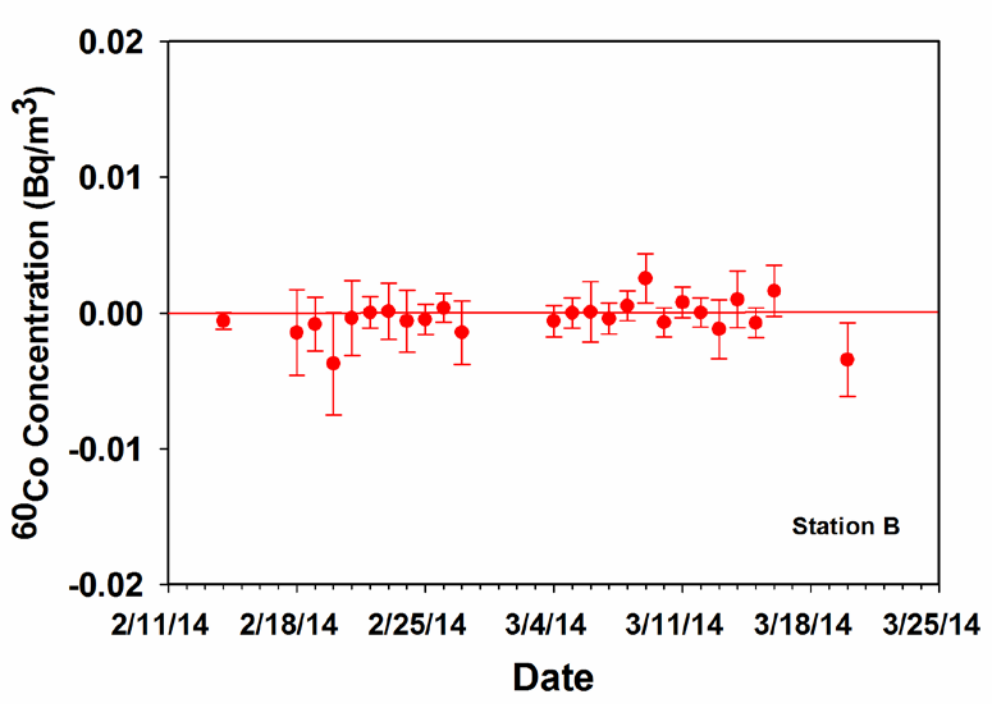


Figure 2.18 The ^{60}Co concentrations in the WIPP exhaust air (Station B, Post-HEPA)

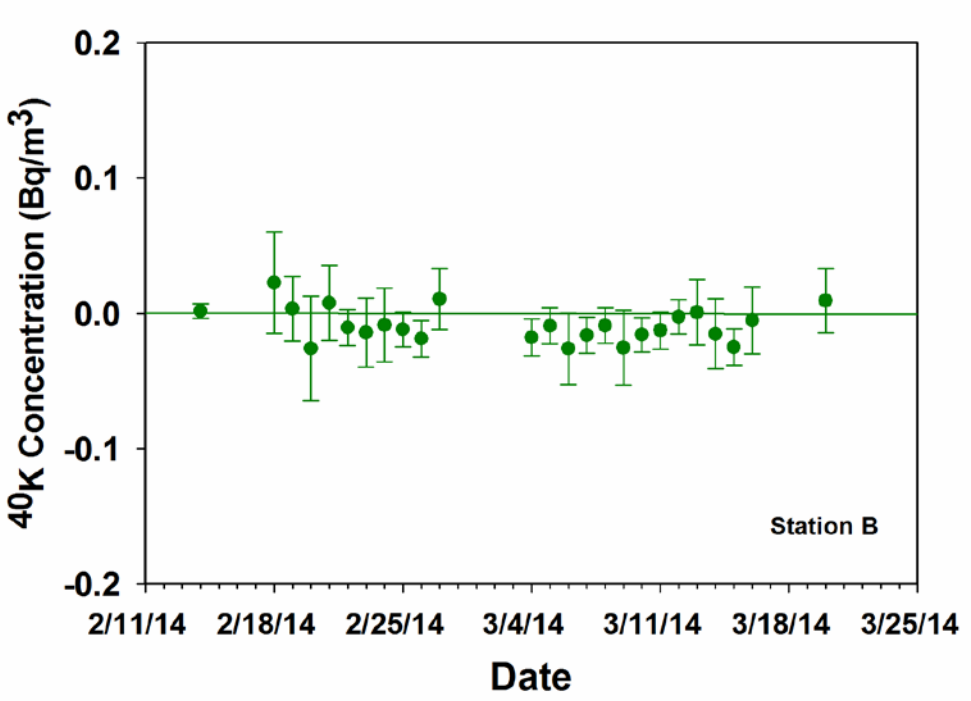


Figure 2.19 The ^{40}K concentrations in the WIPP exhaust air (Station B, Post-HEPA)

Table 2.2 Daily Gross Alpha and Gross Beta concentration (Bq/m^3) measured in Station A (Pre-HEPA) filter

Sample Date	Gross alpha activity Bq/m^3	Unc.(2σ) Bq/m^3	Gross beta activity Bq/m^3	Unc. (2σ) Bq/m^3
3/1/2014	7.66E-02	1.21E-03	9.45E-03	3.12E-04
3/2/2014	5.75E-02	9.46E-04	8.13E-03	2.70E-04
3/3/2014	4.43E-02	8.03E-04	6.51E-03	2.52E-04
3/4/2014	1.19E-01	1.98E-03	1.63E-02	4.95E-04
3/5/2014	5.64E-02	1.18E-03	8.10E-03	3.55E-04
3/6/2014	3.04E-02	7.56E-04	4.77E-03	2.79E-04
3/7/2014	6.83E-02	1.33E-03	1.08E-02	4.14E-04
3/8/2014	2.56E-02	6.81E-04	4.14E-03	2.27E-04
3/9/2014	3.26E-02	7.79E-04	7.09E-03	3.17E-04
3/10/2014	5.53E-02	1.14E-03	8.34E-03	3.58E-04
3/11/2014	5.89E-02	1.14E-03	2.07E-02	5.05E-04
3/12/2014	6.18E-02	5.71E-02	5.85E-02	8.79E-04
3/13/2014	3.20E-01	6.18E-03	4.08E-02	8.91E-04
3/14/2014	2.49E-02	6.73E-04	5.52E-03	2.89E-04

Table 2.2 Continued

Sample Date	Gross alpha activity Bq/m^3	Unc.(2σ) Bq/m^3	Gross beta activity Bq/m^3	Unc. (2σ) Bq/m^3
3/15/2014	5.18E-02	1.09E-03	1.94E-02	4.83E-04
3/16/2014	5.02E-02	1.01E-03	4.96E-02	7.81E-04
3/17/2014	1.97E-02	5.82E-04	2.95E-03	2.41E-04
3/18/2014	6.52E-02	1.28E-03	1.05E-02	3.81E-04
3/19/2014	4.24E-02	9.26E-04	1.66E-02	4.50E-04
3/20/2014	7.13E-02	1.31E-03	4.30E-02	7.45E-04
3/21/2014	5.46E-02	1.09E-03	1.03E-02	3.78E-04
3/22/2014	4.94E-02	1.01E-03	2.44E-02	5.41E-04
3/23/2014	5.00E+00	2.10E-03	1.19E-01	1.41E-03
3/24/2014	7.32E-02	1.33E-03	9.93E-03	3.87E-04
3/25/2014	5.64E-02	1.10E-03	1.18E-02	3.95E-04
3/26/2014	5.15E-02	1.05E-03	2.83E-02	5.86E-04
3/27/2014	7.54E-02	1.33E-03	8.92E-02	1.12E-03
3/28/2014	9.61E-02	1.82E-03	1.35E-02	4.53E-04
3/29/2014	3.13E-02	7.64E-04	8.01E-03	3.30E-04
3/30/2014	3.71E-02	8.38E-04	2.66E-02	5.49E-04
3/31/2014	5.41E-02	1.09E-03	6.86E-02	9.83E-04
4/1/2014	2.33E-02	6.57E-04	5.53E-03	2.83E-04
4/2/2014	3.25E-02	7.93E-04	1.71E-02	4.45E-04
4/3/2014	7.03E-02	1.29E-03	5.78E-02	8.65E-04
4/4/2014	3.71E-02	8.77E-04	7.11E-03	3.28E-04
4/5/2014	2.88E-02	7.23E-04	2.39E-02	5.27E-04
4/6/2014	2.09E-02	6.12E-04	7.10E-03	3.07E-04
4/7/2014	2.48E-02	6.60E-04	1.76E-02	4.45E-04
4/8/2014	2.57E-02	6.81E-04	2.27E-02	5.09E-04
4/9/2014	2.92E-02	7.38E-04	1.82E-02	4.61E-04
4/10/2014	3.09E-02	7.65E-04	2.18E-02	5.30E-04
4/11/2014	2.08E-02	1.98E-02	5.57E-03	2.82E-04
4/12/2014	2.31E-02	6.52E-04	1.72E-02	4.33E-04
4/13/2014	4.74E-02	1.07E-03	4.50E-02	7.82E-04
4/14/2014	1.33E-02	4.72E-04	1.75E-02	4.44E-04
4/15/2014	1.26E-02	4.57E-04	5.65E-03	2.79E-04
4/16/2014	1.70E-02	5.38E-04	2.02E-02	4.78E-04
4/17/2014	5.85E-03	3.10E-04	3.20E-03	2.30E-04
4/18/2014	3.21E-02	8.05E-04	7.23E-03	3.19E-04

Table 2.2 Continued

Sample Date	Gross alpha activity Bq/m^3	Unc.(2σ) Bq/m^3	Gross beta activity Bq/m^3	Unc. (2σ) Bq/m^3
4/19/2014	6.12E-02	1.23E-03	1.57E-02	4.48E-04
4/20/2014	5.61E-02	1.12E-03	3.15E-02	6.10E-04
4/21/2014	1.53E-02	5.08E-04	9.08E-03	3.34E-04
4/22/2014	2.53E-02	6.75E-04	3.35E-02	6.40E-04
4/23/2014	1.15E-02	4.36E-04	2.85E-03	2.37E-04
4/24/2014	5.62E-03	3.03E-04	1.90E-03	1.89E-04
4/25/2014	5.75E-03	3.06E-04	5.02E-03	2.64E-04
4/26/2014	3.47E-03	2.42E-04	1.69E-03	2.00E-04
4/27/2014	3.90E-03	2.49E-04	7.60E-04	1.60E-04
4/28/2014	5.84E-03	3.13E-04	3.88E-03	2.40E-04
4/29/2014	4.87E-03	2.83E-04	4.59E-03	2.61E-04
4/30/2014	1.42E-02	4.82E-04	1.61E-02	4.20E-04
5/1/2014	3.83E-03	2.52E-04	1.75E-03	1.99E-04
5/2/2014	1.11E-02	4.25E-04	5.11E-03	2.59E-04
5/3/2014	7.96E-03	3.71E-04	1.01E-02	3.48E-04
5/4/2014	5.43E-03	2.95E-04	4.94E-03	2.54E-04
5/5/2014	1.75E-02	5.43E-04	2.45E-02	5.22E-04
5/6/2014	5.56E-03	3.02E-04	5.93E-03	2.81E-04
5/7/2014	1.02E-02	4.22E-04	1.11E-02	3.62E-04
5/8/2014	3.97E-03	2.53E-04	2.18E-03	2.12E-04
5/9/2014	6.46E-03	3.25E-04	4.92E-03	2.53E-04
5/10/2014	1.93E-02	5.80E-04	2.13E-02	4.80E-04
5/11/2014	1.05E-02	4.27E-04	5.82E-03	2.88E-04
5/12/2014	1.46E-02	4.99E-04	1.49E-02	4.10E-04
5/13/2014	5.44E-03	2.94E-04	5.22E-03	2.71E-04
5/14/2014	2.86E-02	7.17E-04	2.28E-02	5.05E-04
5/15/2014	1.10E-02	4.29E-04	2.40E-03	2.07E-04
5/16/2014	1.00E-02	4.08E-04	5.06E-03	2.70E-04
5/17/2014	1.39E-03	1.32E-04	1.02E-03	1.26E-04
5/18/2014	2.30E-03	1.17E-04	1.85E-03	8.60E-05
5/19/2014	4.39E-03	1.70E-04	2.01E-03	9.08E-05
5/20/2014	6.07E-03	2.07E-04	5.16E-03	1.45E-04
5/21/2014	5.82E-03	2.03E-04	5.43E-03	1.50E-04
5/22/2014	9.59E-03	2.85E-04	1.58E-03	8.64E-05
5/23/2014	1.01E-02	2.94E-04	1.65E-03	8.85E-05

Table 2.2 Continued

Sample Date	Gross alpha activity Bq/m^3	Unc.(2σ) Bq/m^3	Gross beta activity Bq/m^3	Unc. (2σ) Bq/m^3
5/24/2014	7.93E-03	2.48E-04	1.63E-03	8.55E-05
5/25/2014	3.91E-03	1.60E-04	7.29E-04	6.22E-05
5/26/2014	1.90E-03	1.03E-04	7.53E-04	5.95E-05
5/27/2014	2.14E-03	1.09E-04	5.07E-04	4.82E-05
5/28/2014	5.05E-03	1.85E-04	7.59E-04	6.17E-05
5/29/2014	1.36E-03	8.80E-05	1.22E-03	6.96E-05
5/30/2014	9.19E-03	2.73E-04	2.60E-03	1.05E-04
5/31/2014	1.68E-03	4.29E-05	2.54E-03	5.31E-05
6/1/2014	2.73E-03	1.26E-04	1.13E-03	6.82E-05
6/2/2014	4.86E-03	2.37E-04	1.48E-03	1.40E-04
6/3/2014	1.12E-03	7.72E-05	6.17E-04	5.28E-05
6/4/2014	2.92E-03	1.80E-04	1.10E-03	1.22E-04
6/5/2014	1.97E-03	1.85E-04	1.46E-03	1.70E-04
6/6/2014	8.43E-03	3.74E-04	2.53E-03	2.20E-04
6/7/2014	1.12E-02	4.19E-04	9.26E-03	3.25E-04
6/8/2014	4.44E-03	2.74E-04	1.89E-03	2.07E-04
6/9/2014	3.08E-03	1.98E-04	1.58E-03	1.77E-04
6/10/2014	5.10E-03	2.35E-04	5.43E-03	2.22E-04
6/11/2014	1.90E-02	5.88E-04	2.85E-02	5.89E-04
6/12/2014	4.90E-03	2.80E-04	4.27E-03	2.47E-04
6/13/2014	3.76E-03	2.44E-04	2.97E-03	2.26E-04
6/14/2014	5.52E-03	3.03E-04	6.51E-03	2.87E-04
6/15/2014	1.65E-03	1.70E-04	3.73E-03	2.34E-04
6/16/2014	6.47E-03	3.28E-04	9.93E-03	3.41E-04
6/17/2014	5.10E-03	2.87E-04	8.90E-03	3.26E-04
6/18/2014	2.35E-02	6.45E-04	4.23E-02	7.09E-04
6/19/2014	1.79E-03	1.78E-04	2.29E-03	2.03E-04
6/20/2014	3.70E-03	2.51E-04	4.98E-03	2.60E-04
6/21/2014	1.32E-02	4.69E-04	2.00E-02	4.68E-04
6/22/2014	7.27E-03	3.48E-04	1.14E-02	3.73E-04
6/23/2014	7.43E-03	3.47E-04	8.79E-03	3.21E-04
6/24/2014	5.63E-03	3.17E-04	7.53E-03	3.15E-04
6/25/2014	1.17E-03	1.56E-04	7.51E-04	1.67E-04
6/26/2014	1.89E-03	1.88E-04	1.76E-03	2.01E-04

Table 2.2 Continued

Sample Date	Gross alpha activity Bq/m^3	Unc.(2σ) Bq/m^3	Gross beta activity Bq/m^3	Unc. (2σ) Bq/m^3
6/27/2014	1.16E-03	1.33E-04	2.47E-03	1.65E-04
6/28/2014	1.08E-03	7.77E-05	7.38E-04	5.72E-05
6/29/2014	8.08E-04	6.72E-05	1.63E-03	7.74E-05
6/30/2014	8.93E-04	6.81E-05	1.77E-03	8.05E-05

Table 2.3 Activity concentrations of ^{241}Am (Bq/m^3), in Station A (Pre-HEPA) filters following the February 14 radiological event at WIPP

Sample Date	^{241}Am Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
2/14/2014	4.34E+03	1.26E+03	2.77E+01	Detected
2/15/2014	3.43E+02	6.07E+01	3.18E+00	Detected
2/16/2014	1.35E+01	3.83E-01	3.01E-02	Detected
2/17/2014	1.43E+00	1.38E-01	2.62E-03	Detected
2/18/2014	3.94E-01	2.47E-02	3.48E-05	Detected
2/19/2014	1.60E-01	1.00E-02	2.75E-05	Detected
2/20/2014	1.93E-01	1.32E-02	2.79E-05	Detected
2/21/2014	2.05E-01	1.22E-02	2.68E-05	Detected
2/22/2014	3.67E-01	3.90E-02	2.04E-05	Detected
2/23/2014	1.43E-01	1.54E-02	2.06E-05	Detected
2/24/2014	9.00E-02	9.60E-03	1.34E-05	Detected
2/25/2014	6.29E-02	6.77E-03	1.18E-05	Detected
2/26/2014	2.15E-02	2.33E-03	1.33E-05	Detected
2/27/2014	1.73E-02	1.90E-03	1.46E-05	Detected
2/28/2014	1.22E-02	1.33E-03	6.60E-06	Detected
3/1/2014	2.29E-02	2.50E-03	5.46E-06	Detected
3/2/2014	1.55E-02	1.72E-03	8.15E-06	Detected
3/3/2014	1.27E-02	1.40E-03	7.41E-06	Detected
3/4/2014	3.56E-02	3.86E-03	1.45E-05	Detected
3/5/2014	2.17E-02	2.41E-03	1.31E-05	Detected
3/6/2014	9.30E-03	1.33E-03	6.35E-05	Detected
3/7/2014	2.12E-02	2.33E-03	1.60E-05	Detected
3/8/2014	9.52E-03	1.11E-03	1.23E-05	Detected
3/9/2014	7.70E-03	8.83E-04	1.32E-05	Detected
3/10/2014	1.33E-02	1.51E-03	1.08E-05	Detected
3/11/2014	1.34E-02	1.52E-03	1.29E-05	Detected

Table 2.3 Continued

Sample Date	^{241}Am Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
3/12/2014	1.03E-02	1.22E-03	4.24E-05	Detected
3/13/2014	8.77E-02	9.70E-03	1.19E-05	Detected
3/14/2014	6.41E-03	7.42E-04	1.41E-05	Detected
3/15/2014	1.09E-02	1.27E-03	1.55E-05	Detected
3/16/2014	5.98E-03	6.86E-04	1.02E-05	Detected
3/17/2014	7.53E-03	8.64E-04	1.35E-05	Detected
3/18/2014	1.53E-02	1.71E-03	1.02E-05	Detected
3/19/2014	8.94E-03	1.03E-03	1.49E-05	Detected
3/20/2014	1.45E-02	1.64E-03	1.11E-05	Detected
3/21/2014	1.56E-02	1.80E-03	1.39E-05	Detected
3/22/2014	1.06E-02	1.23E-03	1.17E-05	Detected
3/23/2014	1.89E-02	2.16E-03	1.43E-05	Detected
3/24/2014	1.94E-02	2.32E-03	1.56E-05	Detected
3/25/2014	1.36E-02	1.74E-03	2.83E-05	Detected
3/26/2014	1.06E-02	1.43E-03	2.86E-05	Detected
3/27/2014	7.35E-03	8.88E-04	1.78E-05	Detected
3/28/2014	2.53E-02	3.05E-03	1.67E-05	Detected
3/29/2014	7.63E-03	8.88E-04	1.25E-05	Detected
3/30/2014	6.61E-03	7.77E-04	1.13E-05	Detected
3/31/2014	3.74E-03	4.55E-04	1.53E-05	Detected
4/1/2014	5.68E-03	6.60E-04	1.26E-05	Detected
4/2/2014	6.79E-03	7.84E-04	1.32E-05	Detected
4/3/2014	1.10E-02	1.27E-03	1.76E-05	Detected
4/4/2014	9.41E-03	1.09E-03	1.09E-05	Detected
4/5/2014	4.32E-03	5.25E-04	1.43E-05	Detected
4/6/2014	4.87E-03	5.80E-04	9.98E-06	Detected
4/7/2014	3.37E-03	4.20E-04	1.21E-05	Detected
4/8/2014	2.95E-03	3.75E-04	3.50E-05	Detected
4/9/2014	5.69E-03	6.79E-04	1.18E-05	Detected
4/10/2014	4.99E-03	6.00E-04	1.47E-05	Detected
4/11/2014	4.86E-03	5.81E-04	1.80E-05	Detected
4/12/2014	3.30E-03	4.35E-04	2.83E-05	Detected
4/13/2014	5.79E-03	7.00E-04	1.30E-05	Detected
4/14/2014	1.07E-03	1.53E-04	1.70E-05	Detected
4/15/2014	2.00E-03	2.59E-04	1.24E-05	Detected

Table 2.3 Continued

Sample Date	^{241}Am Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
4/16/2014	5.18E-04	9.10E-05	2.55E-05	Detected
4/17/2014	6.78E-04	1.02E-04	1.91E-05	Detected
4/18/2014	7.75E-03	9.17E-04	1.19E-05	Detected
4/19/2014	1.17E-02	1.38E-03	1.49E-05	Detected
4/20/2014	1.13E-02	1.32E-03	1.41E-05	Detected
4/21/2014	2.65E-03	3.31E-04	1.89E-05	Detected
Weekly Analysis, 2014				
4th week of April	1.18E-03	1.34E-04	1.98E-06	Detected
Ist week of May	1.19E-03	1.35E-04	1.72E-06	Detected
2nd week of May	1.58E-03	1.86E-04	1.31E-06	Detected
3rd week of May	1.73E-03	2.15E-04	2.75E-06	Detected
4th week of May	3.58E-03	4.19E-04	1.07E-06	Detected
Ist week of June	1.31E-03	1.58E-04	2.55E-06	Detected
2nd week of June	7.81E-04	1.02E-04	3.29E-06	Detected
3rd week of June	1.38E-04	2.31E-05	2.76E-06	Detected
4th week of June	2.36E-04	3.10E-05	1.60E-06	Detected

Table 2.4 Activity concentrations of $^{239+240}$Pu (Bq/m^3) in Station A (Pre-HEPA) filters following the February 14 radiological event at WIPP

Sample Date	$^{239+240}$Pu Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
2/14/2014	6.72E+02	7.77E+01	1.34E+00	Detected
2/15/2014	3.88E+01	3.50E+00	1.88E-01	Detected
2/16/2014	7.54E-01	4.07E-02	8.85E-04	Detected
2/17/2014	1.08E-01	9.60E-03	6.59E-04	Detected
2/18/2014	2.97E-02	1.94E-03	2.85E-05	Detected
2/19/2014	1.47E-02	1.01E-03	2.99E-05	Detected
2/20/2014	1.78E-02	1.23E-03	1.88E-05	Detected
2/21/2014	2.01E-02	1.57E-03	2.28E-05	Detected
2/22/2014	4.36E-02	4.71E-03	1.11E-05	Detected
2/23/2014	1.66E-02	1.81E-03	1.04E-05	Detected
2/24/2014	8.23E-03	9.42E-04	2.44E-05	Detected
2/25/2014	5.80E-03	7.30E-04	2.39E-05	Detected
2/26/2014	2.17E-03	2.69E-04	1.36E-05	Detected

Table 2.4 Continued

Sample Date	$^{239+240}Pu$ Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
2/27/2014	1.75E-03	2.23E-04	1.74E-05	Detected
2/28/2014	1.04E-03	1.27E-04	5.34E-06	Detected
3/1/2014	2.40E-03	2.86E-04	6.88E-06	Detected
3/2/2014	1.48E-03	1.76E-04	1.04E-05	Detected
3/3/2014	2.63E-03	3.21E-04	1.39E-05	Detected
3/4/2014	3.44E-03	4.01E-04	1.12E-05	Detected
3/5/2014	2.08E-03	2.54E-04	1.11E-05	Detected
3/6/2014	9.47E-04	1.28E-04	2.18E-05	Detected
3/7/2014	5.51E-04	1.08E-04	3.92E-05	Detected
3/8/2014	9.65E-04	1.32E-04	1.84E-05	Detected
3/9/2014	7.38E-04	1.06E-04	1.11E-05	Detected
3/10/2014	1.19E-03	1.58E-04	1.14E-05	Detected
3/11/2014	1.33E-03	1.78E-04	1.59E-05	Detected
3/12/2014	7.70E-04	1.14E-04	1.98E-05	Detected
3/13/2014	8.84E-03	1.03E-03	1.14E-05	Detected
3/14/2014	6.14E-04	9.48E-05	1.52E-05	Detected
3/15/2014	1.08E-03	1.54E-04	1.35E-05	Detected
3/16/2014	6.74E-04	9.99E-05	1.89E-05	Detected
3/17/2014	6.25E-04	9.38E-05	1.15E-05	Detected
3/18/2014	1.95E-03	2.50E-04	1.32E-05	Detected
3/19/2014	1.01E-03	1.40E-04	1.52E-05	Detected
3/20/2014	1.32E-03	1.84E-04	2.26E-05	Detected
3/21/2014	1.58E-03	2.13E-04	1.39E-05	Detected
3/22/2014	1.04E-03	1.45E-04	1.21E-05	Detected
3/23/2014	1.88E-03	2.44E-04	1.58E-05	Detected
3/24/2014	2.10E-03	2.72E-04	2.05E-05	Detected
3/25/2014	1.51E-03	1.96E-04	1.03E-05	Detected
3/26/2014	1.18E-03	1.62E-04	1.16E-05	Detected
3/27/2014	7.81E-04	1.14E-04	1.13E-05	Detected
3/28/2014	2.73E-03	3.45E-04	1.54E-05	Detected
3/29/2014	1.05E-03	1.52E-04	1.40E-05	Detected
3/30/2014	6.16E-04	9.35E-05	1.38E-05	Detected
3/31/2014	4.10E-04	7.31E-05	1.36E-05	Detected
4/1/2014	6.89E-04	1.06E-04	2.39E-05	Detected
4/2/2014	7.79E-04	1.13E-04	1.38E-05	Detected

Table 2.4 Continued

Sample Date	$^{239+240}$Pu Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
4/3/2014	9.88E-04	1.39E-04	1.47E-05	Detected
4/4/2014	1.10E-03	1.54E-04	1.21E-05	Detected
4/5/2014	5.55E-04	8.85E-05	1.21E-05	Detected
4/6/2014	4.87E-04	7.71E-05	1.06E-05	Detected
4/7/2014	4.25E-04	7.18E-05	1.18E-05	Detected
4/8/2014	3.34E-04	5.91E-05	1.39E-05	Detected
4/9/2014	5.35E-04	8.48E-05	1.43E-05	Detected
4/10/2014	1.03E-03	1.42E-04	1.11E-05	Detected
4/11/2014	4.43E-04	7.26E-05	1.38E-05	Detected
4/12/2014	3.71E-04	6.56E-05	1.50E-05	Detected
4/13/2014	7.42E-04	1.14E-04	1.32E-05	Detected
4/14/2014	8.62E-05	2.50E-05	1.12E-05	Detected
4/15/2014	2.20E-04	4.66E-05	1.56E-05	Detected
4/16/2014	1.14E-04	3.04E-05	1.19E-05	Detected
4/17/2014	1.67E-04	3.93E-05	2.01E-05	Detected
4/18/2014	1.14E-03	1.60E-04	1.58E-05	Detected
4/19/2014	1.13E-03	1.61E-04	1.32E-05	Detected
4/20/2014	1.27E-03	1.90E-04	1.70E-05	Detected
4/21/2014	3.04E-04	5.84E-05	1.28E-05	Detected
Weekly Analysis, 2014				
4th week of April	1.12E-04	1.55E-05	1.55E-06	Detected
Ist week of May	1.26E-04	1.96E-05	1.79E-06	Detected
2nd week of May	1.83E-04	2.68E-05	1.82E-06	Detected
3rd week of May	2.49E-04	3.31E-05	1.42E-06	Detected
4th week of May	3.92E-04	4.73E-05	1.56E-06	Detected
Ist week of June	1.37E-04	1.96E-05	1.76E-06	Detected
2nd week of June	9.10E-05	1.42E-05	1.62E-06	Detected
3rd week of June	2.20E-05	5.81E-06	1.99E-06	Detected
4th week of June	2.63E-05	5.23E-06	1.50E-06	Detected

Table 2.5 Activity concentrations of ^{238}Pu (Bq/m^3) in Station A (Pre-HEPA) filters following the February 14 radiological event at WIPP

Sample Date	^{238}Pu Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
2/14/2014	3.03E+01	6.26E+00	2.47E+00	Detected
2/15/2014	1.90E+00	4.10E-01	1.58E-01	Detected
2/16/2014	8.41E-02	6.26E-03	2.21E-04	Detected
2/17/2014	1.06E-02	4.03E-04	7.60E-05	Detected
2/18/2014	1.38E-03	1.65E-06	8.50E-08	Detected
2/19/2014	6.78E-04	6.45E-07	6.29E-08	Detected
2/20/2014	7.98E-04	6.45E-07	1.78E-08	Detected
2/21/2014	9.13E-04	8.83E-07	3.56E-08	Detected
2/22/2014	1.89E-03	2.29E-04	1.11E-05	Detected
2/23/2014	7.43E-04	1.03E-04	1.32E-05	Detected
2/24/2014	4.60E-04	7.96E-05	1.88E-05	Detected
2/25/2014	4.16E-03	5.37E-04	2.39E-05	Detected
2/26/2014	8.69E-05	2.77E-05	1.72E-05	Detected
2/27/2014	8.06E-05	2.67E-05	1.74E-05	Detected
2/28/2014	4.43E-05	1.25E-05	6.73E-06	Detected
3/1/2014	1.01E-04	2.26E-05	6.88E-06	Detected
3/2/2014	6.25E-05	1.53E-05	6.83E-06	Detected
3/3/2014	1.13E-04	2.91E-05	1.11E-05	Detected
3/4/2014	1.63E-04	3.64E-05	1.41E-05	Detected
3/5/2014	1.03E-04	2.74E-05	1.11E-05	Detected
3/6/2014	4.34E-05	1.76E-05	1.44E-05	Detected
3/7/2014	5.21E-05	2.77E-05	3.92E-05	Detected
3/8/2014	3.68E-05	1.62E-05	1.42E-05	Detected
3/9/2014	3.01E-05	1.42E-05	1.11E-05	Detected
3/10/2014	5.90E-05	2.08E-05	1.44E-05	Detected
3/11/2014	5.64E-05	2.11E-05	1.59E-05	Detected
3/12/2014	3.80E-05	1.70E-05	1.53E-05	Detected
3/13/2014	4.13E-04	6.92E-05	1.44E-05	Detected
3/14/2014	2.80E-05	1.46E-05	1.52E-05	Detected
3/15/2014	5.85E-05	2.21E-05	1.35E-05	Detected
3/16/2014	4.10E-05	1.73E-05	1.47E-05	Detected
3/17/2014	2.98E-05	1.44E-05	1.15E-05	Detected
3/18/2014	6.46E-05	2.33E-05	1.66E-05	Detected
3/19/2014	4.25E-05	1.79E-05	1.52E-05	Detected

Table 2.5 Continued

Sample Date	^{238}Pu Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
3/20/2014	7.33E-05	2.55E-05	1.74E-05	Detected
3/21/2014	7.16E-05	2.49E-05	1.39E-05	Detected
3/22/2014	4.91E-05	1.94E-05	1.53E-05	Detected
3/23/2014	8.17E-05	2.57E-05	1.58E-05	Detected
3/24/2014	8.19E-05	2.60E-05	1.58E-05	Detected
3/25/2014	6.30E-05	2.02E-05	1.03E-05	Detected
3/26/2014	5.37E-05	1.99E-05	1.47E-05	Detected
3/27/2014	4.47E-05	1.76E-05	1.13E-05	Detected
3/28/2014	1.34E-04	3.37E-05	1.22E-05	Detected
3/29/2014	5.87E-05	2.28E-05	1.76E-05	Detected
3/30/2014	2.39E-05	1.26E-05	1.10E-05	Detected
3/31/2014	2.21E-05	1.35E-05	1.36E-05	Detected
4/1/2014	3.72E-05	1.68E-05	1.25E-05	Detected
4/2/2014	2.82E-05	1.40E-05	1.38E-05	Detected
4/3/2014	2.69E-05	1.48E-05	1.90E-05	Detected
4/4/2014	5.26E-05	2.01E-05	1.53E-05	Detected
4/5/2014	1.81E-05	1.16E-05	1.21E-05	Detected
4/6/2014	2.17E-05	1.22E-05	1.34E-05	Detected
4/7/2014	1.92E-05	1.22E-05	1.49E-05	Detected
4/8/2014	1.20E-05	9.57E-06	1.39E-05	Not detected
4/9/2014	2.35E-05	1.31E-05	1.43E-05	Detected
4/10/2014	3.76E-05	1.62E-05	1.40E-05	Detected
4/11/2014	2.09E-05	1.29E-05	1.79E-05	Detected
4/12/2014	1.78E-05	1.14E-05	1.19E-05	Detected
4/13/2014	2.16E-05	1.46E-05	2.16E-05	Not detected
4/14/2014	6.05E-06	6.81E-06	1.12E-05	Not detected
4/15/2014	1.68E-05	1.18E-05	1.56E-05	Detected
4/16/2014	3.21E-06	6.45E-06	1.50E-05	Not detected
4/17/2014	5.02E-06	7.49E-06	1.55E-05	Not detected
4/18/2014	4.96E-05	1.96E-05	1.26E-05	Detected
4/19/2014	5.40E-05	2.10E-05	1.32E-05	Detected
4/20/2014	7.61E-05	2.84E-05	1.70E-05	Detected
4/21/2014	6.94E-06	9.84E-06	2.08E-05	Not detected
Weekly Analysis, 2014				
4th week of April	5.01E-06	1.98E-06	1.55E-06	Detected

Table 2.5 Continued

Sample Date	^{238}Pu Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
Ist week of May	6.28E-06	2.95E-06	2.51E-06	Detected
2nd week of May	1.03E-05	3.78E-06	1.82E-06	Not detected
3rd week of May	1.04E-05	3.41E-06	1.42E-06	Detected
4th week of May	1.64E-05	3.80E-06	1.50E-06	Detected
Ist week of June	4.83E-06	2.28E-06	1.74E-06	Detected
2nd week of June	3.56E-06	1.93E-06	1.45E-06	Detected
3rd week of June	1.08E-06	1.22E-06	1.77E-06	Not detected
4th week of June	8.20E-07	8.60E-07	1.42E-06	Not detected

Table 2.6 Activity concentrations of ^{241}Am (Bq/m^3) in Station B (Post HEPA) filters following the February 14 radiological event at WIPP

Sample Date	^{241}Am Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
2/14/2014	2.28E+00	2.76E-01	1.26E-02	Detected
2/18/2014	5.88E-02	6.79E-03	4.34E-05	Detected
2/19/2014	4.74E-02	3.24E-03	1.81E-05	Detected
2/20/2014	4.68E-02	3.26E-03	1.68E-05	Detected
2/21/2014	3.92E-02	1.04E-03	1.42E-05	Detected
2/22/2014	1.91E-02	2.05E-03	1.02E-05	Detected
2/23/2014	1.22E-02	1.33E-03	1.06E-05	Detected
2/24/2014	6.09E-03	7.74E-04	2.68E-05	Detected
2/25/2014	3.53E-03	4.08E-04	1.11E-05	Detected
2/26/2014	3.96E-03	4.49E-04	2.25E-05	Detected
2/27/2014	3.56E-03	4.06E-04	1.75E-05	Detected
2/28/2014	3.29E-03	3.73E-04	5.05E-06	Detected
3/1/2014	4.56E-03	5.18E-04	5.93E-06	Detected
3/2/2014	1.16E-02	1.28E-03	1.12E-05	Detected
3/3/2014	1.17E-02	1.28E-03	7.86E-06	Detected
3/4/2014	4.81E-03	1.68E-03	3.11E-04	Detected
3/5/2014	1.96E-02	2.24E-03	1.09E-05	Detected
3/6/2014	1.63E-03	2.34E-04	3.91E-05	Detected
3/7/2014	2.97E-03	3.70E-04	1.98E-05	Detected
3/8/2014	4.72E-03	6.16E-04	1.75E-05	Detected
3/9/2014	1.16E-03	1.79E-04	2.04E-05	Detected
3/10/2014	1.02E-03	1.48E-04	1.17E-05	Detected

