2017

ANNUAL REPORT
Revised

Carlsbad Environmental Monitoring & Research Center
1400 University Drive
Carlsbad, NM 88220

Summary of the

WIPP Site

Independent Environmental Report
for *Calendar Year 2017*

DECEMBER 2018

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Executive Summary

The Carlsbad Environmental Monitoring and Research Center (CEMRC) has measured the levels of radiological and non-radiological constituents in samples of the WIPP exhaust air, ambient air, soil and drinking water collected at and in the vicinity of the U.S. Department of Energy's (DOE) Waste Isolation Pilot Plant (WIPP) during calendar year 2017. WIPP is a U.S. DOE mined deep geologic repository that has been in operation since March, 1999. From the first receipt of waste in March 1999 through the end of 2017, 92,446 cubic meters (m^3) of TRU waste have been disposed of at the WIPP facility. Over its lifetime, WIPP is expected to dispose of approximately 175,000 cubic meters of TRU waste from various DOE sites. The repository is now at about half of its planned capacity and is to be sealed in 2033. The primary radionuclides within the disposed waste are long-lived isotopes of plutonium (mainly ^{239}Pu, with a half-life of 24,100 years, and ^{240}Pu, with a half-life of 6,560 years) and shorter-lived isotopes of americium and curium, which account for more than 99% of the total TRU radioactivity disposed and/or scheduled for disposal within the repository. After almost fifteen years of successful and safe operations, the WIPP facility was suddenly shutdown in February 2014, due to an accidental underground radiation release event and an unrelated underground fire event. Since the facility was still undergoing a recovery process from the 2014 underground fire and radiation release events, there were no TRU waste disposal activities conducted at the WIPP facility in 2016. It is important to note that the facility reopened after recovering from these two accidents in January, 2017 and has resumed limited waste disposal operations.

Following the February 2014 underground fire and radiation release events at the WIPP, the CEMRC has continued its efforts to conduct accelerated analyses of the WIPP underground air samples collected from Stations A and B throughout 2017. Rapid analyses were also performed on ambient air samples and on other environmental samples collected from within the vicinity of the WIPP site. The data collected were compared to similar data collected during the monitoring phase of the WIPP prior to the events 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 have been determined to be low and localized, and no negative radiation-related health effects among local workers or the public are expected.

This report summarizes the environmental samples collected and analyzed by the CEMRC during the calendar year 2017 to inform the public that there were no significant adverse impacts on the environment from the WIPP facility operations in 2017, as determined from extensive environmental monitoring for both radiological and non-radiological constituents. In summary, the data from this environmental monitoring program shows that the environment around WIPP continues to be safe and that there are no reasons to suspect that there will be any

negative environmental impact from the February 2014 underground fire or radiation release events.

CHAPTER 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 owned by the U.S. Department of Energy (DOE) for the permanent disposal of defense-related transuranic (TRU) wastes. Located in the Chihuahuan desert of southeastern New Mexico near Carlsbad, the facility is designed to permanently dispose of TRU wastes that were generated from research and the production of nuclear weapons at various DOE sites throughout the nation.

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, 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 its environmental monitoring program 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 from the site during waste handling and/or disposal operations.

CHAPTER 2 | WIPP UNDERGROUND AIR MONITORING

This section summarizes the WIPP's underground air monitoring results for the calendar year 2017. The WIPP facility operates three effluent air monitoring stations 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 47 mm filter. Station A samples the unfiltered underground exhaust air whereas Station B samples the underground exhaust air after HEPA filtration and, sometimes, non-filtered air during maintenance activities. 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 actual waste container serves as the primary confinement barrier in the WHB; while negative building pressure and HEPA filtration provide secondary confinement to potential radiological contamination. The effluent studies at Station A and Station B are a major component of the CEMRC WIPP Environmental Monitoring (WIPP-EM) program as they provide a measure of the level of radioactivity present in the air within the repository (Station A) as well as the level of radioactivity present in the air that is released to the environment (Station B). In addition, if radioactive materials were to be released from the facility, one would expect to detect it at Station A and/or Station B before it is observed in the local population or environment. During the calendar year 2017, the actinides

and gamma analyses were performed weekly on the composite filters collected from Station A and monthly on the composite filters collected from the Station B.

The weekly monitoring of the air filter samples collected from Station A during 2017 showed frequent detections of ^{241}Am and $^{239+240}$Pu due to residual contamination in the underground facility from the 2014 radiation release event as well as ongoing cleanup efforts within the WIPP underground. Results from Station B showed only an occasional detection of these two radionuclides during 2017. The ^{238}Pu level has been below the detection limit for Stations B throughout all of 2017. It is important to note that while still detectable by the CEMRC's sophisticated instrumentation, the levels detected in Station B filters are considered very low and are not expected to cause any adverse health to humans or to the environment.

CHAPTER 3 | AMBIENT AIR MONITORING

This section summarizes the ambient air monitoring results for the calendar year 2017 in the vicinity of the WIPP site. A network of continuously operating ambient air samplers at three locations across the WIPP site are used to determine whether the nuclear waste handling and storage operations at the WIPP have released radionuclides into the environment. In addition, three new sets of high-volume air samplers were installed following the 2014 underground radiation release event and are located at: (1) Carlsbad (behind the CEMRC facility), (2) south side of Loving, and (3) east side of the WIPP facility near the WIPP meteorological station. The CEMRC commenced collecting aerosol samples from the Loving and Carlsbad sampling stations in May 2015. Sampling from the third station, located on the east side of the WIPP, commenced in Sept, 2017. As a result, ambient air samples were collected from 6 separate locations in 2017, representing a total of 106 air particulate filter samples having been collected and analyzed during 2017. These filters were collected over a period of 2 to 4 weeks depending on the levels of particulate matter that accumulated on the filters. Except for a few positive detections of Am and Pu in the nearby ambient air samples due to the ongoing cleanup activities occurring within the WIPP facility, there were no increases in radiological contaminants observed during 2017 that could have been attributed to the recent underground radiation release from the WIPP in the wider region. Additionally, the CEMRC has been monitoring radionuclide concentrations in the ambient air around the WIPP facility since the inception of the WIPP-EM program in 1996. With few exceptions, fallout from atmospheric testing of nuclear weapons has been determined to be the primary source of Pu detected in ambient air prior to the 2014 underground radiation release event. 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 from March until June, which is when strong and gusty winds in the area frequently give rise to blowing dust.

CHAPTER 4 | DRINKING WATER

This section summarizes public drinking water monitoring results for the calendar year 2017. Public drinking water samples are routinely sampled from six drinking water sources in the region of the WIPP including the City of Carlsbad Sheep Draw and Double Eagle water systems, as well as the Hobbs, Loving, Malaga, and Otis municipal water systems. While it is unlikely that

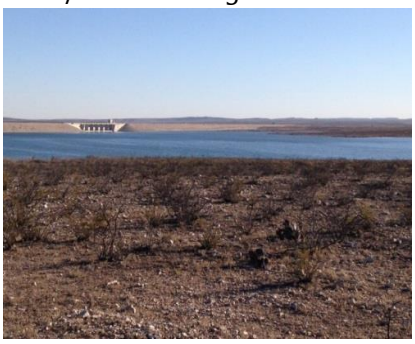
these sampling locations would be affected by any WIPP-related radioactivity releases, the samples are collected and analyzed regularly because water is a primary vector in the food chain and therefore, is important to area constituents. Consequently, the CEMRC's drinking water monitoring program fulfills the following environmental challenges: protecting human and environmental health, assuring local residents about the quality of their drinking water, and assessing the long-term trends and environmental impacts of the WIPP on local water supply systems. The absence of TRU radionuclides in drinking water samples demonstrates that there has been no adverse impact to the population or to the environment from WIPP-related activities.

CHAPTER 5 | SURFACE WATER AND SEDIMENT MONITORING

This section summarizes Surface water and sediment monitoring conducted at three reservoirs on the Pecos River, which is the major perennial freshwater 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 expected, the isotopes of americium and plutonium were not detected in any of the surface water samples, while the levels of radionuclides in sediment samples from the aforementioned three reservoirs in the region showed no detectable increases above those typical of previously measured natural variation, demonstrating no long-term environmental impacts of the February 14 radiation release event. As for the gamma radionuclides, ^{40}K was detected in all sediments and two of the surface water samples, while concentrations of all other gamma radionuclides were typically less than the minimum detectable concentrations.

CHAPTER 6 | NON-RADIOCHEMICAL ANALYSES

This section summarizes the non-radiological monitoring results for the drinking and surface water samples for the calendar year 2017. Six public drinking water samples and three surface water samples in the region of the WIPP are routinely analyzed for inorganic constituents that are likely to be found in the waste emplaced within the WIPP facility. Non-radiological analyses include seven different inorganic anions and over 30 different inorganic metals. Non-radiological data collected in 2017 are similar to data collected in previous years. The only non-radiological contaminants detected were the metals commonly found in the drinking water of southeast New Mexico. Contaminant level values were, in all cases, below the state and federal drinking-water limits. This information will assure the public that WIPP-related activities have not adversely impacted their local water.



CHAPTER 7 | LUNG AND WHOLE-BODY IN VIVO RADIOBIOASSAY MEASUREMENTS

In addition to the monitoring of environmental media (air, soil, and drinking water), the CEMRC also operates a Lung and Whole-Body Counting facility. This facility performs lung and whole-body *in vivo* radiobioassay measurements of the internally deposited radionuclides in public volunteers as well as radiological workers. This facility has been conducting the *Lie Down and Be Counted* (LDBC) project, sponsored by Department of Energy, to directly address the general concern about personal exposure to contaminants shared by residents who live near the WIPP. *In vivo* radiobioassay measurements have been used to establish a baseline profile of internally deposited radionuclides in a sampling of local residents before the WIPP radioactive waste disposal phase operations began. The in vivo radiobioassay measurements are ongoing. This section presents a 1997-2017 review of the LWBC facility and LDBC project.

CHAPTER 8 | VOLATILE ORGANIC COMPOUND

In addition to its WIPP-EM independent environmental monitoring program, the CEMRC also performs additional WIPP-related scientific activities as a subcontractor to the WIPP management and operations contractor Nuclear Waste Partnership, LLC (NWP). One of those contracted activities involves the analysis of air samples collected at the surface and from the underground WIPP facility for the identification of various gases including hydrogen (H), methane (M), and volatile organic compounds (VOCs). The WIPP Hazardous Waste Facility Permit (HWFP), Attachment N, issued by the New Mexico Environment Department (NMED) under the Resource Conservation and Recovery Act (RCRA), mandates the monitoring of VOC emissions from mixed waste that may be entrained in the ambient air from the WIPP underground hazardous waste disposal units (HWDUs) to assure that VOC concentrations do not exceed regulatory limits during or after disposal. Currently, ten target VOCs are actively monitored as they represent 99% of the risks to safety due to air emissions; any other compounds consistently detected in air samples may be added to the list of compounds of interest. This section presents an overview of this activity; however, no sample data are presented as the data are considered to be proprietary to NWP and are not subject to release by the CEMRC. Any requests for data must be forwarded to NWP.

CHAPTER 9 | 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 outlined by 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 is typically verified by a continuing program of internal laboratory quality control as well as replicate sampling and analysis.

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
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

Lc	Decision Level
LANL	Los Alamos National Laboratory
LDBC	"Lie Down and Be Counted"
LWBC	Lung and Whole Body Counting Facility
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
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

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CHAPTER 1

Introduction

The Waste Isolation Pilot Plant, commonly referred to as the WIPP, is a deep geologic 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 approximately 40,000 people, the WIPP facility is the world's first underground repository permitted to safely and permanently dispose of TRU waste generated through defense-related activities and programs (see Figure 1-1). TRU waste is defined in the WIPP Land Withdrawal Act (LWA, Public Law 102-579) as radioactive waste containing more than 100 nanocuries (3,700 becquerels Bq/g) 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, as well as sludges from solidified liquids, glass, metal, construction debris, 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 95,000 cubic meters of Cold-War legacy TRU waste has been removed from temporary locations around the nation and shipped to WIPP for permanent disposal. As defined by the regulatory requirements of 2017, the WIPP is about half full in terms of its regulatory defined capacity.

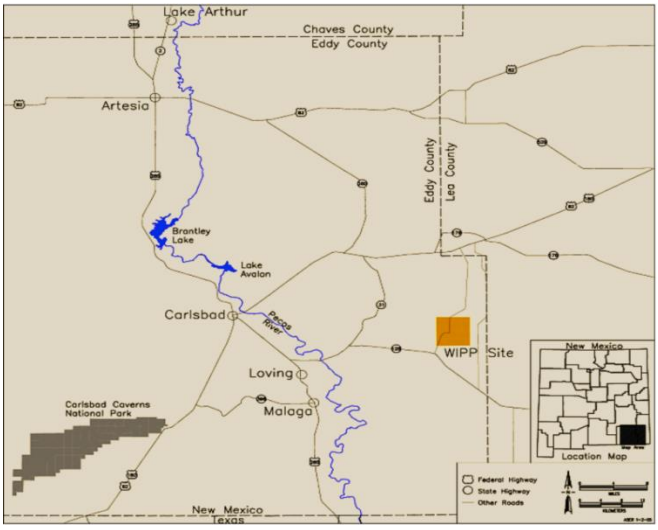


Figure 1-1: Location of the WIPP Site

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 and americium. The TRU waste is subdivided into contact-handled (CH) and remote-handled (RH) waste based on the dose equivalent rate at the surface of the waste container. According to the legal definition, the term "contact-handled transuranic waste" refers to transuranic waste with a surface dose rate not greater than 200 millirems per hour. The term 'remote-handled transuranic waste' refers to transuranic waste with a surface dose rate of 200 millirems 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 on March 26, 1999, for the disposal of TRU waste, and first received mixed waste shipments on September 9, 2000. The WIPP's 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 91,000 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 sits at several DOE sites, awaiting shipment to the WIPP. The WIPP facility was closed to waste emplacement following an underground fire event that occurred on February 5, 2014, and an unrelated underground radiological release event that occurred nine days later on February 14, 2014. The WIPP reopened and began receiving waste again on April 10, 2017. More information about the fire and radiological events can be found in the CEMRC 2014 annual report.

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, 33 feet (10 meters) wide, and 15 feet (4.5 meters) high. Seven of the panels have been excavated; the first six have been closed and sealed from ventilation air. Waste disposal was in progress in the seventh panel at the time of the February 14, 2014 underground radiological event. In addition to panel eight, at least two additional waste storage 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 the presence of HEPA (High-Efficiency Particulate Air) filters which are located at the surface. Additionally, continuous air monitors in the underground areas are used to control whether or not the ventilation air returning to the surface is passed through these large HEPA filter systems or is released directly to the atmosphere. The filtration system results in the removal of approximately 99.97% of radiological contamination from the underground WIPP exhaust air prior to being released to the environment; however, the major drawback of this system is that it significantly reduces the amount of airflow that is drawn through the repository at any one time. For example, prior to the February 14, 2014, underground radiological event, the amount of air moving through the WIPP underground was approximately 460,000 cubic feet per minute (cfm).

As a result of the February 14, 2014, underground radiological event and the potential for airborne contamination to be present in the WIPP underground air, the air must be directed through the HEPA filtration system before being released to the environment, thereby reducing the amount of air moving through the WIPP underground to approximately 60,000 cfm or about one-seventh of the pre-event level. In April 2016, a surface-mounted interim ventilation system (IVS) was installed and certified providing an additional 54,000 cfm of filtered air capacity to the WIPP underground ventilation system, raising the total available underground airflow to approximately 114,000 cfm. This increased underground ventilation was desperately needed to increase the number of personnel and diesel-powered equipment operating in the underground.

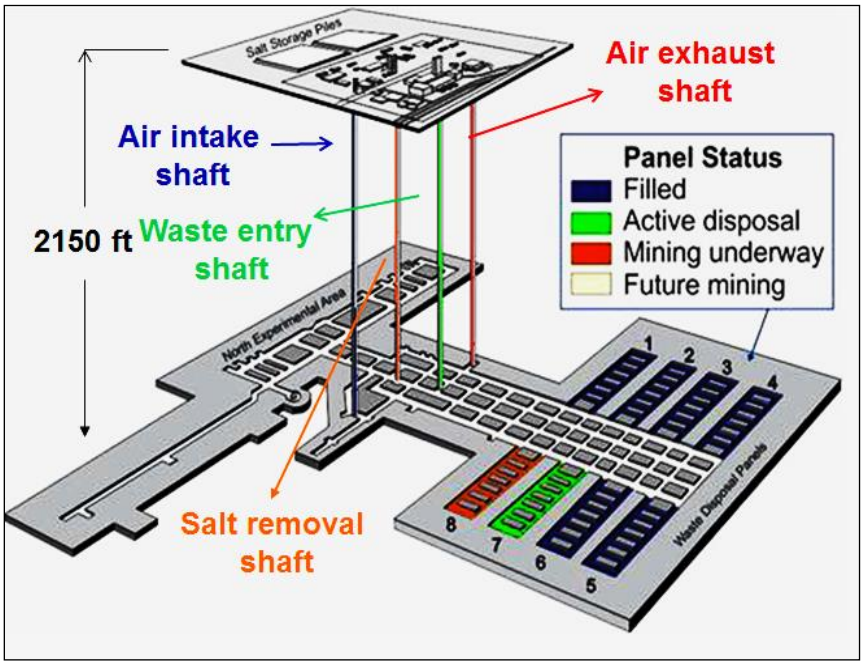


Figure 1-2: WIPP Layout

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 47mm Versapore filter. Representative sampling is assured by system design. Under normal operating conditions (such as those encountered prior to the February 14, 2014, underground radiological event), unfiltered air is drawn through the repository and exhausted from the repository directly to the environment after passing by 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 surface-mounted HEPA filters before being released into the environment.

The Station B fixed air sampler collects the air downstream of the bank of HEPA filters, including the newly operational IVS, 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. The CEMRC, like the New Mexico Environment Department (NMED) and the WIPP contractor (NWP), has 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 February 14, 2014, underground release event, the 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. However, since the underground radiological release event, the 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 decades when the National Research Council Committee on Waste Disposal (1957) 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 long-term 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, constantly moving to fill voids, gaps, or cracks. 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, the DOE agreed to stop storing plutonium wastes at Rocky Flats and began shipping TRU wastes to the Idaho National Engineering and Environmental Laboratory in southeastern Idaho. Idaho was promised that the wastes would be stored there for only ten years while the search began for a site where these wastes could be permanently disposed. The DOE had previously evaluated a site near Lyon, Kansas, in an abandoned salt mine, but strong political opposition by state officials combined with the mine's numerous boreholes 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 current 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 the 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.

Environmental Setting of the WIPP

The WIPP facility is located in Eddy County in Southeastern New Mexico, approximately 26 miles east of Carlsbad. The facility is located on a sandy plain at an elevation of 1,040 m (3,410 ft) above sea level. Prominent natural features near the facility include Levingston Ridge and Nash Draw, about 8 km (5 miles) west of the facility. Nash Draw is a shallow, dog–bone shaped drainage course between 8.5 miles and 11 miles in width and characterized by surface impoundments of brine water. Livingston Ridge is a bluff that marks the eastern edges of Nash Draw. Other prominent features of the region include the Pecos River, located about 22 km (14 miles) west of the facility, and the Carlsbad Caverns National Park, located about 68 km (42 miles) west-southwest of the WIPP facility.