Table 2.6 Continued

Sample Date	^{241}Am Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
3/11/2014	1.64E-02	1.93E-03	1.21E-05	Detected
3/12/2014	4.99E-03	3.54E-04	4.22E-06	Detected
3/13/2014	2.31E-03	2.87E-04	9.96E-06	Detected
3/14/2014	1.14E-03	1.55E-04	1.09E-05	Detected
3/15/2014	3.88E-03	4.76E-04	1.83E-05	Detected
3/16/2014	1.33E-03	1.85E-04	1.74E-05	Detected
3/17/2014	5.97E-04	7.99E-05	7.01E-06	Detected
3/18/2014	2.04E-03	2.42E-04	4.84E-06	Detected
3/19/2014	2.94E-03	3.47E-04	6.84E-06	Detected
3/20/2014	1.63E-03	2.11E-04	1.45E-05	Detected
3/21/2014	9.99E-04	1.36E-04	1.35E-05	Detected
3/22/2014	1.11E-03	1.60E-04	1.66E-05	Detected
3/23/2014	6.30E-04	9.81E-05	1.60E-05	Detected
3/24/2014	5.08E-04	7.83E-05	1.30E-05	Detected
3/25/2014	4.62E-04	7.55E-05	1.46E-05	Detected
3/26/2014	2.08E-04	5.31E-05	1.91E-05	Detected
3/27/2014	3.91E-04	6.59E-05	1.39E-05	Detected
3/28/2014	3.91E-04	6.82E-05	1.55E-05	Detected
3/29/2014	2.79E-04	5.18E-05	1.38E-05	Detected
3/30/2014	3.05E-04	5.53E-05	1.12E-05	Detected
3/31/2014	2.22E-04	4.47E-05	1.41E-05	Detected
4/1/2014	2.98E-04	5.28E-05	1.03E-05	Detected
4/2/2014	6.25E-04	9.29E-05	1.35E-05	Detected
4/3/2014	1.05E-03	1.43E-04	1.07E-05	Detected
4/4/2014	3.93E-04	6.62E-05	2.10E-05	Detected
4/5/2014	5.71E-04	9.32E-05	1.33E-05	Detected
4/6/2014	2.97E-04	5.54E-05	1.15E-05	Detected
4/7/2014	2.99E-04	5.89E-05	1.68E-05	Detected
4/8/2014	2.39E-04	4.95E-05	1.26E-05	Detected
4/9/2014	3.93E-04	7.79E-05	1.75E-05	Detected
4/10/2014	7.32E-04	1.52E-04	4.16E-05	Detected
4/11/2014	4.11E-04	6.83E-05	1.10E-05	Detected
4/12/2014	5.27E-04	8.19E-05	1.08E-05	Detected

Table 2.6 Activity concentrations of ^{241}Am (Bq/m^3) in Station B (Post HEPA) filters following the February 14 radiological event at WIPP (continued)

Sample Date	^{241}Am Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
4/13/2014	4.56E-04	7.63E-05	1.53E-05	Detected
4/14/2014	1.23E-03	1.64E-04	1.76E-05	Detected
4/15/2014	5.21E-04	8.04E-05	1.04E-05	Detected
4/16/2014	1.21E-03	1.69E-04	1.61E-05	Detected
4/17/2014	5.94E-04	8.97E-05	1.34E-05	Detected
4/18/2014	3.22E-03	3.96E-04	1.89E-05	Detected
4/19/2014	5.03E-04	8.04E-05	1.14E-05	Detected
4/20/2014	5.31E-04	1.39E-04	6.57E-05	Detected
4/21/2014	1.11E-04	2.90E-05	1.10E-05	Detected
Weekly Analysis, 2014				
4th week of April	8.98E-05	1.30E-05	1.27E-06	Detected
Ist week of May	4.04E-04	4.81E-05	1.89E-06	Detected
2nd week of May	1.01E-04	1.59E-05	2.08E-06	Detected
3rd week of May	2.98E-05	6.75E-06	2.05E-06	Detected
4th week of May	2.21E-05	5.54E-06	1.92E-06	Detected
Ist week of June	1.84E-03	2.26E-04	3.32E-06	Detected
2nd week of June	2.02E-04	2.81E-05	2.16E-06	Detected
3rd week of June	2.05E-04	3.13E-05	3.14E-06	Detected
4th week of June	9.90E-05	1.48E-05	1.92E-06	Detected

Table 2.7 Activity concentrations of $^{239+240}Pu$ (Bq/m^3) in Station B (Post HEPA) filters following the February 14 radiological event at WIPP

Sample Date	$^{239+240}Pu$ Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
2/14/2014	2.24E-01	2.26E-02	5.82E-03	Detected
2/18/2014	5.11E-03	6.89E-04	4.39E-05	Detected
2/19/2014	5.18E-03	4.47E-04	2.74E-05	Detected
2/20/2014	4.53E-03	3.95E-04	2.10E-05	Detected
2/21/2014	3.75E-03	1.18E-04	1.34E-05	Detected
2/22/2014	1.81E-03	2.22E-04	1.15E-05	Detected
2/23/2014	1.15E-03	1.50E-04	1.13E-05	Detected
2/24/2014	6.35E-04	9.94E-05	1.44E-05	Detected
2/25/2014	3.25E-04	7.14E-05	2.07E-05	Detected

Table 2.7 Continued

Sample Date	$^{239+240}Pu$ Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
2/26/2014	4.28E-04	7.33E-05	1.71E-05	Detected
2/27/2014	3.73E-04	8.44E-05	4.69E-05	Detected
2/28/2014	3.20E-04	4.65E-05	5.27E-06	Detected
3/1/2014	4.51E-04	6.35E-05	5.98E-06	Detected
3/2/2014	1.05E-03	1.29E-04	9.34E-06	Detected
3/3/2014	2.33E-03	2.83E-04	1.35E-05	Detected
3/4/2014	3.11E-04	5.73E-05	1.17E-05	Detected
3/5/2014	1.84E-03	2.41E-04	1.17E-05	Detected
3/6/2014	1.60E-04	3.70E-05	1.91E-05	Detected
3/7/2014	1.01E-03	1.26E-04	6.78E-06	Detected
3/8/2014	3.76E-04	6.39E-05	1.08E-05	Detected
3/9/2014	1.13E-04	2.97E-05	1.15E-05	Detected
3/10/2014	7.54E-05	2.41E-05	1.46E-05	Detected
3/11/2014	1.65E-03	2.19E-04	2.21E-05	Detected
3/12/2014	4.45E-04	7.42E-05	1.20E-05	Detected
3/13/2014	2.22E-04	4.65E-05	1.24E-05	Detected
3/14/2014	1.20E-04	3.11E-05	1.84E-05	Detected
3/15/2014	3.60E-04	6.60E-05	2.77E-05	Detected
3/16/2014	1.27E-04	3.44E-05	1.40E-05	Detected
3/17/2014	3.97E-05	1.64E-05	1.09E-05	Detected
3/18/2014	2.28E-04	3.73E-05	9.51E-06	Detected
3/19/2014	2.94E-04	4.57E-05	1.32E-05	Detected
3/20/2014	1.36E-04	3.44E-05	1.26E-05	Detected
3/21/2014	6.96E-05	2.29E-05	1.19E-05	Detected
3/22/2014	1.04E-04	3.46E-05	2.78E-05	Detected
3/23/2014	3.87E-05	1.83E-05	2.45E-05	Detected
3/24/2014	3.56E-05	1.61E-05	1.44E-05	Detected
3/25/2014	5.45E-05	1.95E-05	1.11E-05	Detected
3/26/2014	2.21E-05	1.25E-05	1.16E-05	Detected
3/27/2014	4.80E-05	1.84E-05	1.40E-05	Detected
3/28/2014	4.29E-05	1.70E-05	1.09E-05	Detected
3/29/2014	4.59E-05	1.82E-05	1.17E-05	Detected
3/30/2014	2.73E-05	1.84E-05	2.00E-05	Detected
3/31/2014	2.71E-05	1.35E-05	1.11E-05	Detected
4/1/2014	4.39E-05	1.82E-05	1.51E-05	Detected

Table 2.7 Continued

Sample Date	$^{239+240}$Pu Activity Bq/m^3	Uncertainty (2σ) Bq/m^3	MDC Bq/m^3	Status
4/2/2014	5.56E-05	2.02E-05	1.17E-05	Detected
4/3/2014	8.75E-05	2.58E-05	1.15E-05	Detected
4/4/2014	4.70E-05	1.87E-05	1.82E-05	Detected
4/5/2014	6.54E-05	2.17E-05	1.41E-05	Detected
4/6/2014	2.92E-05	1.42E-05	1.13E-05	Detected
4/7/2014	3.49E-05	1.51E-05	1.07E-05	Detected
4/8/2014	1.89E-05	1.20E-05	1.46E-05	Detected
4/9/2014	1.86E-05	1.19E-05	1.25E-05	Detected
4/10/2014	3.76E-05	1.69E-05	1.51E-05	Detected
4/11/2014	2.08E-05	1.34E-05	1.93E-05	Detected
4/12/2014	5.25E-05	2.03E-05	2.31E-05	Detected
4/13/2014	4.11E-05	1.74E-05	1.46E-05	Detected
4/14/2014	1.10E-04	3.03E-05	1.23E-05	Detected
4/15/2014	5.09E-05	1.92E-05	1.43E-05	Detected
4/16/2014	3.90E-05	1.72E-05	1.25E-05	Detected
4/17/2014	6.15E-05	2.20E-05	1.26E-05	Detected
4/18/2014	3.10E-04	5.69E-05	1.15E-05	Detected
4/19/2014	5.97E-05	2.13E-05	1.22E-05	Detected
4/20/2014	1.48E-05	1.12E-05	1.36E-05	Detected
4/21/2014	1.31E-05	9.98E-06	1.21E-05	Detected
Weekly Analysis, 2014				
4th week of April	1.12E-05	3.21E-06	1.39E-06	Not detected
Ist week of May	3.66E-05	7.29E-06	1.72E-06	Detected
2nd week of May	1.13E-05	3.62E-06	1.78E-06	Detected
3rd week of May	5.39E-06	2.28E-06	1.55E-06	Detected
4th week of May	1.61E-06	1.14E-06	1.47E-06	Detected
Ist week of June	2.01E-04	2.70E-05	1.49E-06	Detected
2nd week of June	2.08E-05	5.07E-06	1.72E-06	Detected
3rd week of June	2.18E-05	5.12E-06	1.48E-06	Detected
4th week of June	8.74E-06	2.95E-06	1.28E-06	Detected

Table 2.8 Activity concentrations of ^{238}Pu (Bq/m^3), in Station B (Post-HEPA) filter following the February 14 radiological event at WIPP

Sample Date	^{238}Pu Activity Bq/m^3	Uncertainty (2σ) Bq/m^3	MDC Bq/m^3	Status
2/14/2014	3.23E-02	8.65E-03	5.82E-03	Detected
2/18/2014	2.29E-04	7.66E-05	5.06E-05	Detected
2/19/2014	2.79E-04	5.63E-05	2.99E-05	Detected
2/20/2014	1.91E-04	4.25E-05	2.15E-05	Detected
2/21/2014	1.68E-04	3.70E-05	2.13E-05	Detected
2/22/2014	7.01E-05	2.25E-05	1.15E-05	Detected
2/23/2014	5.21E-05	1.90E-05	1.13E-05	Detected
2/24/2014	2.15E-05	1.38E-05	1.44E-05	Detected
2/25/2014	6.19E-05	2.78E-05	2.07E-05	Detected
2/26/2014	7.36E-05	2.49E-05	1.35E-05	Detected
2/27/2014	7.98E-05	3.51E-05	3.10E-05	Detected
2/28/2014	1.50E-05	6.91E-06	5.27E-06	Detected
3/1/2014	2.11E-05	8.75E-06	5.98E-06	Detected
3/2/2014	5.45E-05	1.48E-05	1.10E-05	Detected
3/3/2014	9.76E-05	2.64E-05	1.35E-05	Detected
3/4/2014	1.27E-05	9.66E-06	1.17E-05	Detected
3/5/2014	9.05E-05	2.65E-05	1.17E-05	Detected
3/6/2014	1.60E-06	8.45E-06	2.25E-05	Not detected
3/7/2014	3.96E-05	1.34E-05	1.11E-05	Detected
3/8/2014	2.35E-05	1.24E-05	1.08E-05	Detected
3/9/2014	3.14E-06	5.43E-06	1.15E-05	Not detected
3/10/2014	1.10E-05	9.00E-06	1.16E-05	Not detected
3/11/2014	6.58E-05	2.22E-05	1.46E-05	Detected
3/12/2014	2.11E-05	1.24E-05	1.20E-05	Detected
3/13/2014	5.03E-06	7.54E-06	1.56E-05	Detected
3/14/2014	4.61E-06	6.16E-06	1.13E-05	Not detected
3/15/2014	6.44E-05	2.41E-05	2.46E-05	Detected
3/16/2014	7.60E-06	8.52E-06	1.40E-05	Not detected
3/17/2014	7.37E-06	7.85E-06	1.37E-05	Not detected
3/18/2014	6.34E-06	4.82E-06	5.83E-06	Detected
3/19/2014	1.83E-05	9.02E-06	1.17E-05	Detected
3/20/2014	1.03E-05	9.15E-06	1.26E-05	Not detected
3/21/2014	4.84E-06	7.25E-06	1.50E-05	Not detected
3/22/2014	4.64E-06	8.06E-06	1.70E-05	Not detected

Table 2.8 Continued

Sample Date	^{238}Pu Activity Bq/m^3	Uncertainty (2σ) Bq/m^3	MDC Bq/m^3	Status
3/23/2014	-1.55E-06	6.91E-06	2.18E-05	Not detected
3/24/2014	0.00E+00	4.39E-06	1.14E-05	Not detected
3/25/2014	1.51E-06	5.24E-06	1.41E-05	Not detected
3/26/2014	0.00E+00	4.48E-06	1.47E-05	Not detected
3/27/2014	6.01E-06	8.54E-06	1.81E-05	Not detected
3/28/2014	-1.48E-06	4.19E-06	1.38E-05	Not detected
3/29/2014	0.00E+00	4.47E-06	1.47E-05	Not detected
3/30/2014	8.17E-06	1.09E-05	2.00E-05	Not detected
3/31/2014	0.00E+00	4.27E-06	1.40E-05	Not detected
4/1/2014	0.00E+00	4.61E-06	1.20E-05	Not detected
4/2/2014	4.78E-06	6.39E-06	1.17E-05	Not detected
4/3/2014	1.56E-06	4.41E-06	1.15E-05	Not detected
4/4/2014	6.06E-06	6.80E-06	1.11E-05	Not detected
4/5/2014	1.52E-06	5.25E-06	1.41E-05	Not detected
4/6/2014	3.06E-06	6.15E-06	1.43E-05	Not detected
4/7/2014	-1.45E-06	5.04E-06	1.75E-05	Not detected
4/8/2014	0.00E+00	4.45E-06	1.46E-05	Not detected
4/9/2014	1.69E-05	4.78E-06	1.25E-05	Detected
4/10/2014	0.00E+00	4.61E-06	1.51E-05	Not detected
4/11/2014	0.00E+00	4.54E-06	1.18E-05	Not detected
4/12/2014	0.00E+00	7.16E-06	2.06E-05	Not detected
4/13/2014	1.58E-06	5.46E-06	1.46E-05	Not detected
4/14/2014	-1.67E-06	5.77E-06	2.00E-05	Not detected
4/15/2014	0.00E+00	4.38E-06	1.14E-05	Not detected
4/16/2014	5.08E-06	6.80E-06	1.25E-05	Not detected
4/17/2014	0.00E+00	6.85E-06	2.05E-05	Not detected
4/18/2014	1.40E-05	9.99E-06	1.15E-05	Detected
4/19/2014	0.00E+00	4.69E-06	1.22E-05	Not detected
4/20/2014	-1.85E-06	6.41E-06	2.22E-05	Not detected
4/21/2014	0.00E+00	4.65E-06	1.21E-05	Not detected
Weekly Analysis, 2014				
4th week of April	1.89E-07	6.56E-07	1.76E-06	Not detected
1st week of May	1.61E-06	1.27E-06	1.18E-06	Detected
2nd week of May	-1.96E-07	5.27E-07	1.78E-06	Not detected
3rd week of May	4.28E-08	4.61E-07	1.55E-06	Not detected

Table 2.8 Continued

Sample Date	^{238}Pu Activity Bq/m^3	Uncertainty (2σ) Bq/m^3	MDC Bq/m^3	Status
4th week of May	3.35E-08	3.62E-07	1.22E-06	Not detected
Ist week of June	7.98E-06	2.85E-06	1.33E-06	Detected
2nd week of June	1.08E-06	1.18E-06	2.05E-06	Not detected
3rd week of June	1.16E-06	1.11E-06	1.62E-06	Not detected
4th week of June	6.45E-07	8.85E-07	1.68E-06	Not detected

Table 2.9 Activity concentrations of ^{137}Cs (Bq/m^3), in Station A filters following the February 14 radiological event at WIPP

Sample Date	^{137}Cs Activity Bq/m^3	Uncertainty (2σ) Bq/m^3	MDC Bq/m^3	Status
2/14/2014	4.86E-03	1.85E-03	2.97E-03	Detected
2/15/2014	-3.70E-04	2.63E-03	4.54E-03	No detection
2/16/2014	-4.18E-03	2.27E-03	3.94E-03	No detection
2/17/2014	-4.97E-03	2.26E-03	3.93E-03	No detection
2/18/2014	-3.43E-03	3.20E-03	5.45E-03	No detection
2/19/2014	1.12E-03	3.31E-03	5.63E-03	No detection
2/20/2014	-2.04E-03	3.23E-03	5.52E-03	No detection
2/21/2014	-2.87E-03	3.07E-03	5.21E-03	No detection
2/22/2014	1.12E-03	2.91E-03	4.92E-03	No detection
2/23/2014	-3.00E-04	2.75E-03	4.70E-03	No detection
2/24/2014	-2.22E-03	1.18E-03	2.07E-03	No detection
2/25/2014	-5.03E-04	1.38E-03	2.36E-03	No detection
2/26/2014	7.68E-04	2.81E-03	4.75E-03	No detection
2/27/2014	-2.36E-03	1.17E-03	2.05E-03	No detection
3/4/2014	-1.91E-03	1.14E-03	2.00E-03	No detection
3/5/2014	-1.48E-03	1.14E-03	1.98E-03	No detection
3/6/2014	-1.79E-03	1.40E-03	2.41E-03	No detection
3/7/2014	-1.14E-03	2.87E-03	4.91E-03	No detection
3/8/2014	-5.12E-04	2.73E-03	4.66E-03	No detection
3/9/2014	-1.78E-03	1.48E-03	2.55E-03	No detection
3/10/2014	7.00E-04	2.76E-03	4.67E-03	No detection
3/11/2014	-1.64E-03	1.43E-03	2.47E-03	No detection
3/12/2014	-3.60E-04	1.09E-03	1.87E-03	No detection
3/13/2014	-1.53E-03	1.46E-03	2.51E-03	No detection
3/14/2014	-1.68E-03	1.15E-03	2.00E-03	No detection

Table 2.9 Continued

Sample Date	^{137}Cs Activity Bq/m^3	Uncertainty (2σ) Bq/m^3	MDC Bq/m^3	Status
3/15/2014	-1.13E-03	1.42E-03	2.43E-03	No detection
3/16/2014	6.73E-04	2.74E-03	4.64E-04	No detection
3/17/2014	-5.33E-06	1.13E-03	1.92E-03	No detection
3/18/2014	2.75E-04	1.42E-03	2.41E-03	No detection
3/19/2014	-5.74E-05	2.77E-03	4.72E-03	No detection
3/20/2014	-5.80E-05	1.12E-03	1.90E-03	No detection
3/21/2014	-1.44E-04	1.42E-03	2.42E-03	No detection
3/22/2014	-1.70E-03	2.81E-03	4.83E-03	No detection
3/23/2014	1.07E-03	1.10E-03	1.84E-03	No detection
3/24/2014	3.16E-04	1.41E-03	2.39E-03	No detection
3/25/2014	-7.27E-04	2.34E-03	4.03E-03	No detection
3/26/2014	1.84E-04	1.16E-03	1.96E-03	No detection
3/27/2014	6.89E-05	1.40E-03	2.39E-03	No detection
3/28/2014	-5.44E-04	2.82E-03	4.82E-03	No detection
3/29/2014	9.80E-04	1.11E-03	1.87E-03	No detection
3/30/2014	3.56E-04	2.14E-03	3.64E-03	No detection
3/31/2014	8.84E-04	1.13E-03	1.91E-03	No detection
4/1/2014	8.95E-04	1.07E-03	1.78E-03	No detection
4/2/2014	-8.62E-04	1.42E-03	2.43E-03	No detection
4/3/2014	-2.53E-04	1.48E-03	2.52E-03	No detection
4/4/2014	6.06E-04	1.38E-03	2.33E-03	No detection
4/5/2014	4.84E-04	1.11E-03	1.88E-03	No detection
4/6/2014	3.83E-04	1.39E-03	2.35E-03	No detection
4/7/2014	9.03E-04	2.75E-03	4.66E-03	No detection
4/8/2014	-4.01E-04	1.44E-03	2.46E-03	No detection
4/9/2014	-5.53E-05	1.09E-03	1.86E-03	No detection
4/10/2014	-5.46E-04	1.43E-03	2.44E-03	No detection
4/11/2014	-4.69E-05	2.64E-03	4.50E-03	No detection
4/12/2014	-2.53E-05	1.09E-03	1.86E-03	No detection
4/13/2014	-5.07E-04	9.24E-04	1.57E-03	No detection
4/14/2014	3.89E-04	1.15E-03	1.94E-03	No detection
4/15/2014	3.41E-06	2.20E-03	3.73E-03	No detection
4/16/2014	-3.75E-04	1.13E-03	1.94E-03	No detection
4/17/2014	-5.78E-06	1.43E-03	2.43E-03	No detection
4/18/2014	-3.20E-04	2.71E-03	4.63E-03	No detection

Table 2.9 Continued

Sample Date	^{137}Cs Activity Bq/m^3	Uncertainty (2σ) Bq/m^3	MDC Bq/m^3	Status
4/19/2014	1.35E-04	1.09E-03	1.85E-03	No detection
4/20/2014	-2.49E-04	1.41E-03	2.40E-03	No detection
4/21/2014	2.14E-04	2.67E-03	4.54E-03	No detection
Weekly Analysis, 2014				
4th week of April	2.05E-04	2.83E-04	4.76E-04	No detection
Ist week of May	1.18E-04	3.24E-04	5.48E-04	No detection
2nd week of May	7.18E-05	1.63E-04	2.75E-04	No detection
3rd week of May	4.92E-05	1.54E-04	2.61E-04	No detection
4th week of May	6.65E-06	1.12E-04	1.91E-04	No detection
Ist week of June	-6.41E-05	1.68E-04	2.88E-04	No detection
2nd week of June	-7.11E-05	4.15E-04	7.08E-04	No detection
3rd week of June	-1.74E-04	3.81E-04	6.54E-04	No detection
4th week of June	-1.98E-05	1.20E-04	2.05E-04	No detection

Table 2.10 Activity concentrations of ^{60}Co (Bq/m^3), in Station A filters following the February 14 radiological event at WIPP

Sample Date	^{60}Co Activity Bq/m^3	Uncertainty (2σ) Bq/m^3	MDC Bq/m^3	Status
2/14/2014	-1.16E-03	1.86E-03	3.28E-03	No detection
2/15/2014	-5.46E-05	2.31E-03	3.96E-03	No detection
2/16/2014	-4.17E-04	2.08E-03	3.58E-03	No detection
2/17/2014	-9.00E-04	2.05E-03	3.50E-03	No detection
2/18/2014	1.96E-03	2.47E-03	4.10E-03	No detection
2/19/2014	3.69E-03	2.71E-03	4.64E-03	No detection
2/20/2014	-6.07E-04	2.62E-03	4.47E-03	No detection
2/21/2014	1.46E-03	2.35E-03	4.07E-03	No detection
2/22/2014	-9.37E-04	2.18E-03	3.80E-03	No detection
2/23/2014	1.47E-03	2.03E-03	3.41E-03	No detection
2/24/2014	-9.74E-04	1.16E-03	2.02E-03	No detection
2/25/2014	8.55E-04	1.12E-03	1.88E-03	No detection
2/26/2014	3.47E-04	2.09E-03	3.59E-03	No detection
2/27/2014	-9.46E-04	1.18E-03	2.05E-03	No detection
3/4/2014	-1.54E-02	1.13E-03	1.94E-03	No detection
3/5/2014	-3.84E-04	1.15E-03	1.98E-03	No detection

3/6/2014	4.63E-04	1.13E-03	1.92E-03	No detection

Table 2.10 Continued

Sample Date	^{60}Co Activity Bq/m^3	Uncertainty (2σ) Bq/m^3	MDC Bq/m^3	Status
3/7/2014	1.55E-03	2.00E-03	3.36E-03	No detection
3/8/2014	4.32E-04	2.14E-03	3.66E-03	No detection
3/9/2014	5.69E-04	1.17E-03	1.98E-03	No detection
3/10/2014	7.24E-04	2.06E-03	3.52E-03	No detection
3/11/2014	-2.79E-04	1.19E-03	2.05E-03	No detection
3/12/2014	-3.13E-04	1.08E-03	1.87E-03	No detection
3/13/2014	1.30E-03	1.11E-03	1.84E-03	No detection
3/14/2014	-6.08E-04	1.14E-03	1.97E-03	No detection
3/15/2014	6.55E-04	1.14E-03	1.92E-03	No detection
3/16/2014	1.66E-03	1.94E-03	3.25E-03	No detection
3/17/2014	-2.99E-04	1.16E-03	2.00E-03	No detection
3/18/2014	-2.08E-04	1.15E-03	1.98E-03	No detection
3/19/2014	-1.92E-03	2.72E-03	4.74E-03	No detection
3/20/2014	-7.41E-04	1.16E-03	2.02E-03	No detection
3/21/2014	1.70E-04	1.15E-03	1.96E-03	No detection
3/22/2014	-5.17E-04	2.50E-03	4.31E-03	No detection
3/23/2014	-5.59E-04	1.14E-03	1.97E-03	No detection
3/24/2014	8.57E-04	1.12E-03	1.88E-03	No detection
3/25/2014	-1.05E-03	2.59E-03	4.49E-03	No detection
3/26/2014	9.34E-05	1.16E-03	1.99E-03	No detection
3/27/2014	2.81E-04	1.11E-03	1.88E-03	No detection
3/28/2014	-1.39E-04	2.61E-03	4.49E-03	No detection
3/29/2014	-2.20E-04	1.11E-03	1.90E-03	No detection
3/30/2014	-6.32E-03	1.42E-02	2.46E-02	No detection
3/31/2014	4.71E-05	1.14E-03	1.95E-03	No detection
4/1/2014	-3.91E-04	1.10E-03	1.90E-03	No detection
4/2/2014	-5.76E-05	1.14E-03	1.96E-03	No detection
4/3/2014	-7.04E-04	1.19E-03	2.07E-03	No detection
4/4/2014	-1.30E-03	1.24E-03	2.17E-03	No detection
4/5/2014	-1.58E-04	1.11E-03	1.91E-03	No detection
4/6/2014	-4.30E-04	1.16E-03	1.99E-03	No detection
4/7/2014	-8.18E-04	2.61E-03	4.51E-03	No detection
4/8/2014	4.03E-04	1.15E-03	1.94E-03	No detection

4/9/2014	-8.39E-04	1.14E-03	1.98E-03	No detection
4/10/2014	-1.38E-04	1.15E-03	1.97E-03	No detection

Table 2.10 Continued

Sample Date	^{60}Co Activity Bq/m^3	Uncertainty (2σ) Bq/m^3	MDC Bq/m^3	Status
4/11/2014	-2.84E-03	2.78E-03	4.87E-03	No detection
4/12/2014	-5.50E-04	1.13E-03	1.96E-03	No detection
4/13/2014	-1.61E-04	9.30E-04	1.58E-03	No detection
4/14/2014	-1.07E-04	9.34E-04	1.59E-03	No detection
4/15/2014	-9.18E-04	2.08E-03	3.56E-03	No detection
4/16/2014	-2.48E-04	1.16E-03	2.00E-03	No detection
4/17/2014	-9.89E-05	1.15E-03	1.97E-03	No detection
4/18/2014	-7.18E-04	2.56E-03	4.42E-03	No detection
4/19/2014	-2.84E-04	1.12E-03	1.94E-03	No detection
4/20/2014	3.95E-05	1.14E-03	1.95E-03	No detection
4/21/2014	3.54E-04	2.42E-03	4.14E-03	No detection
Weekly Analysis, 2014				
4th week of April	2.52E-04	2.57E-04	4.29E-04	No detection
Ist week of May	3.18E-04	2.20E-03	3.76E-03	No detection
2nd week of May	-4.62E-05	1.85E-04	3.18E-04	No detection
3rd week of May	-4.04E-05	1.54E-04	2.66E-04	No detection
4th week of May	3.31E-05	1.12E-04	1.91E-04	No detection
Ist week of June	1.84E-05	1.64E-04	2.79E-04	No detection
2nd week of June	-4.70E-05	3.87E-04	6.67E-04	No detection
3rd week of June	-8.91E-05	3.48E-04	6.01E-04	No detection
4th week of June	-7.43E-05	1.23E-04	2.13E-04	No detection

Table 2.11 Activity concentrations of ^{40}K (Bq/m^3), in Station A filters following the February 14 radiological event at WIPP

Sample Date	^{40}K Activity Bq/m^3	Uncertanity (2σ) Bq/m^3	MDC Bq/m^3	Status
2/14/2014	-5.19E-03	1.84E-02	3.22E-02	No detection
2/15/2014	-4.28E-02	2.77E-02	4.85E-02	No detection
2/16/2014	-1.28E-02	2.69E-02	4.36E-02	No detection
2/17/2014	-6.58E-02	2.41E-02	4.25E-02	No detection
2/18/2014	-7.11E-02	2.55E-02	4.47E-02	No detection
2/19/2014	-4.56E-02	4.01E-02	5.51E-02	No detection

2/20/2014	-3.41E-02	3.23E-02	5.61E-02	No detection
2/21/2014	-3.12E-02	1.90E-02	3.33E-02	No detection
2/22/2014	-3.51E-04	2.45E-02	4.97E-03	No detection

Table 2.11 Continued

Sample Date	^{40}K Activity Bq/m^3	Uncertainty (2σ) Bq/m^3	MDC Bq/m^3	Status
2/23/2014	-1.48E-02	2.67E-02	4.66E-02	No detection
2/24/2014	-2.53E-02	1.44E-02	2.55E-02	No detection
2/25/2014	-1.67E-02	1.43E-02	2.48E-02	No detection
2/26/2014	-1.55E-02	2.64E-03	5.03E-02	No detection
2/27/2014	-2.68E-02	1.47E-02	2.59E-02	No detection
3/4/2014	-1.67E-02	1.36E-02	2.39E-02	No detection
3/5/2014	-2.03E-02	1.38E-02	2.43E-02	No detection
3/6/2014	-1.90E-02	1.42E-02	2.46E-02	No detection
3/7/2014	4.85E-03	2.52E-02	4.31E-02	No detection
3/8/2014	-1.70E-02	2.66E-02	4.66E-02	No detection
3/9/2014	-1.02E-02	1.42E-02	2.46E-02	No detection
3/10/2014	-7.10E-03	2.56E-02	4.44E-02	No detection
3/11/2014	-1.13E-02	1.36E-02	2.37E-02	No detection
3/12/2014	-1.16E-02	1.43E-02	2.49E-02	No detection
3/13/2014	-2.03E-02	1.51E-02	2.62E-02	No detection
3/14/2014	-2.40E-02	1.42E-02	2.50E-02	No detection
3/15/2014	-1.68E-02	1.45E-02	2.52E-02	No detection
3/16/2014	-5.16E-03	2.53E-02	4.38E-02	No detection
3/17/2014	-3.23E-03	1.39E-02	2.39E-02	No detection
3/18/2014	1.43E-02	1.31E-02	2.17E-02	No detection
3/19/2014	1.07E-02	2.44E-02	4.16E-02	No detection
3/20/2014	5.70E-03	1.34E-02	2.27E-02	No detection
3/21/2014	8.33E-03	1.35E-02	2.28E-02	No detection
3/22/2014	6.05E-03	2.72E-02	4.64E-02	No detection
3/23/2014	-3.77E-03	1.33E-02	2.29E-02	No detection
3/24/2014	3.75E-03	1.42E-02	2.41E-02	No detection
3/25/2014	-9.85E-03	2.73E-02	4.74E-02	No detection
3/26/2014	5.01E-03	1.39E-02	2.36E-02	No detection
3/27/2014	-8.89E-04	1.39E-02	2.38E-02	No detection
3/28/2014	5.60E-04	2.68E-02	4.61E-02	No detection
3/29/2014	5.22E-03	1.31E-02	2.23E-02	No detection

3/30/2014	-5.16E-03	1.51E-02	2.60E-02	No detection
3/31/2014	4.02E-03	1.32E-02	2.24E-02	No detection
4/1/2014	4.16E-03	1.31E-02	2.22E-02	No detection
4/2/2014	1.36E-02	1.34E-02	2.22E-02	No detection

Table 2.11 Continued

Sample Date	^{40}K Activity Bq/m^3	Uncertainty (2σ) Bq/m^3	MDC Bq/m^3	Status
4/3/2014	1.86E-04	1.41E-02	2.41E-02	No detection
4/4/2014	-7.65E-03	1.46E-02	2.53E-02	No detection
4/5/2014	-4.20E-03	1.39E-02	2.40E-02	No detection
4/6/2014	2.29E-04	1.44E-02	2.46E-02	No detection
4/7/2014	2.10E-02	2.34E-02	3.91E-02	No detection
4/8/2014	4.74E-03	1.43E-02	2.42E-02	No detection
4/9/2014	-9.43E-03	1.42E-02	2.46E-02	No detection
4/10/2014	8.98E-03	1.35E-02	2.27E-02	No detection
4/11/2014	4.26E-03	2.44E-02	4.19E-02	No detection
4/12/2014	-9.82E-04	1.37E-02	2.34E-02	No detection
4/13/2014	4.50E-03	1.10E-02	1.86E-02	No detection
4/14/2014	-1.27E-03	1.17E-02	1.99E-02	No detection
4/15/2014	-2.05E-04	2.04E-02	3.49E-02	No detection
4/16/2014	2.45E-03	1.36E-02	2.32E-02	No detection
4/17/2014	-2.13E-03	1.40E-02	2.40E-02	No detection
4/18/2014	-2.08E-03	2.51E-02	4.34E-02	No detection
4/19/2014	5.51E-03	1.37E-02	2.32E-02	No detection
4/20/2014	-2.14E-03	1.41E-02	2.42E-02	No detection
4/21/2014	-6.42E-03	2.68E-02	5.86E-02	No detection
Weekly Analysis, 2014				
4th week of April	-1.51E-04	3.17E-03	5.42E-03	No detection
Ist week of May	-1.60E-03	2.10E-03	3.64E-03	No detection
2nd week of May	1.63E-04	2.00E-03	3.41E-03	No detection
3rd week of May	2.50E-04	1.97E-03	3.36E-03	No detection
4th week of May	1.03E-04	1.35E-03	2.30E-03	No detection
Ist week of June	-1.77E-03	2.19E-03	3.79E-03	No detection
2nd week of June	1.82E-03	3.73E-03	6.32E-03	No detection
3rd week of June	-5.30E-04	3.55E-03	6.13E-03	No detection
4th week of June	-6.72E-04	1.52E-03	2.63E-03	No detection

Table 2.12 Activity concentrations of ^{137}Cs (Bq/m^3), in Station B filter following the February 14 radiological event at WIPP

Sample Date	^{137}Cs Activity Bq/m^3	Uncertainty (2σ) Bq/m^3	MDC Bq/m^3	Status
2/14/2014	3.63E-04	5.77E-04	9.72E-04	Not detected
2/18/2014	1.37E-03	3.05E-03	5.16E-03	Not detected
2/19/2014	-4.20E-04	2.26E-03	3.84E-03	Not detected
2/20/2014	-4.11E-03	3.95E-03	6.78E-03	Not detected
2/21/2014	-3.71E-04	1.10E-03	1.88E-03	Not detected
2/22/2014	-2.44E-03	1.44E-03	2.49E-03	Not detected
2/23/2014	2.19E-03	2.53E-03	4.24E-03	Not detected
2/24/2014	-1.19E-04	2.67E-03	4.54E-03	Not detected
2/25/2014	-9.51E-04	1.08E-03	1.87E-03	Not detected
2/26/2014	-1.10E-03	1.32E-03	2.26E-03	Not detected
2/27/2014	-1.70E-05	2.70E-03	4.60E-03	Not detected
3/4/2014	-2.40E-03	1.17E-03	2.06E-03	Not detected
3/5/2014	-1.22E-03	1.33E-03	2.29E-03	Not detected
3/6/2014	6.20E-04	2.69E-03	4.55E-03	Not detected
3/7/2014	-1.15E-03	1.10E-03	1.91E-03	Not detected
3/8/2014	-6.32E-04	1.32E-03	2.26E-03	Not detected
3/9/2014	4.10E-04	2.78E-03	4.72E-03	Not detected
3/10/2014	-1.73E-03	1.08E-03	1.89E-03	Not detected
3/11/2014	2.11E-05	1.33E-03	2.26E-03	Not detected
3/12/2014	-1.59E-03	1.10E-03	1.92E-03	Not detected
3/13/2014	1.09E-03	2.65E-03	4.48E-03	Not detected
3/14/2014	-3.39E-04	2.71E-03	4.63E-03	Not detected
3/15/2014	-1.65E-03	1.09E-03	1.91E-03	Not detected
3/16/2014	6.54E-04	2.66E-03	4.51E-03	Not detected
3/20/2014	-1.54E-03	2.69E-03	4.62E-03	Not detected

Table 2.13 Activity concentrations of ^{60}Co (Bq/m^3), in Station B filter following the February 14 radiological event at WIPP

Sample Date	^{60}Co Activity	Uncertainty (2σ)	MDC	Status

	Bq/m^3	Bq/m^3	Bq/m^3	
2/14/2014	-5.92E-04	6.02E-04	1.05E-03	No detection
2/18/2014	-1.46E-03	3.16E-03	5.47E-03	No detection
2/19/2014	-8.37E-04	1.98E-03	3.40E-03	No detection
2/20/2014	-3.73E-03	3.78E-03	6.57E-03	No detection

Table 2.13 Continued

Sample Date	^{60}Co Activity Bq/m^3	Uncertainty (2σ) Bq/m^3	MDC Bq/m^3	Status
2/21/2014	-2.21E-04	1.11E-03	1.90E-03	No detection
2/22/2014	2.55E-05	1.17E-03	2.00E-03	No detection
2/23/2014	1.04E-04	2.06E-03	3.54E-03	No detection
2/24/2014	-6.09E-04	2.28E-03	3.95E-03	No detection
2/25/2014	-4.88E-04	1.12E-03	1.93E-03	No detection
2/26/2014	3.78E-04	1.08E-03	1.83E-03	No detection
2/27/2014	-1.44E-03	2.33E-03	4.07E-03	No detection
3/4/2014	-5.97E-04	1.16E-03	2.01E-03	No detection
3/5/2014	-6.50E-06	1.11E-03	1.90E-03	No detection
3/6/2014	5.87E-05	2.23E-03	3.83E-03	No detection
3/7/2014	-4.31E-04	1.13E-03	1.95E-03	No detection
3/8/2014	5.18E-04	1.09E-03	1.85E-03	No detection
3/9/2014	2.54E-03	1.81E-03	2.96E-03	No detection
3/10/2014	-6.96E-04	1.08E-03	1.88E-03	No detection
3/11/2014	7.71E-04	1.13E-03	1.89E-03	No detection
3/12/2014	2.51E-05	1.08E-03	1.85E-03	No detection
3/13/2014	-1.20E-03	2.16E-03	3.78E-03	No detection
3/14/2014	9.94E-04	2.08E-03	3.52E-03	No detection
3/15/2014	-7.39E-04	1.10E-03	1.91E-03	No detection
3/16/2014	1.61E-03	1.88E-03	3.16E-03	No detection
3/20/2014	-3.45E-03	2.70E-03	4.75E-03	No detection

Table 2.14 Activity concentrations of ^{40}K (Bq/m^3), in Station B filter following the February 14 radiological event at WIPP

Sample Date	^{40}K Activity Bq/m^3	Uncertainty (2σ) Bq/m^3	MDC Bq/m^3	Status
2/14/2014	1.75E-03	5.47E-03	9.33E-03	Not detected
2/18/2014	2.28E-02	3.75E-02	6.32E-02	Not detected
2/19/2014	3.38E-03	2.38E-02	4.06E-02	Not detected

2/20/2014	-2.60E-02	3.87E-02	6.72E-02	Not detected
2/21/2014	1.05E-02	1.30E-02	2.18E-02	Not detected
2/22/2014	-1.04E-02	1.33E-02	2.31E-02	Not detected
2/23/2014	-1.41E-02	2.56E-02	4.47E-02	Not detected
2/24/2014	-8.53E-03	2.71E-02	4.70E-02	Not detected

Table 2.14 Continued

Sample Date	40K Activity Bq/m3	Uncertainty (2σ) Bq/m3	MDC Bq/m3	Status
2/25/2014	-1.17E-02	1.29E-02	2.25E-02	Not detected
2/26/2014	-1.87E-02	1.35E-02	2.35E-02	Not detected
2/27/2014	1.09E-02	2.25E-02	3.81E-02	Not detected
3/4/2014	-1.77E-02	1.37E-02	2.41E-02	Not detected
3/5/2014	-9.10E-03	1.34E-02	2.32E-02	Not detected
3/6/2014	-2.60E-02	2.64E-02	4.65E-02	Not detected
3/7/2014	-1.60E-02	1.33E-02	2.33E-02	Not detected
3/8/2014	-8.94E-03	1.33E-02	2.30E-02	Not detected
3/9/2014	-2.52E-02	2.76E-02	4.85E-02	Not detected
3/10/2014	-1.57E-02	1.27E-02	2.23E-02	Not detected
3/11/2014	-1.25E-02	1.37E-02	2.38E-02	Not detected
3/12/2014	-2.51E-03	1.26E-02	2.17E-02	Not detected
3/13/2014	9.09E-04	2.43E-02	4.19E-02	Not detected
3/14/2014	-1.51E-02	2.60E-02	4.54E-02	Not detected
3/15/2014	-2.48E-02	1.34E-02	2.37E-02	Not detected
3/16/2014	-5.02E-03	2.46E-02	4.26E-02	Not detected
3/20/2014	9.41E-03	2.38E-02	4.05E-02	Not detected

THIS PAGE LEFT INTENTIONALLY BLANK

SECTION 3

Ambient Air Monitoring

Ambient air monitoring essentially means the monitoring of **"the air around us"**. Ambient air monitoring can provide a precautionary measure in the event of accidental releases of radioactivity. The CEMRC operates a network of continuously operating samplers at three locations in the vicinity of the WIPP site to monitor radioactive constituents in the ambient air. The program is design to detect radioactive materials in the air in case of an emergency response situation. The ambient air monitoring is an important aspect of the CEMRC environmental monitoring program that seeks to monitor the source of radionuclides in the WIPP environment, to detect any release of radioactive materials into the environment from the WIPP-related activities, and to ensure the protection of human and environmental health.

Currently, ^{238}Pu, ^{239}Pu and ^{240}Pu isotopes can be measured as traces in environmental samples, with a ^{238}Pu/$^{239+240}$Pu activity ratio of 0.03 at mean latitudes of 40°-50° N tracing their global origin (UNSCEAR, 2000). At present, almost all plutonium being introduced into the atmosphere can be found in the surface soil. Depending on meteorological conditions, physiochemical properties of soil, and human activity, plutonium can migrate vertically with various rates, can be transported into plants or re-suspended into the air with eroded soil particles. These aerosol particles can be trapped on a filter in an air monitoring station or subjected to wash-down from the atmosphere with precipitation (i.e. rainfall or snowfall). Air samples can thus give information about activity levels both in the air and soil of a particular area, and allow evaluation of seasonal variations of plutonium in the air.

Sample Collection

At the CEMRC, ambient aerosols are collected using high volume samplers ("hivols," flow rate ~1.13 m^3 min^{-1}) from three monitoring stations: (1) Onsite, which is about 0.1 km northwest of the WIPP exhaust shaft, (2) Near Field, about 1 km northwest of the facility; and (3) Cactus Flats, about 19 km southeast of the WIPP site. The locations of the three ambient air sampling stations are depicted in **Figure 3.1**. The samplers are primarily located in the prevailing downwind direction and were selected based on an analysis of probable wind-direction and speed scenarios in case of an accident involving a release of radioactivity during the operation of the WIPP. The aerosol samples were collected on 20×25 cm A/E™ glass fiber filters (Pall German Laboratory, Ann Arbor, MI). As shown in **Figure 3.2,** the sampling height of each aerosol station is ~5 m from the ground.

Under normal operating conditions, these filters are collected over a period of 3 to 6 weeks depending on the levels of particulate matter that accumulate on the filters. Following the radiation release event, filters were changed and analyzed weekly.

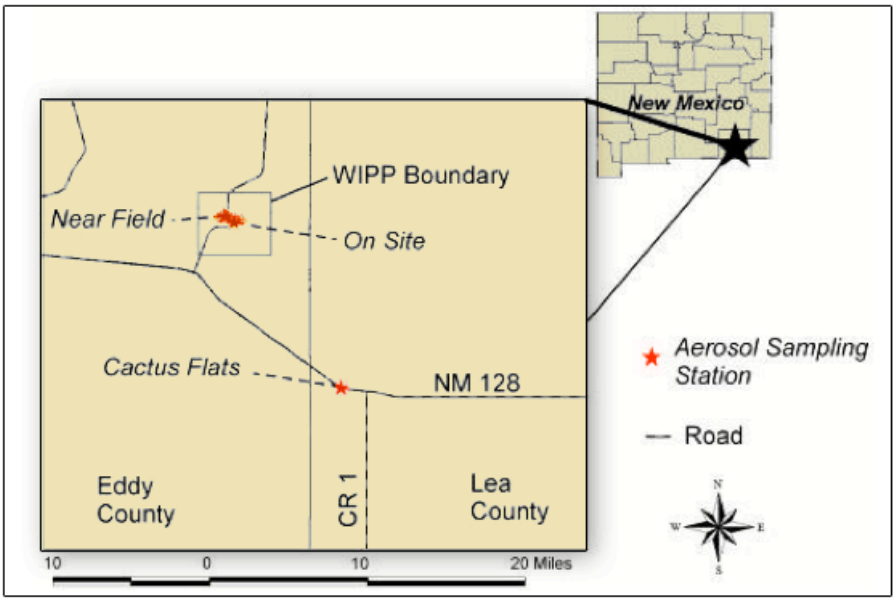


Figure 3.1 Ambient Aerosol Sampling Locations

Figure 3.2 Typical WIPP Site High Volume Air Sampling Station

Sample Preparation

For radiochemical analyses, each filter was treated with strong acid mixtures, HCl+HF+$HClO_4$ up to the complete decomposition of silica. Then it was treated with conc. $HClO_4$ and HNO_3 for the removal of fluoride ions. The inside walls of the beaker were rinsed carefully with HNO_3 to gather residual HF, evaporation was repeated to ensure that all residual HF is removed from the matrix. The residues were dissolved in 1.0 M HCl for subsequent radionuclide separation and analysis. The acid digestates of the filter composite samples were split into two fractions. One fraction was analyzed by gamma spectroscopy for ^{40}K, ^{60}Co, and ^{137}Cs. The other fraction was analyzed for the actinides. The actinides are separated as a group by co-precipitation on $Fe(OH)_3$. Pu isotopes are separated and purified using a two-column anion exchange resin (Dowex1-× 8, Bio-Rad, 100-200 mesh), while TRU chromatography columns are for the separation of Am. The samples are then micro-co-precipitated using an Nd-carrier, deposited onto filters, mounted on planchettes, and counted by Alpha spectroscopy for 24 hours. Gamma-emitting nuclides in the air filters are measured using a high purity germanium detector, HpGe (Canberra).

Data Reporting

The activities of the actinides and gamma radionuclides in the air samples are reported as *activity concentration* (Bq/m^3). *Activity concentration* is calculated as the activity of radionuclides detected in Becquerel (Bq) divided by the volume of air in cubic meters (m^3).

Results and Discussion

Intensified ambient air sampling and accelerated radiochemical analyses were performed in and around the WIPP site to ascertain whether or not there were releases to the ground surface following the radiation release event from the WIPP underground. Trace amounts of ^{241}Am and $^{239+240}$ Pu were briefly detected at two sampling locations (Onsite and Near Field). The filters that were analyzed had been installed at these stations prior to the event, on February 11, 2014 and the Near Field filter was removed on February 16, 2014. The Onsite filter was installed on February 11, 2014 and was removed on February 18, 2014 because the site was not accessible until then. A third ambient air filter station (Cactus Flats), located approximately 19 km (12 miles) southeast of the WIPP site, had a filter installed on February 11, 2014 and removed on February 16, 2014, showed no detectable concentrations of americium or plutonium. The highest concentrations detected were 10.2 µBq/m^3 for $^{239+240}Pu$ and 115.2 µBq/m^3 for ^{241}Am at the Onsite sampling Station, and 81.4 µBq/m^3 for ^{241}Am and 5.78 µBq/m^3 for $^{239+240}Pu$ at the Near Field Station (**Figures 3.3 and 3.4**). The

^{241}Am to $^{239+240}$ Pu ratios of the elevated airborne radioactive concentrations are generally consistent with the waste stream suspected to have been released at WIPP.

The concentrations of $^{239+240}$Pu, ^{241}Am and ^{238}Pu measured in the ambient air filters following the WIPP underground radiation detection event are listed in **Tables 3.1 to 3.3**. Although these values are above the background levels, it is important to note that the levels detected were very low and well below any level of public health or environmental concern. The levels of activity in all ambient air filters have decreased significantly since February 25, 2014. The mid-April analyses indicate that both the ^{241}Am and $^{239+240}$Pu concentrations have returned to previous background levels. These analyses continue to reflect that the air around the WIPP site is safe and poses no health risk to the public.

The WIPP's historical ambient air monitoring data also indicate frequent detection of $^{239+240}$Pu and ^{241}Am in ambient air samples collected around WIPP (**Figures 3.3 and 3.4**). The detection of ^{238}Pu is relatively infrequent because this radionuclide is not primarily from weapons fallout, but was released by the burn-up of nuclear powered satellites such as SNAP-9A (Hardy et al., 1973, Harley 1980). Peaks in $^{239+240}$Pu and ^{241}Am activity concentrations in aerosol samples from the three study sites generally occur from March to June, which is when strong and gusty winds in the area frequently give rise to blowing dust. The observed seasonality in plutonium and americium activity concentrations in the WIPP environment is therefore attributable to the re-suspension of contaminated soil dust. In cases where ^{238}Pu was detected, its activity tended to increase with $^{239+240}$Pu, suggesting that the detected plutonium and americium isotopes are likely being re-suspended by wind and have an atomic-testing and satellite burn-up fallout origin.

Additionally, in the vicinity of WIPP there is a potential local source of anthropogenic radioactivity from an underground nuclear test that was part of the Plowshare project, the Gnome test (USAEC. 1973). The Gnome site is located about 8.8 km southwest of the WIPP site. In 1961 an underground test of a 3.3-kiloton ^{239}Pu device vented radioactive materials to the surface (USAEC. 1973, Faller, 1994) Clean-up efforts at this site have been carried out in several campaigns since that time, and the surface contamination is now well below any level of public health and environmental concern. However, low levels of ^{137}Cs and plutonium are still detectable in some surface soil samples from the Gnome site (CEMRC Annual Report, 2005/2006). The transport of these contaminants from the Gnome site to the WIPP remains a possibility during high wind seasons (Stout and Arimoto, 2010); however, more than fifteen years of monitoring data and the activity levels detected, as well as their atomic ratio measurements, suggest that pre-release-event plutonium and americium in aerosol and soil samples collected near the WIPP facility mainly represent redistributed global fallout.

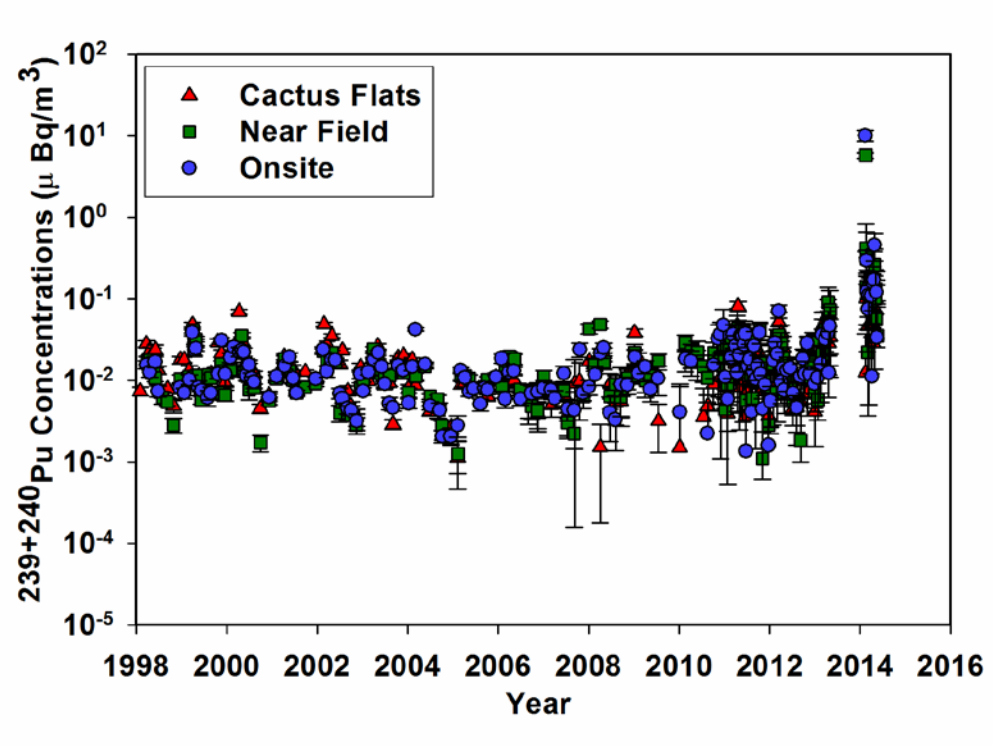


Figure 3.3 The Pre and Post release event $^{239+240}$Pu concentrations in ambient air at three stations in the vicinity of the WIPP site

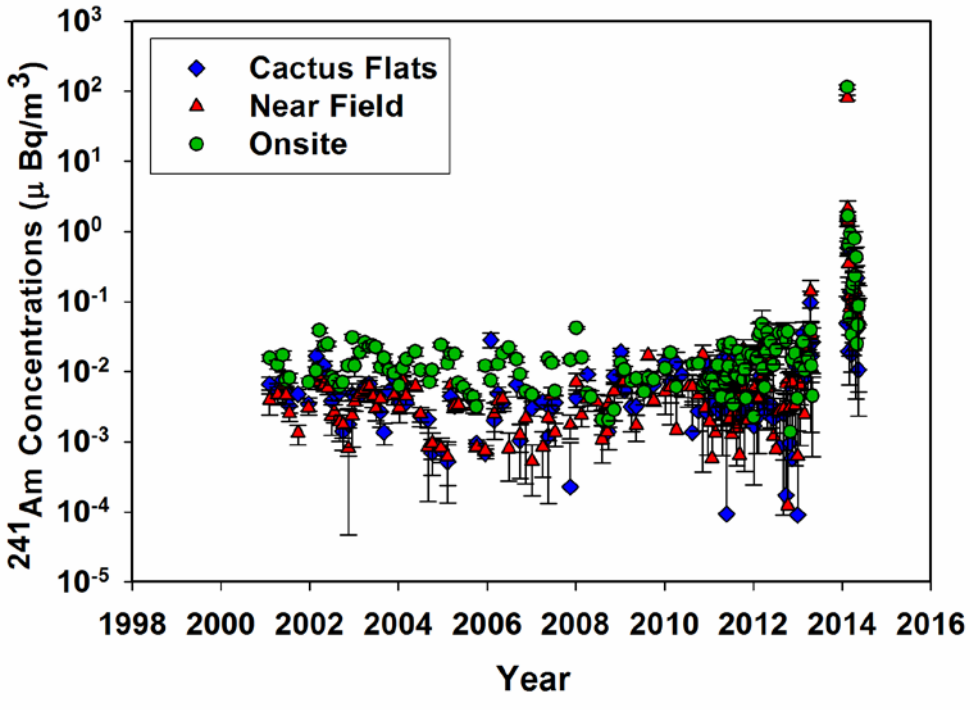


Figure 3.4 The Pre and Post release event ^{241}Am concentrations in ambient air at

three stations in the vicinity of the WIPP site

There were no measurable concentrations of ^{137}Cs or ^{60}Co in any of the air filter samples collected following the radiation release event. However, ^{40}K was detected in a few filter samples. The ^{40}K is ubiquitous in the earth's crust and thus would be expected to show up in environmental air samples. There was no significant difference in the concentrations of ^{40}K among locations. The concentrations of ^{137}Cs and ^{40}K measured in ambient aerosol samples before and after the radiation release event at the WIPP are shown in **Figures 3.5-3.10**.

Additionally, there was no increase in gamma radionuclide concentrations that can be attributed to the February 14, radiation recent release event The individual concentrations of these radionuclides measured in three aerosol stations are listed in **Tables 3.4 to 3.6**.

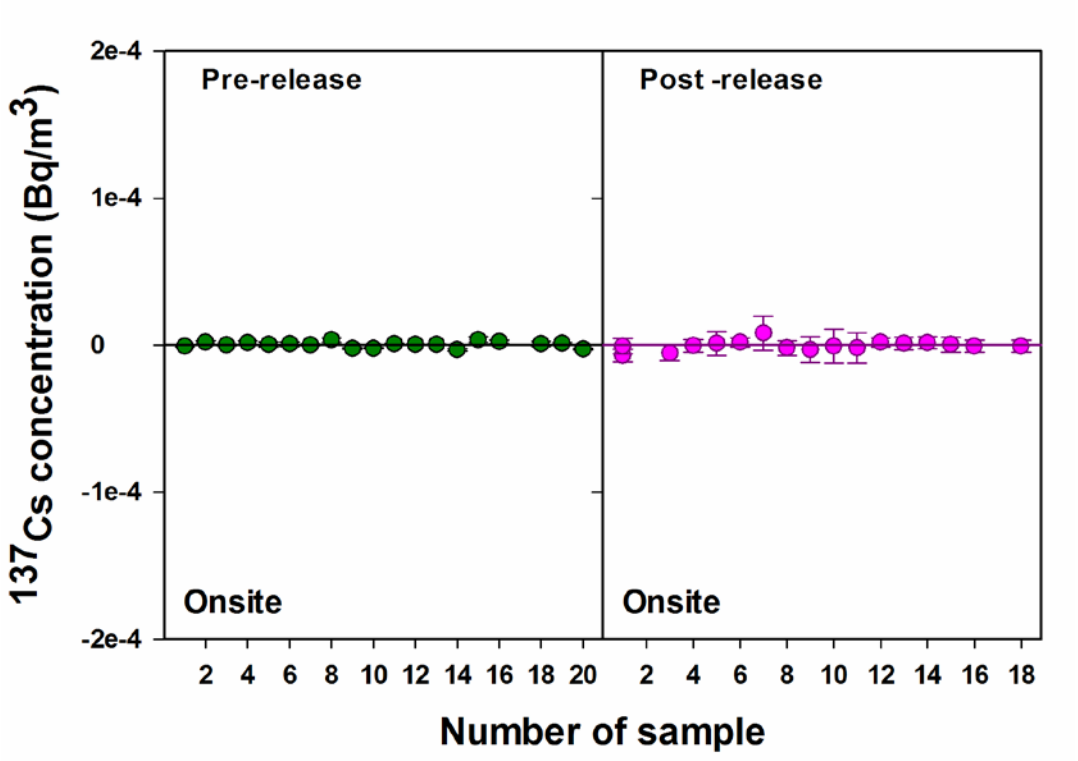


Figure 3.5 The Pre and Post release event ^{137}Cs concentrations in ambient air at Onsite station

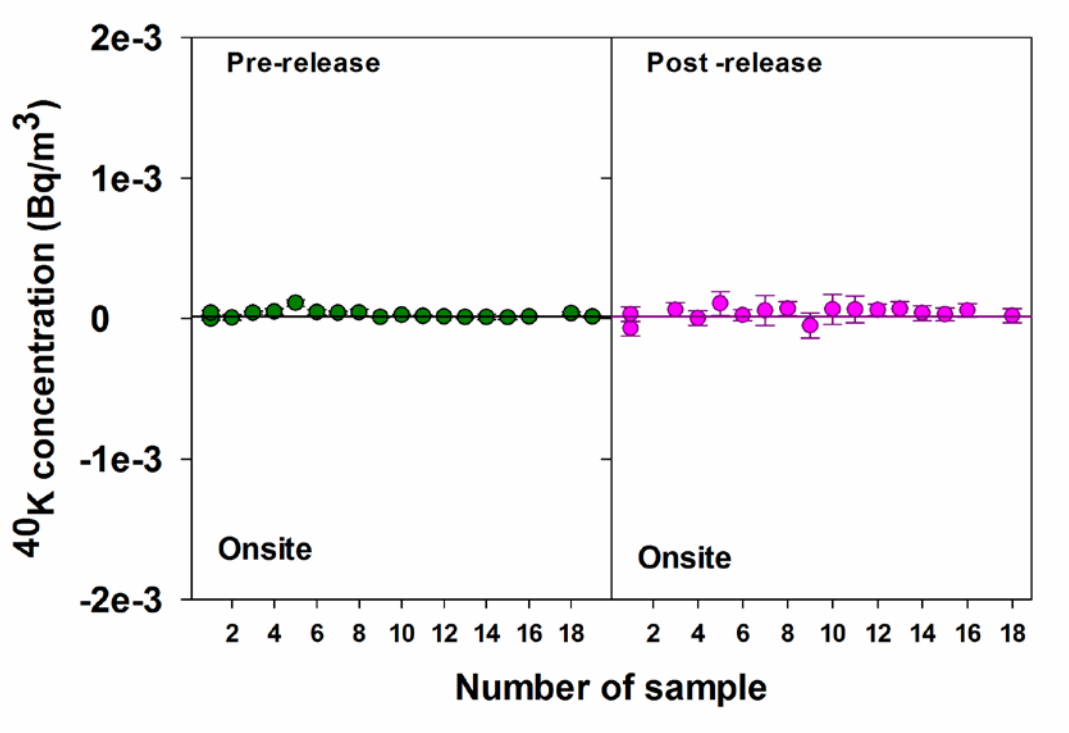


Figure 3.6 The Pre and Post release event ^{40}K concentrations in ambient air at Onsite station

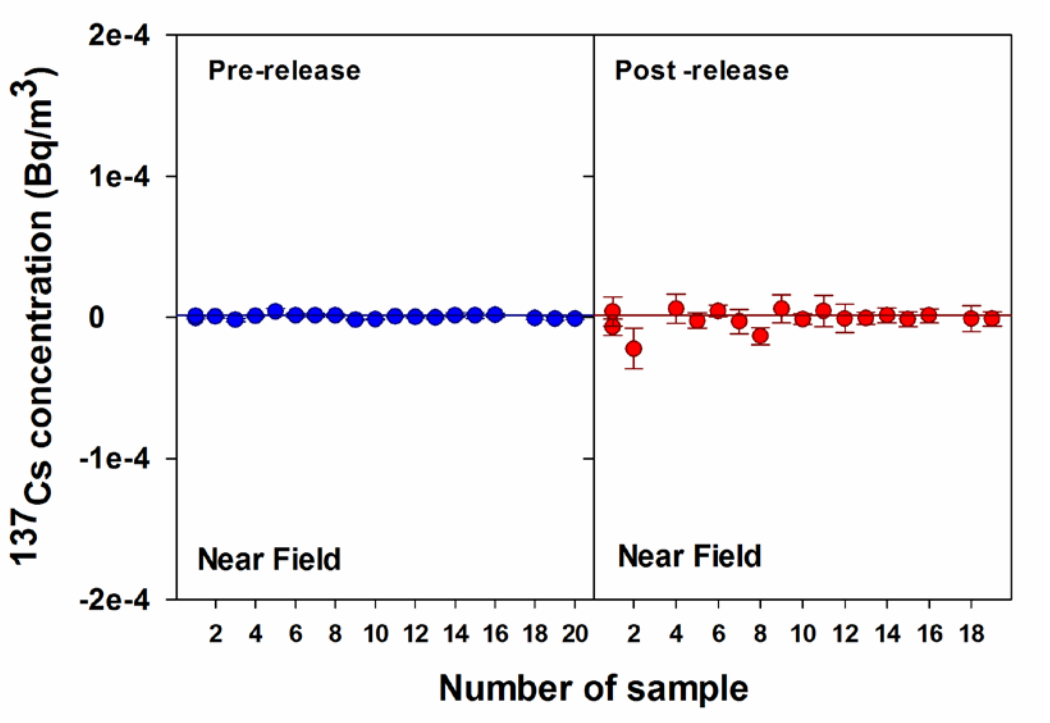


Figure 3.7 The Pre- and Post-release event ^{137}Cs concentrations in ambient air at Near Field station

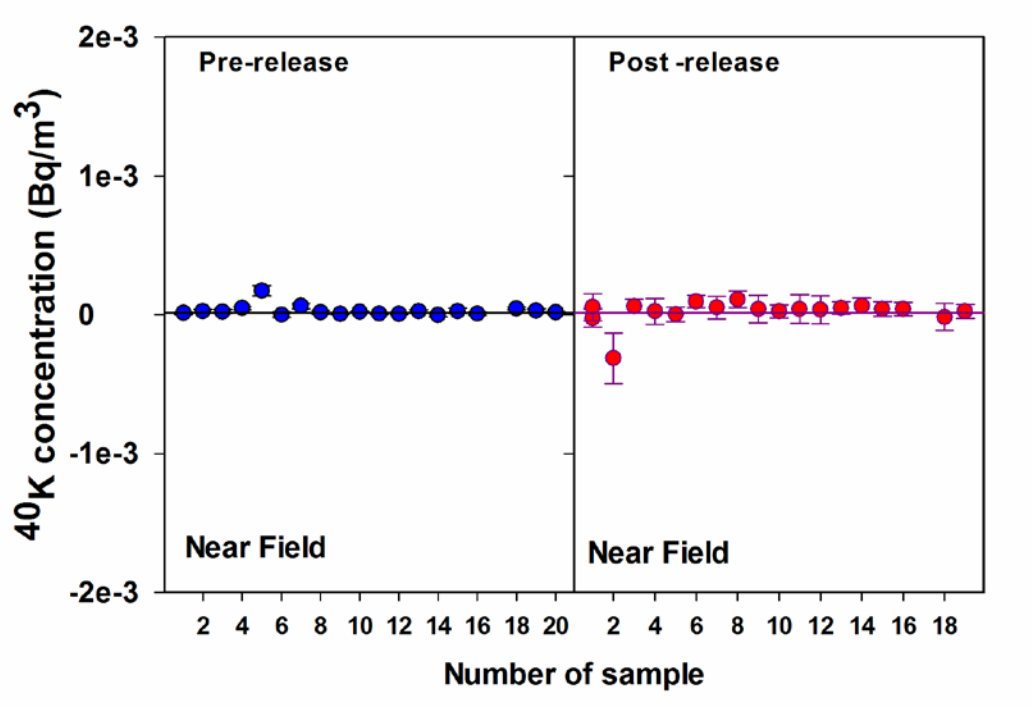


Figure 3.8 The Pre- and Post-release event ^{40}K concentrations in ambient air at Near Field station

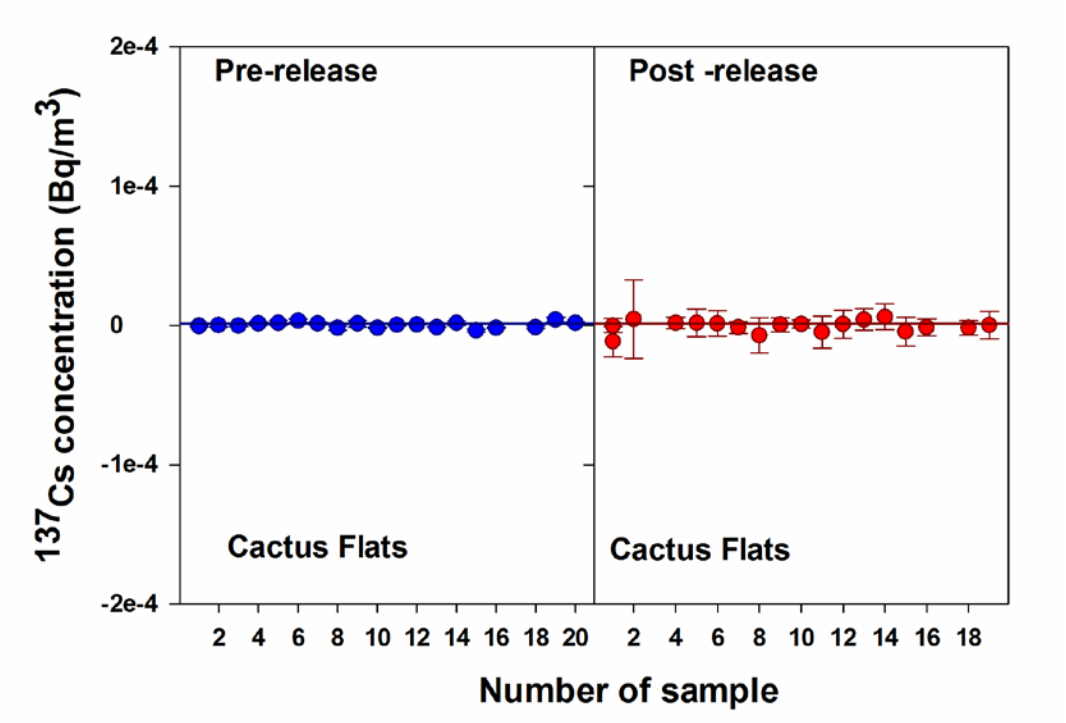


Figure 3.9 The Pre- and Post-release event ^{137}Cs concentrations in ambient air at Cactus Flats station