The majority of the local population within 80.5 km (50 mi) of the WIPP site is concentrated in and around the communities of Carlsbad, Hobbs, Eunice, Loving, Jal, Lovington, and Artesia, New Mexico. According to 2010 census data, the estimated population within this radius is 88,952. The nearest community is the village of Loving (estimated population ~2000), 29 km (18 mi) west-southwest of the WIPP site. The nearest major populated area is Carlsbad, 42 km (26 mi) west of the WIPP site. The 2010 census reported the population of Carlsbad as 26,138.

The transient population within 10 miles of WIPP is associated with ranching, oil and gas exploration/production, and potash mining. Three ranchers (Mills, Smith, and Mobley) have properties in the vicinity of the WIPP facility. The Mills ranch headquarters is located 5.6 km (3.5 miles) south-southwest of the facility center, the Smith headquarters is 8.8 km (5.5 miles) west-northwest of the facility, and the Mobley ranch is 9.6 km (6 miles) southwest of the facility.

The climate in the region of the facility is semi-arid with an average annual precipitation of 280 to 300 mm (11 to 13 inches) with much of the precipitation falling during intense thunderstorms in the spring and summer seasons. Winds are generally from the southeast with an average speed of 14 km/hour (8.8 miles/hour).

Although there are no dairies near the WIPP facility, a large amount of alfalfa is grown in the Pecos Valley between Roswell and Malaga, New Mexico. The alfalfa crop is used in cattle feeding operations mainly in New Mexico and Texas. In addition to alfalfa, cotton and pecans are the other major crops grown in the Pecos Valley region.

Background Radiation

There are several sources of naturally occurring radiation including 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 associated 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 (Figure 1-3).

Naturally occurring radiation in the environment can deliver both internal and external doses to humans. 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 the 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 microrems per hour (Minnema and Brewer, 1983), which would equate to the background gamma radiation dose of 0.67 millisieverts (mSv or 67.0 mrem) per year. A comprehensive radiological baseline study

conducted before the 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 the WIPP facility disposal operations commenced.

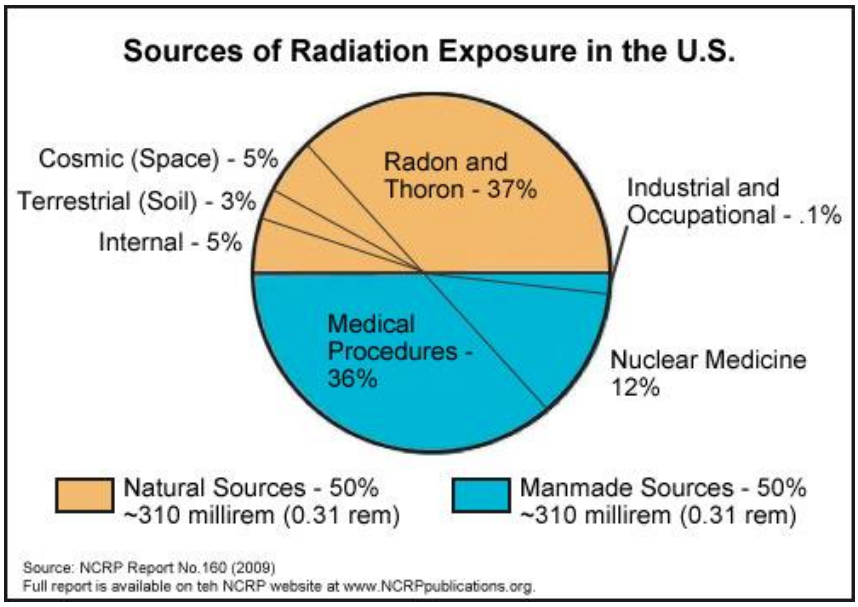


Figure 1-3: Source of Radiation Exposure

Radiological Environment around WIPP

The radiological environment near the WIPP site includes natural radioactivity, global fallout from nuclear weapons tests and, potentially, a local source of anthropogenic (man-made) radioactive contamination remaining in the area from Project Gnome, an underground nuclear test conducted by the U.S. Atomic Energy Commission. In 1961, the surface area of the Gnome site was contaminated with fission radionuclides when an underground test of a 3.3-kiloton ^{239}Pu device vented radioactive materials to the surface (USAEC, 1973). The Gnome project was part of the Plowshare Program intended to demonstrate the peaceful use of atomic energy. The Gnome site is located approximately 8.8 km (5.5 miles) southwest of the WIPP site.

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, despite these cleanup efforts, ^{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); a review of 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 from non-Gnome related incidents.

Independent Environmental Monitoring Program – An Overview

The success of any nuclear facility is strongly tied to the degree of public acceptance and understanding that is established. The WIPP exemplifies where public engagement has constantly been provided 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 activities. In addition to the regulatory compliance monitoring required by the repository licensee, and 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 still now that the WIPP is 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 effects the WIPP operations may have on their lives and health. As a result, some approaches the CEMRC has undertaken to accomplish this mission includes increasing counting times on alpha and gamma spectroscopy systems 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 17.1 keV spectrum, thereby indicating the presence of Pu in the lung. The CEMRC has been conducting independent health and environmental monitoring in the vicinity of WIPP since 1995 and has made the results easily accessible to all interested parties. Public access to the monitoring data and their ability to directly participate in CEMRC's whole body counting program provides a key element of trust and transparency for the public.

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, to identify any releases, and to determine their effects, should they occur. The purpose of the CEMRC WIPP-EM radiological environmental monitoring program is to measure radionuclides in the ambient environmental media. These data allow for a comparison of sample data to the results from previous years and historical baseline data, determining 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. Additionally, the scope of the CEMRC WIPP environmental monitoring activities is broad and includes the radiological screening of local citizens (whole-body counting for the public) as well as routine sampling of water (including both drinking water and surface waters), soil, and sediment for hazardous non-radiological constituents. Routine reporting is done annually and published on the CEMRC website (www.cemrc.org). Non-routine results, if they occur, are reported as they are found after review and interpretation. One of the CEMRC's core competencies is to detect and to report radioactive contaminant levels, even those below the regulatory requirements, as soon as possible and to disseminate this information to the public in a timely and understandable nature. The CEMRC program has capabilities to detect radionuclides rapidly in case of accidental releases from the repository or other portions of the facility during waste handling/waste emplacement operations.

The CEMRC's environmental monitoring activities generally fall into three categories: collecting environmental samples and analyzing them for a variety of contaminants, evaluating whether WIPP-related 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 include WIPP exhaust air, ambient air, drinking water, and human monitoring. For these four elemental areas, sample collection and analyses are more frequent whereas the sampling and analyses frequencies for other environmental media such as soil, sediment, and surface water are generally acquired and analyzed once every two years on an alternating basis.

For ambient air analyses, the CEMRC operates four ambient air samplers in and around the WIPP site and two ambient air samplers in the two closest municipalities nearest the WIPP facility (the Village of Loving and the City of Carlsbad). The fourth high-volume sampling station, located on the east side of the WIPP facility, was deployed and became operational on 9/15/2017; therefore, aerosol sampling at this sampling station had not begun by the cutoff time for annual data sampling for this document. The ambient air monitoring sites nearest the WIPP facility are located in the most prevalent wind directions from the facility, whereas the ambient air monitoring sites in Loving and Carlsbad are located on Village of Loving owned property and at the CEMRC facility primarily as a matter of convenience and cost. The primary purpose of ambient air monitoring 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 or its two closest municipalities.

Public drinking water samples are sampled annually 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 associated with the WIPP and WIPP-related activities.

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 which represent the final release points of the underground repository exhaust ventilation system. Consequently, the CEMRC collects filters from Station A and B each day and then performs a gross alpha/beta screening process on the individual filters for the presence of radioactive contamination. This daily sampling process allows for a careful study of the variability of radioactivity background, trends, and actual releases. Following the gross alpha/beta screening process, the CEMRC then performs the more sensitive radiochemical analyses on the composited weekly and/or monthly filters to identify specific radioactive isotopes.

Alternating on a biennial schedule, soil, sediment, and surface water samples are also collected and analyzed to verify radionuclides concentrations and to establish the variability of background radioactivity along with actual releases. Additionally, soil samples were previously collected from selected areas and control locations outside of the WIPP land withdrawal area, such as the Gnome site, and were analyzed for the presence of radionuclides thereby creating the ability to identify localized surface contamination from non-WIPP related activities. The results of the Gnome study are presented in the 2005/2006 CEMRC Annual Report.

Since the inception of the CEMRC WIPP environmental monitoring program, the CEMRC has been monitoring the concentration of plutonium (Pu) and americium (Am) in the area around the WIPP site for many years, as isotopes of these elements are the major radioactive constituents likely to be found 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 also 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 the abundance of potash mining in the area.

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-EM 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 through the disposal phase and into 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 the 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 provided renewed interest on behalf of resident volunteers. Results of the LDBC, both historically and through December 30, 2017, are reported herein. Also, as a result of the February 14, 2014 radiation release event, the age for public volunteers was reduced from 18 years of age to 13 years of age to accommodate requests by the DOE and interested constituents.

The Recovery from the 2014 Fire and Radiological Release Events at the Waste Isolation Pilot Plant

After months of investigations into the cause of the underground truck fire and the underground radiological release event, the U.S. Department of Energy released a recovery plan at the end of September, 2014 (WIPP-Recovery Plan, Sept, 2014) that outlines the steps necessary to clean up and resume limited waste emplacement operations by early 2017. As seen in Figure 1-4, decontamination of work areas is a key element of the WIPP Recovery Plan as a portion of the underground area was heavily contaminated by the February 14, 2014 underground radiation release event. Other parts of the recovery plan include: (1) continued HEPA filtration of underground exhaust air through an expanded interim ventilation system (IVS); (2) expedited closure of Panel 6, where a few hundred suspect waste drums are assumed to contain the same type of nitrate salt-bearing waste that led to the underground radiological release event are located; and (3) expedited closure of Room 7 in Panel 7, the location of the ruptured waste drum where the February 14, 2014, underground radiation release event occurred. During 2016, several notable recovery-related activities were completed at the WIPP facility. The interim ventilation system (IVS) was installed and is now in operation. Similarly, progress has been made on the supplemental ventilation system. The combined WIPP exhaust circuit with the interim and supplemental ventilation systems (SVS) will provide a total of 5,100 m^3 per minute (180,000 cfm) of airflow in the underground, a sufficient ventilation flow needed to support limited waste emplacement operations and to resume underground mining activities. Airflow from the IVS and WIPP exhaust air will continue to be passed through HEPA filters prior to discharge; whereas airflow from the SVS will comprise a "clean" circuit and will be exhausted through the WIPP Salt Shaft. A new permanent ventilation system (PVS, replacement to the current ventilation system) is being designed to enable the WIPP's underground operations to return to full operation, unrestricted by ventilation rates. Although estimates vary, the new permanent ventilation system is expected to generate flow rates up to 15,000 m^3/min (540,000 cfm). However, this new permanent ventilation system is estimated to cost several hundred million dollars and is not anticipated to be completed until 2021.

The 2014 underground radiological release event has changed WIPP from a "clean" nuclear facility to one that simultaneously operates in contaminated and uncontaminated areas for the foreseeable future. As a result of the underground radiological release event, portions of the WIPP underground - primarily those portions along the ventilation path from the location of the incident to the top of the exhaust shaft continue to exhibit varying levels of contamination. Recovery activities involving decontamination of selected underground areas, including the pathway from the Waste Hoist to the entrance of Panel 7 and all areas south of S-2520, were completed by September 2015 served to reduce the level of restrictions for certain areas and lowered the personnel protective equipment (PPE) required in a significant portion of the underground. It is important to note that a vast majority of the underground was not affected by the radiological event. Additionally, radiological decontamination activities are not expected to be performed in technically challenging areas such as the exhaust shaft (655 vertical meters). As waste emplacement operations resumed in the WIPP underground in early 2017, there are now both clean and contaminated areas present within the WIPP disposal area.

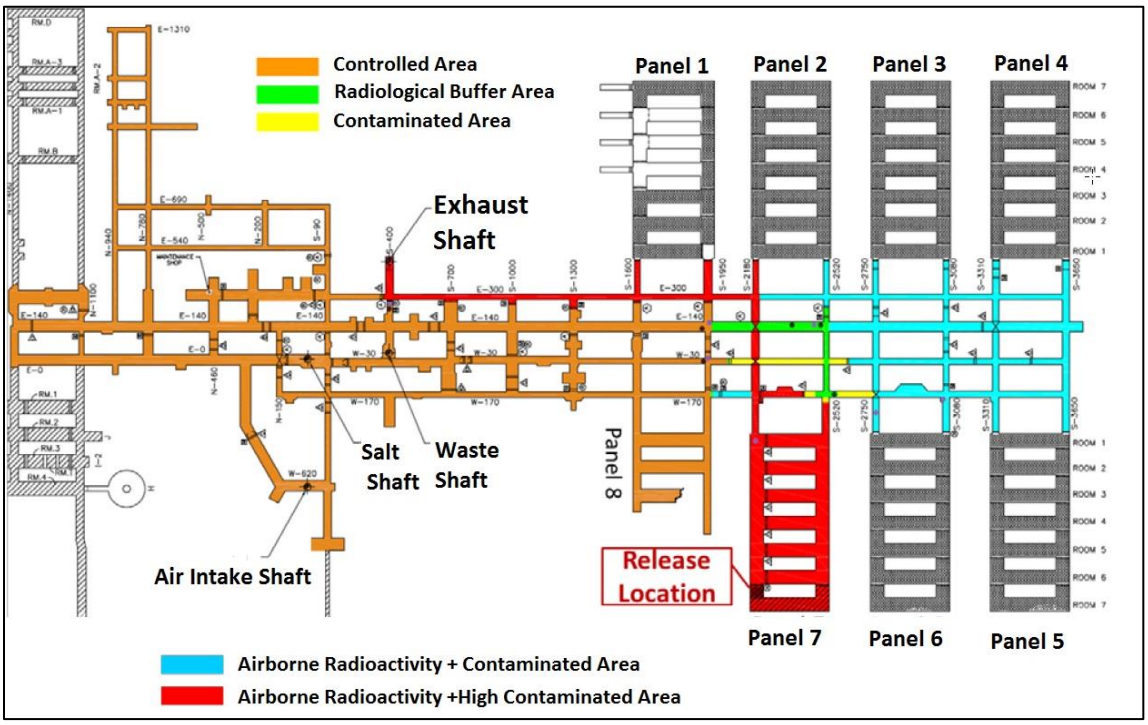


Figure 1-4: Radiological Contamination Map of the WIPP Underground
(Source: Department of Energy, Carlsbad Field Office)

In response to the February 14, 2014, underground radiological release event, the CEMRC has continued its efforts to conduct accelerated analyses of the underground filters collected from Stations A and B, surface ambient air samples, and other environmental samples collected in the vicinity of the WIPP site. This report summarizes the samples collected and analyzed during the calendar year 2017 and presents an evaluation of approximately three years of environmental monitoring data that informed the public pertaining to the levels of radiation

that escaped into the environment from the WIPP underground during the February 14, 2014, underground radiation release event. As reported in the 2014 annual report, the ongoing data from this year's monitoring activities suggest that the 2014 underground radiological release event resulted in the release of very low amounts of contaminants from the WIPP underground and confirms that the escaped contaminants did not harm anyone nor did they pose any long-term consequence to the environment.

CHAPTER 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 funnels air either directly to the environment or into a high-efficiency particulate air (HEPA) filter bank (Figure 2-1). A second sampling station referred to as Station B samples the underground exhaust air after HEPA filtration and, sometimes, non-filtered air during maintenance-related activities (Figure 2-2). While in filtration mode, Station B becomes a post-filtration sampler analyzed by the CEMRC and other entities such as the New Mexico Environment Department (NMED) and the WIPP Environmental Services group (WIPP Labs). When not in filtration mode Station B is not sampling WIPP exhaust air, hence the CEMRC only performs analyses on Station B filters when the system is operating in filtration mode. An Overview of the WIPP ventilation system and normal underground airflow is depicted in Figure 2-3.

Overview of CEMRC's Station A Monitoring Program

As mentioned previously, the aerosol studies at Station A are a major component of CEMRC's WIPP environmental monitoring Program. Station A is used for exhaust air compliance monitoring purposes and the aerosol sampling systems deployed there were designed to collect ≥ 50 % of the 10 µm diameter aerosols under the expected range of exhaust air velocities. CEMRC commenced sampling of the WIPP exhaust air on December 12, 1998. Aerosols samples are collected from within the Exhaust shaft using a cylindrical shrouded probe commonly referred to as a fixed air sampler or FAS. The airflow through the FAS is approximately 170 liters per minute (~6 cfm) flow rate.

There are three shrouded-probe aerosol samplers located at Station A along with three separate sampling skids, denoted as A1, A2, and A3 (Figure 2-4). The airstream sampled by each skid is split among three legs such that three concurrent samples can be collected from each skid.

On January 15, 2000, the CEMRC sampling operations were moved from the original sampling point at Skid A2 (west skid) leg 1 to Skid A1 (east skid) leg 2 to facilitate more direct data comparisons among the three organizations sampling the effluent air. Since that time all groups, CEMRC along with the WIPP Labs and the Environmental Evaluation Group (EEG) - later replaced by the NMED, have sampled from the same skid leg (CEMRC was assigned leg 2 on all sampling skids). In April 2001, primary sampling operations were transferred from Skid A1 to Skid A3 (south skid) to reduce problems associated with water seepage into the exhaust shaft figure 2-4.

During normal sampling activities, the FAS sample filters are changed daily except during holidays, when a filter may run for multiple days. The aerosol sampling operations at Station A have at times been hampered by filter clogging, and during one interval (January 24, 2000 to November 28, 2001), CEMRC and the other organizations changed filters twice daily Monday through Friday. Daily sampling resumed when mass concentrations decreased and flow rates improved. Occasionally, however, more than one sample per day is still collected when the flow rate on any of the sampler legs drops below 0.06 m^3 (~1.8 cfm). If this occurs, a low-flow alarm on the sampler is activated and the filters are changed as needed by WIPP radiological control technicians.

Quarterly composites were initially used for the determination of actinide activities, but monthly compositing was implemented by the CEMRC in July 2004 for better comparison with other groups who use monthly composites. These monthly composites are used for the determination of gamma-emitting radionuclides as well. Only one half of the composite samples are normally used for the determination of the actinide activities. The other half of the samples are used for the measurement of the gamma-emitting radionuclides. After the gamma measurement, the sample aliquot is archived. For some time following the radiation release event, filters at station A were changed every 8 hours and measurements were performed on each filter (and later on daily combined filters) by CEMRC, depending on the levels of contamination found. As airborne concentrations receded, the frequency of filter collection at station A was reduced to daily, but actinide measurements were performed continuously on weekly composite samples.

The sensitivity of the monitoring program at Station A was dramatically demonstrated in January 2001 when CEMRC found elevated gross beta radioactivity in the FAS sample filters. Further investigations eventually traced the source of the beta emitter(s) to the discharge of a fire extinguisher underground, but the incident was more notable because it demonstrated for the first time the ability of the monitoring system to detect a non-routine event. A second incident occurred when scientists from CEMRC reported that they had detected a small quantity of Pu in a composite aerosol sample from the second calendar quarter of 2003. This discovery was later corroborated by both the EEG (Environmental Evaluation Group) and the WIPP's monitoring organization, WIPP Labs, through the analyses of samples that were independently collected and analyzed. The detection of plutonium in the exhaust air led to the issuance of a CEMRC report to the U.S. Department of Energy and a briefing presented to the New Mexico

Environment Department. The activity was extremely low and well within the historic background, but indicated the ability of the monitoring program to detect radionuclides of interest at any level above the MDC. In 2008, 2009, and 2010, CEMRC again detected small quantities of plutonium in composite aerosol samples similar to the 2003 detection, also corroborated by WIPP Labs. Such small occasional detections are to be expected because of the global distribution of plutonium in the environment. Furthermore, the 2003, 2008, 2009 and 2010 positive detections provide a baseline for future events.

Sample Collection

As was mentioned previously, unfiltered exhaust air from the underground repository is sampled at station A. The daily Station A air samples are collected on 47 mm diameter membrane filters (Versapor® membrane filter, PALL Corporation, pore size 3 µm) 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, each probe has a transfer line running to each of three sampling legs; thus a total of three concurrent samples can be collected from each FAS, one each for the CEMRC, the site contractor, WIPP Labs, and the NMED. A previous test of the probes confirmed that this configuration allows for the collection of representative air samples (Gross et al., 2011). 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, a CEMRC Field Program technician collects samples at Station A daily; however, as mentioned above, 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.

Figure 2-1: Location of Station A

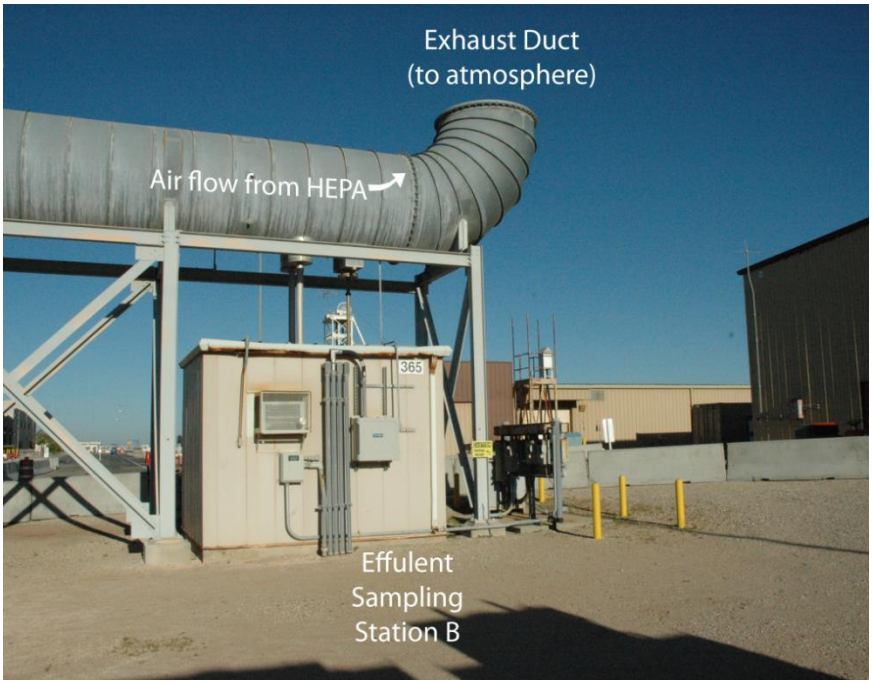


Figure 2-2: Location of Station B

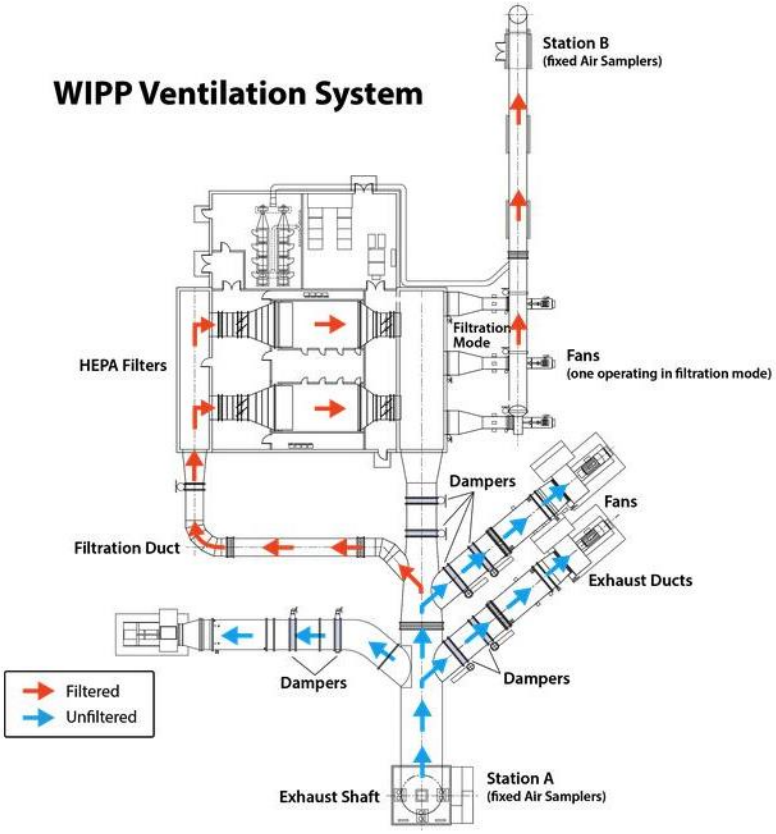


Figure 2-3: Overview of WIPP Ventilation System

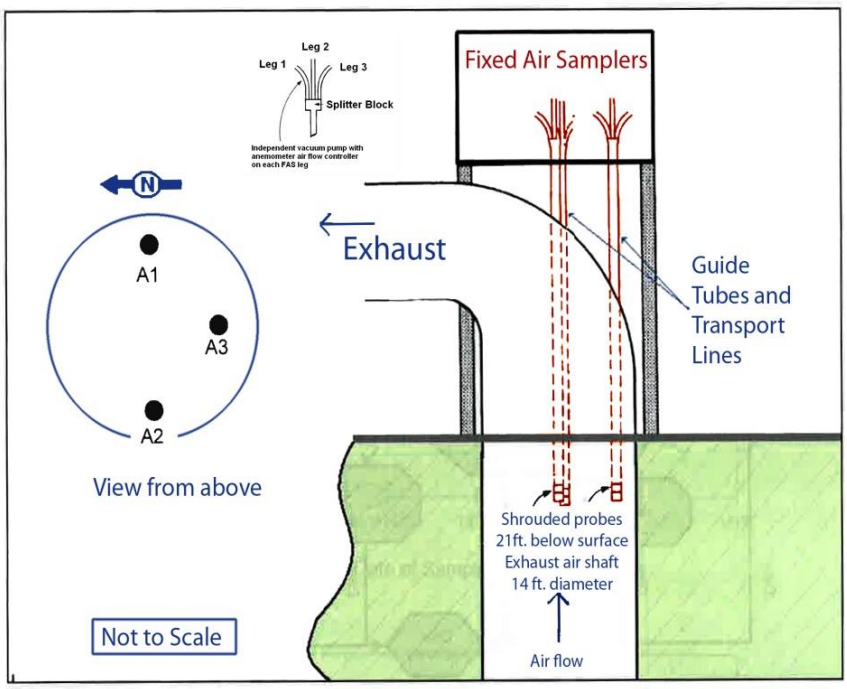


Figure 2-4: Overview of Station A

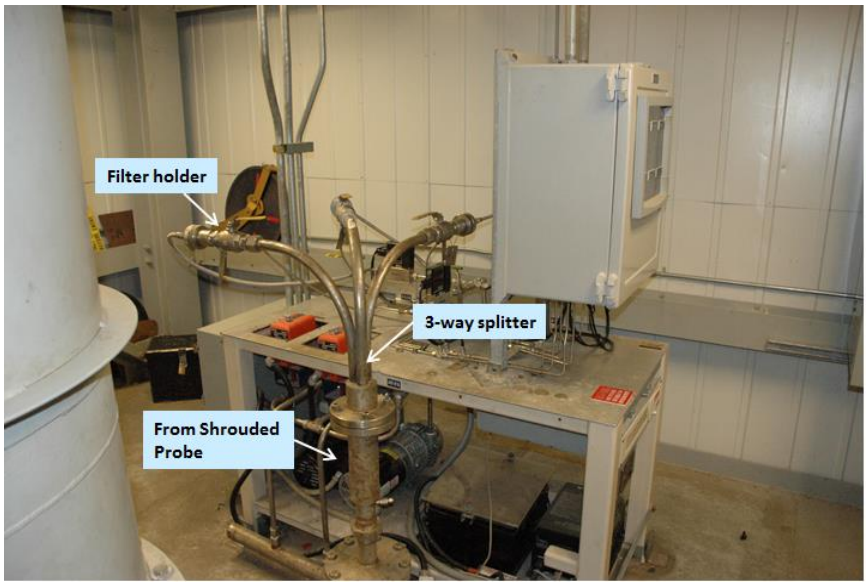


Figure 2-5: Fixed Air Samplers at Station A

Prior to the February 14, 2014, underground radiation release event at the WIPP, weekly filter samples were typically collected by the CEMRC at station B where approximately 583 m^3 (20,603 ft^3) of air is filtered through each of the Versapor filters each week. The WIPP exhaust air samples were combined monthly for Station A for analysis by CEMRC and WIPP Labs, and quarterly for Station B for analysis by WIPP Labs. For some time following the February 2014 underground radiation release event, filters at station A and B were changed every 8 hours and

measurements were performed on each individual filter initially and, eventually, were performed daily on combined filters by the CEMRC depending on the levels of contamination found. As airborne concentrations receded, the frequency of filter collection at station A and station B were reduced to daily; however, actinide measurements continued to be performed weekly on composite samples from Station A and monthly on composite samples from Station B during 2017. Since the repository continues to operate in filtration mode, CEMRC technicians continue to collect and analyze Station B samples daily.

Sample Preparation and Analysis

Gross Alpha and Beta Analysis

Once the samples are collected from the site and returned to the laboratory, individual filters are desiccated for a minimum of 48 hours to guarantee 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 loading concentrations. Following the desiccating and weighing process, the Station A and B filters are counted for gross alpha and beta activities on a Protean MPC 9604 low background gas proportional counter for 1200 minutes.

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). Immediately following the February 14, 2014, underground radiation release event, the planchet was counted on a low-background gas proportional counter for 180-300 minutes. Later, as airborne concentrations continued to recede, beginning July 2014, filters from Stations A and B were counted for 1200 minutes. The sample detectors are gas flow window type counters with an ultra-thin window. The counting gas is P-10, which is a mixture of 90% argon and 10% methane. The operating voltage on the detector is 1,450V. All samples flow at a pressure slightly exceeding atmospheric. The window consists of 80 μg/cm Mylar foil with a tint of evaporated Au. The small size of the detector and the guard ensure a very low background in this system, ~0.5 and ~0.04 counts per minute for beta and alpha respectively (see Figures 9-1 and 9-2). Daily performance checks are done using calibration sources, ^{239}Pu for alpha and ^{90}Sr/^{90}Y for beta, for efficiency control charting (2σ warning and 3σ limits) and to ensure that alpha/beta cross-talk are within limits (≤ 0% α into beta and ≤ 0.1% beta into alpha). Sixty-minute background counts are also recorded daily (count must be within the mean background ±3σ) by counting an empty planchet. The self-absorption curve was obtained individually for alpha and beta and used for all sample counts. The mean counting efficiencies for the systems are found to be around 25% for alpha and 38% for beta (see Figures 9-3 and 9-4).

Sample Preparation for Radiochemical Analysis

After gross alpha/beta measurements, individual filters collected over a period of one week are combined into weekly composites. The weekly composite samples are used for the determination of actinide activities. Gamma analysis is performed concurrently on the same weekly composite. Only one half of each composite sample is used for the determination of the actinide activities. The remaining aliquot is archived.

Filter samples for radiochemical analysis are 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 while the other half is for the gamma analysis. 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 concentrated 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 (http://www.cemrc.org/report). The individual actinides are then micro-co-precipitated with an Nd-carrier and counted using alpha spectrometry. The samples are counted for five days for alpha and 48 hours for gamma radionuclides as per CEMRC's standard counting protocol. 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 in the following two ways: *activity concentration in* Bq/m^3 and *Specific Activity* (Bq/g). *Activity concentration* is calculated as the activity of radionuclides detected in Becquerel (Bq) divided by the volume of air in cubic meters (m^3). *Specific Activity* is calculated as the activity of radionuclides detected in Becquerel (Bq) divided by the aerosol mass collected on the filter in gram (g).

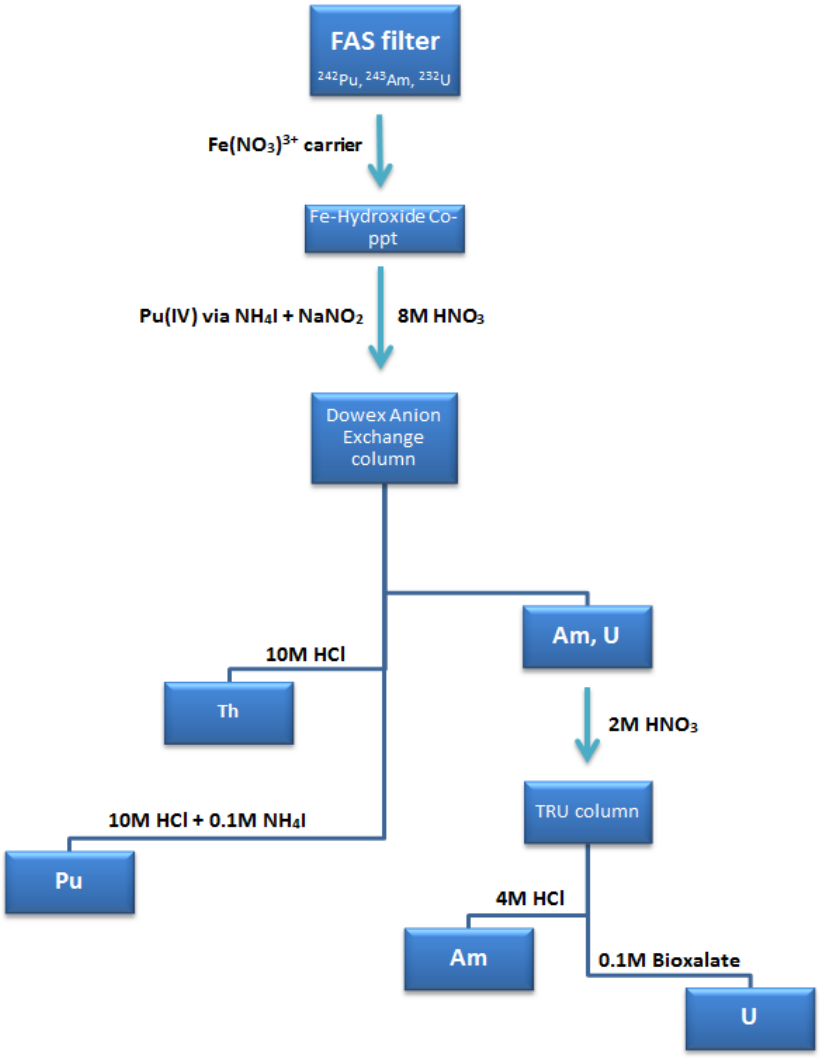


Figure 2-6: Flow Diagram Showing the Analysis of Stations A and B Filters

Results and Discussion

Gross Alpha and Beta concentrations in the WIPP underground Air (Station A, Pre-HEPA Filter)

The daily gross alpha and gross beta concentrations in the unfiltered underground air (air exhaust before the HEPA filtration or Station A) are shown in Figures 2-7 and 2-8. The gross alpha and beta activities appear to have gone back to the pre-release levels in 2015-2017. A small sporadic increase in gross alpha concentrations, shown in Figure 2-7, was attributable to the disturbance of entrained materials allowing them to be transported in the WIPP underground air due to ongoing investigative and clean-up efforts by underground personnel.