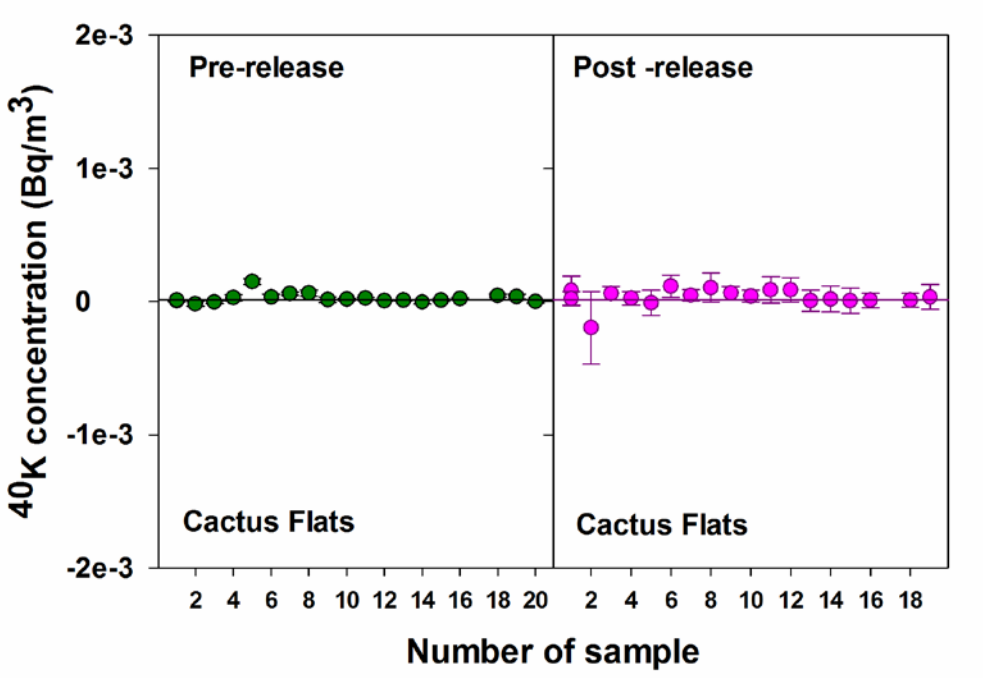


Figure 3.10 The Pre- and Post-release event ^{40}K concentrations in ambient air at Cactus Flats station

Table 3.1 Activity concentrations of ^{241}Am, $^{239+240}$Pu and ^{238}Pu (Bq/m^3), in Onsite station following the February 14 radiological event at WIPP

Radionuclides	Sample Date 2014	Activity Bq/m^3	Unc.(2σ) Bq/m^3	MDC Bq/m^3	Status
^{241}Am	Feb 11 to Feb 18	1.15E-04	6.94E-06	3.37E-08	Detected
	Feb. 18 to Feb. 25	1.66E-06	2.53E-07	4.40E-08	Detected
	Feb. 25 to March 4	6.51E-07	1.54E-07	6.35E-08	Detected
	March 4 to March 11	5.84E-08	5.20E-08	7.17E-08	Not detected
	March 11 to March 21	9.34E-07	2.45E-07	9.42E-08	Detected
	March 21 to March 29	3.35E-08	2.37E-08	1.39E-08	Detected
	March 29 to April 4	1.54E-07	1.02E-07	1.30E-07	Detected
	April 4 to April 11	1.82E-07	9.26E-08	7.83E-08	Detected
	April 11 to April 19	7.86E-07	2.07E-07	9.99E-08	Detected
	April 19 to April 25	2.33E-07	1.73E-07	2.40E-07	Not detected
	April 25 to May 2	4.32E-07	1.68E-07	1.06E-07	Detected
	May 2 to May 9	2.52E-08	9.47E-08	2.63E-07	Not detected
	May 9 to May 16	4.65E-08	5.34E-08	9.07E-08	Not detected
	May 16 to May 23	8.77E-08	8.26E-08	9.10E-08	Not detected
	May 23 to June 6	1.69E-07	7.70E-08	5.27E-08	Detected

Table 3.1 Continued

Radionuclides	Sample Date 2014	Activity. Bq/m^3	Unc.(2σ) Bq/m^3	MDC Bq/m^3	Status
	June 6 to June 13	7.10E-08	1.05E-07	1.97E-07	Not detected
	June 13 to June 20	1.22E-07	1.26E-07	1.85E-07	Not detected
	June 20 to June 27	2.26E-07	1.87E-07	2.52E-07	Not detected
$^{239+240}$Pu	Feb 11 to Feb 18	1.02E-05	1.49E-06	1.03E-07	Detected
	Feb. 18 to Feb. 25	3.01E-07	9.50E-08	3.21E-08	Detected
	Feb. 25 to March 4	1.24E-07	1.01E-07	1.30E-07	Not detected
	March 4 to March 11	7.54E-08	7.17E-08	1.17E-07	Not detected
	March 11 to March 21	1.12E-07	1.07E-07	1.91E-07	Not detected
	March 21 to March 29	0.00E+00	5.42E-08	1.78E-07	Not detected
	March 29 to April 4	1.09E-07	9.72E-08	1.34E-07	Not detected
	April 4 to April 11	1.12E-08	3.88E-08	1.04E-07	Not detected
	April 11 to April 19	1.60E-07	8.87E-08	1.14E-07	Detected
	April 19 to April 25	1.74E-07	2.14E-07	4.03E-07	Not detected
	April 25 to May 2	4.64E-07	1.70E-07	1.00E-07	Detected
	May 2 to May 9	-1.36E-08	7.05E-08	2.01E-07	Not detected
	May 9 to May 16	1.22E-07	9.61E-08	8.93E-08	Detected
	May 16 to May 23	3.39E-08	4.60E-08	7.74E-08	Not detected
	May 23 to June 6	3.45E-08	3.87E-08	6.34E-08	Not detected
	June 6 to June 13	2.71E-08	4.00E-08	7.51E-08	Not detected
	June 13 to June 20	4.30E-08	6.34E-08	1.19E-07	Not detected
	June 20 to June 27	5.45E-08	6.97E-08	1.24E-07	Not detected
^{238}Pu	Feb 11 to Feb 18	3.73E-07	1.83E-07	1.03E-07	Detected
	Feb. 18 to Feb. 25	3.01E-07	9.50E-08	3.21E-08	Detected
	Feb. 25 to March 04	1.24E-07	1.01E-07	1.30E-07	Not detected
	March 4 to March 11	1.26E-08	4.35E-08	1.17E-07	Not detected
	March 11 to March 21	1.60E-08	4.52E-08	1.18E-07	Not detected
	March 21 to March 29	3.85E-08	6.67E-08	1.41E-07	Not detected
	March 29 to April 4	0.00E+00	7.29E-08	2.19E-07	Not detected
	April 4 to April 11	1.12E-08	3.17E-08	8.25E-08	Not detected
	April 11 to April 19	1.90E-08	3.28E-08	6.97E-08	Not detected
	April 19 to April 25	1.74E-07	1.96E-07	3.20E-07	Not detected
	April 25 to May 2	9.53E-08	9.10E-08	1.64E-07	Not detected
	May 2 to May 9	1.22E-07	1.38E-07	2.01E-07	Not detected

Table 3.1 Continued

Radionuclides	Sample Date 2014	Activity. Bq/m^3	Unc.(2σ) Bq/m^3	MDC Bq/m^3	Status
	May 9 to May 16	0.00E+00	3.92E-08	1.40E-07	Not detected
	May 16 to May 23	-1.31E-08	2.86E-08	1.02E-07	Not detected
	May 23 to June 6	-6.89E-09	1.86E-08	6.26E-08	Not detected
	June 6 to June 13	-4.51E-09	2.34E-08	6.70E-08	Not detected
	June 13 to June 20	1.07E-08	3.72E-08	1.06E-07	Not detected
	June 20 to June 27	1.70E-08	5.05E-08	1.33E-07	Not detected

Table 3.2 Activity concentrations of ^{241}Am, $^{239+240}$Pu, and ^{238}Pu (Bq/m^3), in Near Field station following the February 14 radiological event at WIPP

Radionuclides	Sample Date 2014	Activity Bq/m^3	Unc.(2σ) Bq/m^3	MDC Bq/m^3	Status
^{241}Am	Feb. 11 to Feb. 16	8.14E-05	6.61E-06	1.64E-07	Detected
	Feb. 16 to Feb. 18	2.14E-06	6.13E-07	2.52E-07	Detected
	Feb. 18 to Feb. 25	1.45E-06	2.60E-07	5.14E-08	Detected
	Feb. 25 to March 04	3.48E-07	1.27E-07	7.52E-08	Detected
	March 4 to March 11	8.28E-08	6.62E-08	9.62E-08	Not detected
	March 11 to March 21	1.2E-07	6.96E-08	7.93E-08	Detected
	March 21 to March 29	3.68E-08	6.40E-08	1.36E-07	Not detected
	March 29 to April 4	1.06E-07	8.05E-08	9.76E-08	Detected
	April 4 to April 11	1.76E-07	9.55E-08	1.02E-07	Detected
	April 11 to April 19	2.26E-08	4.52E-08	1.05E-07	Not detected
	April 19 to April 25	1.49E-07	1.58E-07	2.77E-07	Not detected
	April 25 to May 2	8.79E-08	8.39E-08	1.51E-07	Not detected
	May 2 to May 9	1.04E-07	7.39E-08	7.17E-08	Detected
	May 9 to May 16	8.75E-08	9.83E-08	1.61E-07	Not detected
	May 16 to May 23	5.69E-08	5.46E-08	7.95E-08	Not detected
	May 23 to June 6	3.82E-08	7.26E-08	1.65E-07	Not detected
	June 6 to June 13	1.00E-07	1.49E-07	2.99E-07	Not detected
	June 13 to June 20	-2.04E-08	7.19E-08	2.26E-07	Not detected
	June 20 to June 27	0.00E+00	7.17E-08	2.56E-07	Not detected
$^{239+240}$Pu	Feb 11 to Feb 16	5.78E-06	4.67E-07	1.77E-07	Detected
	Feb 16 to Feb 18	1.41E-07	2.42E-07	5.14E-07	Not detected
	Feb. 18 to Feb. 25	4.24E-07	2.30E-07	1.84E-07	Detected

Table 3.2 Continued

Radionuclides	Sample Date 2014	Activity Bq/m^3	Unc.(2σ) Bq/m^3	MDC Bq/m^3	Status
	Feb. 25 to March 04	1.17E-07	7.45E-08	7.79E-08	Detected
	March 4 to March 11	2.23E-08	3.88E-08	8.21E-08	Not detected
	March 11 to March 21	1.35E-07	8.77E-08	1.43E-07	Not detected
	March 21 to March 29	8.46E-08	9.50E-08	1.56E-07	Not detected
	March 29 to April 4	1.14E-07	1.40E-07	2.65E-07	Not detected
	April 4 to April 11	1.15E-07	8.08E-08	1.07E-07	Detected
	April 11 to April 19	1.24E-07	7.93E-08	8.27E-08	Detected
	April 19 to April 25	6.29E-08	7.75E-08	1.46E-07	Not detected
	April 25 to May 2	2.64E-07	1.49E-07	1.38E-07	Detected
	May 2 to May 9	1.02E-07	1.15E-07	1.88E-07	Not detected
	May 9 to May 16	5.7E-08	9.14E-08	2.01E-07	Not detected
	May 16 to May 23	3.55E-08	5.17E-08	1.06E-07	Not detected
	May 23 to June 6	5.24E-09	2.78E-08	8.71E-08	Not detected
	June 6 to June 13	2.54E-08	4.41E-08	9.36E-08	Not detected
	June 13 to June 20	1.46E-08	4.14E-08	1.08E-07	Not detected
	June 20 to June 27	5.25E-08	7.21E-08	1.37E-07	Not detected
^{238}Pu	Feb 11 to Feb 16	1.97E-07	1.80E-07	2.08E-07	Not detected
	Feb 16 to Feb 18	3.01E-08	1.42E-07	4.39E-07	Not detected
	Feb. 18 to Feb. 25	4.24E-07	2.30E-07	1.84E-07	Detected
	Feb. 25 to March 04	2.12E-08	4.24E-08	9.84E-08	Not detected
	March 4 to March 11	2.23E-08	3.88E-08	8.21E-08	Not detected
	March 11 to March 21	2.71E-08	5.41E-08	1.27E-07	Not detected
	March 21 to March 29	0.00E+00	8.46E-08	2.54E-07	Not detected
	March 29 to April 4	1.01E-07	8.26E-08	1.06E-07	Not detected
	April 4 to April 11	0.00E+00	3.26E-08	8.47E-08	Not detected
	April 11 to April 19	2.25E-08	3.91E-08	8.27E-08	Not detected
	April 19 to April 25	4.71E-08	6.31E-08	1.16E-07	Not detected
	April 25 to May 2	1.13E-07	1.00E-07	1.38E-07	Not detected
	May 2 to May 9	5.09E-09	5.49E-08	1.84E-07	Not detected
	May 9 to May 16	0.00E+00	6.76E-08	2.04E-07	Not detected
	May 16 to May 23	-6.68E-09	2.55E-08	1.02E-07	Not detected
	May 23 to June 6	2.10E-08	3.79E-08	7.77E-08	Not detected
	June 6 to June 13	-5.10E-09	2.87E-08	1.11E-07	Not detected
	June 13 to June 20	8.77E-09	4.41E-08	1.28E-07	Not detected
	June 20 to June 27	6.99E-09	5.33E-08	1.6E-07	Not detected

Table 3.3 Activity concentrations of ^{241}Am, $^{239+240}Pu$, and ^{238}Pu (Bq/m^3), in Cactus Flats station following the February 14 radiological event at WIPP

Radionuclides	Sample Date 2014	Activity Bq/m^3	Unc.(2σ) Bq/m^3	MDC Bq/m^3	Status
^{241}Am	Feb 11 to Feb 16	4.90E-08	6.91E-08	4.76E-08	Detected
	Feb 16 to Feb 18	1.41E-06	2.54E-07	1.16E-07	Detected
	Feb. 18 to Feb. 25	5.87E-07	1.38E-07	5.73E-08	Detected
	Feb. 25 to March 4	1.95E-08	3.4E-08	7.18E-08	Not detected
	March 4 to March 11	1.11E-07	7.81E-08	1.03E-07	Detected
	March 11 to March 21	1.37E-07	8.71E-08	1.06E-07	Detected
	March 21 to March 29	1.77E-08	4.34E-08	1.06E-07	Detected
	March 29 to April 4	6.07E-08	7.47E-08	1.41E-07	Not detected
	April 4 to April 11	9.21E-08	7.52E-08	9.69E-08	Not detected
	April 11 to April 19	1.28E-07	8.28E-08	1.19E-07	Detected
	April 19 to April 25	6.00E-08	2.09E-07	5.57E-07	Not detected
	April 25 to May 2	3.99E-08	5.34E-08	9.79E-08	Not detected
	May 2 to May 9	2.19E-07	1.08E-07	6.15E-08	Detected
	May 9 to May 16	4.28E-08	6.32E-08	1.19E-07	Not detected
	May 16 to May 23	1.06E-08	3.66E-08	1.04E-07	Not detected
	May 23 to June 6	3.96E-08	4.46E-08	6.52E-08	Not detected
	June 6 to June 13	6.25E-08	8.36E-08	1.53E-07	Not detected
	June 13 to June 20	0.00E+00	5.76E-08	2.04E-07	Not detected
	June 20 to June 27	1.03E-07	1.23E-07	2.02E-07	Not detected
$^{239+240}Pu$	Feb 11 to Feb 16	1.25E-08	2.47E-08	1.04E-07	Not detected
	Feb 16 to Feb 18	3.57E-07	4.77E-07	8.82E-07	Not detected
	Feb. 18 to Feb. 25	1.01E-07	5.24E-08	3.18E-08	Not detected
	Feb. 25 to March 4	-1.05E-08	3.63E-08	1.26E-07	Not detected
	March 4 to March 11	4.71E-08	5.31E-08	8.68E-08	Not detected
	March 11 to March 21	1.69E-07	9.37E-08	1.32E-07	Detected
	March 21 to March 29	0.00E+00	5.55E-08	1.44E-07	Not detected
	March 29 to April 4	5.24E-08	7.01E-08	1.28E-07	Not detected
	April 4 to April 11	0.00E+00	3.35E-08	1.1E-07	Not detected
	April 11 to April 19	5.00E-08	5.32E-08	9.28E-08	Not detected
	April 19 to April 25	2.87E-08	1.28E-07	3.44E-07	Not detected
	April 25 to May 2	1.03E-07	8.94E-08	1.37E-07	Not detected
	May 2 to May 9	1.04E-07	1.25E-07	2.03E-07	Not detected
	May 9 to May 16	7.32E-08	9.82E-08	1.79E-07	Not detected

Table 3.3 Continued

Radionuclides	Sample Date 2014	Activity Bq/m^3	Unc.(2σ) Bq/m^3	MDC Bq/m^3	Status
	May 16 to May 23	3.69E-08	5.9E-08	1.24E-07	Not detected
	May 23 to June 6	-2.85E-09	1.48E-08	4.21E-08	Not detected
	June 6 to June 13	2.77E-08	4.08E-08	7.68E-08	Not detected
	June 13 to June 20	3.54E-08	5.23E-08	9.82E-08	Not detected
	June 20 to June 27	1.68E-08	4.12E-08	1.02E-07	Not detected
^{238}Pu	Feb 11 to Feb 16	-8.34E-09	8.57E-08	1.73E-07	Not detected
	Feb 16 to Feb 18	1.89E-07	3.35E-07	6.73E-07	Not detected
	Feb. 18 to Feb. 25	-3.83E-09	1.47E-08	5.85E-08	Not detected
	Feb. 25 to March 4	1.05E-08	3.63E-08	9.73E-08	Not detected
	March 4 to March 11	0.00E+00	3.33E-08	1.10E-07	Not detected
	March 11 to March 21	9.35E-08	6.30E-08	6.89E-08	Detected
	March 21 to March 29	1.96E-08	5.55E-08	1.44E-07	Not detected
	March 29 to April 4	8.41E-08	1.08E-07	1.31E-07	Not detected
	April 4 to April 11	3.56E-08	4.76E-08	8.74E-08	Not detected
	April 11 to April 19	9.99E-09	3.47E-08	9.28E-08	Not detected
	April 19 to April 25	2.87E-08	8.11E-08	2.11E-07	Not detected
	April 25 to May 2	7.38E-08	7.86E-08	1.37E-07	Not detected
	May 2 to May 9	1.84E-08	6.36E-08	1.82E-07	Not detected
	May 9 to May 16	7.32E-08	1.00E-07	1.90E-07	Not detected
	May 16 to May 23	2.84E-09	3.06E-08	1.03E-07	Not detected
	May 23 to June 6	0.00E+00	1.55E-08	5.55E-08	Not detected
	June 6 to June 13	2.31E-09	2.48E-08	8.39E-08	Not detected
	June 13 to June 20	1.76E-08	4.34E-08	1.07E-07	Not detected
	June 20 to June 27	-1.40E-08	3.07E-08	1.09E-07	Not detected

Table 3.4 Activity concentrations of ^{137}Cs, ^{60}Co and ^{40}K (Bq/m^3), in Onsite station following the February 14 radiological event at WIPP

Radionuclides	Sampling Date 2014	Activity Bq/m^3	Unc.(2σ) Bq/m^3	MDC Bq/m^3	Status
^{137}Cs	Feb 11 to Feb 18	-6.88E-06	4.20E-06	1.38E-03	Not detected
	Feb. 18 to Feb. 25	-	-	-	-
	Feb. 25 to March 04	-5.18E-06	5.23E-06	1.66E-03	Not detected
	March 04 to March 11	-2.01E-07	4.16E-06	1.28E-03	Not detected
	March 11 to March 21	1.28E-06	8.29E-06	3.17E-03	Not detected

Table 3.4 Continued

Radionuclides	Sampling Date 2014	Activity Bq/m^3	Unc.(2σ) Bq/m^3	MDC Bq/m^3	Status
	March 21 to March 29	2.15E-06	3.26E-06	1.24E-03	Not detected
	March 29 to April 4	8.24E-06	1.17E-05	3.01E-03	Not detected
	April 04 to April 11	-1.78E-06	5.20E-06	1.68E-03	Not detected
	April 11 to April 19	-2.85E-06	8.73E-06	3.20E-03	Not detected
	April 19 to April 25	-5.08E-07	1.14E-05	3.17E-03	Not detected
	April 25 to May 2	-1.61E-06	1.01E-05	3.23E-03	Not detected
	May 2 to May 9	2.13E-06	3.24E-06	1.03E-03	Not detected
	May 9 to May 16	1.28E-06	4.16E-06	1.31E-03	Not detected
	May 16 to May 23	1.97E-06	4.07E-06	1.30E-03	Not detected
	May 23 to June 6	5.03E-07	4.97E-06	3.19E-03	Not detected
	June 6 to June 13	-4.47E-07	4.07E-06	1.31E-03	Not detected
	June 13 to June 20	-3.51E-07	5.22E-06	1.68E-03	Not detected
	June 20 to June 27	-4.75E-07	3.96E-06	1.28E-03	Not detected
^{60}Co	Feb 11 to Feb 18	-5.22E-06	4.37E-06	7.66E-06	Not detected
	Feb. 18 to Feb. 25	-	-	-	Not detected
	Feb. 25 to March 04	-1.82E-06	4.28E-06	7.38E-06	Not detected
	March 04 to March 11	-8.72E-07	4.25E-06	7.31E-06	Not detected
	March 11 to March 21	-3.06E-07	7.62E-06	1.31E-05	Not detected
	March 21 to March 29	-2.88E-06	3.52E-06	6.13E-06	Not detected
	March 29 to April 4	-1.66E-06	1.14E-05	1.96E-05	Not detected
	April 04 to April 11	-7.76E-07	4.21E-06	7.24E-06	Not detected
	April 11 to April 19	-1.19E-05	8.84E-06	1.56E-05	Not detected
	April 19 to April 25	-1.05E-06	1.06E-05	1.83E-05	Not detected
	April 25 to May 2	-1.03E-05	9.91E-06	1.74E-05	Not detected
	May 2 to May 9	-3.42E-08	3.25E-06	5.53E-06	Not detected
	May 9 to May 16	-5.56E-06	4.25E-06	7.48E-06	Not detected
	May 16 to May 23	-6.48E-08	4.35E-06	7.45E-06	Not detected
	May 23 to June 6	-4.46E-06	4.74E-06	8.31E-06	Not detected
	June 6 to June 13	-2.23E-06	4.07E-06	7.06E-06	Not detected
	June 13 to June 20	2.02E-06	4.07E-06	6.87E-06	Not detected
	June 20 to June 27	-2.48E-06	4.12E-06	7.15E-06	Not detected
^{40}K	Feb 11 to Feb 18	-6.98E-05	5.15E-05	9.04E-05	Not detected
	Feb. 18 to Feb. 25	-	-	-	-

Table 3.4 Continued

Radionuclides	Sampling Date 2014	Activity Bq/m^3	Unc.(2σ) Bq/m^3	MDC Bq/m^3	Status
	Feb. 25 to March 04	6.22E-05	5.06E-05	8.35E-05	Not detected
	March 04 to March 11	2.68E-06	5.18E-05	8.85E-05	Not detected
	March 11 to March 21	1.08E-04	8.49E-05	1.40E-04	Not detected
	March 21 to March 29	2.50E-05	4.10E-05	6.92E-05	Not detected
	March 29 to April 4	5.75E-05	1.08E-04	1.83E-04	Not detected
	April 04 to April 11	7.18E-05	5.16E-05	8.46E-05	Not detected
	April 11 to April 19	-4.99E-05	9.05E-05	1.58E-04	Not detected
	April 19 to April 25	6.65E-05	1.08E-04	1.82E-04	Not detected
	April 25 to May 2	6.59E-05	9.36E-05	1.58E-04	Not detected
	May 2 to May 9	6.18E-05	3.98E-05	6.60E-05	Not detected
	May 9 to May 16	6.85E-05	5.15E-05	8.54E-05	Detected
	May 16 to May 23	3.85E-05	5.36E-05	9.02E-05	Not detected
	May 23 to June 6	3.07E-05	4.54E-05	7.66E-05	Not detected
	June 6 to June 13	5.86E-05	4.87E-05	8.11E-05	Not detected
	June 13 to June 20	3.19E-05	5.16E-05	8.69E-05	Not detected
	June20 to June 27	1.99E-05	4.93E-05	8.35E-05	Not detected

Table 3.5 Activity concentrations of ^{137}Cs, ^{60}Co and ^{40}K (Bq/m^3), in Near Field station following the February 14 radiological event at WIPP

Radionuclides	Sampling Date 2014	Activity Bq/m^3	Unc.(2σ) Bq/m^3	MDC Bq/m^3	Status
^{137}Cs	Feb 11 to Feb 16	-6.88E-06	5.74E-06	1.30E-03	Not detected
	Feb 16 to Feb 18	-2.21E-05	1.44E-05	1.38E-03	Not detected
	Feb. 18 to Feb. 25	-	-	-	-
	Feb. 25 to March 04	6.25E-06	1.04E-05	3.24E-03	Not detected
	March 04 to March 11	-2.34E-06	5.39E-06	1.68E-03	Not detected
	March 11 to March 21	4.63E-06	4.12E-06	1.60E-03	Not detected
	March 21 to March 29	-2.94E-06	8.64E-06	3.30E-03	Not detected
	March 29 to April 4	-1.32E-05	6.16E-06	1.63E-03	Not detected
	April 04 to April 11	6.27E-06	9.81E-06	3.11E-03	Not detected
	April 11 to April 19	-1.18E-06	3.71E-06	1.34E-03	Not detected
	April 19 to April 25	4.63E-06	1.12E-05	3.09E-03	Not detected
	April 25 to May 2	-7.31E-07	1.01E-05	3.15E-03	Not detected
	May 2 to May 9	-5.31E-07	4.35E-06	1.34E-03	Not detected
	May 9 to May 16	1.52E-06	5.31E-06	1.61E-03	Not detected

Table 3.5 Continued

Radionuclides	Sampling Date 2014	Activity Bq/m^3	Unc.(2σ) Bq/m^3	MDC Bq/m^3	Status
	May 16 to May 23	-1.31E-06	5.28E-06	1.67E-03	Not detected
	May 23 to June 6	1.32E-06	4.85E-06	1.66E-03	Not detected
	June 6 to June 13	4.28E-06	1.03E-05	3.12E-03	Not detected
	June 13 to June 20	-8.57E-07	8.97E-06	2.80E-03	Not detected
	June 20 to June 27	-9.71E-07	5.19E-06	1.65E-03	Not detected
^{60}Co	Feb 11 to Feb 16	-3.99E-06	5.43E-06	9.33E-06	Not detected
	Feb 16 to Feb 18	-4.38E-06	1.37E-05	2.36E-05	Not detected
	Feb. 18 to Feb. 25	-	-	-	-
	Feb. 25 to March 04	5.79E-07	8.92E-06	1.53E-05	Not detected
	March 04 to March 11	-1.26E-06	4.31E-06	7.42E-06	Not detected
	March 11 to March 21	-6.09E-07	3.38E-06	5.81E-06	Not detected
	March 21 to March 29	-4.14E-06	8.09E-06	1.40E-05	Not detected
	March 29 to April 4	1.31E-06	4.85E-06	8.25E-06	Not detected
	April 04 to April 11	-4.99E-06	1.00E-05	1.74E-05	Not detected
	April 11 to April 19	-1.33E-06	3.67E-06	6.34E-06	Not detected
	April 19 to April 25	-3.92E-06	1.10E-05	1.91E-05	Not detected
	April 25 to May 2	-3.74E-06	9.56E-06	1.66E-05	Not detected
	May 2 to May 9	-1.38E-06	3.61E-06	6.16E-06	Not detected
	May 9 to May 16	3.62E-06	4.06E-06	6.79E-06	Not detected
	May 16 to May 23	9.70E-07	4.31E-06	7.34E-06	Not detected
	May 23 to June 6	4.51E-07	3.92E-06	6.69E-06	Not detected
	June 6 to June 13	3.27E-06	9.20E-06	1.56E-05	Not detected
	June 13 to June 20	-6.55E-06	9.81E-06	1.71E-05	Not detected
	June 20 to June 27	-9.71E-07	5.19E-06	8.85E-06	Not detected
^{40}K	Feb 11 to Feb 16	-2.31E-05	6.67E-05	1.14E-04	Not detected
	Feb 16 to Feb 18	-3.14E-04	1.84E-04	3.24E-04	Not detected
	Feb. 18 to Feb. 25	-	-	-	-
	Feb. 25 to March 04	2.47E-05	9.43E-05	1.61E-04	Not detected
	March 04 to March 11	5.01E-06	5.24E-05	8.94E-05	Not detected
	March 11 to March 21	9.62E-05	4.49E-05	7.11E-05	Detected
	March 21 to March 29	5.30E-05	8.07E-05	1.36E-04	Not detected
	March 29 to April 4	1.12E-04	6.09E-05	9.78E-05	Detected
	April 04 to April 11	4.17E-05	9.87E-05	1.68E-04	Not detected

Table 3.5 Continued

Radionuclides	Sampling Date 2014	Activity Bq/m^3	Unc.(2σ) Bq/m^3	MDC Bq/m^3	Status
	April 11 to April 19	2.48E-05	4.57E-05	7.72E-05	Not detected
	April 19 to April 25	4.24E-05	1.02E-04	1.73E-04	Not detected
	April 25 to May 2	3.69E-05	1.01E-04	1.71E-04	Not detected
	May 2 to May 9	5.06E-05	4.40E-05	7.30E-05	Not detected
	May 9 to May 16	6.66E-05	5.43E-05	8.95E-05	Not detected
	May 16 to May 23	4.31E-05	5.28E-05	8.84E-05	Not detected
	May 23 to June 6	4.32E-05	4.88E-05	8.14E-05	Not detected
	June 6 to June 13	5.60E-05	9.67E-05	1.63E-04	Not detected
	June 13 to June 20	-1.47E-05	9.69E-05	1.67E-04	Not detected
	June 20 to June 27	2.53E-05	5.11E-05	8.64E-05	Not detected

Table 3.6 Activity concentrations of ^{137}Cs, ^{60}Co and ^{40}K (Bq/m^3), in Cactus Flats station following the February 14 radiological event at WIPP

Radionuclides	Sampling Date 2014	Activity Bq/m^3	Unc.(2σ) Bq/m^3	MDC Bq/m^3	Status
^{137}Cs	Feb 11 to Feb 16	-1.15E-05	1.08E-05	3.44E-03	Not detected
	Feb 16 to Feb 18	4.65E-06	2.82E-05	2.64E-03	Not detected
	Feb. 18 to Feb. 25	-	-	-	-
	Feb. 25 to March 04	1.94E-06	4.01E-06	1.28E-03	Not detected
	March 4 to March 11	1.81E-06	9.88E-06	3.08E-03	Not detected
	March 11 to March 21	1.53E-06	9.11E-06	3.26E-03	Not detected
	March 21 to March 29	-1.37E-06	4.31E-06	1.63E-03	Not detected
	March 29 to April 4	-7.10E-06	1.26E-05	3.40E-03	Not detected
	April 4 to April 11	6.85E-07	5.03E-06	1.61E-03	Not detected
	April 11 to April 19	1.14E-06	2.81E-06	1.02E-03	Not detected
	April 19 to April 25	-4.73E-06	1.14E-05	3.19E-03	Not detected
	April 25 to May 2	9.58E-07	1.01E-05	3.24E-03	Not detected
	May 2 to May 9	4.30E-06	7.79E-06	2.47E-03	Not detected
	May 9 to May 16	6.31E-06	9.38E-06	2.99E-03	Not detected
	May 16 to May 23	-4.36E-06	1.02E-05	3.30E-04	Not detected
	May 23 to June 6	-1.07E-06	6.00E-06	3.17E-03	Not detected
	June 6 to June 13	4.16E-08	5.13E-06	1.64E-03	Not detected
	June 13 to June 20	-1.69E-06	5.15E-06	1.68E-03	Not detected
	June 20 to June 27	2.51E-07	1.00E-05	3.19E-03	Not detected

Table 3.6 Continued

Radionuclides	Sampling Date 2014	Activity Bq/m^3	Unc.(2σ) Bq/m^3	MDC Bq/m^3	Status
^{60}Co	Feb 11 to Feb 16	2.06E-06	8.78E-06	1.48E-05	Not detected
	Feb 16 to Feb 18	-8.83E-07	1.87E-05	3.21E-05	Not detected
	Feb. 18 to Feb. 25	-	-	-	-
	Feb. 25 to March 04	-3.51E-07	4.02E-06	6.91E-06	Not detected
	March 4 to March 11	-1.85E-06	9.40E-06	1.62E-05	Not detected
	March 11 to March 21	-3.25E-06	8.40E-06	1.46E-05	Not detected
	March 21 to March 29	5.10E-07	3.42E-06	5.83E-06	Not detected
	March 29 to April 4	-5.03E-06	1.14E-05	1.97E-05	Not detected
	April 4 to April 11	-4.51E-06	4.44E-06	7.74E-06	Not detected
	April 11 to April 19	-7.73E-07	3.82E-06	6.56E-06	Not detected
	April 19 to April 25	-6.95E-06	1.09E-05	1.89E-05	Not detected
	April 25 to May 2	-5.22E-06	9.30E-06	1.62E-05	Not detected
	May 2 to May 9	-3.33E-06	7.52E-06	1.29E-05	Not detected
	May 9 to May 16	-4.53E-07	9.26E-06	1.59E-05	Not detected
	May 16 to May 23	-6.37E-06	9.84E-06	1.72E-05	Not detected
	May 23 to June 6	-2.14E-06	5.73E-06	9.93E-06	Not detected
	June 6 to June 13	-1.48E-06	4.18E-06	7.21E-06	Not detected
	June 13 to June 20	-1.69E-06	5.15E-06	8.80E-06	Not detected
	June 20 to June 27	2.51E-07	1.00E-05	1.71E-05	Not detected
^{40}K	Feb 11 to Feb 16	8.37E-05	1.08E-04	1.81E-04	Not detected
	Feb 16 to Feb 18	-1.97E-04	2.74E-04	4.72E-04	Not detected
	Feb. 18 to Feb. 25	-	-	-	-
	Feb. 25 to March 04	2.53E-05	4.90E-05	8.29E-05	Not detected
	March 4 to March 11	-7.58E-06	9.56E-05	1.65E-04	Not detected
	March 11 to March 21	1.15E-04	8.37E-05	1.37E-04	Not detected
	March 21 to March 29	4.72E-05	4.25E-05	7.04E-05	Not detected
	March 29 to April 4	1.06E-04	1.09E-04	1.81E-04	Not detected
	April 4 to April 11	6.69E-05	4.87E-05	7.98E-05	Not detected
	April 11 to April 19	4.25E-05	4.42E-05	7.35E-05	Not detected
	April 19 to April 25	8.92E-05	9.99E-05	1.67E-04	Not detected
	April 25 to May 2	8.75E-05	9.17E-05	1.53E-04	Not detected
	May 2 to May 9	8.04E-06	7.82E-05	4.47E-05	Not detected
	May 9 to May 16	2.01E-05	9.72E-05	1.66E-04	Not detected
	May 16 to May 23	6.38E-06	9.62E-05	1.65E-04	Not detected

Table 3.6 Continued

Radionuclides	Sampling Date 2014	Activity Bq/m^3	Unc.(2σ) Bq/m^3	MDC Bq/m^3	Status
	May 23 to June 6	1.06E-05	5.49E-05	9.40E-05	Not detected
	June 6 to June 13	2.27E-05	5.12E-05	8.66E-05	Not detected
	June 13 to June 20	1.10E-05	5.20E-05	8.85E-05	Not detected
	June 20 to June 27	3.56E-05	9.38E-05	1.60E-04	Not detected

SECTION 4

Soil Monitoring

Soil is weathered material, mainly composed of disintegrated rock and organic material that sustains growing plants. Soil can contain pollutants originally released directly to the ground, to the air, or through liquid effluents. The U.S. Department of Energy (DOE) guidance for environmental monitoring states that soil should be sampled to determine if there is a measurable, long-term buildup of radionuclides in the terrestrial environment and to estimate environmental radionuclide inventories (U.S. DOE 1991).