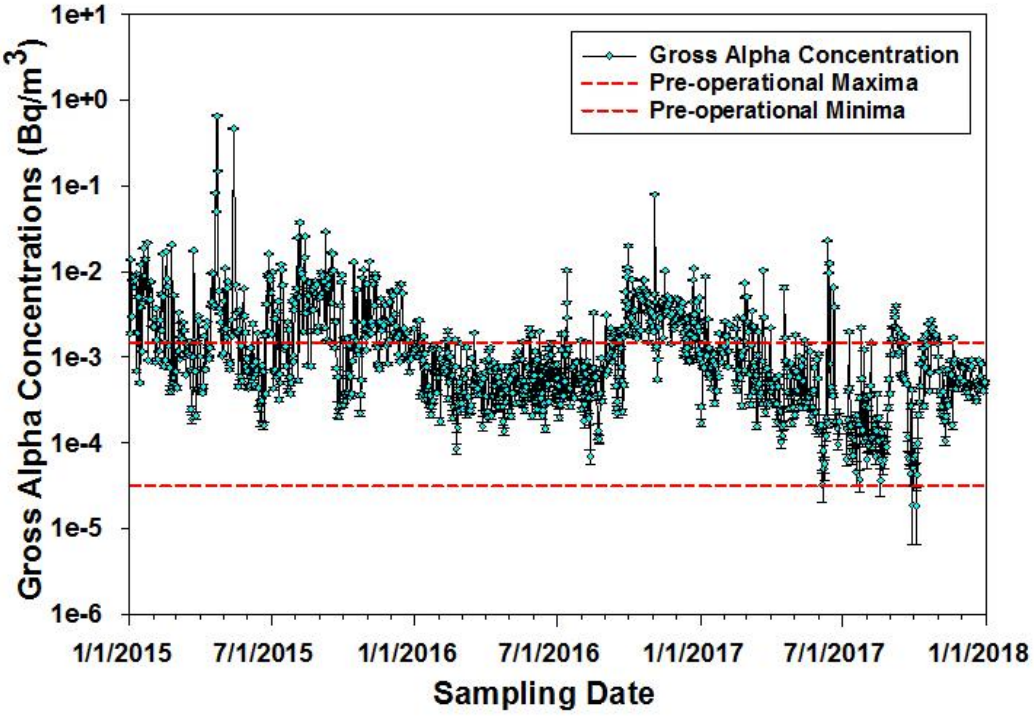


Figure 2-7: The Gross Alpha Concentrations in the WIPP Exhaust Air Before (Station A) HEPA Filtration During 2015-2017

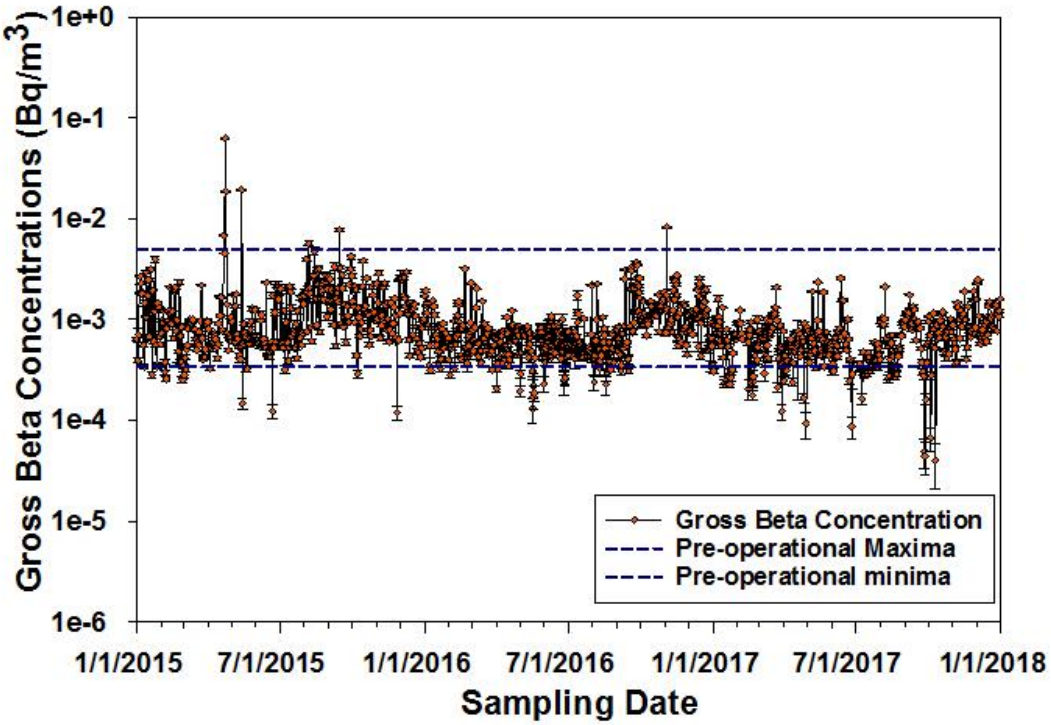


Figure 2-8: The Gross Beta Concentrations in the WIPP Exhaust Air Before (Station A) HEPA Filtration During 2015-2017

The pre- and post-release gross alpha and gross beta concentrations in the Station A filters are shown in Figures 2-9 and 2-10 for trend analysis purposes. There is no data for the period between February and June 2014. This is because gross alpha and beta screening was not performed immediately following the February 14, 2014, underground radiation release event; instead, an emergency actinide separation campaign was carried out on individual or daily filters collected from Station A and Station B. However, as radiation levels receded, the gross alpha and beta analysis resumed beginning in March 2014 for the Station A filters and July 2014 for the Station B filters.

Prior to the February 14 radiological event, the pre-operational baseline data were compared with the operational data to assess the integrity of the WIPP project. The gross alpha and beta activity in air filters prior to the arrival of waste at the WIPP were used as a baseline concentration. The bulk of the activity in those samples were results from naturally occurring radioactive materials, specifically radon daughters. The baseline concentrations of gross alpha and gross beta activities were 1.49E-03 Bq/m^3 and 4.90E-03 Bq/m^3, respectively. These data are then compared against disposal phase data to assess the radiological and ecological effects of radiation on workers and the general public that live and work around the WIPP. The minimum detectable activity concentrations and specific activity for the gross alpha emitters are ≈ 1 ×10-7 Bq/m^3 and ≈ 0.7 Bq/g, respectively, while for gross beta emitters the corresponding values are ≈ 2 ×10-7 Bq/m^3 and ≈ 1.7 Bq/g. The reported gross alpha and beta activities are normalized by dividing the measured activities by the mass loadings on the sample filters or by the volume of air sampled. Therefore trends in the specific activity could either be due to changes in the amount of radioactivity in the sample or the aerosol mass in the samples as the volume of air sampled, which is not shown, has changed little during the course of the program and therefore, should have little or no effect on the activity concentrations.

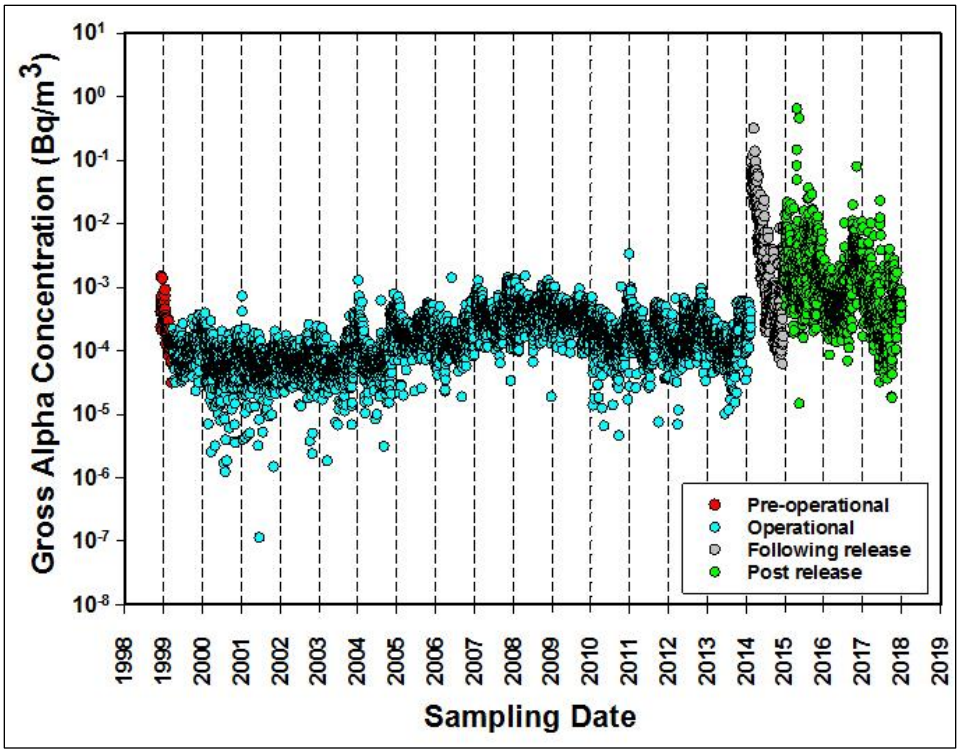


Figure 2-9: Pre- and Post-release Gross Alpha Concentration in Station A (Pre-HEPA) Filter

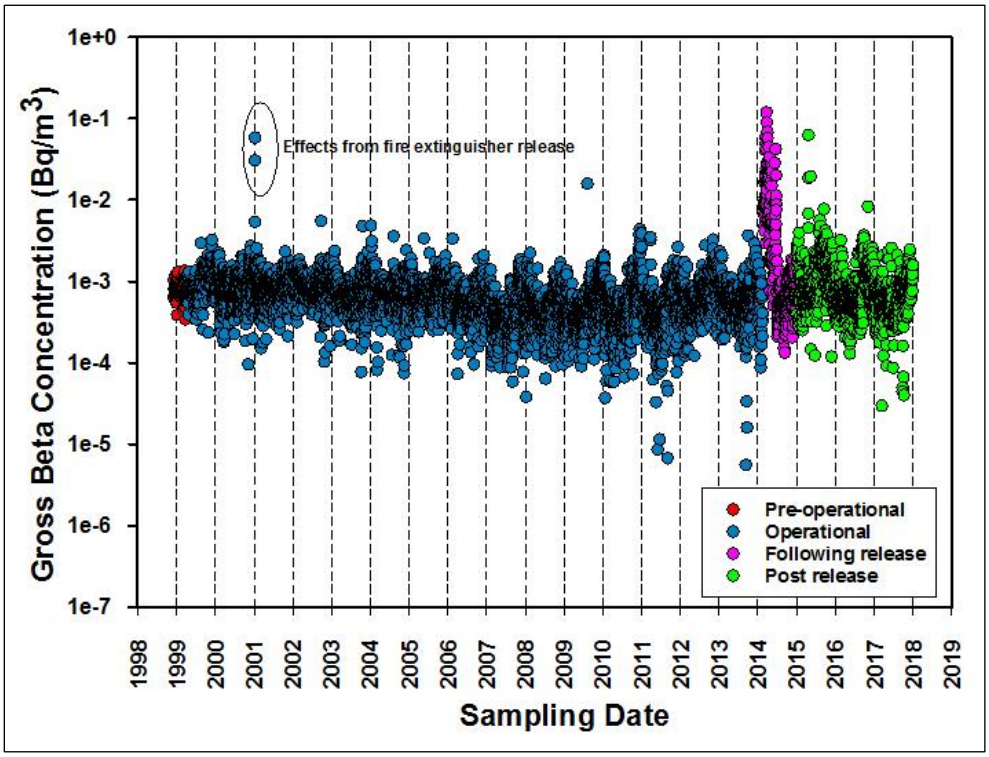


Figure 2-10: Pre- and Post-release Gross Beta Concentration in Station A (Pre-HEPA) Filter

The gross beta concentration measured in filter samples collected from Station A for the period 1998-2017 is shown in (Figure 2-10). The two samples with elevated gross beta activity concentrations ca. 0.058 Bq/m^3 observed in early 2001 (Figure 2-10) are because of contamination 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.

A time series plot of the gross alpha and gross beta specific activity (Bq/g) are shown in Figures 2-11 and 2-12. The current levels are within the range of our normal background for this particular Station. Since no gravimetric data was collected from the Station A filters following the radiation release event, no data are available for the period between February and July 2014. The CEMRC resumed collecting gravimetric data beginning in August 2014.

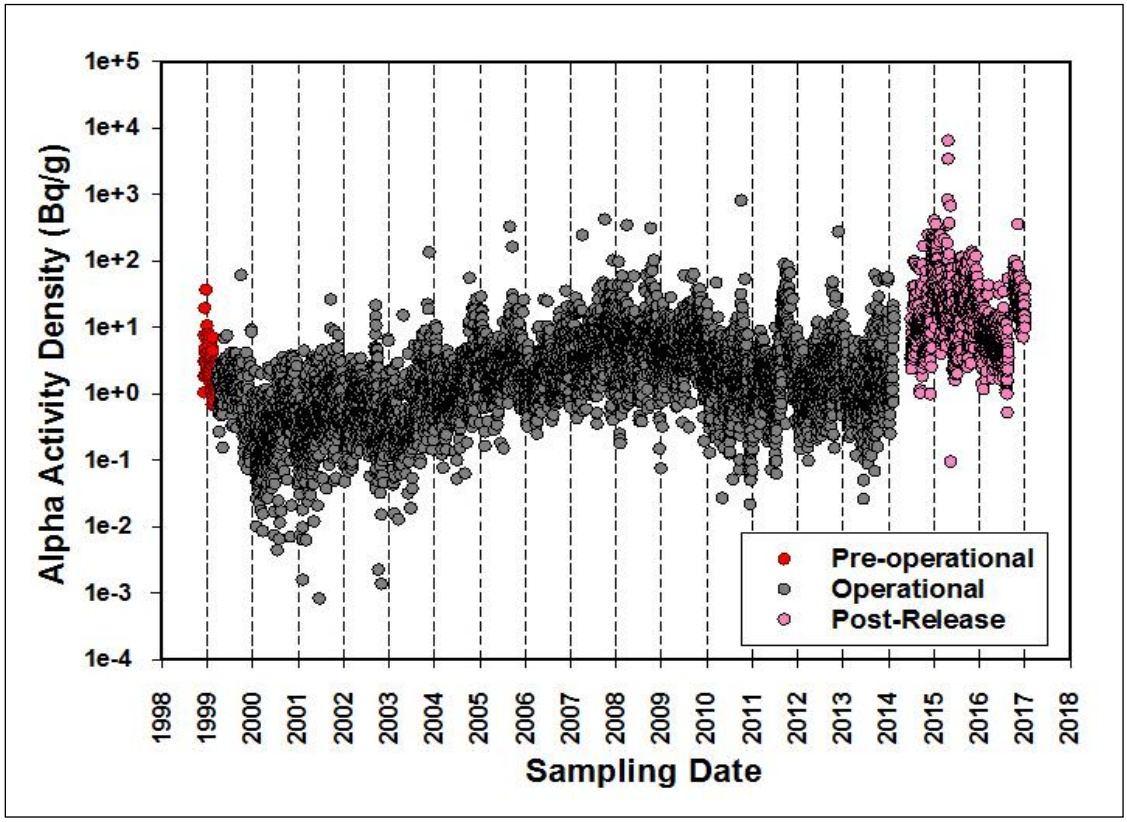


Figure 2-11: Gross Alpha Specific Activity Measured in Station A Filters

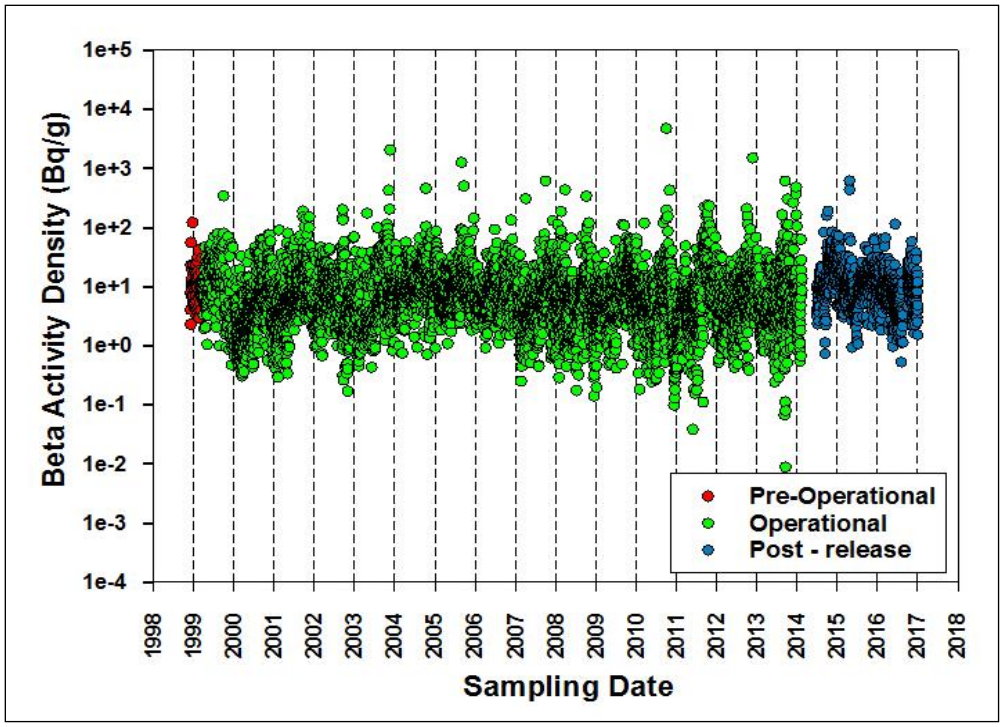


Figure 2-12: Gross Beta Specific Activity Measured in Station A Filters

Actinide Concentrations in the WIPP's Unfiltered Underground Air (Pre-HEPA, Station A) in 2017

The time series of the activity concentrations of transuranic radionuclides $^{239+240}$Pu and ^{241}Am measured at Station A (Pre- HEPA filtration) since the February 2014 underground radiation release event are shown in Figure 2-13. As anticipated, the values detected at Station A immediately after the underground radiation release event were considerably higher than those historically measured for this Station. The maximum air concentrations of americium and plutonium 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. By the morning of February 21, 2014, these levels had dropped 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.

As the levels of ^{241}Am and $^{239+240}$Pu in the WIPP exhaust air prior to HEPA filtration continued to decrease, as measured by the Station A sampling skid, a weekly composite filter sample has been used for the determination of actinides since April 22, 2014, from the Station A location. The weekly composite filter sample results from Station A are summarized in Tables 2-1 through 2-3. As can be seen, trace amounts of ^{241}Am and $^{239+240}$Pu continue to be measurable above MDC (minimum detectable concentration) in these filters; however, current levels are very

low and are not known to be associated with any adverse health or environmental consequences. The weekly activity concentrations of ^{241}Am, $^{239+240}$Pu, and ^{238}Pu measured by filter samples collected from Station A since April 2014 are shown in Figure 2-14. Although the values measured were above the pre-release 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. There is no known risk to anyone from contamination levels this low. Additionally, it is relevant to emphasize that the levels reported were only detectable because of the ultra-sensitivity of modern radiation monitoring equipment and the radiochemical analyses methods performed.

The specific activity data immediately following the radiation release event were not available as filters collected during that period were not weighed. However, the aerosol mass data collected since July 2014 showed that the specific activity remained fairly consistent through December 2017. The $^{239+240}$Pu specific activity (activity per unit mass aerosol collected) at Station A was in the range of 0.16-8.22 Bq/g, while that of ^{241}Am was in the range of 1.04-77.1 Bq/g. The weekly specific activity of ^{241}Am, $^{239+240}$Pu, and ^{238}Pu at Station A are shown in Figure 2-15 and the individual values are listed in Tables 2-4 through 2-6.

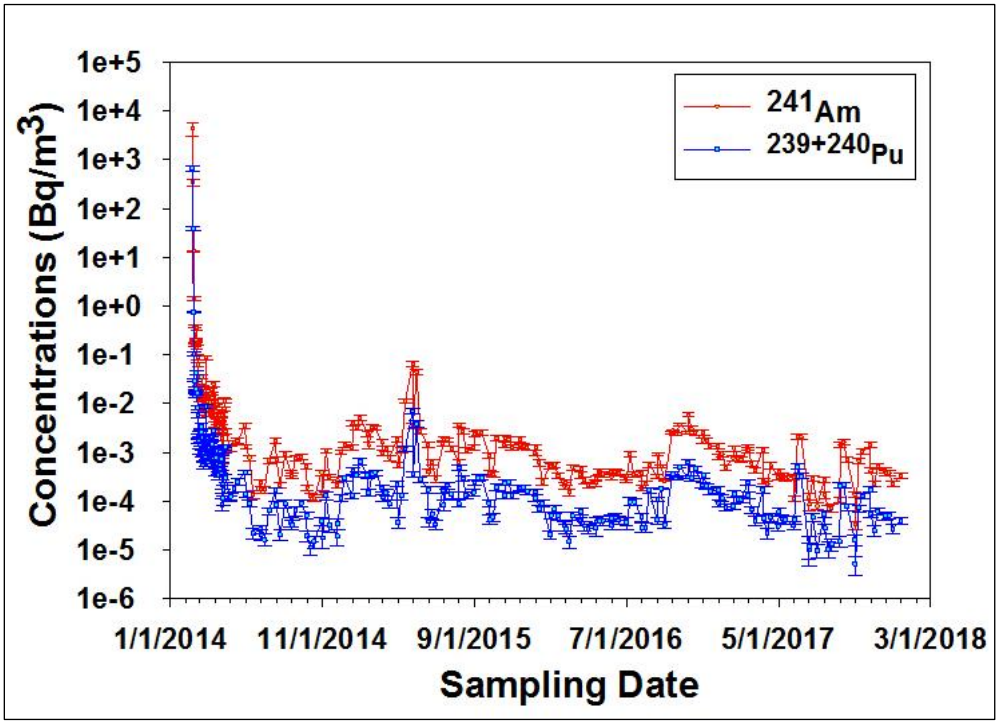


Figure 2-13: Times Series of ^{241}Am and $^{239+240}$Pu Concentrations in Station A (Pre-HEPA) filters for the Period 2014-2017

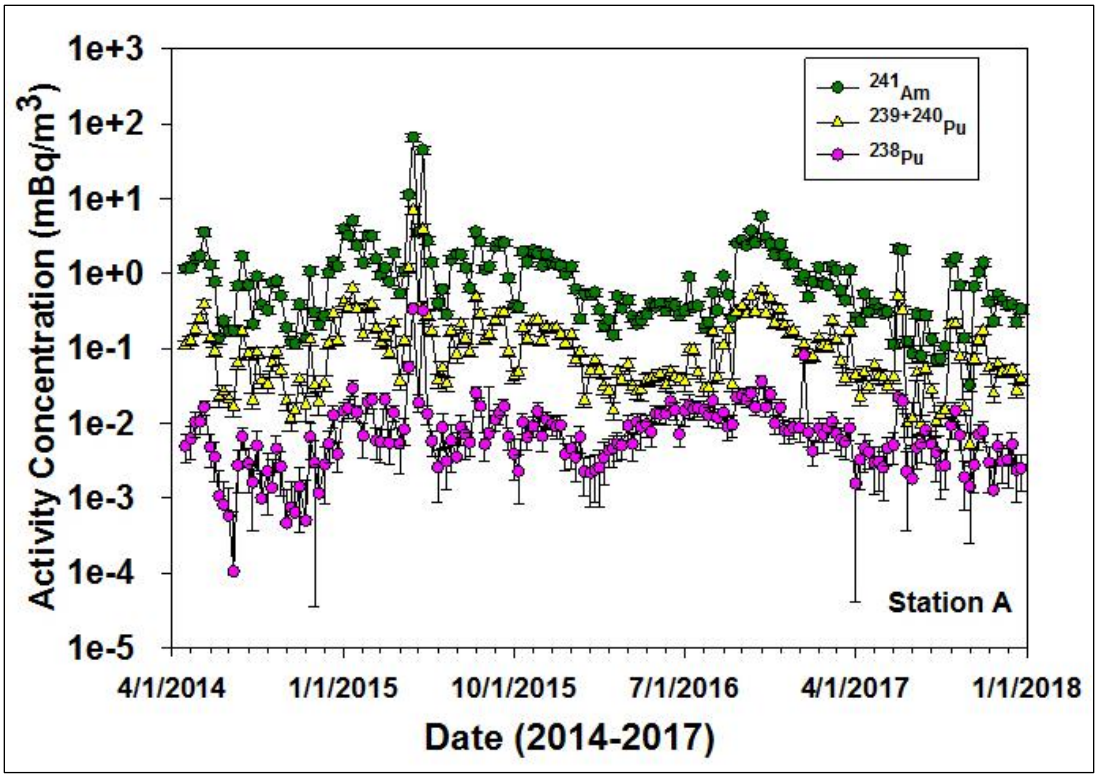


Figure 2-14: The Weekly ^{241}Am, $^{239+240}$Pu and ^{238}Pu Concentrations in Station A (Pre-HEPA) filters during 2014-2017

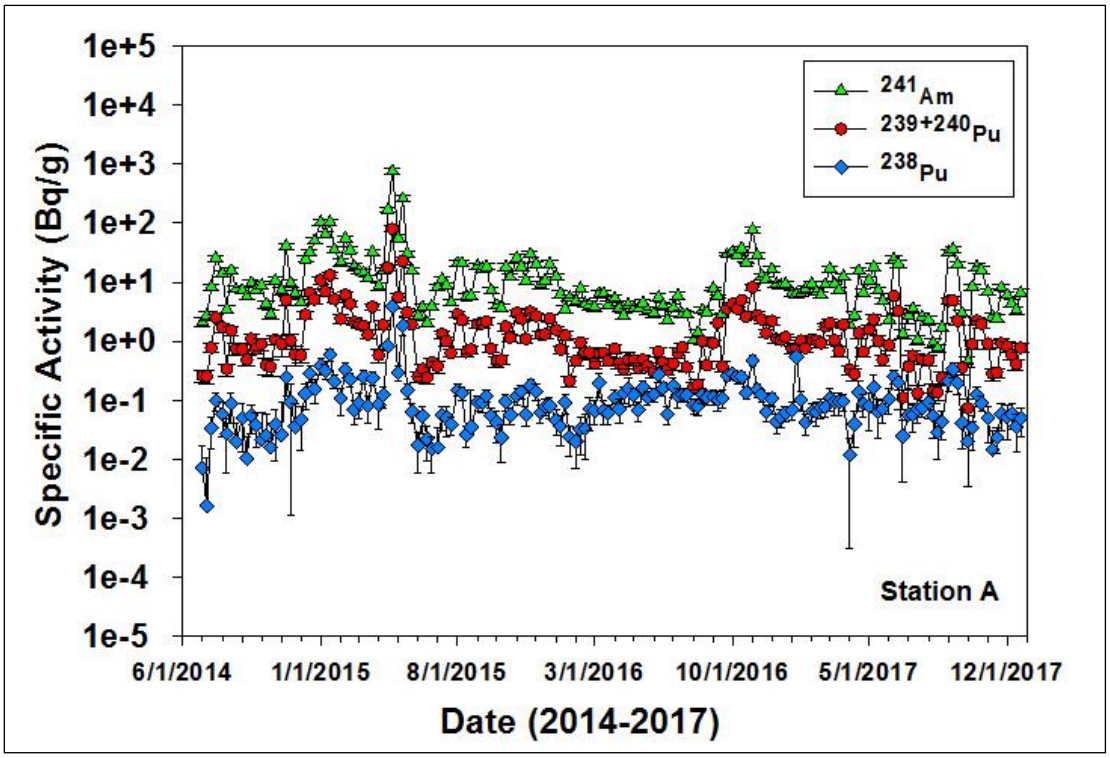


Figure 2-15: The Weekly ^{241}Am, $^{239+240}$Pu and ^{238}Pu Specific Activity in Station A (Pre-HEPA) filters during 2014-2017

Gross Alpha and Beta concentrations in the WIPP underground Air (Station B, Post-HEPA Filter)

In order to determine the amount and type of radionuclides that were ultimately released into the environment, an analysis of Station B filters was performed as these filters sampled the underground exhaust air after HEPA filtration. The daily gross alpha and gross beta concentrations in the WIPP underground air after HEPA filtration (Station B) are shown in Figure 2-16. It is important to note that the CEMRC has been performing gross alpha and gross beta analyses on Station B filters since July 2014. Filter samples collected prior to July 2014 were not counted for gross alpha and gross beta and instead, an emergency actinide separation campaign was carried out on the individual or daily filters collected from Station B in order to provide isotopic results to interested parties as quickly as possible. The pre-operational gross alpha and gross beta concentration values measured at Station A were used as a baseline concentration for the filter samples collected from Station B as the CEMRC had not routinely conducted gross alpha/beta analyses on Station B filters prior to the February 14, 2014, underground radiation release event. As would be expected, the Station B analyses showed much lower levels of activity as compared to those of Station A.

A spike in gross alpha activity during the third week of October 2014 is attributed to the restart of the 860A fan on October 21, 2014. The 860A fan was initially started on February 14, 2014, when continuous air monitors (CAM) in the WIPP underground facility detected elevated levels of radioactive contamination and shifted the underground ventilation system into filtration mode, forcing all air exiting the facility through the HEPA filtration system. Naturally, due to remaining contamination in the exhaust drift of the repository, the WIPP underground facility has remained in filtration mode since the event occurred. The 860A fan ran for approximately two months following the February 2014 underground radiological incident before being taken off-line for maintenance-related activities. Since that time, the 860B or the 860C fans have been operating to continue the air filtration process. Because the 860A fan was operational immediately following the radiological release, it is expected that a small amount of residual contamination could be present in the adjacent ductwork and the interior workings of the fan which could result in a low level of contamination being released during the restart. The current gross alpha and beta activities at Station B are comparable to the pre-operational gross alpha and beta values measured for Station A filters prior to the arrival of TRU wastes in the WIPP and are typical "background gross alpha and beta" values.

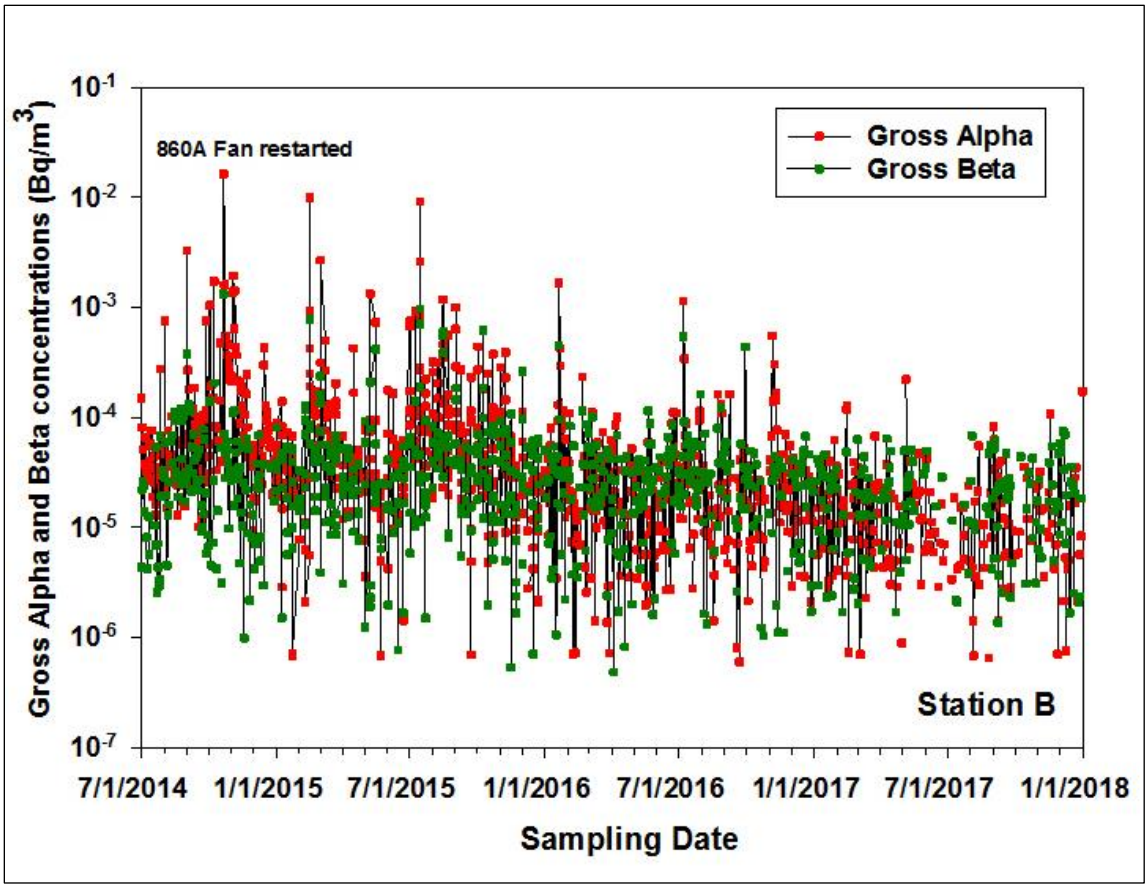


Figure 2-16: Daily Gross Alpha and Gross Beta Activity in the Filtered Underground Air (Station B) during 2014-2017

Actinide concentrations in the WIPP underground Air (Station B, Post-HEPA filter) in 2017

Sampling results from Station B (WIPP exhaust air released to the environment after filtration) showed much lower levels, about 2.3 Bq/m^3 of air for ^{241}Am and 0.22 Bq/m^3 of air for $^{239+240}$Pu, when it was collected on February 18, 2014, at the first collection opportunity four days after the underground radiation release event occurred. 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, $^{239+240}$Pu, and ^{238}Pu that may have been released into the environment. By February 21, 2014, a Station B sample had only about 0.43 Bq/m^3 of combined Pu and Am activity. By the middle of April 2014, the concentrations of ^{241}Am and $^{239+240}$Pu measured at Station B were in the range 0.11 to 0.53 Bq/m^3 and 0.01 to 0.06 Bq/m^3 respectively. The ^{238}Pu level has been below the detection limit in samples from February 19, 2015, to the present. The time series of the activity concentrations of transuranic radionuclides $^{239+240}$Pu and ^{241}Am measured at Station B (Post-HEPA filtration) since the release-event are shown in Figure 2-17. As the concentration levels of these radionuclides receded, beginning April 22, 2014, actinide analyses have been performed on weekly composite

samples. The weekly actinide analyses of Station B filters were continued until December 2015 and then beginning January 2016, monthly composite samples have been used for the actinides analyses. The activity concentrations of ^{241}Am and $^{239+240}$Pu in the daily/weekly/monthly filters collected from Station B since April 2014 are shown in Figure 2-18. The monthly composite filter results from Station B measured during 2017 are summarized in Tables 2-7 through 2-9.

CEMRC began collecting aerosol mass data of Station B filters beginning August 2014. The $^{239+240}$Pu specific activity (activity per unit mass aerosol collected) at Station B was in the range 0.051-1.05 Bq/g, while that of ^{241}Am was in the range of 0.41-9.59 Bq/g. The weekly specific activity of ^{241}Am and $^{239+240}$Pu at Station B are shown in Figure 2-19; the individual values are summarized in Tables 2-10 through 2-12.

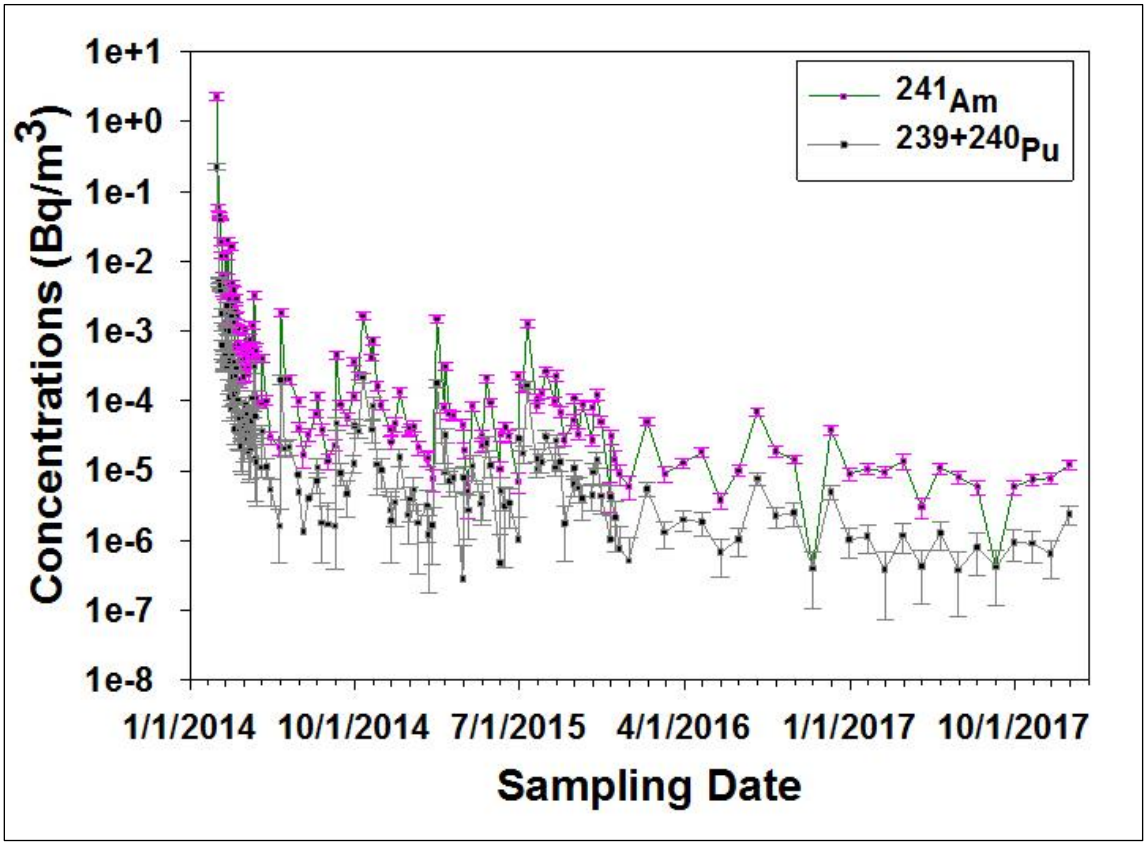


Figure 2-17: Times Series of ^{241}Am and $^{239+240}$Pu Concentrations in Station B (Post-HEPA) during 2014-2017

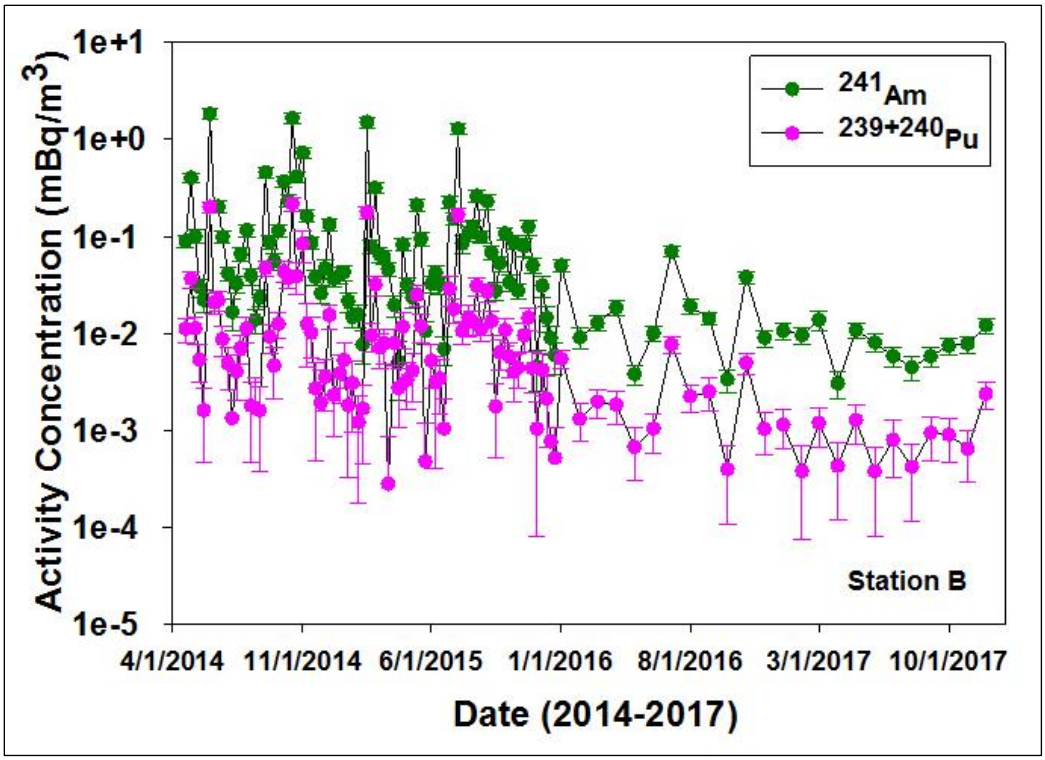


Figure 2-18: The Weekly ^{241}Am and $^{239+240}$Pu Concentrations in Station B (Post-HEPA) filters 2014-2017