Soil monitoring are of high interest to the CEMRC environmental monitoring program because aerosol releases of contaminants would eventually be deposited in surface soils, which then can serve as a source for continuing contaminant exposure and uptake via direct contact, food chain pathways, and re-suspension. From these perspectives, soil is an integrating medium of primary concern in predictive ecosystem and contaminant transport modeling that requires good information about the dispersion of analytes of concern across the landscape. The source of transuranic radionuclides in soils are mainly because of integrated global fallout from the testing of above-ground nuclear devices, such as ^{238}Pu injected into the stratosphere by the burn-up of a failed radioactive thermal generator in 1964 (Krey, 1967), a release at the Gnome Site, and the regional fallout from the above-ground testing at the Nevada Test Site (NTS) or Nevada National Security Site (NNSS) as it is known today. Each of these sources has characteristic radionuclide signatures and /or abundances that can, in principle, be used to identify their presence in the soils and to estimate their concentrations. In order to determine if such a signature exists for the WIPP, routine soil sampling occurs at locations near the WIPP site.

Since 1998, surface soil sampling near the WIPP site has been part of a continuing CEMRC monitoring program designed to measure any changes in environmental levels of radioactivity and to evaluate any increase in radioactivity that might have resulted from WIPP operations. These samples have been analyzed for transuranic actinides and gamma-emitting radionuclides. Following the radiation release event at WIPP, several soil samples were collected from within a 10-mile radius of WIPP to assess the regional impact of the February 14 radiation release event to the local environment, if any.

Sample Collection

Soil samples at the depth of (0-2 cm) were collected at random short distances and orientations from the 'Near Field' location about 1 km from the WIPP site following the release event. The sampling location of soil is shown in **Figure 4.1**. Individual sampling sites were selected on the basis of relatively flat topography, minimum surface erosion, and

minimum surface disturbance by human or livestock activity. Approximately 4L of soil were collected from within a 50×50 cm area for radionuclide analyses. As shown in **Figure 4.2**, soil samples were excavated using a trowel and placed in plastic bags for transport and storage. Sampling equipment was cleaned and surveyed for radiological contamination between samples. Samples were sieved through a 1 mm mesh screen to remove rocks, roots, and other large material. The soil samples were then grounded with a ball mill and homogenized by mixing.

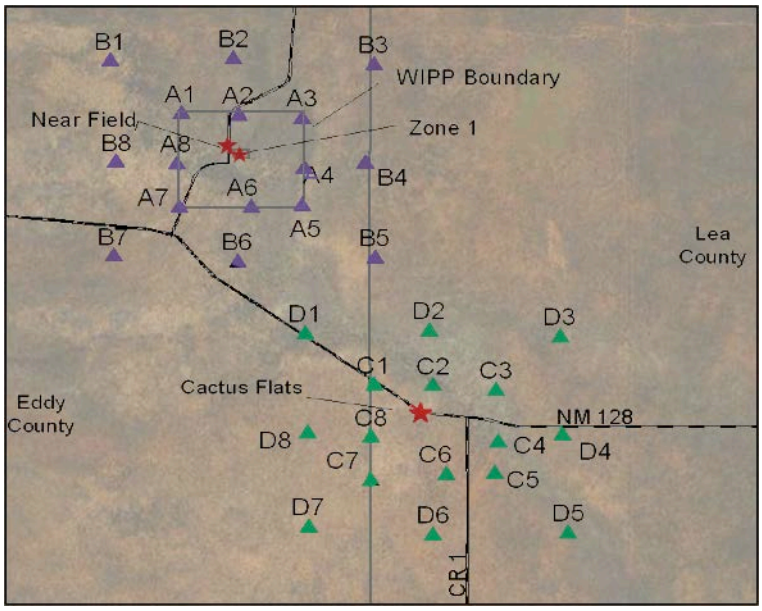


Figure 4.1 Soil Sampling locations in the vicinity of the WIPP Site

Figure 4.2 Soil Sampling in the vicinity of the WIPP site by CEMRC Personnel

Sample Preparation

Soil samples were dried at 110°C and blended prior to sampling. For actinides analyses, 10g of sample were heated in a muffle furnace at 500°C for at least 6 hours to combust organic material. Each sample was then spiked with a radioactive trace and digested in a Teflon beaker with 30 ml of HCl, 10 ml of HNO_3 and 40 ml of HF. Sea sand was used as a matrix for Laboratory Control Standard (LCS) and reagent blank. The samples were heated at 250°C for at least 2 hours; longer heating does no harm. After digestion is complete, the samples were evaporated to dryness and 40 ml of $HClO_4$ was added and evaporated to complete dryness. This step was repeated once more with 30 ml of $HClO_4$. Then 20 ml of HF were added and evaporated to dryness. To each beaker 80 ml of 8M HNO_3, 1.5 g of H_3BO_3 and 0.5 ml of 30% H_2O_2 were added, covered with a watch glass and heated to boiling for 30 minutes. After cooling, samples were transferred to a 50 ml centrifuge tube and centrifuged at 3600 rpm for 10 minutes. The leachate was filtered through a 0.45 micron filter and transferred to a 250 ml beaker.

Determination of Individual Radionuclides

The oxidation state of Pu was adjusted by adding 1 ml of 1.0M NH_4I with a 10 min wait step, followed by 2 ml of $NaNO_2$. The sample solutions were then ready for the purification procedure with anion exchange and by extraction chromatography. Next Pu was separated from Am and U using an anion exchange column. U was separated from Am on TRU and the Am subsequently purified from lanthanides with TEVA as shown in **Figure 4.3.** Finally, Pu, Am and U were micro co-precipitated on stainless steel discs for alpha spectrometry (Canberra). The soil samples were counted for 24 hours, so that results can be made immediately available to the public and other interested parties and also for five days as per CEMRC's standard counting protocol.

The samples for gamma analysis were sealed in a 300-mL paint-can and stored for a few days to allow radon progeny to reach equilibrium with parent radionuclides before counting. Dried and sieved soil samples were counted for 48 hours in a high purity germanium detector, HpGe (Canberra).

Data Reporting

The activities of the actinides and gamma radionuclides in the soil samples are reported as *activity concentration* in Bq/kg. The *Activity concentration* is calculated as the activity of radionuclides detected in Becquerel (Bq) divided by the weight of the soil in kilograms (kg).

Results and Discussion

The ^{238}Pu, $^{239+240}$Pu, ^{241}Am and gamma radionuclides ^{40}K, ^{137}Cs and ^{60}Co were analyzed for all the soil samples. The individual concentrations of these radionuclides collected from the Near Field grid are presented in **Tables 4.1 (A and B) and 4.2**. The $^{239+240}$Pu concentrations in the Near Field ranged from 0.032 to 0.28 Bq/kg, with a mean value of 0.012 Bq/kg, while that for ^{241}Am ranged from 0.048 to 0.14 Bq/kg, with a mean value of 0.082 Bq/kg. All detected concentration of $^{239+240}$Pu, ^{238}Pu, and ^{241}Am were extremely low and were relatively close to the respective MDCs. The concentrations of these nuclides are comparable to our historical data recorded for these areas prior to arrival of TRU wastes in the WIPP and are typical "background soil" values.

The range of $^{239+240}$Pu concentrations (0.032-0.28 Bq/kg) fell within the range reported by Kenney et al., 1995 at the WIPP site (0-0.74 Bq/kg). These values are lower than those measured at Hueston Woods and Urbana, Ohio (0.7-1.0 Bq/kg) (Alberts et al., 1980) and between Ft. Collins and Colorado Springs, Colorado (0.6-1.7 Bq/kg) (Hodge et al., 1996). These results demonstrate that significant variability in background levels of soil contaminants and constituents can occur in areas having relatively low variability in soil texture. The high correlations of the radionuclides and many of the non-radioactive metals to the percentages of silt and clay in the soil explain much of the between-sample variability. The background concentrations of ^{137}Cs, $^{239+240}$Pu and ^{241}Am (Bq/kg) in surface soil around the WIPP site are summarized in **Table 4.3**.

The ^{137}Cs was detected in all soil samples (**Table 4.2**). The activity concentration of ^{137}Cs in the Near Field surface soil ranged from 0.00 to 3.89 Bq/kg, with a mean value of 1.90 Bq/kg. Variability among the ^{137}Cs concentrations was not very significant. Although ^{137}Cs is a fission product, it is ubiquitous in soils because of global fallout from atmospheric weapons testing (Beck and Bennett, 2002 and UNSCEAR, 2000). Like, ^{137}Cs, the ^{40}K was detected in every sample (**Table 4.2**). This naturally occurring gamma-emitting radionuclide is ubiquitous in soils. The concentrations of ^{40}K fell within the range of values previously measured for the WIPP soil samples. There was no significant difference between concentrations of ^{137}Cs and ^{40}K among sampling locations and the values fell within the range of concentrations previously observed in WIPP soils. The ^{60}Co was not detected at any sampling locations. Historical plots of $^{239+240}$Pu, ^{238}Pu, ^{241}Am, ^{137}Cs, and ^{40}K concentrations in soil in the vicinity of the WIPP site are shown in **Figures 4.4 to 4.8**. The concentrations have remained relatively constant over the past 10+ years and generally are indicative of worldwide fallout. Some degree of variability is always associated with collecting and analyzing environmental samples; therefore, variations in sample concentrations from year to year are expected.

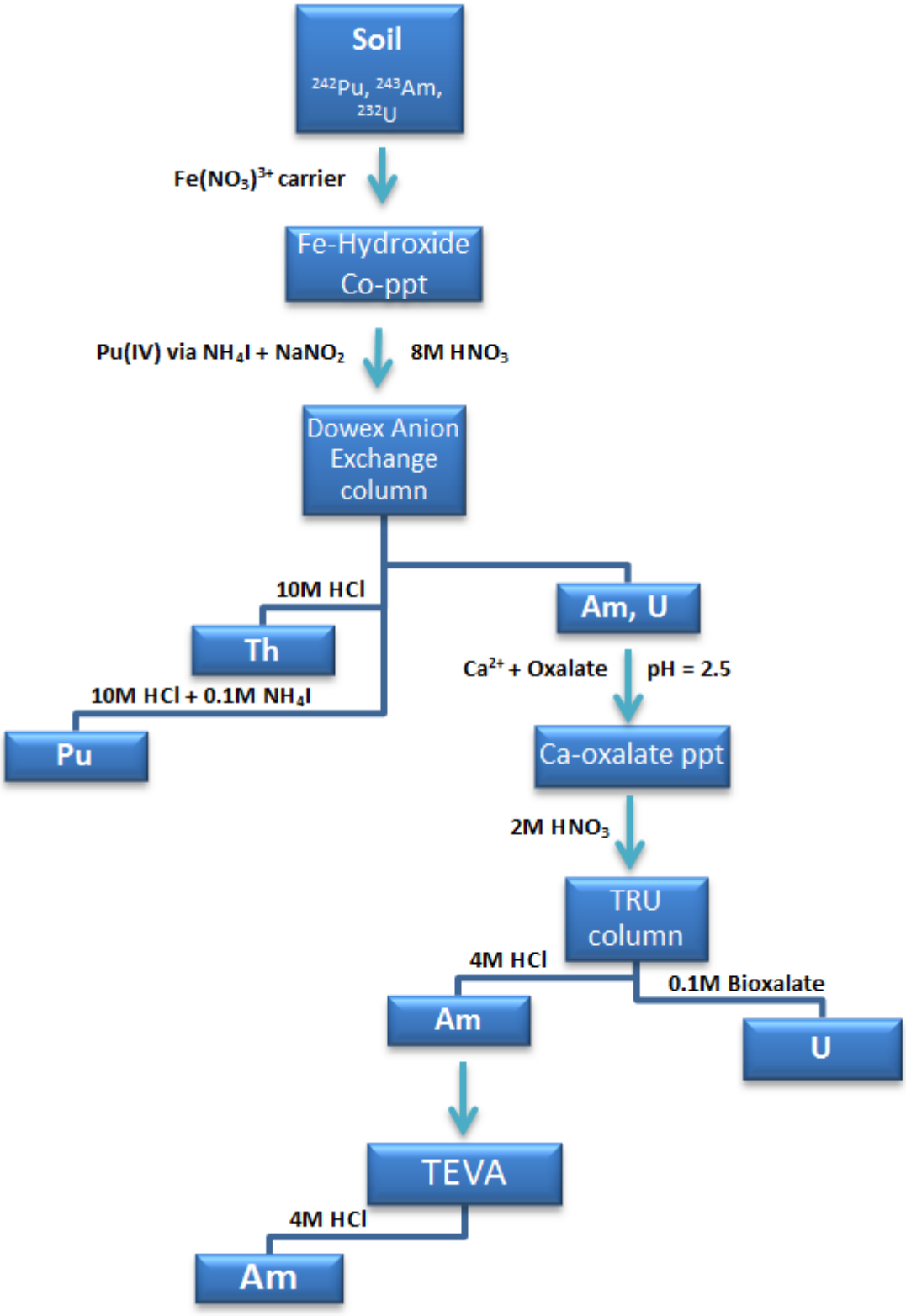


Figure 4.3 Radiochemical separation of Soil Samples

Surface soils were not collected from Cactus Flats following the radiation release event. However those collected in 1998 to 2005 and in 2012 show activity concentrations of $^{239+240}$Pu ranging from 0.01 to 0.51 Bq/kg, while that of ^{241}Am varied from 0.01 to 0.26 Bq/kg. The ^{137}Cs concentration ranged from 0.69 to 14.83 Bq/kg. The concentration of ^{137}Cs in the surface soil at Cactus Flats is approximately 3 times higher than that of surface soil at Near Field, while concentrations of $^{239+240}$Pu and ^{241}Am are approximately 2-3 times higher. However, there is no apparent difference between the radionuclides concentration in soil collected before and after WIPP started receiving TRU waste. The Cactus Flats soil radionuclide concentrations are higher than those measured in the soil samples collected following the radiation release event at the WIPP.

One finding presented in the CEMRC 2000 Report was that there were significant differences in many analyte concentrations between the Near Field and Cactus Flats grids. In a subsequent publication differences in soil texture were identified as a likely cause for these observations (Kirchner et al., 2002).

Additionally, the Gnome Site lies approximately 9 km southwest of the WIPP Site and was contaminated with actinide and fission products in 1961 when an underground detonation of a 3-kiloton ^{239}Pu device vented to the atmosphere. The concentrations of $^{239+240}$Pu, ^{238}Pu, and ^{241}Am in Gnome soil were in the range 0.073-1550 Bq/kg, 0.016-219 Bq/kg and 0.043-346 Bq/kg, respectively with an overall mean of 149.0 Bq/kg, 28.8 Bq/kg and 36.1 Bq/kg, respectively (CEMRC Annual Report, 2005/2006). In addition, the WIPP ^{137}Cs concentration in the surface soil was significantly lower than the Gnome soil (CEMRC Annual Report, 2005/2006). The maximum concentration of ^{137}Cs for the Gnome samples, 2890 Bq/kg, was more than 100 times larger than the largest concentration (3.89 Bq/kg) seen in the WIPP surface soil samples following the radiation release. The monitoring results indicate that there is no evidence of increase in soil radionuclide concentrations that can be attributed to the recent radiation release event at the WIPP.

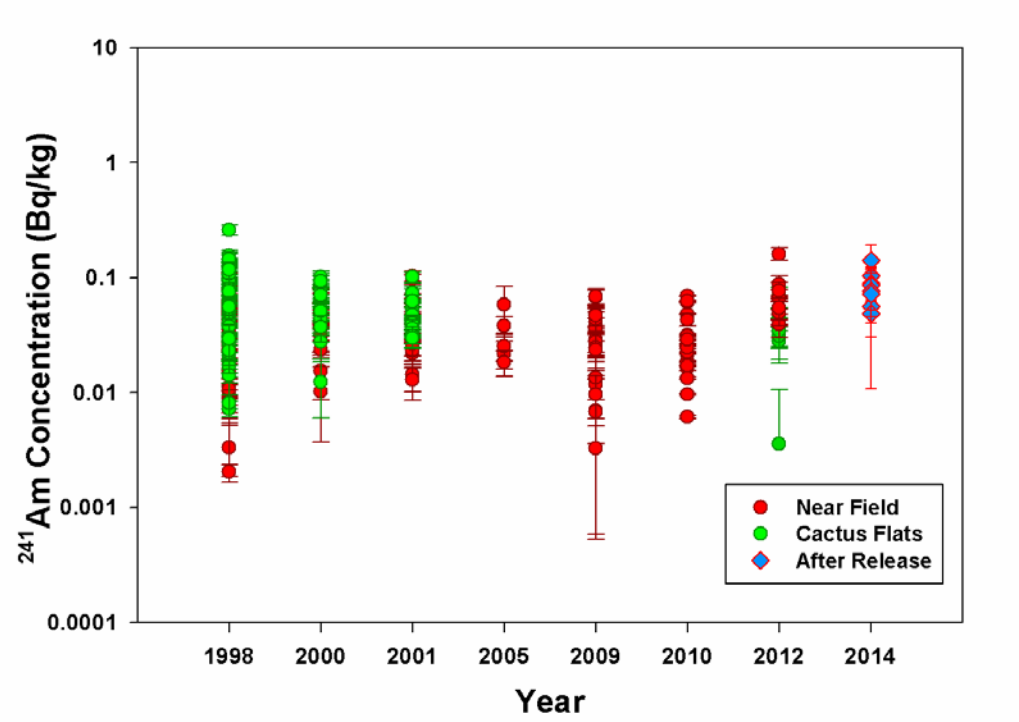


Figure 4.4 The Pre- and Post-release event soil concentrations of ^{241}Am in the vicinity of the WIPP site

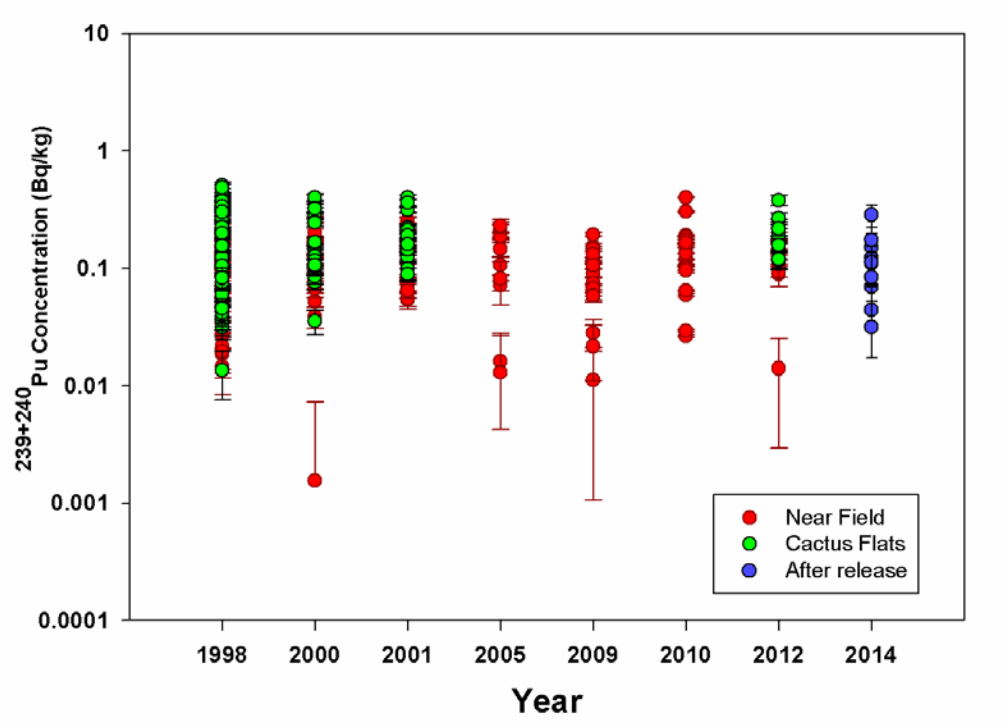


Figure 4.5 The Pre- and Post-release event soil concentrations of $^{239+240}$Pu in the vicinity of the WIPP site

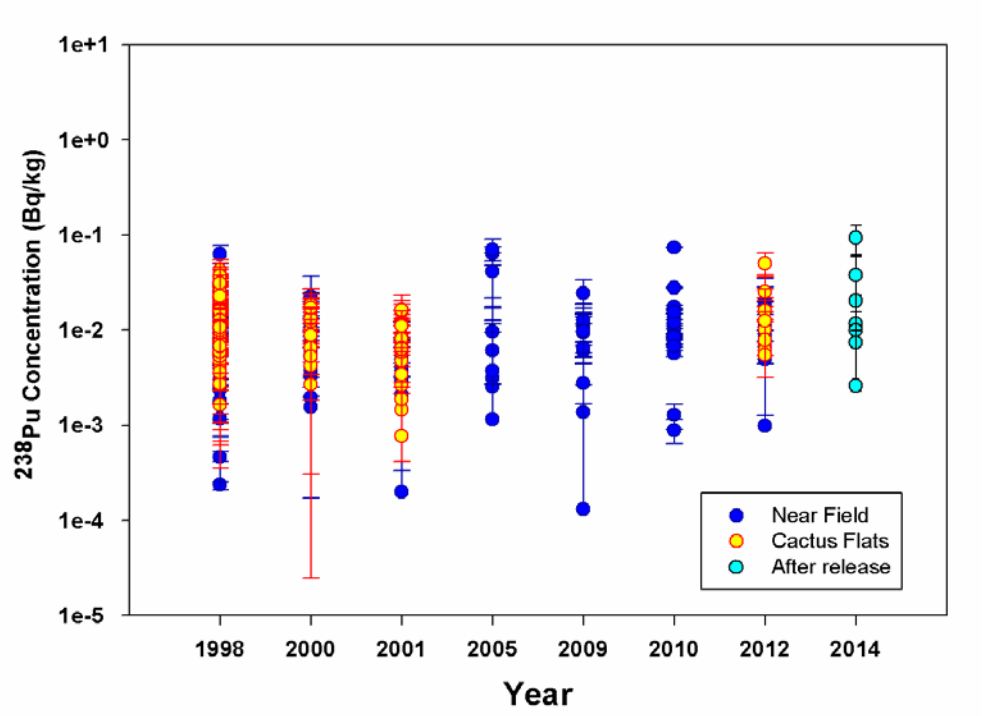


Figure 4.6 The Pre- and post-release event soil concentrations of ^{238}Pu In the vicinity of the WIPP site

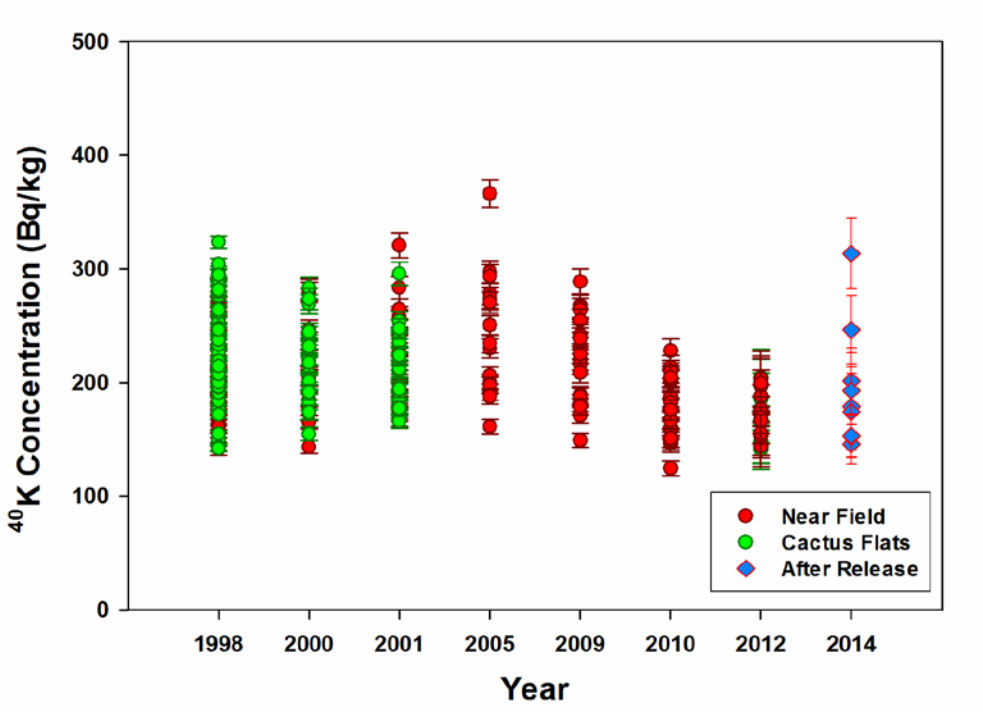


Figure 4.7 The Pre- and Post-release event soil concentrations of ^{40}K in the vicinity of the WIPP site

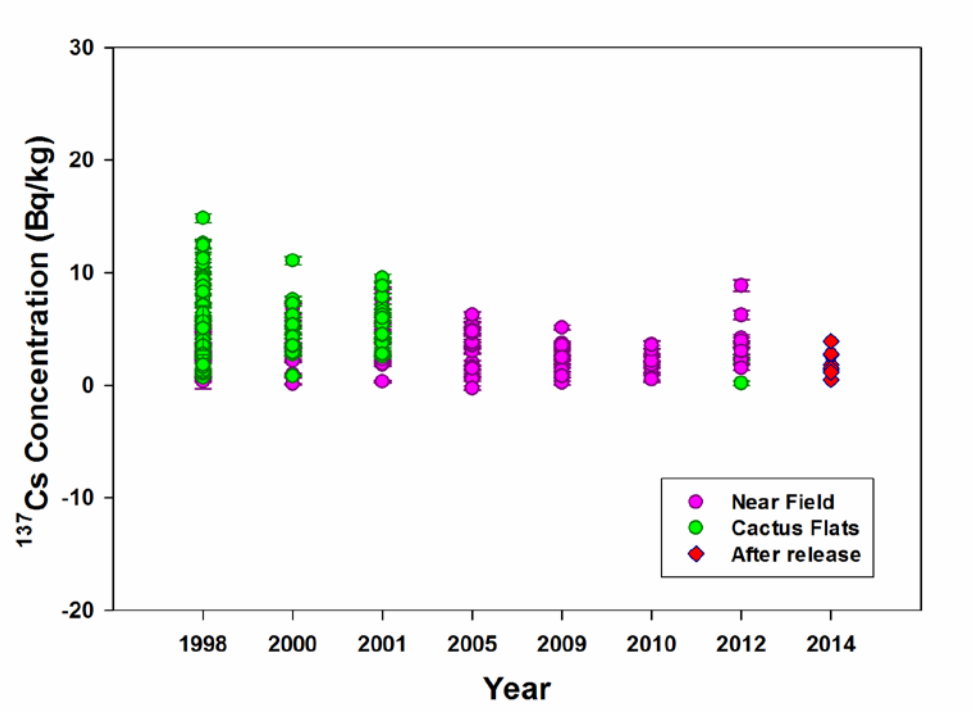


Figure 4.8 The Pre- and Post-release event soil concentrations of ^{137}Cs in the vicinity of the WIPP site

Table 4.1A Activity concentrations of ^{241}Am, $^{239+240}Pu$ and ^{238}Pu (Bq/kg) in soil samples collected in the vicinity of the WIPP site following the February 14 radiological event at WIPP (counting results for 24 hours)

Radionuclides	Location	Grid Nodes	Sampling Date	Activity Bq/kg	Unc. (2σ) Bq/kg	MDC Bq/kg	Status
^{241}Am	Near field	A-2	3/13/2014	9.49E-02	8.44E-02	1.17E-01	No detection
	Near field	A-1	3/13/2014	1.20E-01	9.21E-02	1.00E-01	Detected
	Near field	A-3	3/13/2014	9.96E-02	8.12E-02	1.05E-01	No detection
	Near field	A-4	3/13/2014	9.42E-02	1.14E-01	2.26E-01	No detection
	Near field	A-5	3/13/2014	1.93E-01	1.18E-01	1.19E-01	Detected
	Near field	A-6	3/13/2014	1.17E-01	8.73E-02	1.21E-01	No detection
	Near field	A-6 (Dup)	3/13/2014	6.76E-02	7.60E-02	1.25E-01	No detection
	Near field	A-7	3/13/2014	3.25E-02	6.50E-02	1.51E-01	No detection
	Near field	A-8	3/13/2014	6.69E-02	6.06E-02	8.82E-02	No detection
	Blank	-	-	8.41E-02	7.34E-02	1.26E-01	No detection
$^{239+240}Pu$	Near field	A-2	3/13/2014	1.58E-01	1.20E-01	1.45E-01	Detected
	Near field	A-1	3/13/2014	3.04E-01	1.31E-01	9.31E-02	Detected

Table 4.1A Continued

Radionuclides	Location	Grid Nodes	Sampling Date	Activity Bq/kg	Unc. (2σ) Bq/kg	MDC Bq/kg	Status
	Near field	A-3	3/13/2014	1.92E-01	1.23E-01	1.28E-01	Detected
	Near field	A-4	3/13/2014	4.72E-02	6.32E-02	1.16E-01	No detection
	Near field	A-5	3/13/2014	1.49E-01	1.19E-01	1.73E-01	No detection
	Near field	A-6	3/13/2014	1.56E-01	1.05E-01	1.15E-01	Detected
	Near field	A-6 (Dup)	3/13/2014	7.52E-02	8.45E-02	1.38E-01	No detection
	Near field	A-7	3/13/2014	7.04E-02	8.66E-02	1.64E-01	No detection
	Near field	A-8	3/13/2014	1.98E-01	1.07E-01	9.65E-02	Detected
	Blank	-	-	-1.41E-02	4.00E-02	1.31E-01	No detection
^{238}Pu	Near field	A-2	3/13/2014	9.88E-02	9.74E-02	1.45E-01	No detection
	Near field	A-1	3/13/2014	1.26E-02	3.59E-02	9.31E-02	No detection
	Near field	A-3	3/13/2014	0.00E+00	4.93E-02	1.62E-01	No detection
	Near field	A-4	3/13/2014	9.44E-02	8.40E-02	1.16E-01	No detection
	Near field	A-5	3/13/2014	9.30E-02	9.19E-02	1.37E-01	No detection
	Near field	A-6	3/13/2014	1.09E-01	9.45E-02	1.45E-01	No detection
	Near field	A-6 (Dup)	3/13/2014	0.00E+00	5.31E-02	1.75E-01	No detection
	Near field	A-7	3/13/2014	7.04E-02	1.00E-01	2.11E-01	No detection
	Near field	A-8	3/13/2014	3.93E-02	5.26E-02	9.65E-02	No detection
	Blank	-	-	2.82E-02	4.89E-02	1.04E-01	No detection

Table 4.1B Activity concentrations of ^{241}Am, $^{239+240}$Pu and ^{238}Pu (Bq/kg) in soil samples collected in the vicinity of the WIPP site following the February 14 radiological event at WIPP (counting results for 5 days)

Radionuclides	Location	Grid Nodes	Sampling Date	Activity Bq/kg	Unc. (2σ) Bq/kg	MDC Bq/kg	Status
^{241}Am	Near field	A-2	3/13/2014	7.14E-02	3.12E-02	2.27E-02	Detected
	Near field	A-1	3/13/2014	1.04E-01	4.20E-02	2.82E-02	Detected
	Near field	A-3	3/13/2014	7.61E-02	1.35E-02	5.92E-03	Detected
	Near field	A-4	3/13/2014	5.64E-02	6.17E-02	1.36E-01	No detection
	Near field	A-5	3/13/2014	1.41E-01	5.15E-02	8.44E-02	Detected
	Near field	A-6	3/13/2014	4.84E-02	3.76E-02	7.59E-02	No detection
	Near field	A-6 (Dup)	3/13/2014	8.80E-02	3.57E-02	2.40E-02	Detected
	Near field	A-7	3/13/2014	8.63E-02	3.42E-02	2.27E-02	Detected
	Near field	A-8	3/13/2014	7.68E-02	3.09E-02	3.94E-02	Detected
	Blank	-	-	7.18E-02	4.16E-02	8.18E-02	No detection

Table 4.1B Continued

Radionuclides	Location	Grid Nodes	Sampling Date	Activity Bq/kg	Unc. (2σ) Bq/kg	MDC Bq/kg	Status
$^{239+240}$Pu	Near field	A-2	3/13/2014	6.96E-02	3.53E-02	3.60E-02	Detected
	Near field	A-1	3/13/2014	2.84E-01	6.14E-02	1.85E-02	Detected
	Near field	A-3	3/13/2014	1.50E-01	4.84E-02	2.51E-02	Detected
	Near field	A-4	3/13/2014	1.22E-01	4.26E-02	2.42E-02	Detected
	Near field	A-5	3/13/2014	1.10E-01	5.79E-02	1.03E-01	Detected
	Near field	A-6	3/13/2014	1.13E-01	3.94E-02	2.24E-02	Detected
	Near field	A-6 (Dup)	3/13/2014	4.39E-02	2.68E-02	2.69E-02	Detected
	Near field	A-7	3/13/2014	8.39E-02	5.06E-02	9.46E-02	No detection
	Near field	A-8	3/13/2014	1.74E-01	4.64E-02	1.91E-02	Detected
	Blank	-	-	3.16E-02	3.70E-02	8.11E-02	No detection
^{238}Pu	Near field	A-2	3/13/2014	1.16E-02	2.57E-02	6.14E-02	No detection
	Near field	A-1	3/13/2014	9.31E-02	3.24E-02	1.85E-02	Detected
	Near field	A-3	3/13/2014	-6.83E-03	3.62E-02	9.61E-02	No detection
	Near field	A-4	3/13/2014	9.90E-03	1.33E-02	2.42E-02	No detection
	Near field	A-5	3/13/2014	7.33E-03	1.27E-02	2.69E-02	No detection
	Near field	A-6	3/13/2014	-1.22E-02	3.10E-02	8.59E-02	No detection
	Near field	A-6 (Dup)	3/13/2014	-1.46E-02	3.73E-02	1.03E-01	No detection
	Near field	A-7	3/13/2014	2.01E-02	1.79E-02	2.47E-02	No detection
	Near field	A-8	3/13/2014	2.60E-03	7.34E-03	1.91E-02	No detection
	Blank	-	-	1.15E-02	1.69E-02	3.64E-02	No detection

Table 4.2 Activity concentrations of ^{137}Cs, ^{40}K and ^{60}Co (Bq/kg) in soil samples collected in the vicinity of the WIPP site following the February 14 radiological event at WIPP

Radionuclides	Location	Grid Nodes	Sampling Date	Activity Bq/kg	Unc. (2σ) Bq/kg	MDC Bq/kg	Status
^{137}Cs	Near field	A-2	3/13/2014	1.80E+00	3.20E-01	4.64E-01	Detected
	Near field	A-1	3/13/2014	2.68E+00	2.52E-01	3.37E-01	Detected
	Near field	A-3	3/13/2014	2.65E+00	3.46E-01	4.41E-01	Detected
	Near field	A-4	3/13/2014	1.36E+00	3.09E-01	4.74E-01	Detected
	Near field	A-5	3/13/2014	2.79E+00	3.61E-01	4.58E-01	Detected
	Near field	A-6	3/13/2014	1.47E+00	2.05E-01	3.07E-01	Detected
	Near field	A-6 (Dup)	3/13/2014	4.85E-01	1.95E-01	4.47E-01	Detected
	Near field	A-7	3/13/2014	1.14E+00	1.98E-01	3.08E-01	Detected
	Near field	A-8	3/13/2014	3.89E+00	2.99E-01	3.55E-01	Detected

Table 4.2 Continued

Radionuclides	Location	Grid Nodes	Sampling Date	Activity Bq/kg	Unc. (2σ) Bq/kg	MDC Bq/kg	Status
^{40}K	Near field	A-2	3/13/2014	1.79E+02	3.47E+01	5.05E+00	Detected
	Near field	A-1	3/13/2014	2.01E+02	2.46E+01	2.55E+00	Detected
	Near field	A-3	3/13/2014	3.13E+02	3.11E+01	5.06E+00	Detected
	Near field	A-4	3/13/2014	1.74E+02	3.38E+01	5.30E+00	Detected
	Near field	A-5	3/13/2014	1.93E+02	3.74E+01	5.23E+00	Detected
	Near field	A-6	3/13/2014	1.46E+02	1.79E+01	2.41E+00	Detected
	Near field	A-6 (Dup)	3/13/2014	1.52E+02	1.87E+01	2.53E+00	Detected
	Near field	A-7	3/13/2014	1.53E+02	1.88E+01	2.46E+00	Detected
	Near field	A-8	3/13/2014	2.46E+02	3.01E+01	5.41E+00	Detected
^{60}Co	Near field	A-2	3/13/2014	-3.72E-01	3.75E-01	6.41E-01	No detection
	Near field	A-1	3/13/2014	4.15E-02	9.32E-02	3.09E-01	No detection
	Near field	A-3	3/13/2014	-1.42E-01	3.65E-01	6.21E-01	No detection
	Near field	A-4	3/13/2014	-4.99E-02	3.65E-01	6.20E-01	No detection
	Near field	A-5	3/13/2014	1.47E-01	3.71E-01	6.25E-01	No detection
	Near field	A-6	3/13/2014	7.43E-02	1.64E-01	2.76E-01	No detection
	Near field	A-6 (Dup)	3/13/2014	-9.91E-02	1.75E-01	2.99E-01	No detection
	Near field	A-7	3/13/2014	9.51E-03	1.67E-01	2.83E-01	No detection
	Near field	A-8	3/13/2014	-1.77E-01	1.04E-01	3.47E-01	No detection

Table 4.3 The background concentrations of ^{137}Cs, $^{239+240}$Pu and ^{241}Am (Bq/kg) in surface soil in the vicinity of the WIPP site

Location	Year	^{137}Cs	$^{239+240}$Pu	^{241}Am	Reference
100 M NW of WIPP Met. Tower	1991	0.00	0.00	-	Kenny et al., 1995
390 M east of WIPP exhaust	1990	7.4	0.37	-	Kenny et al., 1995
530 M south of WIPP exhaust	1994-1995	0.00	0.74	-	Kenny et al., 1995
775 M west of WIPP exhaust	1990	3.7	0.37	-	Kenny et al., 1995
1000 M NW of WIPP exhaust	1989	7.4	0.00	-	Kenny et al., 1995
WIPP vicinity, Near Field	1998	0.31-5.96	0.015-0.22	0.002-0.13	CEMRC Data 1998
WIPP vicinity, Cactus Flats	1998	0.70- 14.8	0.013-0.51	0.007-0.26	CEMRC Data 1998
WIPP vicinity	1995	0-7.40	0.00-0.74	-	Kenny et al., 1995
Gnome site	1995	2.59-3090	4.4-48000	0.40-7600	Kenny et al., 1995
Gnome site	2002	45.9-2980	0.07-1550	0.04-3460	CEMRC Data 2005/2006
Distant Locations	1982-1987	6.45-47.25	0.13-6.98	-	Krey and Beck, 1981

SECTION 5

Sediment Monitoring

Sediments are defined as finely divided solid materials that have settled out of a liquid stream or standing water. The sediments accumulate soluble radionuclides by sorption on suspended sediment and insoluble radionuclides by settling. The CEMRC has been monitoring sediment samples from the 3 public reservoirs in the vicinity of WIPP (Brantley Lake, Lake Carlsbad, and Red Bluff Lake) since 1998. Many of the sediment samples were found to contain fission-product ^{137}Cs; a few contained fission products ^{90}Sr and ^{134}Cs, activation-products ^{60}Co, ^{58}Co, ^{54}Mn, and ^{65}Zn, and the transuranic isotopes $^{239+240}$Pu and ^{241}Am. The presence of these radionuclides in sediments is attributed mostly to discharges at the monitored facilities. Some ^{137}Cs, ^{90}Sr, and ^{239}Pu are fallout from atmospheric nuclear tests, which peaked in 1962-1963 and to a minor extent from the nuclear accidents such as Chernobyl and Fukushima. Naturally occurring radionuclides uranium, thorium and ^{40}K also were also detected. Many of the measured values were low, near the limits of detection. The accumulation of radioactive materials in sediment could lead to exposure of humans through ingestion of aquatic species, through sediment re-suspension into drinking water supplies, or as an external radiation source (U.S. Department of Energy 1991).

To evaluate current conditions, CEMRC sampled sediment in the vicinity of the WIPP site shortly after the February 14, 2014 underground radiation event occurred. The sediment samples were collected from three regional reservoirs situated on the Pecos river at a considerable distance from the WIPP site including Brantley Lake, ~55 km (34 miles) north-northwest of the WIPP site, Red Bluff reservoir on the Pecos River, the upstream end of which is the nearest standing water body ~ 48 km (30 miles) to the east of the WIPP site, and Lake Carlsbad in the center of Carlsbad about 40 km (25 miles) northwest from the WIPP site. The Pecos River is the dominant surface-water body in the vicinity of the WIPP Site and is used for a variety of recreational activities including fishing, boating, water skiing, and swimming. Accelerated radiochemical analyses were performed to evaluate the current trend of the radionuclides, especially Pu and Am, in the vicinity of the WIPP site. The results presented here indicate that there is no evidence of increased radiological contamination in sediment samples collected in the region that could be attributed to recent radiation release from the WIPP.

Sample collection

Sediment samples were collected from 3 locations around the WIPP site as shown in **Figure 5.1**, with one duplicate sample collected from one site chosen at random. Routinely in early spring, water levels are lowered in the Pecos River so that the city of Carlsbad and

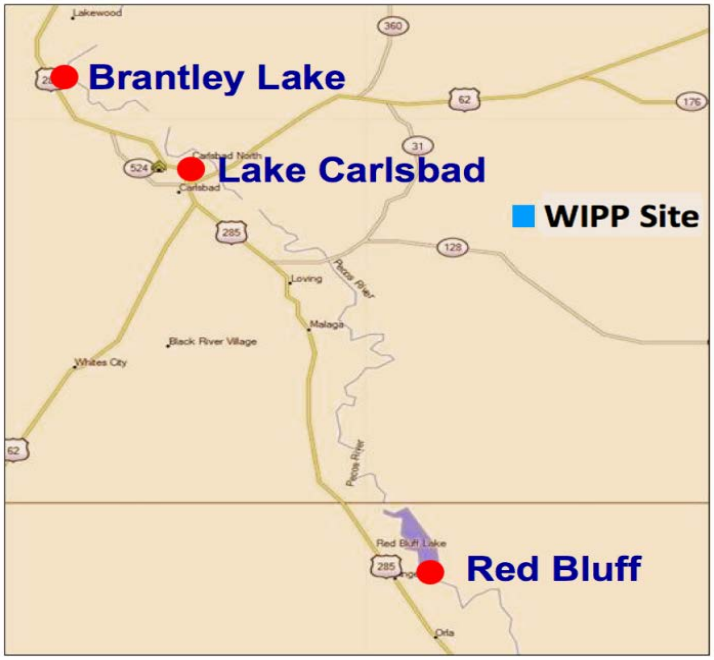


Figure 5.1 Sediment Sampling locations in the vicinity of the WIPP Site

Figure 5.2 Sediment Samples collection by the CEMRC Personnel

riverfront residents can do maintenance and repair work on docks or other features. Due to the low water levels, the post-event sediment samples for the Lake Carlsbad reservoir were collected from near Lower Tansil Dam, which is just downstream from city of Carlsbad and represents a deep basin area for the reservoir. Deep basins were chosen for sampling to minimize the disturbance and particle mixing effects of current and wave action that occur at shallower depths. Also, many of the analytes of interest tend to concentrate in the fine sediments that settle in the deep reservoir basins; thus, measurements from these areas would typically represent the highest levels that might be expected for a given reservoir. Sediment samples were collected using an Eckman dredge and excess water was decanted from the sediment **(See Figure 5.2)**. Approximately 5 L of sediment was sealed in a pre-cleaned plastic bucket in the field and transported to CEMRC laboratory for preparation prior to analyses.

Sample Preparation

In the laboratory, the sediment samples were air-dried, pulverized to pass a 2-mm sieve, and homogenized for radiochemical analyses. Samples for radiochemical analyses were dried at 105° for at least 12 hours and pulverized in a jar mill prior to analysis. Approximately 300-mL (500g) aliquots were used for gamma spectroscopy analysis. The samples for gamma analysis were sealed in a ~ 300-mL can and counted for 48 hours using a high purity HPGe detector. A set of soil matrix standards procured from Eckert and Ziegler Analytics (GA) was used to establish matrix-specific calibration and counting efficiencies. Reported concentrations are blank-corrected.

For actinides analyses, 5-10g of sample was heated in a muffle furnace at 500°C for at least 6 hours or more to combust organic material. Each sample was then spiked with a radioactive trace and digested in a Teflon beaker with 30 ml of HCl, 10 ml of HNO_3 and 40 ml of HF. Sea sand was used as a matrix for Laboratory Control Standard (LCS) and reagent blank. The samples were heated at 250°C for at least 2 hours; longer heating does no harm. After digestion was complete, the samples were evaporated to dryness and 40 ml of $HClO_4$ was added and evaporated to complete dryness. This step was repeated once more with 30 ml of $HClO_4$. Then 20 ml of HF were added and evaporated to dryness. To each beaker 80 ml of 8M HNO_3, 1.5 g of H_3BO_3 and 0.5 ml of 30% H_2O_2 were added, covered with a watch glass and heated to boiling for 30 minutes. After cooling, samples were transferred to a 50 ml centrifuge tube and centrifuged at 3600 rpm for 10 minutes. The leachate was filtered through a 0.45 micron filter and transferred to a 250 ml beaker.

Actinides Separation

The actinides are separated as a group by co-precipitation on $Fe(OH)_3$. The oxidation state of Pu was adjusted by adding 1 ml of 1.0M NH_4I with a 10 min wait step, followed by 2 ml of 2M $NaNO_2$. Pu isotopes are then separated and purified using a two-column anion exchange resin (Dowex1-× 8, 100-200 mesh), while TRU chromatography columns are used for the separation of Am. The Am fraction is subsequently purified from lanthanides using a TEVA column. The samples are then micro-co-precipitated using an Nd-carrier and counted on the alpha spectrometer for 24 hours, so that results can be made immediately available to the public and other interested parties. The samples are also counted for five days as per CEMRC's standard counting protocol.

Data Reporting

The activities of the actinides and gamma radionuclides are reported as *activity concentration* in Bq/g. *Activity concentration* is calculated as the activity of radionuclides detected in Becquerel (Bq) divided by the weight of the sediment in *grams* (g).

Results and Discussion

The concentrations of ^{241}Am, $^{239+240}Pu$ and ^{238}Pu in the sediment samples collected from three regional reservoirs are listed in Tables 5.1A and 5.1B. The ^{241}Am and $^{239+240}Pu$ concentrations slightly greater than MDC were detected in all sediment samples, whereas ^{238}Pu was not detected in any sediment samples. The activity concentrations of ^{241}Am in the sediment samples ranged from 0.095-0.18 mBq/g, while that of $^{239+240}Pu$ varied from 0.14-0.27 mBq/g. The baseline concentrations of $^{239+240}Pu$ ranged from 0.07 to 0.41 mBq/g with the mean values of 0.13±0.03 mBq/g for the Lake Carlsbad, 0.26±0.02 mBq/g for the Brantley lake and 0.36±0.07 mBq/g for the Red Bluff reservoir (CEMRC Annual Report, 1998). The concentrations of $^{239+240}Pu$ and ^{241}Am measured in sediments samples following the February, 14 release were within the range of the baseline phase data for the sediment samples collected in 1998. As in the case of soil, levels of radionuclides in sediment samples from the aforementioned three reservoirs in the region following the February 14 radiation release event showed no detectable increases above those typical of previously measured natural variation.

The ^{241}Am activities in sediment samples from the three reservoirs are lower than $^{239+240}Pu$ activities. The $^{239+240}Pu$ activities are highest in the sediment collected from Red Bluff Reservoir (0.26 mBq/g). Maxima range from 0.43 mBq/g observed in the baseline phase compared to 0.45 mBq/g in the monitoring phase. Maxima $^{239+240}Pu$ activities from Lake Carlsbad are lower ranging from 0.163 mBq/g in the baseline phase compared to 0.28 mBq/g

in the monitoring phase. The $^{239+240}Pu$ activities in samples from Brantley Lake are intermediate between Red Bluff Reservoir and Lake Carlsbad.

The gamma radionuclides ^{40}K, ^{137}Cs, and ^{60}Co were analyzed for all the sediment samples. The individual concentrations of these radionuclides collected are listed in Tables 5-2. The ^{137}Cs was detected in all sediment samples collected (Table 5.2). Variability among the ^{137}Cs concentrations was not very significant. Maximum activity concentrations for ^{137}Cs (6.1 m Bq/g) decreased slightly in the monitoring phase relative to the baseline phase for samples collected from all three reservoirs. The ^{137}Cs is a fission product and is consistently found in sediment and soil because of global fallout from atmospheric nuclear weapons testing (Beck and Bennett, 2002; UNSCEAR, 2000). The ^{40}K was also detected in every sediment sample (**Table 5.2**). This naturally occurring gamma-emitting radionuclide is ubiquitous in sediments. There was no significant difference between concentrations of ^{40}K among sampling locations and the values fell within the range of concentrations observed previously in WIPP sediments. As shown in **Table 5.2**, the ^{60}Co were not detected at any sampling location. Comparison of activity concentrations of radionuclide determined following the February 14, radiation release event at the WIPP to that of the baseline and monitoring phase activities reflects no increase in radionuclide concentrations (**Figures 5.3 to 5.7**).

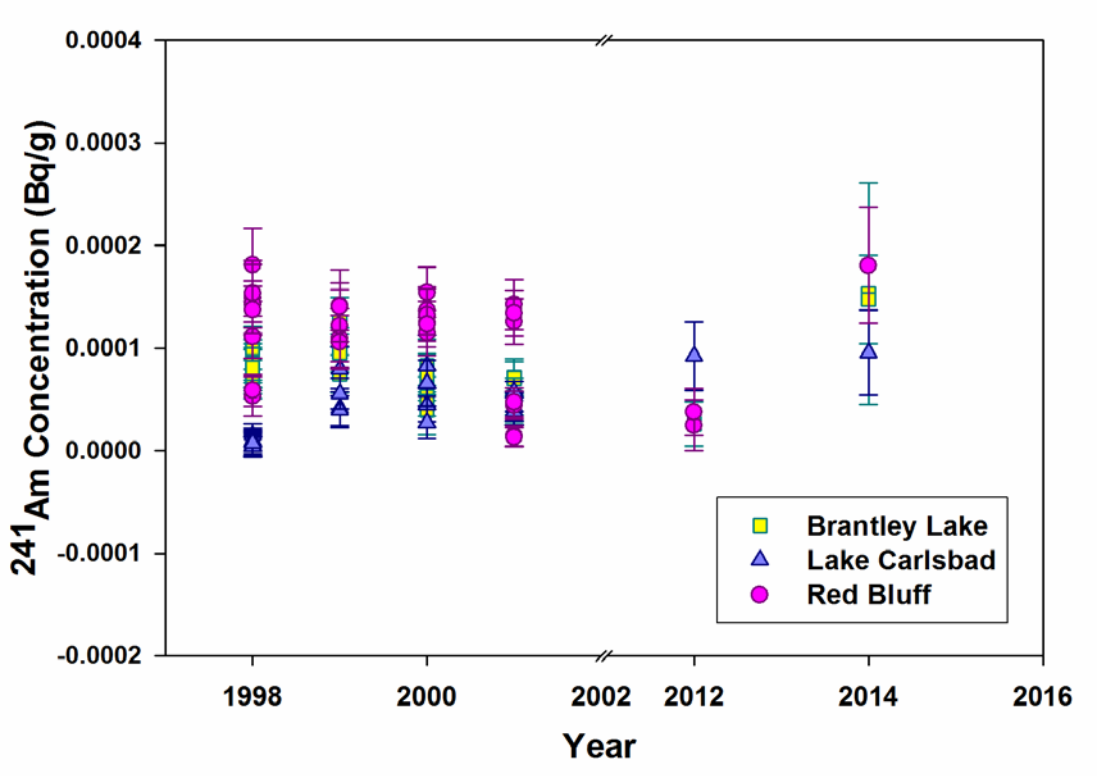


Figure 5.3 The Pre- and Post-release event sediment concentrations of ^{241}Am from the three reservoirs in the vicinity of the WIPP site

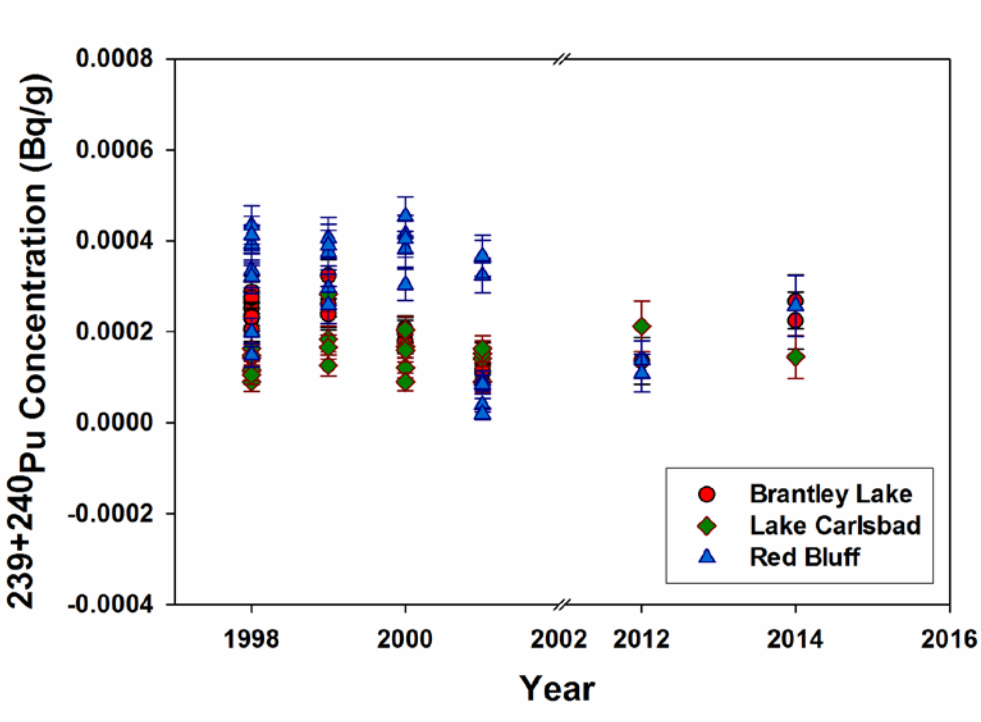


Figure 5.4 The Pre- and Post-release event sediment concentrations of $^{239+240}$Pu from the three reservoirs in the vicinity of the WIPP site

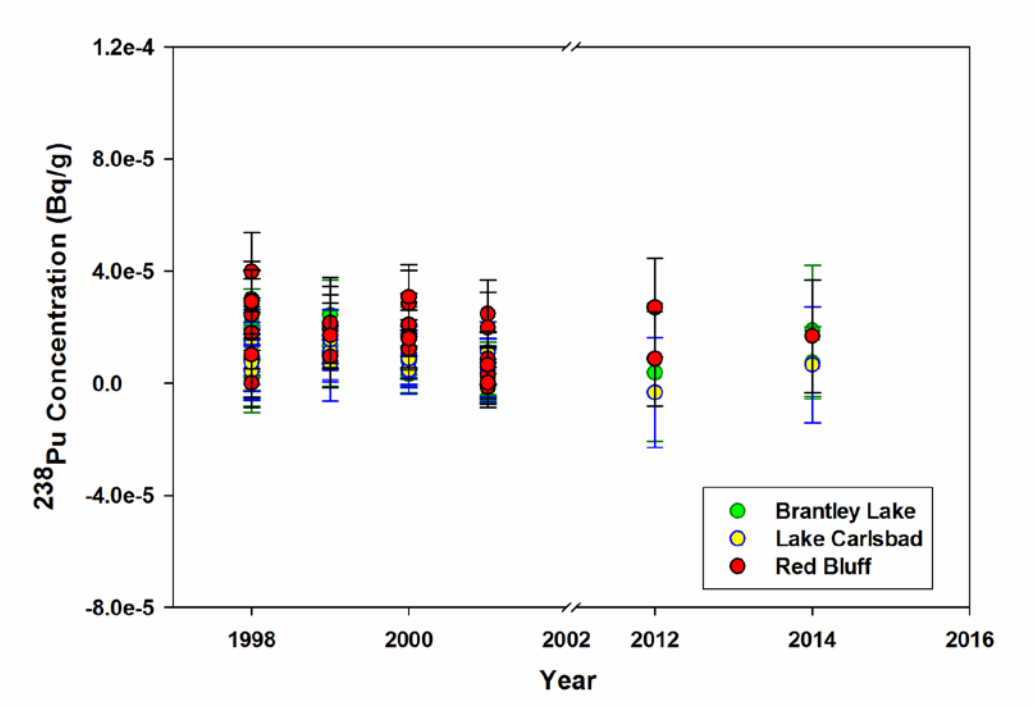


Figure 5.5 The Pre- and Post-release event sediment concentrations of ^{238}Pu from the three reservoirs in the vicinity of the WIPP site

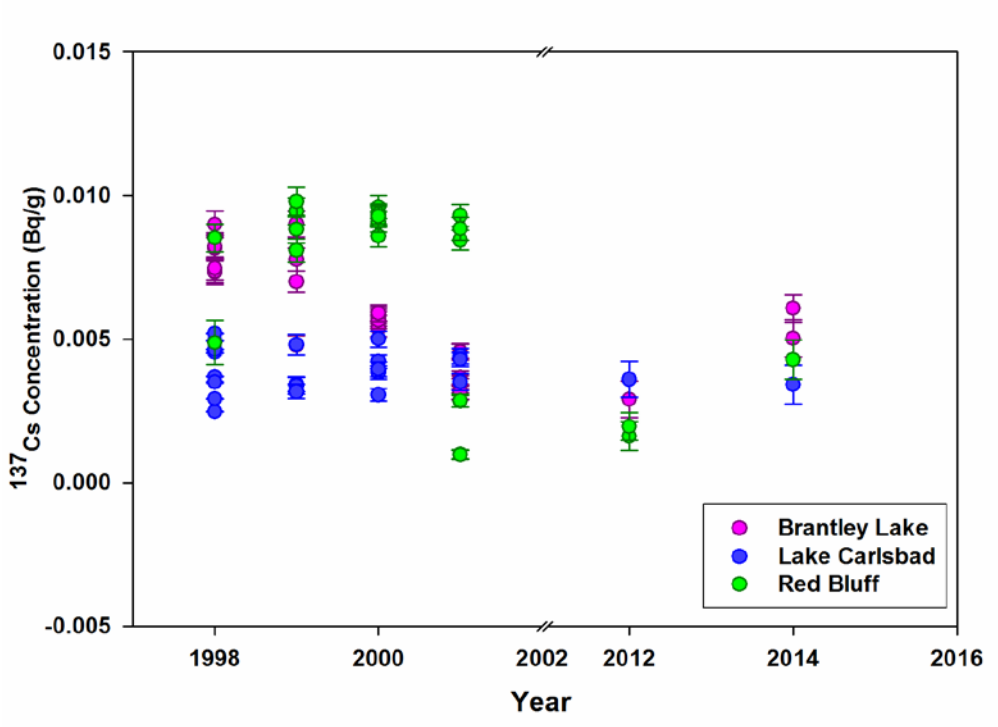


Figure 5.6 The Pre- and Post-release event sediment concentrations of ^{137}Cs from the three reservoirs in the vicinity of the WIPP site

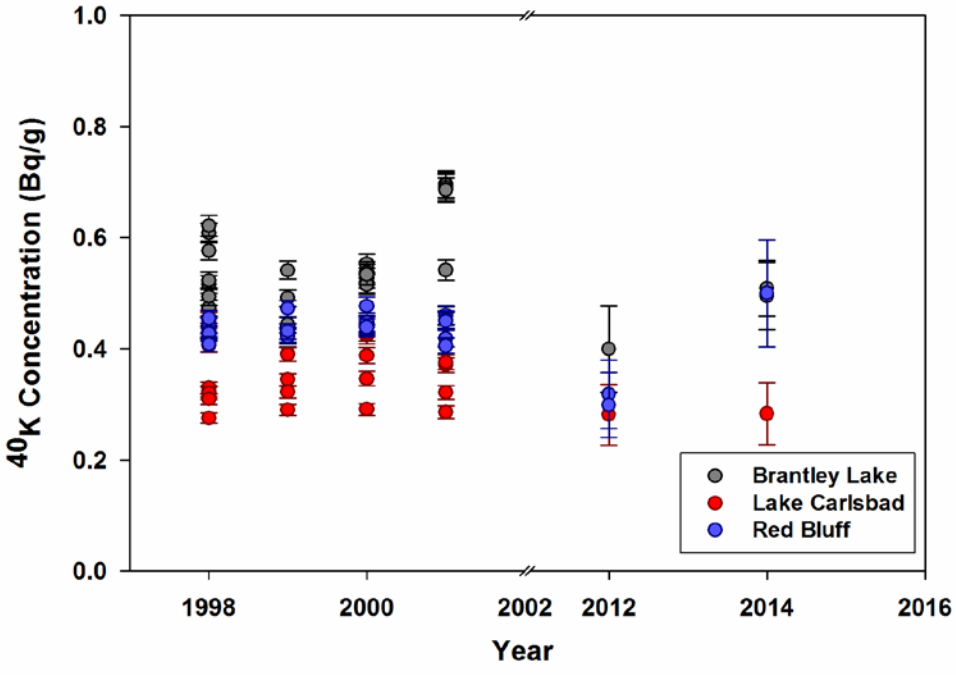


Figure 5.7 The Pre- and Post-release event sediment concentrations of ^{40}K from the three reservoirs in the vicinity of the WIPP site

Table 5.1A Activity concentrations of ^{241}Am, $^{239+240}Pu$ and ^{238}Pu (Bq/g) in sediment samples collected from the three reservoirs in the vicinity of the WIPP site following the February 14 radiological event at WIPP (counting results for 24 hours)

Radionuclides	Location	Sample Date	Activity Bq/g	Unc. (2σ) Bq/g	MDC Bq/g	Status
^{241}Am	Red Bluff	3/20/2014	2.02E-04	1.20E-04	1.23E-04	Detected
	Brantley Lake	3/20/2014	1.53E-04	1.08E-04	1.15E-04	Detected
	Brantley Lake	3/20/2014	1.45E-04	8.64E-05	7.84E-05	Detected
	Lower Tansill	3/28/2014	9.74E-05	8.68E-05	1.04E-04	No detection
	Blank	-	1.25E-05	7.41E-05	2.04E-04	No detection
$^{239+240}Pu$	Red Bluff	3/20/2014	2.28E-04	1.26E-04	1.06E-04	Detected
	Brantley Lake	3/20/2014	2.75E-04	1.50E-04	1.53E-04	Detected
	Brantley Lake	3/20/2014	3.44E-04	1.39E-04	8.39E-05	Detected
	Lower Tansill	3/28/2014	1.79E-04	1.14E-04	1.20E-04	Detected
	Blank	-	1.36E-05	4.76E-05	1.37E-04	No detection
^{238}Pu	Red Bluff	3/20/2014	-6.44E-06	3.29E-05	9.46E-05	No detection
	Brantley Lake	3/20/2014	3.87E-05	6.25E-05	1.27E-04	No detection
	Brantley Lake	3/20/2014	7.43E-06	2.62E-05	7.48E-05	No detection
	Lower Tansill	3/28/2014	3.03E-06	3.50E-05	1.19E-04	No detection
	Blank	-	4.55E-05	8.20E-05	1.80E-04	No detection

Table 5.1B Activity concentrations of ^{241}Am, $^{239+240}Pu$ and ^{238}Pu (Bq/g) in sediment samples collected from the three reservoirs in the vicinity of the WIPP site following the February 14 radiological event at WIPP (counting results for 5 days)

Radionuclides	Location	Sample Date	Activity Bq/g	Unc. (2σ) Bq/g	MDC Bq/g	Status
^{241}Am	Red Bluff	3/20/2014	1.81E-04	5.68E-05	5.84E-05	Detected
	Brantley Lake	3/20/2014	1.53E-04	1.08E-04	1.24E-04	Detected
	Brantley Lake	3/20/2014	1.47E-04	4.28E-05	3.46E-05	Detected
	Lower Tansill	3/28/2014	9.55E-05	4.13E-05	4.40E-05	Detected
	Blank	-	1.46E-05	4.37E-05	1.06E-04	No detection
$^{239+240}Pu$	Red Bluff	3/20/2014	2.57E-04	6.67E-05	4.72E-05	Detected
	Brantley Lake	3/20/2014	2.25E-04	6.25E-05	6.28E-05	Detected
	Brantley Lake	3/20/2014	2.67E-04	5.92E-05	3.42E-05	Detected
	Lower Tansill	3/28/2014	1.45E-04	4.66E-05	2.42E-05	Detected
	Blank	-	1.39E-05	2.45E-05	5.56E-05	No detection

Table 5.1B Continued

Radionuclides	Location	Sample Date	Activity Bq/g	Unc. (2σ) Bq/g	MDC Bq/g	Status
^{238}Pu	Red Bluff	3/20/2014	1.68E-05	2.02E-05	4.03E-05	No detection
	Brantley Lake	3/20/2014	1.87E-05	2.34E-05	4.94E-05	No detection
	Brantley Lake	3/20/2014	7.28E-06	1.29E-05	2.92E-05	No detection
	Lower Tansill	3/28/2014	6.58E-06	2.08E-05	5.21E-05	No detection
	Blank	-	4.63E-05	4.15E-05	8.04E-05	No detection

Table 5.2 Activity concentrations of ^{137}Cs, ^{40}K and ^{60}Co (Bq/g) in sediment samples collected from the three reservoirs in the vicinity of the WIPP site following the February 14 radiological event at WIPP

Radionuclides	Location	Sample Date	Activity Bq/g	Unc. (2σ) Bq/g	MDC Bq/g	Status
^{137}Cs	Red Bluff	3/20/2014	4.29E-03	6.88E-04	9.79E-04	Detected
	Brantley Lake	3/20/2014	5.03E-03	6.51E-04	8.51E-04	Detected
	Brantley Lake	3/20/2014	6.07E-03	4.72E-04	5.74E-04	Detected
	Lower Tansill	3/28/2014	3.42E-03	6.74E-04	9.99E-04	Detected
^{40}K	Red Bluff	3/20/2014	5.00E-01	9.67E-02	9.21E-03	Detected
	Brantley Lake	3/20/2014	5.09E-01	5.01E-02	7.91E-03	Detected
	Brantley Lake	3/20/2014	4.95E-01	6.04E-02	4.14E-03	Detected
	Lower Tansill	3/28/2014	2.83E-01	5.55E-02	1.21E-02	Detected
^{60}Co	Red Bluff	3/20/2014	7.08E-05	7.11E-04	1.20E-03	No detection
	Brantley Lake	3/20/2014	6.23E-05	6.02E-04	1.02E-03	No detection
	Brantley Lake	3/20/2014	2.09E-04	3.09E-04	5.18E-04	No detection
	Lower Tansill	3/28/2014	3.89E-04	7.98E-04	1.34E-03	No detection

THIS PAGE LEFT INTENTIONALLY BLANK

SECTION 6

Surface Water Monitoring

Surface water is a term used to describe water in a watercourse, lake or wetland, and includes water flowing over or lying on land after having precipitated naturally, or after having risen to the surface naturally from underground (groundwater). Rivers, lakes, streams, ponds, wetlands and oceans are all examples of surface water. Continually replenished by precipitation or rain runoff, surface water is a body of water easily seen as it flows downhill to where it collects. Retention of radionuclide fallout by catchment soils and river and lake sediments plays an important role in determining subsequent transport in aquatic systems. In rivers and small lakes, the radioactive contamination results mainly from erosion of the surface layers of soil in the watershed, followed by runoff in the water bodies; However, deposition of radioactive materials also occurs on water surfaces. The fraction of a radionuclide that is adsorbed to suspended particles (which varies considerably in surface waters) strongly influences both its transport and its bio-accumulation.

Samples of surface water in the vicinity of the WIPP site were collected and analyzed to determine the concentrations of radiological contaminants in the aquatic environment attributed to the recent radiation event at the WIPP. The surface water samples were collected from three regional reservoirs situated on the Pecos river at a considerable distance from the WIPP site-Brantley Lake, ~55 km (34 miles) north-northwest of the WIPP site, Red Bluff reservoir on the Pecos River, the upstream end of which is the nearest standing water body ~ 48 km (30 miles) to the east of the WIPP site, and Lake Carlsbad in the center of Carlsbad about 40 km (25 miles) northwest from the WIPP site. The Pecos River is the dominant surface-water body in the vicinity of the WIPP Site and is used for a variety of recreational activities including fishing, boating, water skiing, and swimming. Accelerated radiochemical analyses were performed to assess the regional impact of the February 14 radiation release event to the surface waters in the local environment.

Sample Collection

The surface water samples were collected in the same general area as the sediment samples **(See Figure 6.1)**. At each sampling location, one sample was collected from the surface (~ 0.5 to 1 m depth) and a second sample from approximately 0.5 to 1 m above the sediment bed. Approximately 8 L of surface water was collected from each location **(See Figure 6.2)**.

Figure 6.1 Lower Tansill Dam

Figure 6.2 Surface water samples collection from the Brantley Lake by the CEMRC Personnel

Sample Preparation

In the laboratory, surface water samples collected for radiological analyses were acidified with HNO_3 to a pH < 2 and the sample containers were shaken to distribute suspended material evenly. One 2-L portion was used for gamma spectroscopy and another 1L portion was used for sequential analysis of the uranium/transuranic isotopes. The first aliquot was transferred to 2L Marinelli beakers for the measurement of the gamma-emitting radionuclides potassium (^{40}K), cobalt (^{60}Co), and cesium (^{137}Cs) by gamma spectroscopy using a high purity germanium (HPGe) detector. Before collecting the measurements, the gamma system was calibrated for energy and efficiency to enable both qualitative and quantitative analysis of the water samples. The energy and efficiency calibrations were carried out using a mixed standards material from Eckert and Ziegler, Analytics (GA) in the energy range between 60 to 2000 keV for a 2L Marinelli geometry. The counting time for each sample was 48 hours.

The second, 1L aliquot, was used for actinides analyses. Tracers consisting of uranium, americium, and plutonium (^{232}U, ^{243}Am, and ^{242}Pu) were added to the samples and the samples were digested using concentrated nitric acid and hydrofluoric acid. The samples were heated to dryness and wet-ashed using concentrated nitric acid and hydrogen peroxide. Finally, the samples were heated to dryness again, and the isotopic separation steps were initiated.

Actinides Separation

The actinides are separated as a group by co-precipitation on $Fe(OH)_3$. The oxidation state of Pu is adjusted by adding 1 ml of 1.0M NH_4I with a 10 min wait step, followed by 2 ml of 2M $NaNO_2$. Pu isotopes are then separated and purified using a two-column anion exchange resin (Dowex1-× 8, 100-200 mesh), while TRU chromatography columns are for the separation of Am. The samples are then micro-co-precipitated using an Nd-carrier and counted on the alpha spectrometer for 24 hours, so that results can be made immediately available to the public and other interested parties. The samples are also counted for five days as per CEMRC's standard counting protocol.