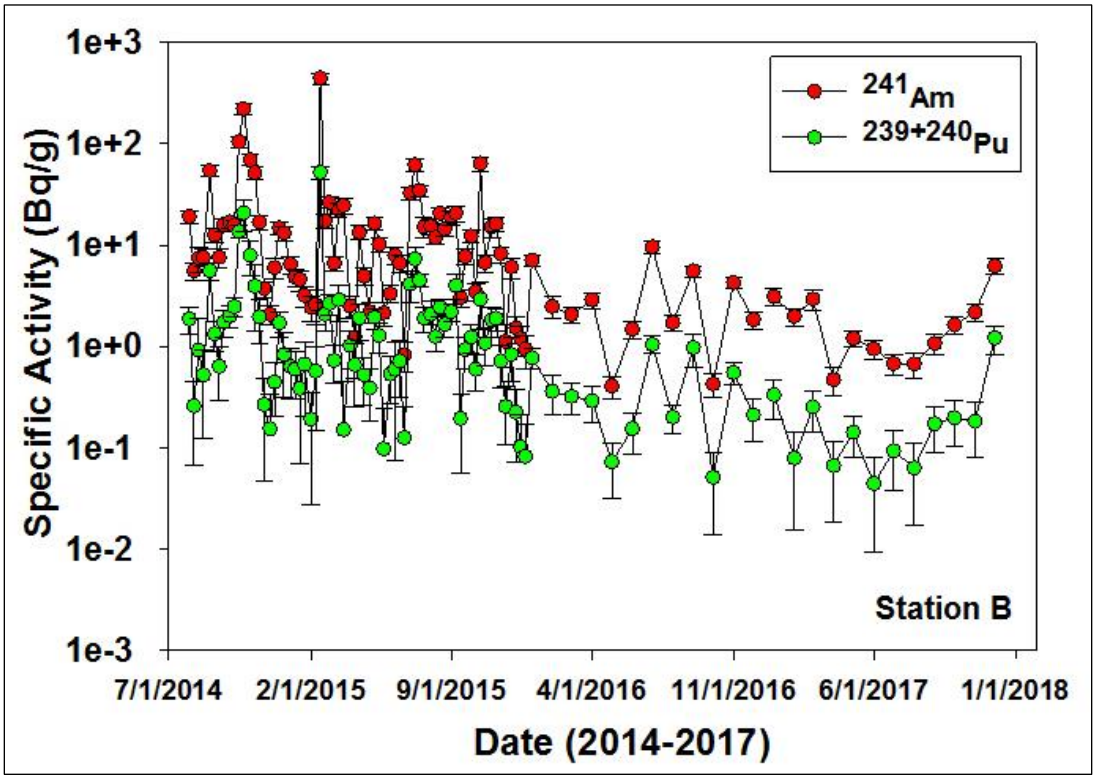


Figure 2-19: The Weekly ^{241}Am and $^{239+240}$Pu Specific Activity in Station B (Post-HEPA) filters 2014-2017

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 over time (Figure 2-20). From 2000 through 2013, only nine Station A measurements can be declared as containing 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 consistent with a global fallout origin as reported in different studies (Kelly et al., 1999, Hardy et al., 1973). This similarity 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. Based on extensive analyses of these data, the CEMRC concludes that there has been no unambiguous evidence of releases from WIPP operations prior to the February 14, 2014 underground radiation release event.

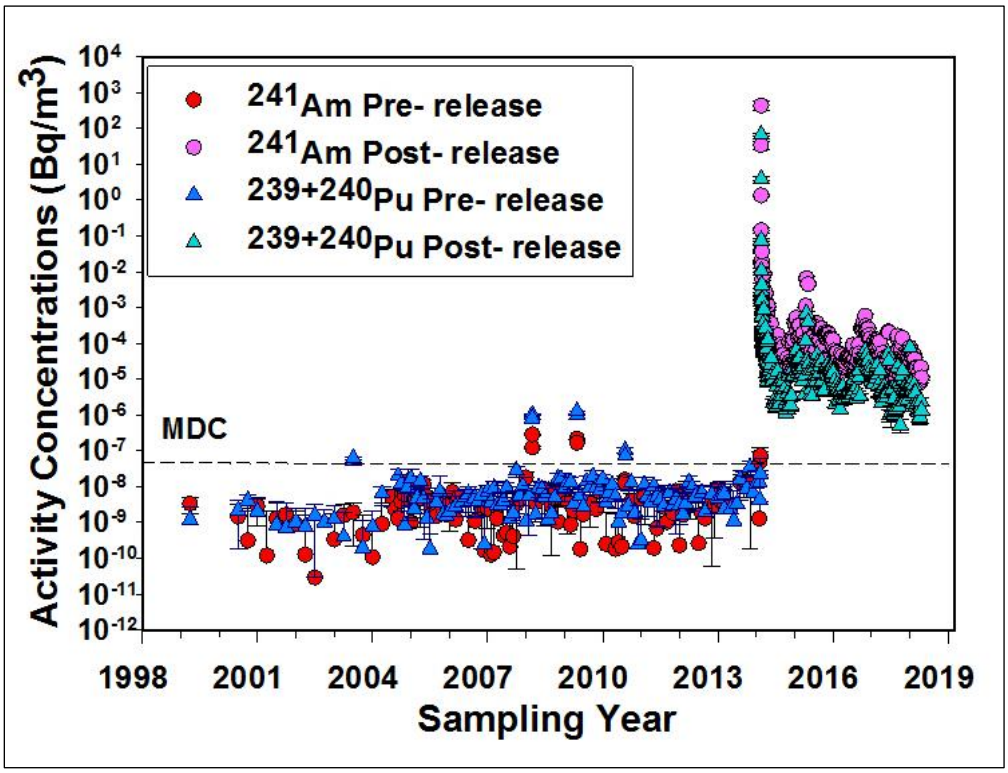


Figure 2-20: Pre- and Post-radiological Event of $^{239+240}$Pu and ^{241}Am Concentrations in the WIPP Exhaust Air at Station A (Pre-HEPA)

Uranium concentrations in the WIPP underground Air (Station A and Station B)

The naturally occurring isotopes of uranium were detected in some monthly composites samples collected from Station A and Station B in 2017. Uranium is a naturally occurring radionuclide found in the environment. Thus, the detection of uranium in the WIPP underground air is normal. The highest concentrations detected were 9.51E-07 Bq/m^3 for ^{234}U and 4.19E-07 Bq/m^3 for ^{238}U at Station A and 6.45E-07 Bq/m^3 for ^{234}U and 4.19E-07 Bq/m^3 for ^{238}U at Station B. The ^{235}U was not detected in any monthly composites samples from Station A and Station B. The individual concentrations and specific activity values measured are summarized in Tables 2-17 and 2-18 (Station A) and Tables 2-19 and 2-20 (Station B).

Where detected, the ^{234}U results were similar to those of ^{238}U for activity concentration and specific activity, indicating secular equilibrium between the two isotopes. These results are consistent with those reported in previous CEMRC reports. The concentrations of uranium isotopes measured in Station A and Station B filter samples are shown in Figures 2-21 through 2-24.

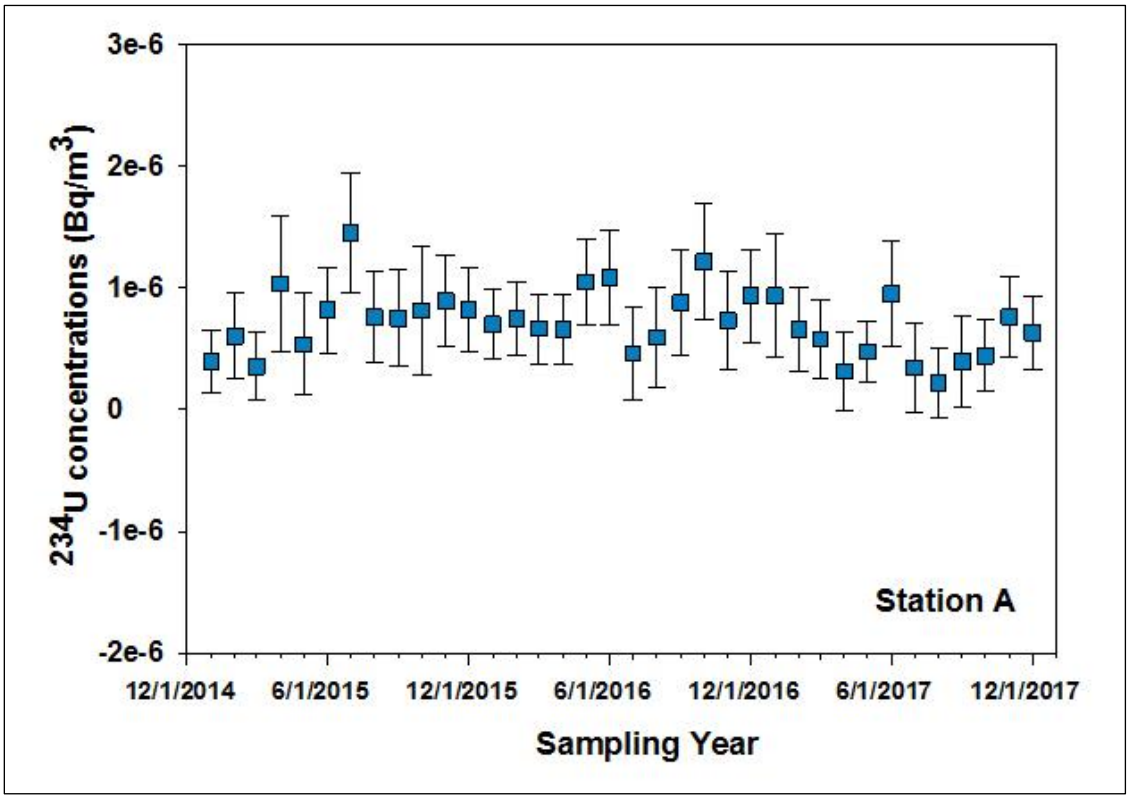


Figure 2-21: The ^{234}U Concentrations in the WIPP Exhaust air at Station A (Pre-HEPA) in 2015-2017

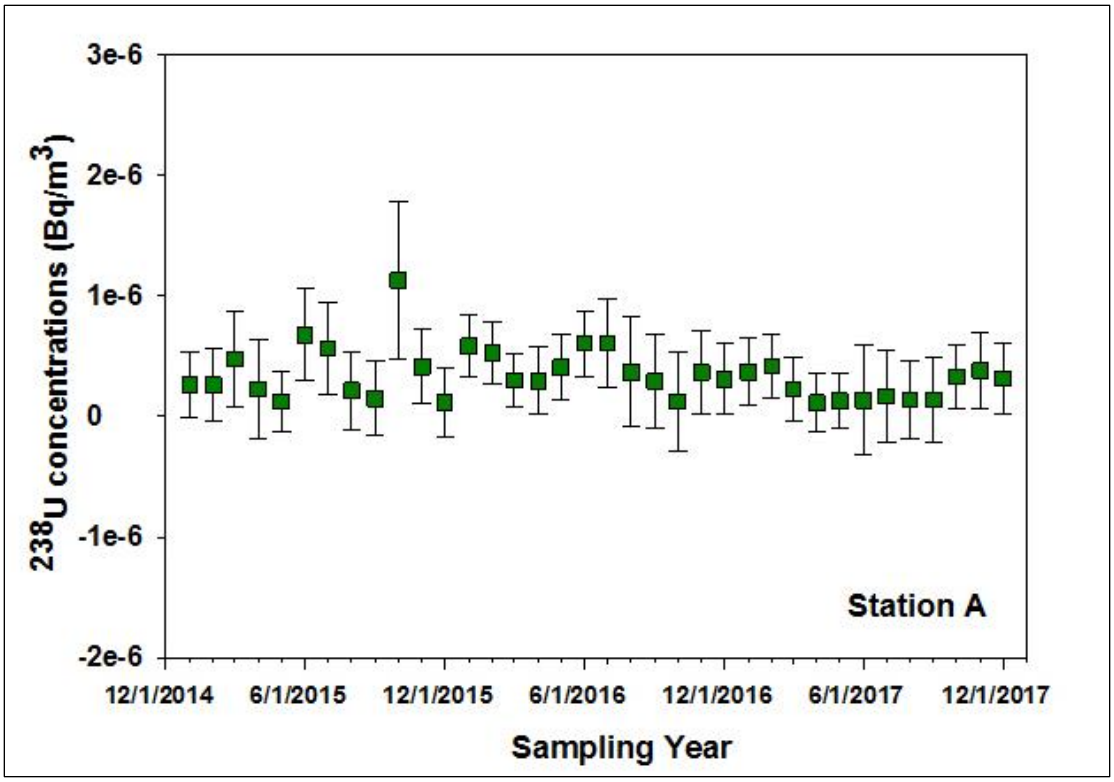


Figure 2-22: The ^{238}U Concentrations in the WIPP Exhaust air at Station A (Pre-HEPA) in 2015-2017

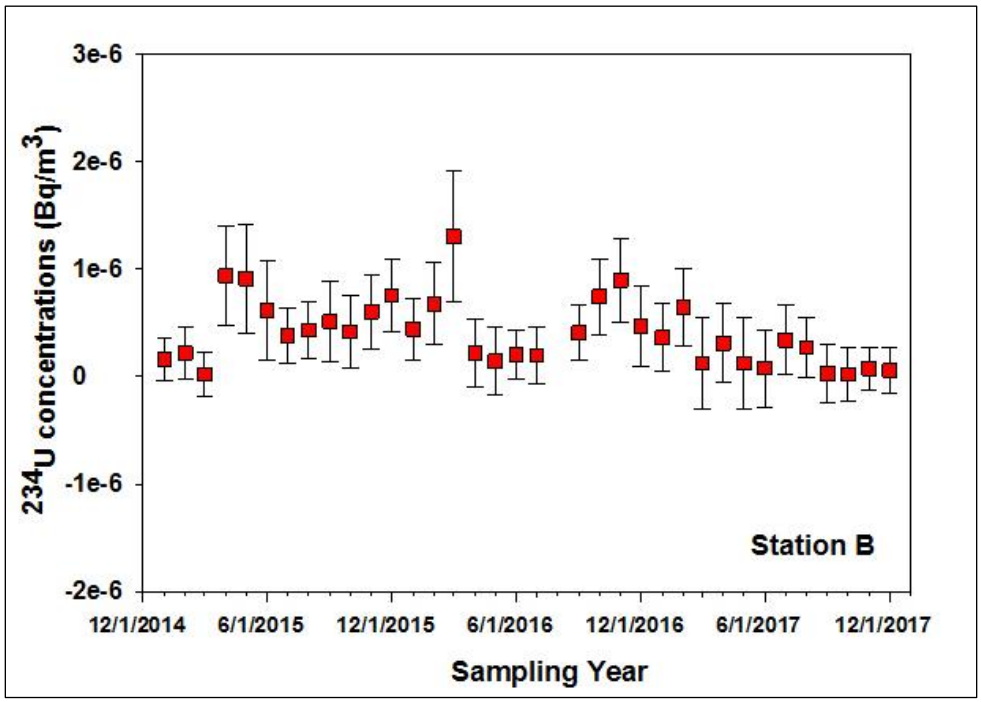


Figure 2-23: The ^{234}U Concentrations in the WIPP Exhaust air at Station B (Post-HEPA) in 2015-2017

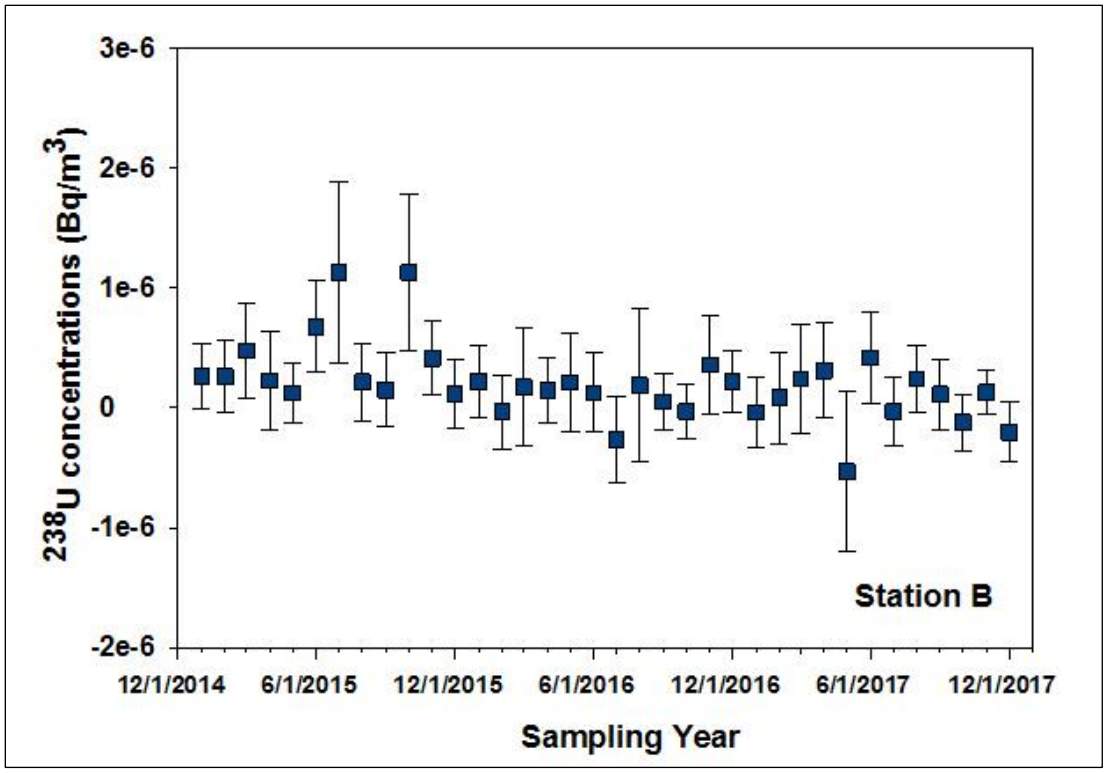


Figure 2-24: The ^{238}U Concentrations in the WIPP Exhaust air at Station B (Post-HEPA) in 2015-2017

Gamma radionuclide concentrations in the WIPP underground Air (Station A and Station B)

The concentrations of gamma-emitters ^{137}Cs, ^{60}Co, and ^{40}K measured in Station A and Station B filter samples are shown in Figures 2-25 through 2-30. The individual values measured are summarized in Tables 2-21 through 2-23 (Station A) and Tables 2-24 through 2-26 (Station B). No detectable gamma-emitting radionuclides were observed in any of the filter samples collected from Station A or Station B in 2017. An analysis of historical operational data indicates detection of ^{137}Cs only once in a Station A filter collected on February 14, 2014, immediately following the underground radiation release event at the WIPP.