Data Reporting

The activities of the actinides and gamma radionuclides are reported as *activity concentration* in Bq/L. *Activity concentration* is calculated as the activity of radionuclides detected in Becquerel (Bq) divided by weight of the surface water in *liters* (L).

Results and Discussion

The activity concentrations measured for ^{241}Am, ^{238}Pu, and $^{239+240}$Pu were below the respective MDCs for each analyte in all surface water samples collected following the radiation release event at the WIPP (**Figures 6.3 to 6.5**). The individual values of ^{241}Am, ^{238}Pu, and $^{239+240}$Pu measured in the three reservoirs are listed in **Table 6.1 (A and B)**. Since 1998, neither $^{239+240}$Pu, ^{238}Pu or ^{241}Am have been measured above the MDC in any surface water samples. **Figures 6.6 to 6.8** show the historic values for $^{239+240}$Pu, ^{238}Pu and ^{241}Am at all sites as a function of their range (vertical lines), medians (stars), and boxes indicating with horizontal lines the means plus or minus two standard deviations. The interpretation of Figures 6.6 to 6.8 is that activities of these radionuclides measured were close to zero (all are below the MDC). No detection of WIPP radionuclides in surface water samples indicates that the recent radiation release event at the WIPP has not impacted the regional reservoirs.

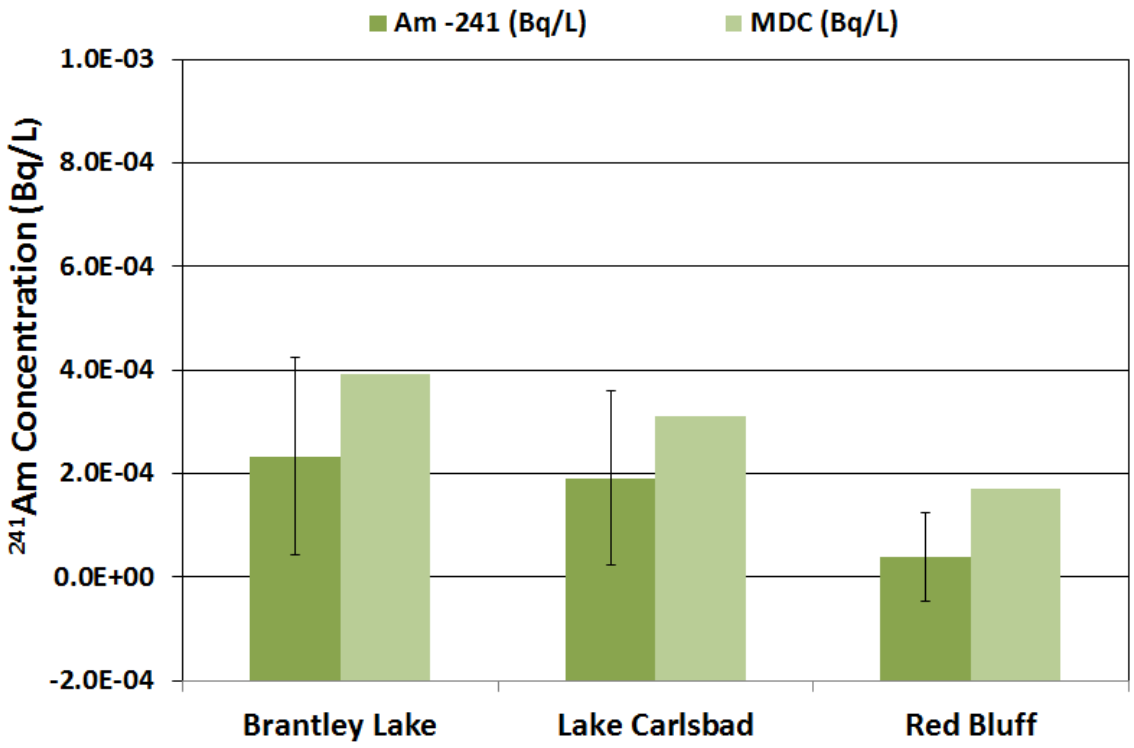


Figure 6.3 ^{241}Am concentration in surface water samples in three regional reservoirs following the February 14 release event at the WIPP

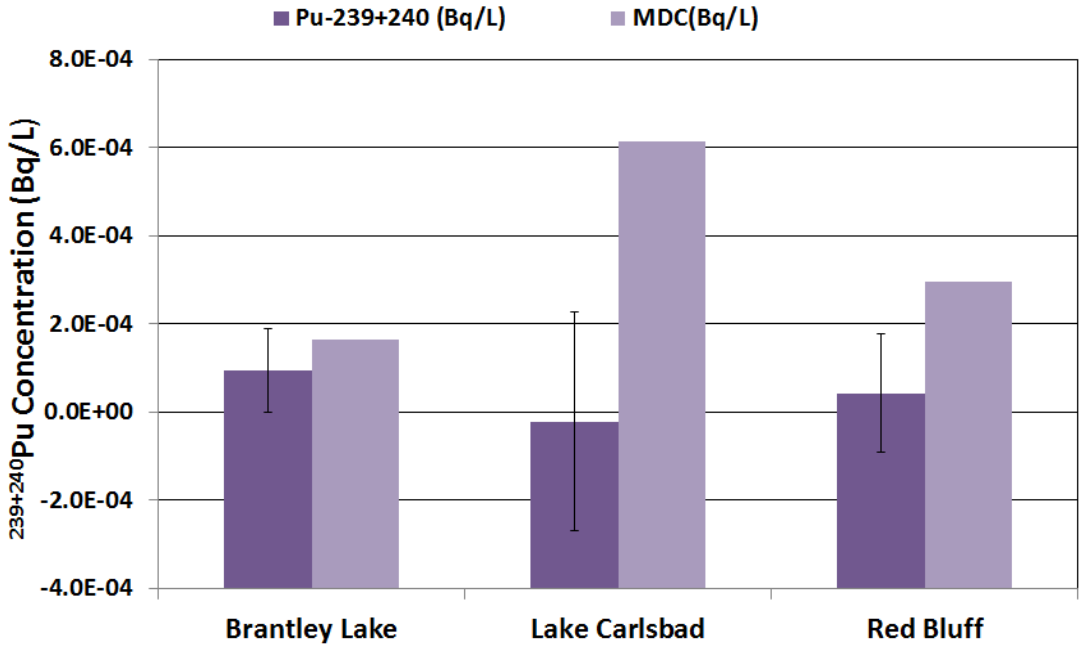


Figure 6.4 $^{239+240}$Pu concentration in surface water samples in three regional reservoirs following the February 14 release event at the WIPP

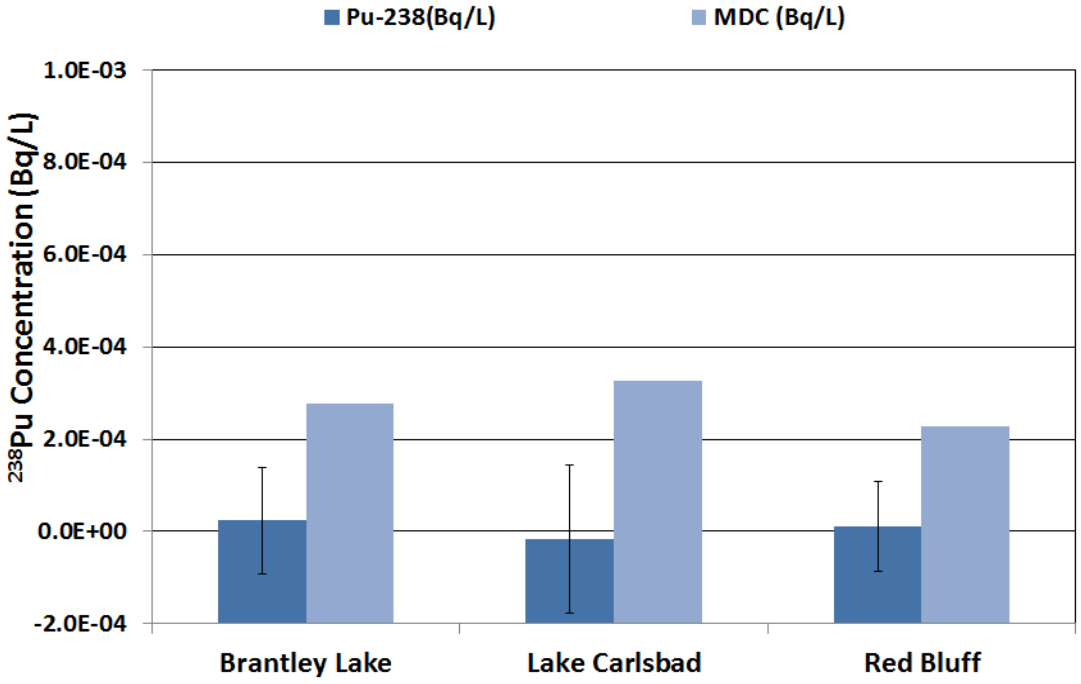


Figure 6.5 ^{238}Pu concentration in surface water samples in three regional reservoirs following the February 14 release event at the WIPP

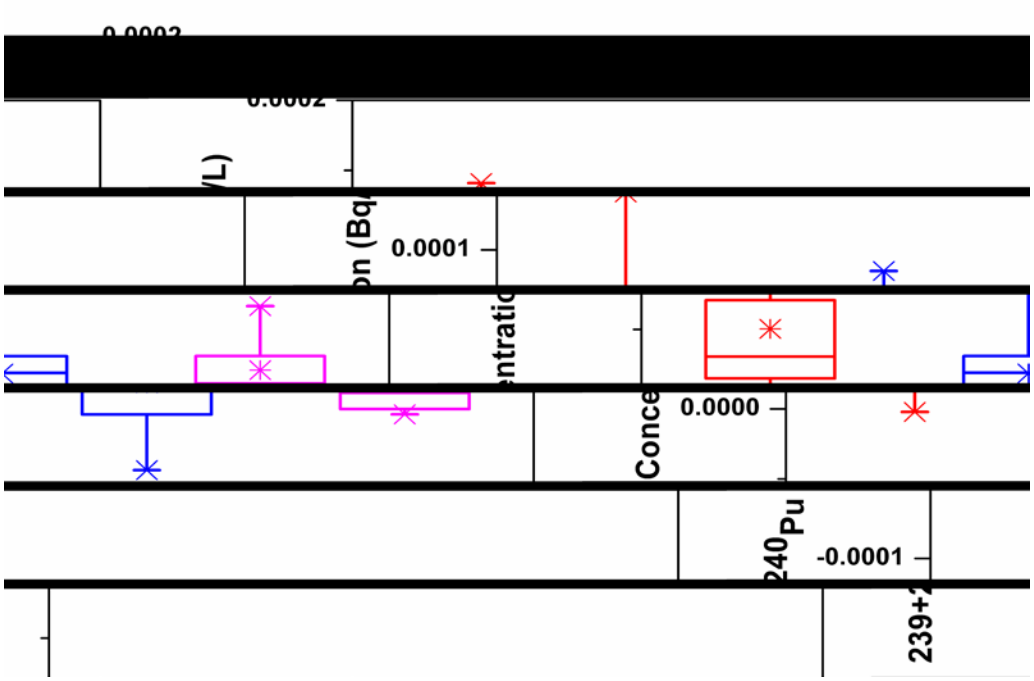


Figure 6.6 $^{239+240}$Pu activity in regional surface water in three regional reservoirs from 1998 to 2014 (All samples are below MDC)

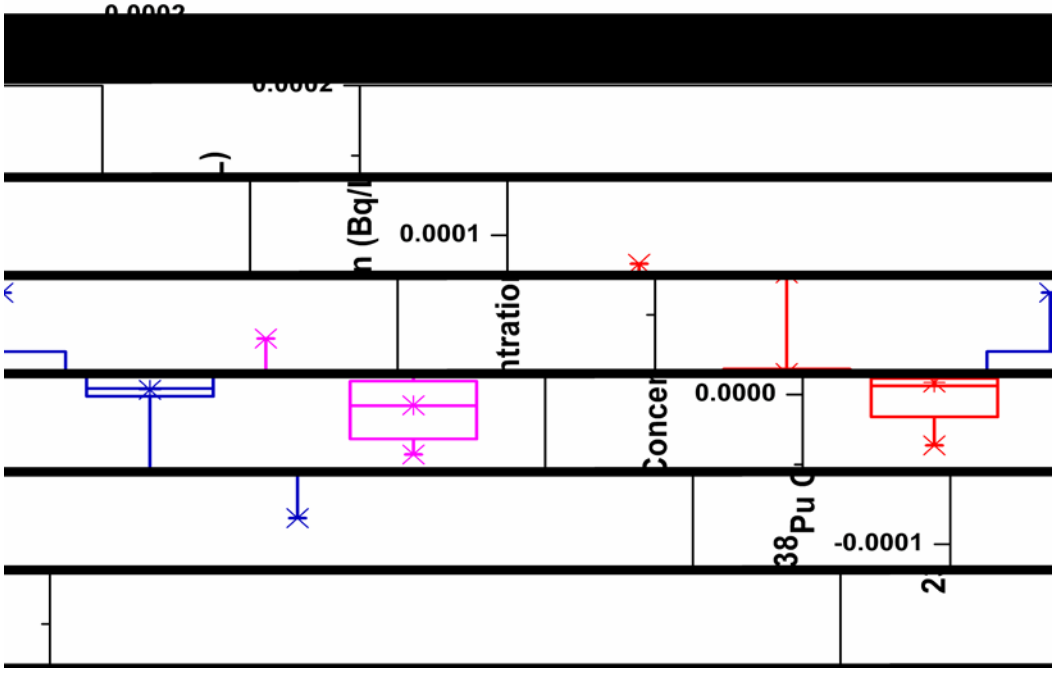


Figure 6.7 ^{238}Pu activity in regional surface water in three regional reservoirs from 1998 to 2014 (All samples are below MDC)

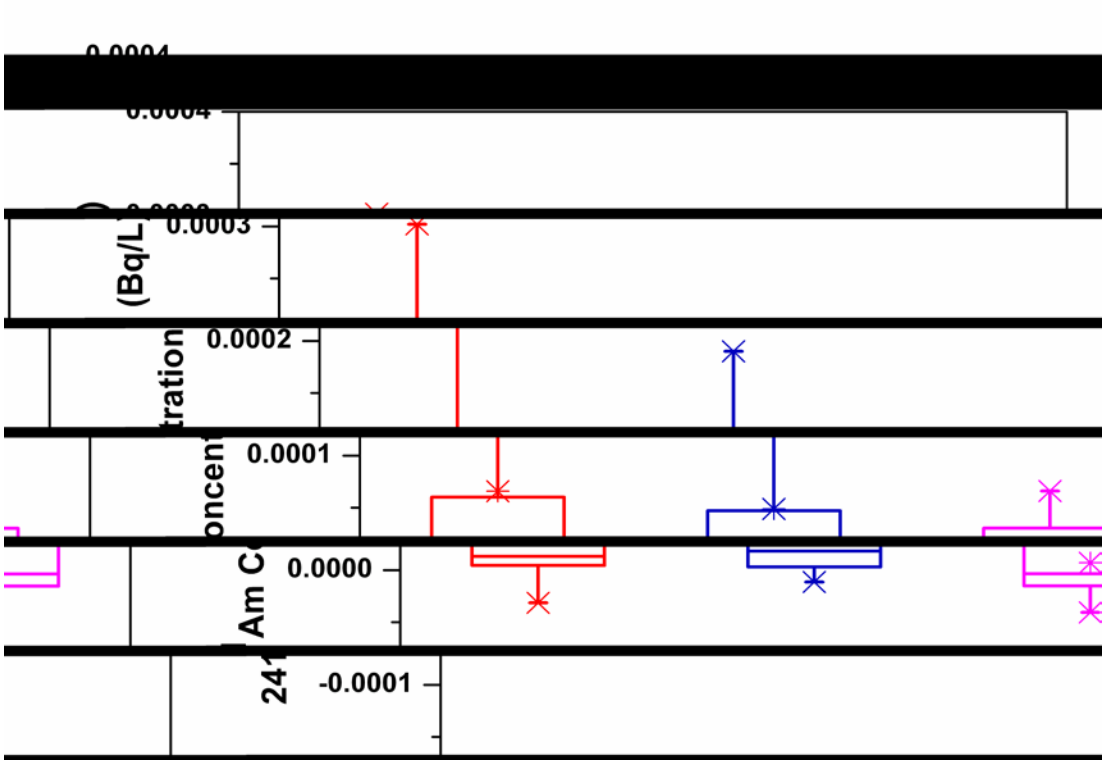


Figure 6.8 ^{241}Am activity in regional surface water in three regional reservoirs from 1998 to 2014 (All samples are below MDC)

The analysis data for the gamma isotopes are presented in **Table 6.2**. As shown in the table, ^{40}K was detected in two of the surface water samples collected from Red Bluff reservoir (1.57-1.94 Bq/L). The Red Bluff was the only location, where ^{40}K was detected in 1998, 2000, and 2012 (CEMRC Annual Report, 1998, 2000, 2012). The concentrations detected were in the range: 0.81-1.25 Bq/L in 1998; 1.22-1.25 Bq/L in 2000; and 2.47-2.72 Bq/L in 2012. The other two gamma radionuclides (^{137}Cs and ^{60}Co) were not detected in any of the surface water samples (**Table 6.2**). Since these isotopes were not detected, no comparisons between years or among locations were performed.

Table 6.1A Activity concentrations of ^{241}Am, $^{239+240}$Pu and ^{238}Pu (Bq/L) in Surface water samples collected from the three reservoirs in the vicinity of the WIPP site following the February 14 radiological event at WIPP (counting results for 24 hours)

Radionuclides	Location	Sample Date	Activity Bq/L	Unc. (2σ) Bq/L	MDC Bq/L	Status
^{241}Am	Red Bluff (shallow)	3/20/2014	2.47E-04	2.77E-04	4.54E-04	Not detected
	Red bluff (deep)	3/20/2014	-1.37E-05	1.39E-04	3.40E-04	Not detected
	Brantley (shallow)	3/20/2014	0.00E+00	1.62E-04	5.32E-04	Not detected
	Brantley (shallow) duplicate	3/20/2014	1.79E-04	2.68E-04	5.56E-04	Not detected
	Brantley (deep)	3/20/2014	3.49E-04	3.72E-04	6.49E-04	Not detected
	Brantley (deep) duplicate	3/20/2014	2.86E-04	4.29E-04	8.89E-04	Not detected
	Lower Tansill (shallow)	3/28/2014	7.42E-05	2.58E-04	6.92E-04	Not detected
	Lower Tansill (deep)	3/28/2014	3.59E-04	3.19E-04	4.40E-04	Not detected
	Blank	3/28/2014	0.00E+00	2.05E-04	5.34E-04	Not detected
$^{239+240}$Pu	Red Bluff (shallow)	3/20/2014	-1.28E-04	2.19E-04	7.53E-04	Not detected
	Red Bluff (deep)	3/20/2014	5.95E-05	1.69E-04	4.38E-04	Not detected
	Brantley (shallow)	3/20/2014	1.11E-04	1.92E-04	4.08E-04	Not detected
	Brantley (shallow) duplicate	3/20/2014	0.00E+00	1.64E-04	4.26E-04	Not detected
	Brantley (deep)	3/20/2014	2.33E-04	2.92E-04	5.59E-04	Not detected
	Brantley (deep) duplicate	3/20/2014	1.65E-04	2.21E-04	4.06E-04	Not detected
	Lower Tansill (shallow)	3/28/2014	-2.02E-04	2.96E-04	1.04E-03	Not detected
	Lower Tansill (deep)	3/28/2014	5.63E-05	2.81E-04	7.59E-04	Not detected
	Blank	3/28/2014	1.88E-04	2.52E-04	4.62E-04	Not detected
^{238}Pu	Red Bluff (shallow)	3/20/2014	5.85E-05	2.15E-04	5.81E-04	Not detected
	Red bluff (deep)	3/20/2014	1.19E-04	2.07E-04	4.38E-04	Not detected
	Brantley (shallow)	3/20/2014	5.30E-05	1.95E-04	5.26E-04	Not detected
	Brantley (shallow) duplicate	3/20/2014	1.16E-04	2.01E-04	4.26E-04	Not detected
	Brantley (deep)	3/20/2014	5.63E-05	2.07E-04	5.59E-04	Not detected
	Brantley (deep) duplicate	3/20/2014	-2.40E-06	1.59E-04	5.24E-04	Not detected
	Lower Tansill (shallow)	3/28/2014	-7.21E-05	2.93E-04	9.22E-04	Not detected
	Lower Tansill (deep)	3/28/2014	0.00E+00	1.74E-04	4.54E-04	Not detected
	Blank	3/28/2014	-1.34E-04	2.60E-04	9.08E-04	Not detected

Table 6.1B Activity concentrations of ^{241}Am, $^{239+240}Pu$ and ^{238}Pu (Bq/L) in Surface water samples collected from the three reservoirs in the vicinity of the WIPP site following the February 14 radiological event at WIPP (counting results for 5 days)

Radionuclides	Location	Sample Date	Activity Bq/L	Unc. (2σ) Bq/L	MDC Bq/L	Status
^{241}Am	Red Bluff (shallow)	3/20/2014	9.07E-05	1.30E-04	2.11E-04	Not detected
	Red bluff (deep)	3/20/2014	-1.39E-05	3.92E-05	1.29E-04	Not detected
	Brantley (shallow)	3/20/2014	2.23E-05	3.87E-05	8.21E-05	Not detected
	Brantley (shallow) duplicate	3/20/2014	3.24E-04	1.84E-04	3.38E-04	Not detected
	Brantley (deep)	3/20/2014	2.99E-04	2.06E-04	4.02E-04	Not detected
	Brantley (deep) duplicate	3/20/2014	2.89E-04	3.35E-04	7.45E-04	Not detected
	Lower Tansill (shallow)	3/28/2014	2.11E-04	2.02E-04	4.26E-04	Not detected
	Lower Tansill (deep)	3/28/2014	1.72E-04	1.36E-04	1.93E-04	Not detected
$^{239+240}Pu$	Red Bluff (shallow)	3/20/2014	0.00E+00	1.99E-04	4.99E-04	Not detected
	Red bluff (deep)	3/20/2014	8.65E-05	7.04E-05	9.09E-05	Not detected
	Brantley (shallow)	3/20/2014	7.08E-05	6.29E-05	8.69E-05	Not detected
	Brantley (shallow) duplicate	3/20/2014	9.98E-05	9.21E-05	1.34E-04	Not detected
	Brantley (deep)	3/20/2014	1.25E-04	1.59E-04	3.52E-04	Not detected
	Brantley (deep) duplicate	3/20/2014	8.16E-05	6.65E-05	8.58E-05	Not detected
	Lower Tansill (shallow)	3/28/2014	-6.89E-05	2.96E-04	7.40E-04	Not detected
	Lower Tansill (deep)	3/28/2014	2.54E-05	2.00E-04	4.91E-04	Not detected
^{238}Pu	Red Bluff (shallow)	3/20/2014	-3.86E-05	1.34E-04	3.63E-04	Not detected
	Red bluff (deep)	3/20/2014	6.18E-05	6.08E-05	9.09E-05	Not detected
	Brantley (shallow)	3/20/2014	2.36E-05	1.34E-04	3.33E-04	Not detected
	Brantley (deep)	3/20/2014	-1.25E-05	1.35E-04	3.52E-04	Not detected
	Brantley (shallow) duplicate	3/20/2014	7.23E-05	6.42E-05	8.86E-05	Not detected
	Brantley (deep) duplicate	3/20/2014	1.17E-05	1.30E-04	3.29E-04	Not detected
	Lower Tansill (shallow)	3/28/2014	-1.24E-04	2.48E-04	6.45E-04	Not detected
	Lower Tansill (deep)	3/28/2014	8.88E-05	7.24E-05	9.34E-05	Not detected

Table 6.2 Activity concentrations of ^{137}Cs, ^{40}K and ^{60}Co (Bq/L) in surface water samples collected from the three reservoirs in the vicinity of the WIPP site following the February 14 radiological event at WIPP

Radionuclides	Location	Sample Date	Activity Bq/L	Unc. (2σ) Bq/L	MDC Bq/L	Status
^{137}Cs	Red Bluff (shallow)	3/20/2014	-8.16E-03	5.71E-02	9.68E-02	No detection
	Red bluff (deep)	3/20/2014	1.12E-02	5.67E-02	9.57E-02	No detection
	Brantley (shallow)	3/20/2014	1.83E-02	5.61E-02	9.46E-02	No detection
	Brantley (shallow) duplicate	3/20/2014	5.67E-04	5.58E-02	9.44E-02	No detection
	Brantley (deep)	3/20/2014	3.44E-02	5.65E-02	9.49E-02	No detection
	Brantley (deep) duplicate	3/20/2014	-2.84E-02	5.65E-02	9.61E-02	No detection
	Lower Tansill (shallow)	3/28/2014	1.45E-02	5.56E-02	9.38E-02	No detection
	Lower Tansill (deep)	3/28/2014	3.20E-02	5.64E-02	9.49E-02	No detection
^{40}K	Red Bluff (shallow)	3/20/2014	1.57E+00	6.81E-01	1.11E+00	Detected
	Red bluff (deep)	3/20/2014	1.94E+00	6.74E-01	1.08E+00	Detected
	Brantley (shallow)	3/20/2014	5.26E-01	6.77E-01	1.14E+00	No detection
	Brantley (deep)	3/20/2014	3.46E-01	6.57E-01	1.11E+00	No detection
	Brantley (shallow) duplicate	3/20/2014	2.50E-01	6.61E-01	1.12E+00	No detection
	Brantley (deep) duplicate	3/20/2014	7.42E-01	6.61E-01	1.10E+00	No detection
	Lower Tansill (shallow)	3/28/2014	4.23E-01	6.60E-01	1.11E+00	No detection
	Lower Tansill (deep)	3/28/2014	1.11E-01	6.76E-01	1.14E+00	No detection
^{60}Co	Red Bluff (shallow)	3/20/2014	5.87E-03	5.17E-02	8.76E-02	No detection
	Red bluff (deep)	3/20/2014	2.22E-02	5.25E-02	8.86E-02	No detection
	Brantley (shallow)	3/20/2014	2.34E-02	5.11E-02	8.62E-02	No detection
	Brantley (shallow) duplicate	3/20/2014	2.76E-03	5.17E-02	8.78E-02	No detection
	Brantley (deep)	3/20/2014	1.72E-02	5.23E-02	8.83E-02	No detection
	Brantley (deep) duplicate	3/20/2014	3.20E-02	5.11E-02	8.61E-02	No detection
	Lower Tansill (shallow)	3/28/2014	4.59E-02	5.06E-02	8.49E-02	No detection

	Lower Tansill (deep)	3/28/2014	3.86E-02	5.24E-01	8.81E-02	No detection
	Blank	3/28/2014	-1.34E-04	2.60E-04	9.08E-04	No detection

SECTION 7

Whole Body Counting (Lie Down and Be Counted)

Introduction

The internal dosimetry (ID) laboratory at the Carlsbad Environmental Monitoring and Research Center (CEMRC) has a dedicated, high efficiency, Lung and Whole Body Counting (LWBC) facility to perform *in vivo* measurements of the internally deposited radionuclides in humans. The CEMRC ID LWBC facility, is located in Carlsbad, NM, approximately 33 miles (53 km) northwest of the WIPP site. The facility is funded through a financial assistance grant by the Department of Energy (DOE) and by other private agencies.

The LWBC facility has been performing lung and whole body *in vivo* radiobioassay services since 1997 for public volunteers, living within a 100-mile radius of the WIPP, through a program entitled, "Lie Down and Be Counted (LDBC)". The LWBC facility has also been providing support to the Waste Isolation Pilot Plant (WIPP) and other contract agencies by conducting *in vivo* radiobioassays for radiation workers on an on-going basis since 1999. On February 14, 2014 there was an underground radiation incidence at the WIPP site resulting in a small release of radioactive contamination into the environment. In response to this event, the LWBC facility performed immediate *in vivo* analyses looking specifically for the presence of Pu Isotope, ^{241}Am, ^{137}Cs and ^{60}Co radionuclides in the radiation workers of the WIPP site as well as for LDBC volunteers during this time.

The 17 year time period of the WIPP-related *in vivo* radio-bioassay measurement program can be divided into four categories, shown pictorially in Figure 7.1, and described as:

1) Baseline *in vivo* analyses on public volunteers, from 1997 to 1999, prior to the opening of the Waste Isolation Pilot Plant (WIPP).
2) *In vivo* analyses performed on public and contract personnel from 1999 up to the WIPP radiation incidence on February 14, 2014.
3) *In vivo* analyses performed on public and contract personnel during WIPP radiation incidence from February 14, to June 30, 2014
4) *In vivo* analyses performed on public and contract personnel after WIPP radiation incidence from July 1, 2014 to August 31, 2014.

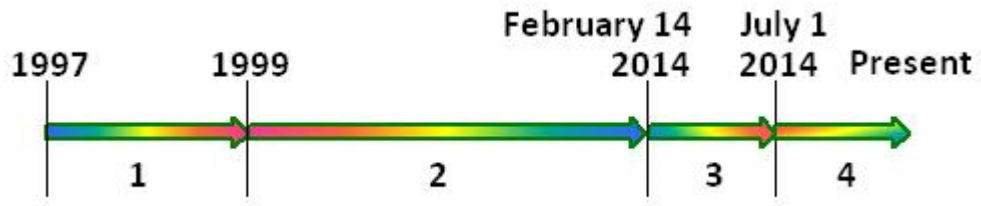


Figure 7.1 Time periods (not drawn to scale) of the LDBC *in vivo* radio-bioassay measurements of the public volunteers

This report provides only the Public results of the *in vivo* measurements of internally deposited radionuclides performed during the above mentioned time period as CEMRC's contract requirements with other agencies prevent disclosure of the results of their radiation workers.

Purpose and Usefulness of *In Vivo* Radiobioassay

In vivo radiobioassay is a direct measurement of internally deposited radio nuclides in the whole body. Lung and whole body counting (*in vivo* radio-bioassay) are the direct measurement of radioactive material in the lungs (including the bronchial region) and whole body, respectively, by the detection of the photons emitted from the body within the confines of the counting geometry.

The utmost advantages of the *in vivo* radio-bioassay are 1) it is non-invasive, 2) it does not expose the subject to any additional radiation but rather measures the radioactivity inside the body, 3) it is a direct method and results are available as soon as the measurement is finished, and 4) it is ecofriendly meaning that it does not generate any radio-chemical or waste products for each measurement obtained.

In vivo lung and whole body counters provide adequate detection of gamma-emitting fission and activation products. In addition, lung counters are useful in the detection and quantification of thorium, uranium, transuranics and other special nuclear material. The CEMRC ID lab has specially designed lung and whole body counters that can be operated simultaneously and conveniently. The high efficiency and high resolution lung detectors of the CEMRC ID lab are unique in the nation with respect to the capability of measuring *in vivo* Plutonium and Americium isotopes.

Additionally, *in vivo* lung and whole body measurements, when performed as soon as possible after a suspected intake of photon emitting radionuclides, provide valuable information on the initial deposition of material in the body. While the absence of external contamination is preferred, even in the event that external contamination is present, *in vivo*

lung and whole body measurements can still provide an upper limit of the initial deposition, which can aid in the planning of a special bioassay program. The CEMRC ID lab provided such valuable information to the public and to contract personnel during the WIPP radiation incidence, by being available immediately following the incidence's occurrence.

CEMRC Internal Dosimetry Lung and Whole Body Counting Facility

The *in vivo* counting facility consists of a large shielded counting room, instrument control workstation, two change rooms with showers and toilets, and a reception area. Routine radio-bioassays are generally performed from the instrument control work station. The instrument control workstation includes a video display terminal (VDT) and intercom that are used to monitor subjects during the bioassay. An additional VDT and intercom are located in the office of the primary instrument operator. A compact stereo has been installed so that counting subjects may listen to music during the bioassay counting process. Signal processing electronics are located outside the counting shield next to the instrument control workstation. The facility was completed and the LWBC equipment became operational in the summer of 1997. In order to maintain a low background environment, construction materials were selected for low naturally occurring and anthropogenic radioactive contamination.

Shielded Counting Room

The counting shield is an essential component to a sensitive, low background *in vivo* monitoring system. The shielded counting room (Figure 7.2) is 9 feet wide, 10 feet long and 9 feet high. It is constructed from 10-inch thick cast iron (Fe) obtained from pre-World War II iron found in Texas and Oklahoma. When assembled, these individual pieces of the shield overlap to eliminate the streaming of radiation through spaces from outside sources.

The door to the counting shield weighs in excess of 6 tons. It is operated using an air-over-oil hydraulic system. Open, close, and stop controls are provided inside and outside the shield. The hydraulic system controlling the door is configured such that the door defaults to the open position in case of a power failure. A 60-gallon air tank is maintained at 120 pounds per square inch (PSI) to provide reserve pressure to open the door following a loss of power.

A graded-Z liner (Z represents the charge of an element) was added to the inside of the thick Fe walls of the shield to attenuate the photons that are produced through cosmic radiation interactions within the shield walls.

Conditioned air is provided to the shield from the Center's centralized heating and cooling system. The air is high efficiency particulate air (HEPA) filtered just prior to entering the room to remove any particulate that may contain radioactive contamination. In addition, an oxygen monitor is installed inside the shield to monitor oxygen levels in the room.

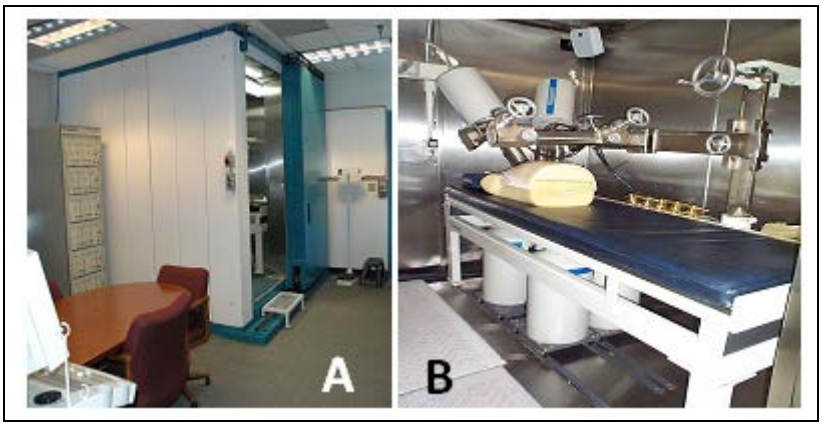


Figure 7.2 An overview of CEMRC Whole Body Counting Room

Specially Designed Counting Bed and Detector Positioning Mechanism

Inside the shielded room, a specially designed counting bed and positioning mechanism is housed. This bed was designed to allow for simultaneous lung and whole body counts. The bed is constructed from low background steel and provides minimal attenuation of photons between the counting subject and whole body counting detectors. The positioning mechanism for the lung counting detectors was designed to support four, 3800 mm^2 detectors mounted in two cryostats. Sufficient positioning flexibility is provided in the positioning mechanism for longitudinal and vertical positioning as well as independent lateral angle and longitudinal tilt adjustment between the two cryostats (Figure 3).

Lung and Whole body Counting

Subjects to be monitored report to the *in vivo* monitoring facility at their appointed time, watch an informational video, and are directed to change out of their street clothes into scrubs provided by the CEMRC. The subject's height and weight are measured and recorded for input into the chest wall thickness algorithm. Subjects lie down comfortably on a table in the shielded chamber, and the lung detectors are positioned onto the chest. The whole body detectors are located under the bed and are positioned behind the lower thorax of the counting subject. The measurement test is initiated and runs for 30 minutes, a process commonly referred to as counting.

Minimum Detectable Activity of CEMRC Lung and Whole body Counting System

In vivo counting of radionuclides listed below is based on radionuclides identified in the WIPP Internal Dosimetry Technical Basis Document and the WIPP Environmental Impact Statement.