An analysis of historical operational data indicates that 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 comparison between years or among locations was performed.

Conclusion

In this chapter, the WIPP underground air sampling results just before (Station A) and after filtration (Station B) are presented for the calendar year 2017. The results indicate that the ^{241}Am and $^{239+240}$Pu on the WIPP exhaust air both before and after the HEPA filtration continued to remain low after April 22, 2014. It is also important to note that the levels detected were very low and well below any level of public health or environmental concern. The occasional detection of extremely low levels of $^{239+240}$Pu, ^{238}Pu, and ^{241}Am in the WIPP exhaust air prior to the 2014 radiation release event is largely due to their presence in the global environment, although an occasional higher detection level may be attributed to minute particles with contamination being released from the surface of a waste container during handling. The sensitivity of the performed measurements make it likely that just a few atoms would be detected; therefore, there is no reason to believe that the WIPP is a source of environmental contamination that can be considered significant by any health-based standard

As expected, the naturally occurring isotopes of uranium were detected in some monthly composites samples collected from Station A and Station B in 2017. With the exception of occasional detections from ^{40}K , no detectable gamma emitting radionuclides were observed during the monitoring period 2017.

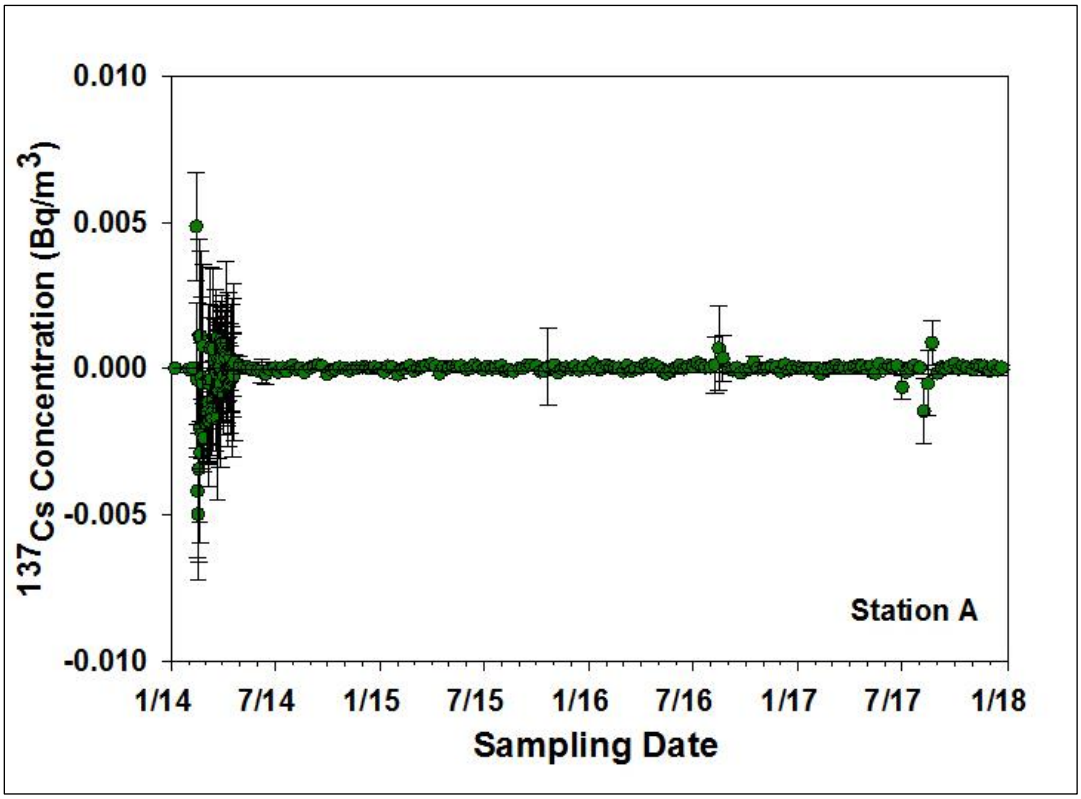


Figure 2-25: The ^{137}Cs Concentrations in the WIPP exhaust air at Station A (Pre-HEPA)

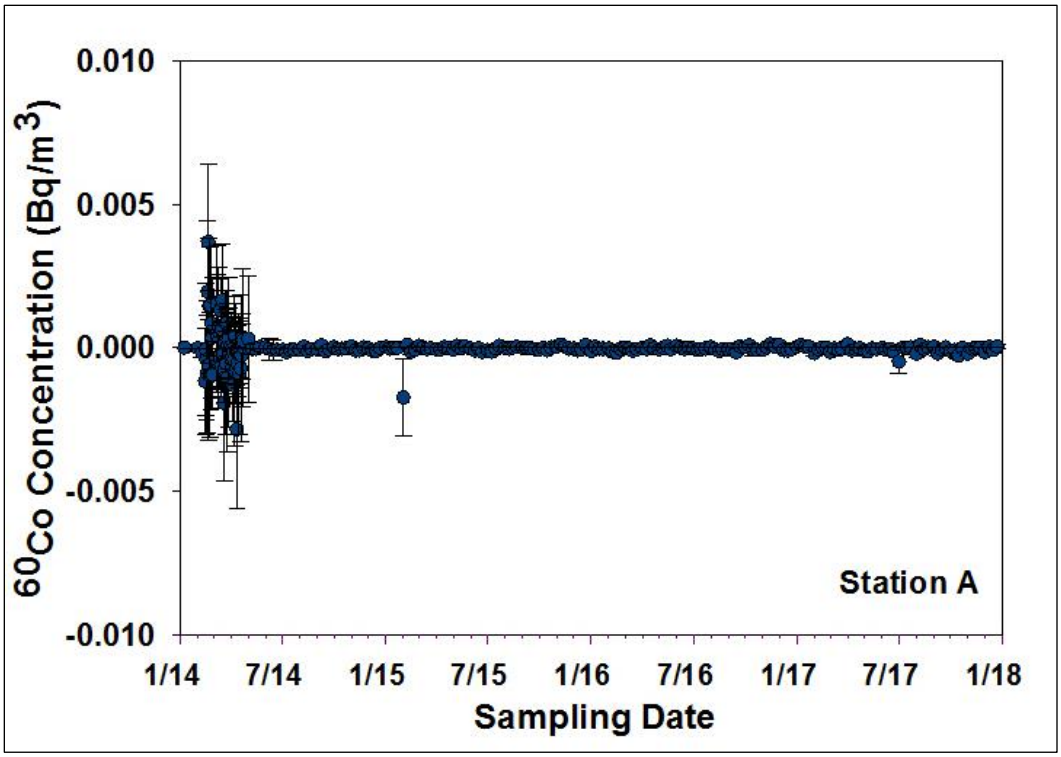


Figure 2-26: The ^{60}Co Concentrations in the WIPP exhaust air at Station A (Pre-HEPA)

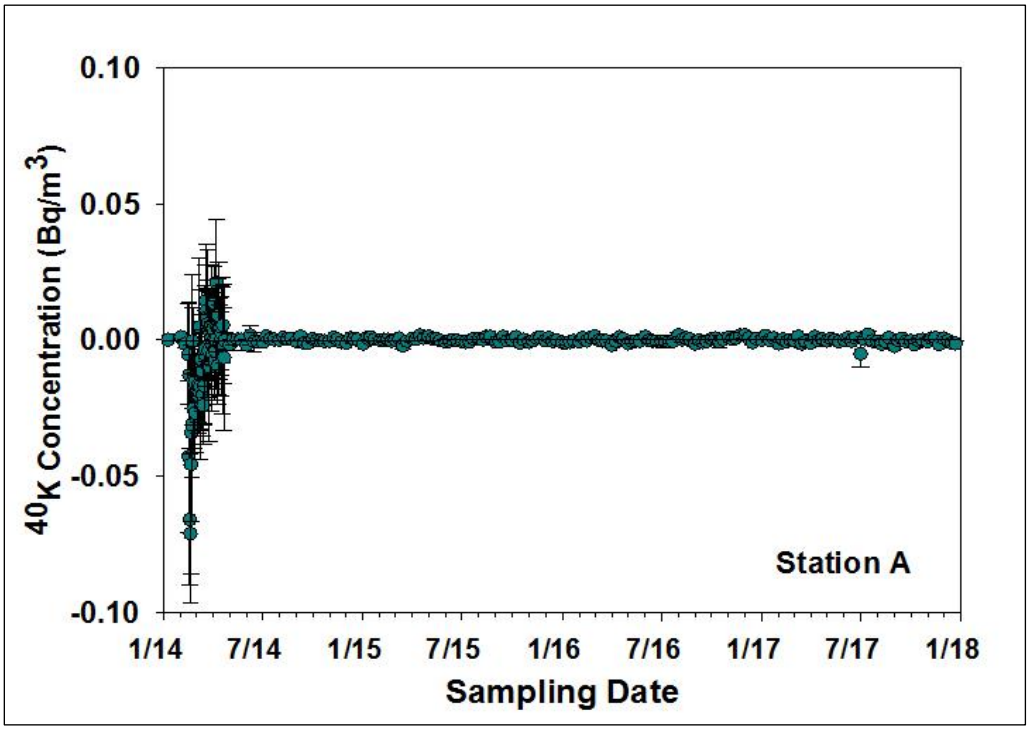


Figure 2-27: The ^{40}K Concentrations in the WIPP exhaust air at Station A (Pre-HEPA)

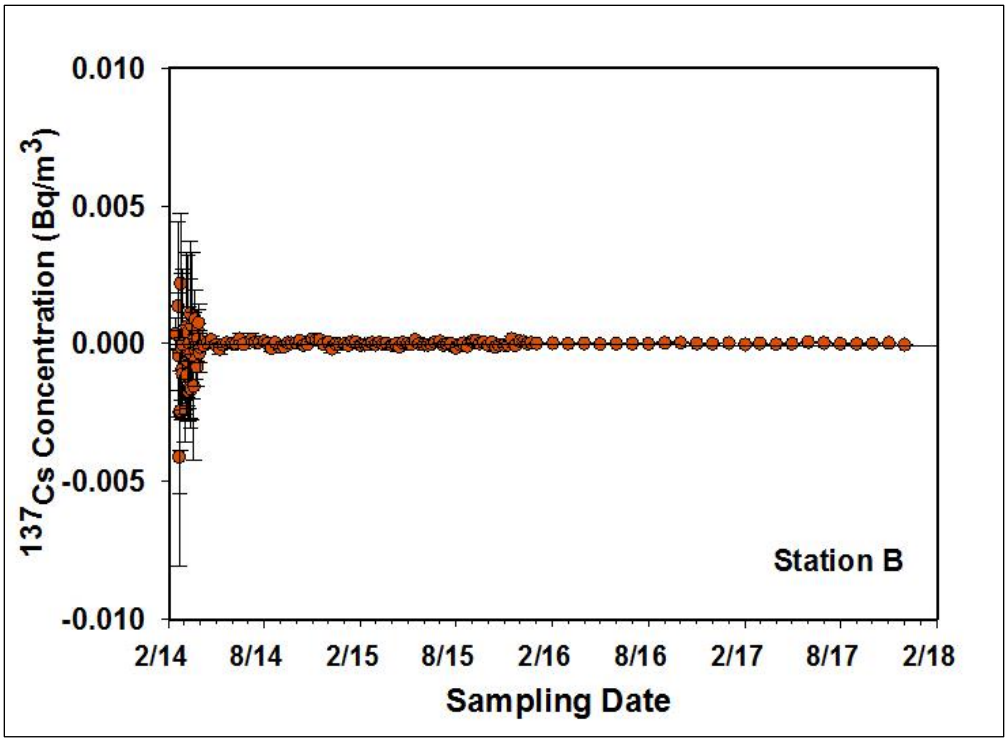


Figure 2-28: The ^{137}Cs Concentrations in the WIPP exhaust air at Station B (Post-HEPA)

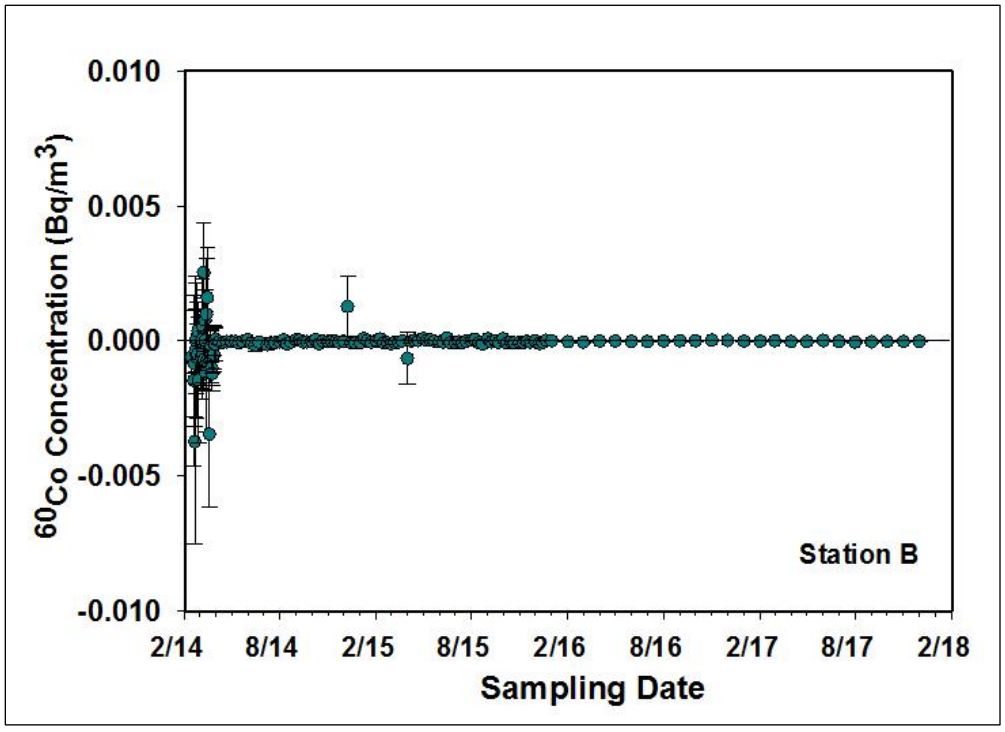


Figure 2-29: The ^{60}Co Concentrations in the WIPP exhaust air at Station B (Post-HEPA)

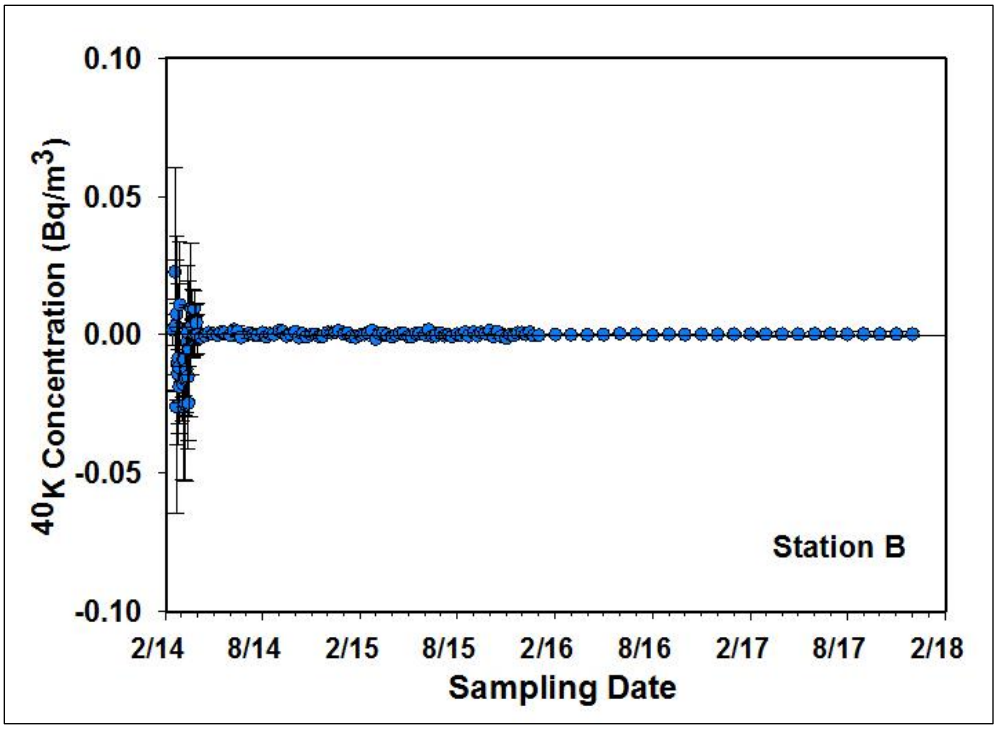


Figure 2-30: The ^{40}K Concentrations in the WIPP exhaust air at Station B (Post-HEPA)

Table 2-1: Weekly Activity concentrations of ^{241}Am (Bq/m^3) in Station A (Pre-HEPA) filters in 2017

Sample Date	^{241}Am Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
January 2017				
1st week	8.13E-04	1.00E-04	2.35E-06	Detected
2nd week	9.43E-04	1.18E-04	2.12E-06	Detected
3rd week	4.90E-04	7.38E-05	6.35E-06	Detected
4th week	7.76E-04	1.02E-04	3.88E-06	Detected
February 2017				
1st week	1.21E-03	1.48E-04	1.91E-06	Detected
2nd week	7.60E-04	9.46E-05	1.86E-06	Detected
3rd week	7.02E-04	8.66E-05	1.67E-06	Detected
4th week	1.25E-03	1.66E-04	2.77E-06	Detected
March 2017				
1st week	1.10E-03	1.37E-04	1.98E-06	Detected
2nd week	6.01E-04	7.65E-05	1.72E-06	Detected
3rd week	4.37E-04	5.88E-05	2.38E-06	Detected
4th week	1.13E-03	1.37E-04	1.63E-06	Detected
April 2017				
1st week	2.59E-04	3.78E-05	4.89E-06	Detected
2nd week	2.29E-04	3.35E-05	2.40E-06	Detected
3rd week	5.40E-04	7.01E-05	2.41E-06	Detected
4th week	3.11E-04	4.45E-05	3.41E-06	Detected
May 2017				
1st week	4.01E-04	5.82E-05	5.21E-06	Detected
2nd week	3.35E-04	4.34E-05	2.05E-06	Detected
3rd week	2.93E-04	3.82E-05	1.51E-06	Detected
4th week	3.09E-04	3.95E-05	1.55E-06	Detected
June 2017				
1st week	1.13E-04	1.66E-05	2.18E-06	Detected
2nd week	2.15E-03	2.62E-04	2.25E-06	Detected
3rd week	2.06E-03	2.52E-04	2.24E-06	Detected
4th week	1.23E-04	1.94E-05	2.99E-06	Detected