The Minimum Detectable Activity (MDA) indicates the ability of a facility to detect a radionuclide in a person, but should not be used to decide if a specific radiobioassay has or has not detected activity within a person. The MDA represents the amount of a radionuclide that, if present, would be detected 95% of the time under routine operation of a facility. The MDAs of CEMRC ID Lung and Whole Body counters for the period 2013-2014 are given in Tables 7.1A and 7.1B. Minimum testing levels (MTL) of radionuclides for *in vivo* radiobioassay, listed in ANSI N13.30 1996 and accredited by American National Standard Institute, are also provided in Tables 7.1A and 7.1B. It can be seen from Tables 7.1A and 7.1B that the CEMRC Lung and Whole Body counting system MDAs are much better than the MTLs except for the detection of Pu isotopes. However, *in vivo* measurements of plutonium isotopes provide not only immediate confirmation of the presence of the isotope but also an approximate concentration deposited in the body.

Table 7.1A Minimum Detectable Activities for 2013-2014

Radionuclides Deposited in the Lungs									
Radionuclide	Energy	MDA (nCi) as a function of Chest Wall Thickness (cm)							ANSI N13.30
		Chest Wall Thickness (CWT) cm							
		1.6 cm	2.22 cm	3.01 cm	3.33 cm	4.18 cm	5.1 cm	6.0 cm	Minimum Testing Level
		MDA							
	keV	nCi	nCi	nCi	nCi	nCi	nCi	nCi	nCi
Am-241	59.50	0.18	0.23	0.30	0.34	0.46	0.64	0.88	2.7
Ce-144	133.50	0.47	0.56	0.71	0.78	1.00	1.31	1.71	810
Cf-252	19.20	16.84	34.18	84.20	121	320	912	2541	
Cm-244	18.10	15.94	34.70	93.62	140	407	1288	3986	
Eu-155	105.30	0.27	0.33	0.43	0.48	0.62	0.84	1.12	
Np-237	86.50	0.49	0.60	0.78	0.87	1.15	1.57	2.13	
Pu-238	17.10	17.27	40.68	121	189	612	2191	7615	240
Pu-239	17.10	43.94	103	305	475	1532	5432	18667	
Pu-240	17.10	17.26	40.61	120	187	602	2134	7334	
Pu-242	17.10	20.82	48.98	145	225	726	2574	8847	
Ra-226	186.10	1.63	1.92	2.36	2.57	3.22	4.10	5.20	
Th-232 via Pb-212	238.60	0.15	0.17	0.22	0.23	0.29	0.38	0.48	
Th-232	59.00	33.62	42.03	55.97	62.80	85.48	119	165	
Th-232 via Th-228	84.30	4.81	5.90	7.71	8.61	11.47	15.67	21.22	
U-233	440.30	0.66	0.76	0.93	1.00	1.22	1.53	1.91	
U-235	185.70	0.10	0.12	0.15	0.16	0.20	0.25	0.32	810
Nat U via Th-234	63.30	1.61	2.00	2.66	2.98	4.03	5.59	7.72	14

Table 7.1B Minimum Detectable Activities for 2013-2014

Radionuclides Deposited in the Whole Body			
Radionuclide	Energy	MDA	ANSI N13.30 MTL
	keV	nCi	nCi
Ba-133	356	0.81	
Ba-140	537	1.59	
Ce-141	145	1.69	
Co-58	811	0.38	
Co-60	1333	0.37	81
Cr-51	320	4.65	
Cs-134	604	0.37	81
Cs-137	662	0.43	81
Eu-152	344	1.67	
Eu-154	1275	0.99	
Eu-155	105	4.00	
Fe-59	1099	0.69	
I-131	365	0.50	
I-133	530	0.44	
Ir-192	317	0.57	
Mn-54	835	0.46	81
Ru-103	497	0.42	
Ru-106	622	3.44	
Sb-125	428	1.40	
Th-232 via Ac-228	911	1.30	
Y-88	898	0.39	
Zn-65	1116	1.15	
Zr-95	757	0.62	

Results of 17 Years *In Vivo* Measurements of Internally Deposited Radionuclides in Volunteers from 1997 to 2014

To determine whether or not an activity has been detected in a particular person, the parameter, Decision Level (L_C) is used. The L_C represents the 95th percentile of a null distribution that results from the differences of repeated, pair-wise background measurements. An individual count result (net count rate) is assumed to be statistically greater than background if it was greater than L_C. The use of this criterion (L_C) will result in a

statistically inherent 5% false positive error rate per pair-wise comparison (5% of all measurements will be determined to be positive when there is actually no activity in the person). Decision levels are calculated using the equation based on the recommendations of the *Performance Criteria for Radiobioassay* (ANSI N13.30 1996).

Table 7.2 Comparison of Percentage of (Count Results > Decision Limit) for "Lie Down and Be Counted" Public Volunteers from 1997 to 2014

Radionuclide	*In Vivo* count type	Baseline Counts	Operational Monitoring Counts		
		(Data prior to 3/27/1999)	(3/27 1999 to 2/13/2014)	(2/14/2014 to 6/30/2014)	(7/1/2014 to 8/31/2014)
		N = 366	N = 991	N = 40	N = 4
		% of Results > LC	% of Results > LC	% of Results > LC	% of Results > LC
		(Margin of error)	(Margin of error)	(Margin of error	(Margin of error)
Am-241	Lung	5.2 (4.0 to 6.4)	4.2 (3.6 to 4.9)	0 (0 to 0)	0 (0 to 0)
Ce-144	Lung	4.6 (3.5 to 5.7)	4.2 (3.6 to 4.9)	7.5 (3.4 to 11.6)	0 (0 to 0)
Cf-252	Lung	4.1 (3.1 to 5.1)	5.8 (5 to 6.5)	5 (1.6 to 8.4)	0 (0 to 0)
Cm-244	Lung	5.7 (4.5 to 7.0)	5.8 (5 to 6.5)	5 (1.6 to 8.4)	25 (3.8 to 46.2)
Eu-155	Lung	7.1 (5.8 to 8.4)	5.1 (4.5 to 5.8)	5 (1.6 to 8.4)	0 (0 to 0)
Np-237	Lung	3.6 (2.6 to 4.5)	3.7 (3.1 to 4.3)	2.5 (0.1 to 4.9)	0 (0 to 0)
Pb-210	Lung	4.4 (3.3 to 5.4)	6.3 (5.5 to 7)	12.5 (7.4 to 17.6)	0 (0 to 0)
Pu-Isotopes	Lung	5.7 (4.5 to 7.0)	5.3 (4.6 to 6)	0 (0 to 0)	0 (0 to 0)
Th-232 via Pb-212	Lung	34.2 (31.7 to 36.6)	31.1 (29.6 to 32.5)	40 (32.4 to 47.6)	25 (3.8 to 46.2)
Th-232	Lung	4.9 (3.8 to 6.0)	5.3 (4.6 to 6)	7.5 (3.4 to 11.6)	0 (0 to 0)
Th-232 via Th-228	Lung	4.1 (3.1 to 5.1)	4.9 (4.2 to 5.5)	0 (0 to 0)	0 (0 to 0)
U-233	Lung	5.7 (4.5 to 7.0)	9.3 (8.4 to 10.2)	10 (5.4 to 14.6)	0 (0 to 0)
U-235	Lung	10.7 (9.0 to 12.3)	11.4 (10.4 to 12.4)	0 (0 to 0)	25 (3.8 to 46.2)
Natural U via Th-234	Lung	5.2 (4.0 to 6.4)	6.1 (5.3 to 6.8)	0 (0 to 0)	0 (0 to 0)
Ba-133	Whole Body	3.6 (2.6 to 4.5)	2.9 (2.4 to 3.5)	5 (1.6 to 8.4)	0 (0 to 0)
Ba-140	Whole Body	5.2 (4.0 to 6.4)	3.9 (3.3 to 4.5)	5 (1.6 to 8.4)	0 (0 to 0)
Ce-141	Whole Body	3.6 (2.6 to 4.5)	4.8 (4.2 to 5.5)	5 (1.6 to 8.4)	0 (0 to 0)
Co-58	Whole Body	4.4 (3.3 to 5.4)	2.9 (2.4 to 3.5)	10 (5.4 to 14.6)	25 (3.8 to 46.2)
Co-60	Whole Body	54.6 (52.0 to 57.2)	31.2 (29.7 to 32.6)	5 (1.6 to 8.4)	0 (0 to 0)
Cr-51	Whole Body	5.7 (4.5 to 7.0)	4.2 (3.6 to 4.9)	2.5 (0.1 to 4.9)	0 (0 to 0)
Cs-134	Whole Body	1.6 (1.0 to 2.3)	2.6 (2.1 to 3.1)	0 (0 to 0)	0 (0 to 0)
Cs-137	Whole Body	28.4 (26.1 to 30.8)	18.2 (17 to 19.4)	17.5 (11.6 to 23.4)	25 (3.8 to 46.2)
Eu-152	Whole Body	7.4 (6.0 to 8.7)	6.2 (5.4 to 6.9)	0 (0 to 0)	0 (0 to 0)
Eu-154	Whole Body	3.8 (2.8 to 4.8)	3.3 (2.8 to 3.9)	2.5 (0.1 to 4.9)	0 (0 to 0)
Eu-155	Whole Body	3.8 (2.8 to 4.8)	3.6 (3.1 to 4.2)	5 (1.6 to 8.4)	0 (0 to 0)

Fe-59	Whole Body	3.8 (2.8 to 4.8)	6.1 (5.3 to 6.8)	5 (1.6 to 8.4)	0 (0 to 0)
I-131	Whole Body	5.2 (4.0 to 6.4)	4.1 (3.5 to 4.8)	5 (1.6 to 8.4)	0 (0 to 0)
I-133	Whole Body	3.3 (2.3 to 4.2)	3.9 (3.3 to 4.5)	10 (5.4 to 14.6)	0 (0 to 0)
Ir-192	Whole Body	4.1 (3.1 to 5.1)	4.1 (3.5 to 4.8)	7.5 (3.4 to 11.6)	0 (0 to 0)
K-40	Whole Body	100 (100 to 100)	100 (100 to 100)	100 (100 to 100)	100 (100 to 100)

Table 7.2 Continued

Radionuclide	*In Vivo* count type	Baseline Counts	Operational Monitoring Counts		
		(Data prior to 3/27/1999)	(3/27 1999 to 2/13/2014)	(2/14/2014 to 6/30/2014)	(7/1/2014 to 8/31/2014)
		N = 366	N = 991	N = 40	N = 4
		% of Results > LC	% of Results > LC	% of Results > LC	% of Results > LC
		(Margin of error)	(Margin of error)	(Margin of error)	(Margin of error)
Mn-54	Whole Body	12.3 (10.6 to 14.0)	12 (11 to 13)	12.5 (7.4 to 17.6)	0 (0 to 0)
Ru-103	Whole Body	2.2 (1.4 to 3.0)	1.7 (1.3 to 2.1)	2.5 (0.1 to 4.9)	0 (0 to 0)
Ru-106	Whole Body	4.4 (3.3 to 5.4)	4.5 (3.9 to 5.2)	5 (1.6 to 8.4)	0 (0 to 0)
Sb-125	Whole Body	5.2 (4.0 to 6.4)	4.3 (3.7 to 5)	5 (1.6 to 8.4)	25 (3.8 to 46.2)
Th-232 via Ac-228	Whole Body	34.7 (32.2 to 37.2)	25.6 (24.2 to 27)	22.5 (16 to 29)	25 (3.8 to 46.2)
Y-88	Whole Body	7.7 (6.3 to 9.0)	6.1 (5.3 to 6.8)	5 (1.6 to 8.4)	25 (3.8 to 46.2)
Zr-95	Whole Body	6.6 (5.3 to 7.9)	4 (3.4 to 4.6)	2.5 (0.1 to 4.9)	0 (0 to 0)

N = Total number of individuals counted

The percentages of individuals with count results greater than L_C, for the four time periods, namely,

- Prior to WIPP operation (from 7/21/1997 to 3/27/1999)
- After operation and prior to WIPP radiation incidence (from 3/27/1999 to 2/14/2014)
- During WIPP radiation incidence (from 2/14/2014 to 7/1/2014)
- After WIPP incidence (from 7/1/2014 to 9/1/2014) are listed in Table 7.2.

The margin of error represents the 95% confidence interval of the observed percentage; under replication of this experiment, one would expect 95% of the confidence intervals to include the true population if the sample was representative of the true population. Margin of errors are also listed in Table 7.2. Baseline counts include only the initial counts during this baseline period. Operational monitoring counts include the counting of new individuals and the recounting of previously measured participants.

From Table 7.2, it can be seen that the percentage results of the operational monitoring counts during the WIPP radiation incidence were in the same range of the percentage results of baseline counts and counts performed prior to the WIPP radiation incidence, except for the following radionuclides, namely, ^{144}Ce, ^{210}Pb, ^{232}Th (determined via ^{212}Pb), ^{58}Co, ^{133}I and ^{192}Ir. The percentage results of these nuclides were about 1.5 to less than

3 times higher than the base line percentage results. While the percentage results of these nuclides (with the exception of Th) may have been higher during the WIPP incidence, the activities were in the same range as pre-event measurements as shown in Table 7.3. The activity range of ^{232}Th appears to be fluctuating over time and thus, is not abnormal. The 25% results of radionuclides, for operational monitoring counts during the period 7/1/2014 to 8/31/2014, in the last column of Table 7.4, do not represent the true range, because of a small number (n=4) of individuals counted during that period. This data is included only to provide a complete picture.

The important thing to note is that none of the radionuclides listed in Table 7.3 are related to the WIPP radiation release event, where the main radionuclides of interest were ^{241}Am and Plutonium isotopes. The percentage results of operational monitoring counts for ^{241}Am and Pu-Isotopes were **"zero"** during the WIPP radiation release event for all public counts performed during that time period.

Table 7.3 Activity ranges of select radionuclides during different periods of the LDBC program

Radionuclide	Prior to WIPP Installation 7/21/1997 to 3/27/1999	Prior to WIPP Incidence 3/27/1999 to 2/13/2014	During WIPP Incidence 2/14/2014 to 6/30/2014
Ce-144	0.2 - 0.6	0.2 - 1.0	0.3 - 0.5
Pb-210	0.4 - 3.3	0.5 - 28	0.7 - 4.5
Th-232 (via Pb-212)	7 - 78	9 - 58	35 - 99
Co-58	0.1 - 0.4	0.1 - 0.3	0.1 - 0.2
I-133	0.2 - 0.3	0.1 - 0.3	0.1 - 0.2

The residents of Carlsbad and surrounding neighborhood, within a 100 mile radius of the WIPP, always showed special interest in the environmental and personal monitoring of radioactivity. This is mainly because of their awareness about the presence of the WIPP facility. Their interest can be seen by the number of the individuals who returned to the CEMRC facility to be measured more than once. The number of individuals who were counted more than once during the past 17 years is given in Table 7.4.

Table 7.4 Number of individuals counted more than once in the LDBC program from 1997 to 2014

LDBC Period	Number of individuals counted more than once
7/21/1997 to 3/26/1999	6

3/27/1999 to 2/13/2014	289
2/14/2014 to 6/30/2014	3
7/01/2014 to 8/31/2014	0

In additon to public volunteers, the number of WIPP personnel counted during the underground radiation event period 2/14/2014 to 6/30/2014 was about 144.

In conclusion, the CEMRC ID LWBC facility and the LDBC program are unique because of the following reasons: (1) The CEMRC LWBC facility is a one of a kind, high efficiency and high resolution lung and whole body counting facility, monitoring both the public and radiation workers on an ongoing basis; (2) The establishment of radio-bioassay measurements of the public during the period 7/21/1997 to 3/26/1999 provides baseline information prior to WIPP operations to determine the impact, if any, that the WIPP facility may have on the local population. This is in contrast to most cohort studies done with uranium miners or WWII studies, where similar baseline studies were unavailable. (3) The establishment of radio-bioassay measurements during the period 1999 up to 2/13/2014 provides base line information prior to the occurrence of the February 14, 2014 radiation event. (4) The radio-bioassay measurements of the public from 2/14/2014 to 6/30/2014 provides radionuclide deposition information necessary to perform a before and after comparison of the February 14, 2014 WIPP radiation release event on the local population.

The comparison of the operational monitoring results during the February 14, 2014 WIPP radiation incidence along with the information from the two different baseline periods, proves beyond doubt, that there is no measureable effect on the public inhabiting the surrounding areas of the WIPP facility as a result of the February 14, 2014 radiation release event.

SECTION 8
QUALITY ASSURANCE

General Analytical Quality Assurance

Quality assurance and quality control practices encompass all aspects of CEMRC's WIPP Environmental Monitoring Programs (WIPP-EM). The development and implementation of an independent health and environmental monitoring program has been CEMRC's primary activity. The multilayered components of the CEMRC Quality Assurance (QA) Program ensure that all analytical data reported in this report are reliable and of high quality, and that all environmental monitoring data meet quality assurance and quality control objectives.

The CEMRC is subject to the policies, procedures and guidelines adopted by NMSU, as well as state and federal laws and regulations that govern the operation of the University and radiological facilities. Since its inception, CEMRC's WIPP-EM program has been conducted as a scientific investigation, that is, without any compliance, regulatory, or oversight responsibilities. As such, there are no specific requirements for reporting data other than good scientific practices.

Samples for the CEMRC's WIPP-EM Programs were collected by personnel trained in accordance with approved procedures. Established sampling locations were accurately identified and documented to ensure continuity of data. Field duplicate samples were used to assess sampling and measurement precision. Quality control in the analytical laboratories is maintained through tracking and verification of analytical instrument performance, use of American Chemical Society certified reagents, use of National Institute of Standards and Technology (NIST) traceable radionuclide solutions and verification testing of radionuclide concentrations for tracers not purchased directly from NIST or Eckert and Ziegler Analytics. When making laboratory solutions, volumes and lot numbers of stock chemicals are recorded. Prior to weighing radionuclide tracers and samples, the balance being used is checked using NIST traceable weights.

Control checks were performed on all nuclear counting instrumentation each day or prior to counting a new sample. The type of instrument and methods used for performance checks were as follows: for the Protean 9604 gas-flow α/β proportional counter used for the FAS program, efficiency control charting was performed using ^{239}Pu and ^{90}Sr check sources along with ensuring that α/β cross-talk was within limits. Sixty-minute background counts were recorded daily. Two blanks per week for the FAS program were counted for 20 hours and were used as a background history for calculating results.

Routine background determinations were made on the HPGe detector systems by counting blank samples, and the data was used to blank correct the sample concentrations.

For the alpha spectrometer, efficiency, resolution and centroid control charting was performed using Eckert and Ziegler Analytics check sources on a regular basis. Before each sample count, pulser checks were performed to ensure acceptable detector resolution and centroid. Blanks counted for 5 days were used as a background history for calculating results. Analytical data are verified and validated as required by project-specific quality objectives before being used to support decision making.

CEMRC also participates in the two national performance evaluation programs, NIST Radiochemistry Intercomparison Program (NIST-RIP) and the DOE-Mixed-Analyte Performance Evaluation Program (MAPEP) for soil, air filter and water analysis. The proficiency tests help to ensure the accuracy of analytical results reported to DOE and other stakeholders, while also providing an efficient means for laboratories to demonstrate analytical proficiency. Under these programs, CEMRC analyzed blind check samples, and the analysis results were compared with the official results measured by the MAPEP, and NRIP laboratories. During 2012, CEMRC radio-analytical program analyzed MAPEP- air filter, water, soil, gross alpha/beta on air filters and NIST-NRIP - glass fiber filters, soil and acidified water samples. Isotopes of interest in these performance evolution programs were $^{233/234}$U, ^{238}U, ^{238}Pu, $^{239+240}$Pu, and ^{241}Am and gamma emitters. The analyses were carried out using CEMRC's actinide separation procedures, and were treated as a regular sample set to test regular performance. CEMRC's results were consistently close to the known value. MAPEP and NIST-NRIP results were presented in CEMRC's 2012 Annual Report. Only one analysis result for MAPEP, (air filter) was deemed not acceptable for ^{241}Am. Based on the number of A (Acceptable) ratings earned by CEMRC for the analysis of performance evaluation samples, the laboratory provided accurate and reliable radionuclide analysis data for the WIPP environmental samples. In addition, for each set of samples, reagent blank and tracer spikes are also carried through the entire separation and counting process for recovery determination and quality control.

Conclusion

After almost fifteen years of successful waste disposal operations, the WIPP repository had its first minor accident on February 14, 2014. It was the first unambiguous release at the WIPP. The accident released moderate levels of radioactivity into the underground air. A small but measurable amount of radioactivity was also vented to the surface and was detected beyond the site's inner boundary. The results were reported to the public as they were obtained and verified. Releases were low and localized, and no radiation-related health effects among local workers or the public would be expected.

The wisdom, on the part of the DOE as well as the city of Carlsbad and regional and state leadership in establishing CEMRC was made apparent in early 2014. In the wake of the radiation-release incident of February 14, 2014, CEMRC began an intensified ambient air sampling campaign and accelerated its radiochemical analyses of samples obtained in and around the WIPP site, and, more importantly, notified the public through news releases and through participation in "town hall" meetings arranged by the Mayor's Office of the City of Carlsbad in cooperation with the Carlsbad Field office of the DOE.

The accelerated air monitoring campaign, which began on February 15, 2014 shows that except for the brief detection of americium and plutonium in the nearby ambient air samples, there is no increase in radiological contaminants that could be attributed to the recent radiation release from the WIPP in the wider region. The highest activity detected offsite was 115.2 µBq/m^3 for ^{241}Am and 10.2 µBq/m^3 for $^{239+240}$ Pu. These concentrations in air were very small, localized, and below any level of public-health or environmental concern. In terms of radiological risk at or in the vicinity of the WIPP site, the increased risk from the WIPP releases is exceedingly small, approaching zero.

The release of any radioactivity has the potential to alarm portions of the general population who do not understand the difference between actual radiological risk and perceived risk. It is not surprising that some media treatment of the WIPP radiation release event has amplified the public's perception of their risk. The WIPP release incident was news worthy, but it was and is not dangerous to any member of the public, and the utmost care is being taken to assure that WIPP workers are also safe. CEMRC's independence and its extensive monitoring program played a crucial role in providing timely information to the local populations on the levels and types of radiation released from the WIPP, helping eliminate unnecessary hysteria surrounding fear of radiation by engaging local populations through local newspapers and by participating in "town hall" meetings, which had a calming influence on the community. The event at WIPP was an operational misery for the facility, which had a perfect radiological safety record for more than 14 years. The facility has served the nation in the clean-up of its radioactive waste generated during the decades of weapons production. The CEMRC's independence and its extensive monitoring program and constant

public engagement provide confidence to the local populace in evaluating their own safety, which has a direct relationship to their continuing acceptance of a nearby nuclear facility.

In the past, CEMRC's independence and its extensive monitoring program and constant public engagement provided a model of how to garner confidence in the local public in acceptance of a nearby nuclear facility and trust in the scientific methods employed. Following the radiation release event at WIPP, CEMRC's independent monitoring program and independent communications effort has proven its value in terms of assuring continued local acceptance of the facility. The CEMRC independent monitoring and communications model perhaps ought to be considered as part of the infrastructure needed to assure local acceptance of planned repositories elsewhere.

Helpful Information

The following information is provided to assist the reader in understanding this report. Included here is information on scientific notation, radioactivity units, understanding data tables and data uncertainty, understanding graphs, and selected mathematical symbols.

Scientific Notation

Scientific notation is used to express very large or very small numbers. For example, the number 1 billion could be written as 1,000,000,000 or, by using scientific or E notation, written as 1×10^{9} or 1.0E+09. Translating from scientific notation to a more traditional number requires moving the decimal point either left or right from its current location. If the value given is 2.0×10^{3} (or 2.0E+03), the decimal point should be moved three places to the **right** so that the number would then read 2,000. If the value given is 2.0×10^{-5} (or 2.0E-05), the decimal point should be moved five places to the **left** so that the result would be 0.00002.

Radioactivity Units

Much of this report provides data on levels of radioactivity in various environmental media. Radioactivity in this report is usually discussed in units of **curies (Ci)**, with conversions to **becquerels (Bq)**, the International System of Units measure (Table A.1). The curie is the basic unit used to describe the amount of activity present, and activities are generally expressed in terms of curies per mass or volume (e.g., picocuries per liter). One curie is equivalent to 37 billion disintegrations per second or is a quantity of any radionuclide that decays at the rate of 37 billion disintegrations per second. One becquerel is equivalent to one disintegration per second. Nuclear disintegrations produce spontaneous emissions of alpha or beta particles, gamma radiation, or combinations of these.

Understanding the Data Tables

Some degree of variability, or uncertainty, is associated with all analytical measurements. This uncertainty is the consequence of random or systematic inaccuracies related to collecting, preparing, and analyzing the samples. These inaccuracies could include errors associated with reading or recording the result, handling or processing the sample, calibrating the counting instrument, and numerical rounding. With radionuclides, inaccuracies can also result from the randomness of radioactive decay. In this report, the uncertainties used include standard deviation, total propagated analytical uncertainty, and standard error of the mean.

Table 1: Names and symbols for Units of Radioactivity			
Symbol	Name	Symbol	Name
Ci	curie	Bq	becquerel (2.7 x 10^{-11} Ci)
mCi	millicurie (1 x 10^{-3} Ci)	kBq	kilobecquerel (1 x 10^{3} Bq)
µCi	microcurie (1 x 10^{-6} Ci)	MBq	megabecquerel (1 x 10^{6} Bq)
nCi	nanocurie (1 x 10^{-9} Ci)	mBq	millibecquerel (1 x 10^{-3} Bq)
pCi	picocurie (1 x 10^{-12} Ci)	GBq	gigabecquerel (1 x 10^{9} Bq)
fCi	femtocurie (1 x 10^{-15} Ci)	TBq	terabecquerel (1 x 10^{12} Bq)

Standard Deviation

The standard deviation (SD) of sample data relates to the variation around the mean of a set of individual sample results. If differences in analytical results occur among samples, then two times the standard deviation (or ±2 SD) implies that 95% of the time, a re-count or re-analysis of the same sample would give a value somewhere between the mean result minus two times the standard deviation and the mean result plus two times the standard deviation.

Negative Concentrations

Instruments used in the laboratory to measure radioactivity in WIPP Site environmental samples are sensitive enough to measure natural, or background, radiation along with any contaminant radiation in a sample. To obtain a true measure of the contaminant level in a sample, the background radiation level must be subtracted from the total amount of radioactivity measured by an instrument. Because of the randomness of radio-active emissions, the very low activities of some contaminants, or the presence of undesirable materials, it is possible to obtain a background measurement that is larger than the actual contaminant measurement. When the larger background measurement is subtracted from the smaller contaminant measurement, a negative result is generated. The negative results are reported because they are essential when conducting statistical evaluations of the data.

Understanding Graphs

Graphs are useful when comparing numbers collected at several locations or at one location over time. Graphs often make it easy to visualize differences in data where they exist. However, careful consideration should be given to the scale (linear or logarithmic) and units. Some of the data graphed in this report may be plotted using logarithmic, or

compressed, scales. Logarithmic scales are useful when plotting two or more numbers that differ greatly in size or are very close together. For example, a sample with a concentration of 5 grams per liter would get lost at the bottom of the graph if plotted on a linear scale with a sample having a concentration of 1,000 grams per liter (Figure 1). A logarithmic plot of these same two numbers allows the reader to see both data points clearly (Figure 2). The mean (average) and median (defined earlier) values seen in graphics in this report have vertical lines extending above and below the data point. When used with a value, these lines (called error bars) indicate the amount of uncertainty (standard deviation, total propagated analytical uncertainty, or two standard error of the mean) in the reported value.

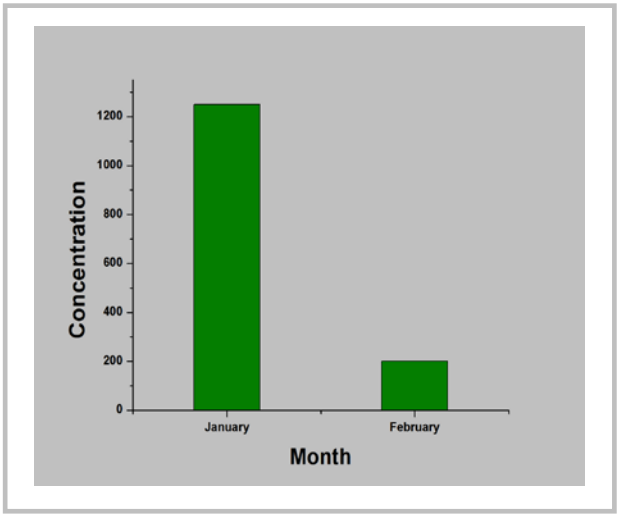


Figure 1. Data plotted using a linear scale

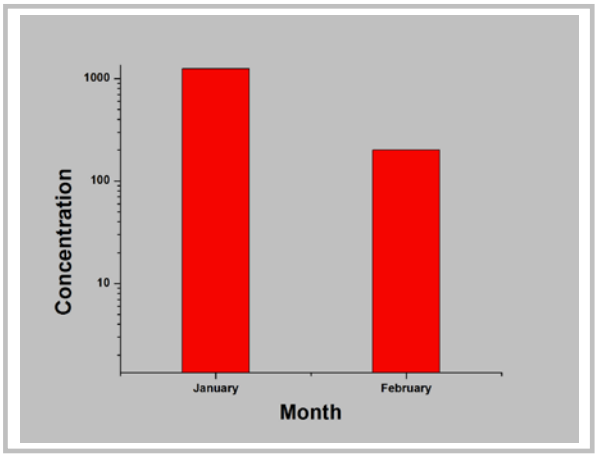


Figure 2. Data plotted using a logarithmic

The error bars in this report represent a 95% chance that the value is between the upper and lower ends of the error bar and a 5% chance that the true value is either lower or higher than the error bar. For example, in Figure 3, the first plotted value is 2.0 ± 1.1, so there is a 95% chance that the true value is between 0.9 and 3.1, a 2.5% chance that it is less than 0.9, and a 2.5% chance that it is greater than 3.1. Error bars are computed statistically, employing all of the information used to generate the value. These bars provide a quick, visual indication that one value may be statistically similar to or different from another value. If the error bars of two or more values overlap, as is the case with values 1 and 3 and values 2 and 3, the values may be statistically similar. If the error bars do not overlap (values 1 and 2), the values may be statistically different. Values that appear to be very different visually (values 2 and 3) may actually be quite similar when compared

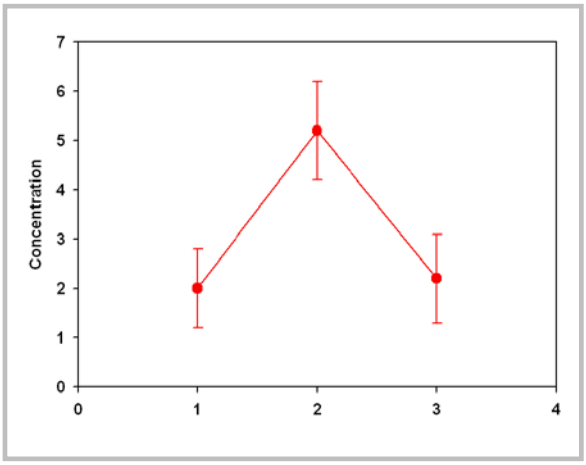


Figure 3. Data with error bars plotted using a linear scale

statistically.

REFERENCES

Alberts, J.J., Bobula, C.M., Farrar, T. A comparison of the distribution of industrially released ^{238}Pu and Fallout $^{239,240}Pu$ in temperate, Northern United States soils. J. Environ. Qual. 9, 592-596 (1980).

Beck, H. L., Bennet, G.B. Historical overview of atmospheric nuclear weapon testing and estimates of fallout in the continental United States. Health Phys. 82, 591-608 (2002)

CEMRC, Carlsbad Environmental Monitoring & Research Center, 1998 Report. Carlsbad, New Mexico.

CEMRC, Carlsbad Environmental Monitoring & Research Center, 2000 Report. Carlsbad, New Mexico.

CEMRC, Carlsbad Environmental Monitoring & Research Center, 2005/2006. Carlsbad, New Mexico.

CEMRC, Carlsbad Environmental Monitoring & Research Center, 2011 Report. Carlsbad, New Mexico.

CEMRC, Carlsbad Environmental Monitoring & Research Center, 2012 Report. Carlsbad, New Mexico.

DOE/WIPP-92-037. 1992. *Statistical Summary of the Radiological Baseline for the Waste Isolation Pilot Plant*. Waste Isolation Pilot Plant, Carlsbad, NM.

EPA 402-R-99-001. 1999. *Cancer Risk Coefficients for Environmental Exposure to Radionuclides*. Federal Guidance Report No. 13, Office of Radiation and Indoor Air, U.S. Environmental Protection Agency, Washington, D.C.

Faller, S. Residual soil radioactivity at the Gnome Test Site in Eddy County, New Mexico, Report No. EPA 600/R-94/117, July 1994. Washington, D.C., Environmental Protection Agency.

Hardy, E.P., Krey, P.W., Volchok, H.L. Global inventory and distribution of fallout plutonium. Nature, 241, 444-445 (1973).

Harley, J.H. Plutonium in the environment-A review. Jpn. J. Radiat Res. 21, 83-104(1980).

Hodge, V., Smith, C., Whiting, J. Radiocesium and plutonium: still together in background" soils after more than thirty years. Chemosphere, 32, 2067-2075 (1996).

Kelly, J. M.; Bond, L. A.; Beasley, T. M. Global distribution of Pu isotopes and ^{237}Np. Sci. Total Environ. 237/238, 483-500 (1999).

Kenney, J.W. Downes, P.S. Gray, D.H. Ballard, S.C., Radionuclide baseline in soil near project Gnome and the Waste Isolation Pilot Plant, Environmental Evaluation Group, EEG-58, 1995.

Kirchner, T.B., Webb, J.L., Webb, S.B., Arimoto, R., Schoep, D.A., Stewart, B.D. Variability in background levels of surface soil radionuclides in the vicinity of the USDOE waste isolation pilot plant, J. Environ. Radioact. 60, 275-291 (2002).

Krey, P.W. Atmospheric burn-up of a plutonium-238 generator. Science, 158: 769-771 (1967).

Krey, P.W., Beck, H.L., The distribution throughout of Utah of ^{137}Cs and $^{239+240}Pu$ from Nevada Test Site detonations. US Department of Energy, Environmental Laboratory, EML-400 (1981).

Minnema, D. M., Brewer. L.W. *Background Radiation Measurements at Waste Isolation Pilot Plant Site*. SAND83-1296. Sandia National Laboratories, Carlsbad, NM, 1983.

National Council on Radiation Protection and Measurements. 2009. *Ionizing Radiation Exposure of the Population of the United States*. NCRP Report No. 160, Washington, D.C.

Rodgers, J. C. (1987). Exhaust stack monitoring issues at the Waste Isolation Pilot Plant. Report EEG-37; DOE/AL/10752-37. Environmental Evaluation Group, Environmental Improvement Division, Health and Environment Department, State of New Mexico, P.O. Box 968, Santa Fe, New Mexico 87503.

Stout, J.E., Arimoto, R. Threshold wind velocities for sand movement in the Mescalero Sands of southeastern New Mexico, J. of Arid Environ. 74, 1456-1460 (2010).

U.S. Congress 1992. The Waste Isolation Pilot Plant Land Withdrawal Act, as amended. Public Law 102-579. Available at: <http://www.emnrd.state.nm.us/WIPP/lwa.htm.

U.S. DOE- Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance. Washington, DC: U.S. Department of Energy, DOE/EH-0173T (1991).

UNSCEAR. 2000. Sources and effects of ionizing radiation. 2000 Report, Vol. 1.United Nations Scientific Committee on the Effects of Atomic Radiation.

US AEC. 1973. Gnome/Coach site disposal options. U.S. Atomic Energy Commission NVO-131. Las Vegas, Nevada.