Table 2-1: Weekly Activity concentrations of ^{241}Am (Bq/m^3) in Station A (Pre-HEPA) filters in 2017 (continued)

Sample Date	^{241}Am Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
July 2017				
1st week	8.56E-05	2.14E-05	9.76E-06	Detected
2nd week	2.92E-04	3.95E-05	1.93E-06	Detected
3rd week	7.91E-05	1.26E-05	1.42E-06	Detected
4th week	2.78E-04	3.60E-05	1.44E-06	Detected
August 2017				
1st week	1.34E-04	2.41E-05	3.46E-06	Detected
2nd week	6.98E-05	1.16E-05	2.18E-06	Detected
3rd week	7.28E-05	1.24E-05	1.93E-06	Detected
4th week	1.07E-04	1.50E-05	1.11E-06	Detected
September 2017				
1st week	1.41E-03	1.74E-04	1.63E-06	Detected
2nd week	1.61E-03	1.97E-04	1.73E-06	Detected
3rd week	6.99E-04	8.88E-05	1.63E-06	Detected
4th week	1.38E-04	1.89E-05	1.11E-06	Detected
October 2017				
1st week	3.26E-05	6.53E-06	1.62E-06	Detected
2nd week	6.75E-04	8.51E-05	1.72E-06	Detected
3rd week	1.04E-03	1.28E-04	2.20E-06	Detected
4th week	1.42E-03	1.72E-04	1.16E-06	Detected
November 2017				
1st week	4.23E-04	5.35E-05	1.72E-06	Detected
2nd week	2.30E-04	3.05E-05	1.85E-06	Detected
3rd week	5.22E-04	6.59E-05	2.64E-06	Detected
4th week	4.32E-04	5.41E-05	1.16E-06	Detected
December 2017				
1st week	3.75E-04	4.81E-05	2.01E-06	Detected
2nd week	3.87E-04	4.92E-05	1.95E-06	Detected
3rd week	2.26E-04	3.04E-05	1.69E-06	Detected
4th week	3.37E-04	4.27E-05	9.38E-07	Detected

Table 2-2: Weekly Activity concentrations of $^{239+240}$Pu (Bq/m^3) in Station A (Pre-HEPA) filters in 2017

Sample Date	$^{239+240}$Pu Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
January 2017				
1st week	9.23E-05	1.43E-05	1.43E-06	Detected
2nd week	1.15E-04	1.72E-05	1.74E-06	Detected
3rd week	7.54E-05	1.20E-05	1.22E-06	Detected
4th week	7.78E-05	1.13E-05	8.87E-07	Detected
February 2017				
1st week	1.40E-04	2.01E-05	1.53E-06	Detected
2nd week	1.12E-04	1.80E-05	2.30E-06	Detected
3rd week	1.07E-04	1.62E-05	1.63E-06	Detected
4th week	2.41E-04	3.26E-05	1.59E-06	Detected
March 2017				
1st week	1.32E-04	1.98E-05	1.55E-06	Detected
2nd week	6.72E-05	1.12E-05	1.32E-06	Detected
3rd week	4.01E-05	7.75E-06	1.75E-06	Detected
4th week	1.73E-04	2.39E-05	1.10E-06	Detected
April 2017				
1st week	4.41E-05	8.65E-06	1.75E-06	Detected
2nd week	2.26E-05	5.64E-06	1.58E-06	Detected
3rd week	4.75E-05	9.37E-06	2.24E-06	Detected
4th week	3.08E-05	5.87E-06	9.91E-07	Detected
May 2017				
1st week	6.00E-05	1.05E-05	1.52E-06	Detected
2nd week	4.31E-05	8.55E-06	2.45E-06	Detected
3rd week	4.10E-05	7.99E-06	1.80E-06	Detected
4th week	3.16E-05	6.23E-06	1.18E-06	Detected
June 2017				
1st week	4.19E-05	8.04E-06	1.88E-06	Detected
2nd week	5.09E-04	6.54E-05	1.86E-06	Detected
3rd week	3.27E-04	4.25E-05	1.47E-06	Detected
4th week	9.98E-06	3.69E-06	2.52E-06	Detected

Table 2-2: Weekly Activity concentrations of $^{239+240}Pu$ (Bq/m^3) in Station A (Pre-HEPA) filters in 2017 (continued)

Sample Date	$^{239+240}Pu$ Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
July 2017				
1st week	1.17E-05	7.03E-06	7.56E-06	Detected
2nd week	4.69E-05	8.82E-06	1.82E-06	Detected
3rd week	9.82E-06	3.20E-06	1.47E-06	Detected
4th week	5.37E-05	8.77E-06	1.22E-06	Detected
August 2017				
1st week	2.79E-05	6.35E-06	2.07E-06	Detected
2nd week	1.04E-05	3.79E-06	2.26E-06	Detected
3rd week	1.30E-05	3.92E-06	1.62E-06	Detected
4th week	1.49E-05	3.61E-06	1.17E-06	Detected
September 2017				
1st week	2.11E-04	2.86E-05	1.48E-06	Detected
2nd week	2.16E-04	2.95E-05	1.55E-06	Detected
3rd week	7.73E-05	1.24E-05	2.17E-06	Detected
4th week	1.64E-05	3.92E-06	1.62E-06	Detected
October 2017				
1st week	5.24E-06	2.20E-06	1.37E-06	Detected
2nd week	7.22E-05	1.16E-05	1.36E-06	Detected
3rd week	1.28E-04	1.85E-05	2.11E-06	Detected
4th week	1.72E-04	2.29E-05	1.02E-06	Detected
November 2017				
1st week	5.49E-05	9.66E-06	1.47E-06	Detected
2nd week	2.49E-05	5.70E-06	1.90E-06	Detected
3rd week	6.20E-05	1.07E-05	1.53E-06	Detected
4th week	4.89E-05	8.28E-06	1.32E-06	Detected
December 2017				
1st week	5.02E-05	8.98E-06	1.07E-06	Detected
2nd week	5.17E-05	9.21E-06	1.58E-06	Detected
3rd week	2.75E-05	5.75E-06	1.34E-06	Detected
4th week	3.93E-05	6.74E-06	1.05E-06	Detected

Table 2-3: Weekly Activity concentrations of ^{238}Pu (Bq/m^3) in Station A (Pre-HEPA) filters in 2017

Sample Date	^{238}Pu Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
January 2017				
1st week	8.66E-06	2.94E-06	1.43E-06	Detected
2nd week	8.16E-05	2.89E-06	1.32E-06	Detected
3rd week	7.54E-06	2.70E-06	1.70E-06	Detected
4th week	4.26E-06	1.62E-06	1.04E-06	Detected
February 2017				
1st week	8.47E-06	2.93E-06	2.01E-06	Detected
2nd week	6.99E-06	3.09E-06	3.12E-06	Detected
3rd week	8.77E-06	3.07E-06	2.14E-06	Detected
4th week	1.05E-05	3.35E-06	2.08E-06	Detected
March 2017				
1st week	7.23E-06	2.85E-06	2.32E-06	Detected
2nd week	6.05E-06	2.47E-06	1.61E-06	Detected
3rd week	5.64E-06	2.39E-06	1.63E-06	Detected
4th week	8.65E-06	2.75E-06	9.22E-07	Detected
April 2017				
1st week	1.57E-06	1.53E-06	2.60E-06	Detected
2nd week	3.25E-06	1.98E-06	1.94E-06	Detected
3rd week	4.66E-06	2.44E-06	2.08E-06	Detected
4th week	4.13E-06	1.75E-06	8.32E-07	Detected
May 2017				
1st week	2.97E-06	1.83E-06	2.26E-06	Detected
2nd week	3.06E-06	1.83E-06	1.64E-06	Detected
3rd week	2.58E-06	1.64E-06	1.67E-06	Detected
4th week	4.61E-06	1.95E-06	1.39E-06	Detected
June 2017				
1st week	5.17E-06	2.32E-06	1.88E-06	Detected
2nd week	2.21E-05	5.36E-06	1.73E-06	Detected
3rd week	1.98E-05	4.67E-06	1.58E-06	Detected
4th week	2.25E-06	1.89E-06	2.97E-06	Detected

Table 2-3: Weekly Activity concentrations of ^{238}Pu (Bq/m^3) in Station A (Pre-HEPA) filters in 2017 (continued)

Sample Date	^{238}Pu Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
July 2017				
1st week	1.82E-06	3.27E-06	7.12E-06	Detected
2nd week	4.69E-06	2.29E-06	2.32E-06	Detected
3rd week	5.29E-06	2.31E-06	1.72E-06	Detected
4th week	8.11E-06	2.49E-06	1.37E-06	Detected
August 2017				
1st week	5.26E-06	2.44E-06	1.95E-06	Detected
2nd week	4.07E-06	2.41E-06	2.88E-06	Detected
3rd week	2.68E-06	1.73E-06	1.90E-06	Detected
4th week	2.73E-06	1.42E-06	1.34E-06	Detected
September 2017				
1st week	9.35E-06	3.06E-06	2.10E-06	Detected
2nd week	1.47E-05	4.03E-06	2.11E-06	Detected
3rd week	6.92E-06	2.61E-06	1.75E-06	Detected
4th week	1.91E-06	1.21E-06	1.24E-06	Detected
October 2017				
1st week	1.44E-06	1.19E-06	1.61E-06	Detected
2nd week	2.78E-06	1.63E-06	1.78E-06	Detected
3rd week	7.10E-06	2.66E-06	2.18E-06	Detected
4th week	7.95E-06	2.34E-06	1.16E-06	Detected
November 2017				
1st week	3.00E-06	1.83E-06	2.34E-06	Detected
2nd week	1.29E-06	1.35E-06	2.43E-06	Detected
3rd week	4.90E-06	2.25E-06	1.68E-06	Detected
4th week	3.11E-06	1.52E-06	1.12E-06	Detected
December 2017				
1st week	3.19E-06	1.84E-06	2.21E-06	Detected
2nd week	5.20E-06	2.32E-06	2.15E-06	Detected
3rd week	2.38E-06	1.49E-06	1.67E-06	Detected
4th week	2.52E-06	1.27E-06	9.60E-07	Detected

Table 2-4: Weekly Specific Activity of ^{241}Am (Bq/g) in Station A (Pre-HEPA) filters in 2017

Sample Date	^{241}Am Activity Bq/g	Unc. (2σ) Bq/g	MDC Bq/g	Status
January 2017				
1st week	6.46E+00	7.98E-01	1.87E-02	Detected
2nd week	6.35E+00	7.94E-01	1.42E-02	Detected
3rd week	6.57E+00	9.90E-01	8.53E-02	Detected
4th week	7.61E+00	9.98E-01	3.81E-02	Detected
February 2017				
1st week	9.31E+00	1.14E+00	1.46E-02	Detected
2nd week	6.98E+00	8.69E-01	1.71E-02	Detected
3rd week	6.08E+00	7.50E-01	1.44E-02	Detected
4th week	9.20E+00	1.23E+00	2.05E-02	Detected
March 2017				
1st week	1.69E+01	2.10E+00	3.03E-02	Detected
2nd week	9.38E+00	1.19E+00	2.68E-02	Detected
3rd week	7.34E+00	9.87E-01	4.00E-02	Detected
4th week	1.24E+01	1.52E+00	1.80E-02	Detected
April 2017				
1st week	1.94E+00	2.83E-01	3.66E-02	Detected
2nd week	2.79E+00	4.08E-01	2.93E-02	Detected
3rd week	1.57E+01	2.04E+00	7.02E-02	Detected
4th week	6.64E+00	9.52E-01	7.30E-02	Detected
May 2017				
1st week	1.08E+01	1.56E+00	1.40E-01	Detected
2nd week	1.81E+01	2.35E+00	1.11E-01	Detected
3rd week	7.27E+00	9.47E-01	3.74E-02	Detected
4th week	4.79E+00	6.12E-01	2.41E-02	Detected
June 2017				
1st week	2.32E+00	3.40E-01	4.47E-02	Detected
2nd week	2.45E+01	2.99E+00	2.56E-02	Detected
3rd week	2.06E+01	2.52E+00	2.23E-02	Detected
4th week	1.35E+00	2.14E-01	3.29E-02	Detected

Table 2-4: Weekly Specific Activity of ^{241}Am (Bq/g) in Station A (Pre-HEPA) filters in 2017 (continued)

Sample Date	^{241}Am Activity Bq/g	Unc. (2σ) Bq/g	MDC Bq/g	Status
July 2017				
1st week	2.70E+00	6.76E-01	3.08E-01	Detected
2nd week	3.54E+00	4.80E-01	2.34E-02	Detected
3rd week	1.06E+00	1.70E-01	1.91E-02	Detected
4th week	2.59E+00	3.35E-01	1.34E-02	Detected
August 2017				
1st week	2.31E+00	4.16E-01	5.97E-02	Detected
2nd week	9.28E-01	1.54E-01	2.90E-02	Detected
3rd week	7.67E-01	1.31E-01	2.03E-02	Detected
4th week	1.71E+00	2.40E-01	1.77E-02	Detected
September 2017				
1st week	3.24E+01	4.00E+00	3.74E-02	Detected
2nd week	3.66E+01	4.47E+00	3.92E-02	Detected
3rd week	2.01E+01	2.55E+00	4.67E-02	Detected
4th week	3.00E+00	4.10E-01	2.40E-02	Detected
October 2017				
1st week	4.57E-01	9.15E-02	2.27E-02	Detected
2nd week	8.34E+00	1.05E+00	2.12E-02	Detected
3rd week	1.82E+01	2.25E+00	3.87E-02	Detected
4th week	1.61E+01	1.95E+00	1.31E-02	Detected
November 2017				
1st week	7.00E+00	8.85E-01	2.85E-02	Detected
2nd week	2.59E+00	3.43E-01	2.08E-02	Detected
3rd week	2.48E+00	3.13E-01	1.25E-02	Detected
4th week	8.12E+00	1.02E+00	2.19E-02	Detected
December 2017				
1st week	6.09E+00	7.80E-01	3.27E-02	Detected
2nd week	4.40E+00	5.60E-01	2.22E-02	Detected
3rd week	3.36E+00	4.51E-01	2.51E-02	Detected
4th week	6.64E+00	8.42E-01	1.85E-02	Detected

Table 2-5: Weekly Specific Activity of $^{239+240}Pu$ (Bq/g) in Station A (Pre-HEPA) filters in 2017

Sample Date	$^{239+240}Pu$ Activity Bq/g	Unc. (2σ) Bq/g	MDC Bq/g	Status
January 2017				
1st week	7.33E-01	1.14E-01	1.13E-02	Detected
2nd week	7.72E-01	1.16E-01	1.17E-02	Detected
3rd week	1.01E+00	1.61E-01	1.63E-02	Detected
4th week	7.63E-01	1.11E-01	8.71E-03	Detected
February 2017				
1st week	1.07E+00	1.55E-01	1.17E-02	Detected
2nd week	1.03E+00	1.66E-01	2.11E-02	Detected
3rd week	9.24E-01	1.41E-01	1.41E-02	Detected
4th week	1.78E+00	2.41E-01	1.17E-02	Detected
March 2017				
1st week	2.03E+00	3.03E-01	2.38E-02	Detected
2nd week	1.05E+00	1.75E-01	2.06E-02	Detected
3rd week	6.74E-01	1.30E-01	2.93E-02	Detected
4th week	1.91E+00	2.64E-01	1.21E-02	Detected
April 2017				
1st week	3.30E-01	6.47E-02	1.31E-02	Detected
2nd week	2.75E-01	6.88E-02	1.93E-02	Detected
3rd week	1.38E+00	2.72E-01	6.51E-02	Detected
4th week	6.58E-01	1.26E-01	2.12E-02	Detected
May 2017				
1st week	1.61E+00	2.83E-01	4.08E-02	Detected
2nd week	2.33E+00	4.62E-01	1.32E-01	Detected
3rd week	1.02E+00	1.98E-01	4.45E-02	Detected
4th week	4.90E-01	9.66E-02	1.83E-02	Detected
June 2017				
1st week	8.59E-01	1.65E-01	3.86E-02	Detected
2nd week	5.81E+00	7.46E-01	2.12E-02	Detected
3rd week	3.26E+00	4.24E-01	1.47E-02	Detected
4th week	1.10E-01	4.05E-02	2.78E-02	Detected

Table 2-5: Weekly Specific Activity of $^{239+240}$Pu (Bq/g) in Station A (Pre-HEPA) filters in 2017 (continued)

Sample Date	$^{239+240}$Pu Activity Bq/g	Unc. (2σ) Bq/g	MDC Bq/g	Status
July 2017				
1st week	3.69E-01	2.22E-01	2.39E-01	Detected
2nd week	5.70E-01	1.07E-01	2.21E-02	Detected
3rd week	1.32E-01	4.30E-02	1.97E-02	Detected
4th week	4.99E-01	8.16E-02	1.14E-02	Detected
August 2017				
1st week	4.82E-01	1.10E-01	3.58E-02	Detected
2nd week	1.39E-01	5.04E-02	3.01E-02	Detected
3rd week	1.37E-01	4.13E-02	1.71E-02	Detected
4th week	2.38E-01	5.76E-02	1.87E-02	Detected
September 2017				
1st week	4.84E+00	6.56E-01	3.40E-02	Detected
2nd week	4.90E+00	6.68E-01	3.52E-02	Detected
3rd week	2.22E+00	3.55E-01	6.23E-02	Detected
4th week	3.55E-01	8.50E-02	3.53E-02	Detected
October 2017				
1st week	7.34E-02	3.08E-02	1.92E-02	Detected
2nd week	8.92E-01	1.43E-01	1.68E-02	Detected
3rd week	2.25E+00	3.25E-01	3.71E-02	Detected
4th week	1.96E+00	2.59E-01	1.15E-02	Detected
November 2017				
1st week	9.08E-01	1.60E-01	2.43E-02	Detected
2nd week	2.80E-01	6.41E-02	2.14E-02	Detected
3rd week	2.94E-01	5.08E-02	7.28E-03	Detected
4th week	9.20E-01	1.56E-01	2.48E-02	Detected
December 2017				
1st week	8.14E-01	1.46E-01	1.74E-02	Detected
2nd week	5.88E-01	1.05E-01	1.80E-02	Detected
3rd week	4.09E-01	8.55E-02	1.99E-02	Detected
4th week	7.74E-01	1.33E-01	2.06E-02	Detected

Table 2-6: Weekly Specific Activity of ^{238}Pu (Bq/g) in Station A (Pre-HEPA) filters in 2017

Sample Date	^{238}Pu Activity Bq/g	Unc. (2σ) Bq/g	MDC Bq/g	Status
January 2017				
1st week	6.88E-02	2.34E-02	1.13E-02	Detected
2nd week	5.50E-01	1.94E-02	8.89E-03	Detected
3rd week	1.01E-01	3.62E-02	2.28E-02	Detected
4th week	4.18E-02	1.59E-02	1.02E-02	Detected
February 2017				
1st week	6.50E-02	2.25E-02	1.54E-02	Detected
2nd week	6.42E-02	2.84E-02	2.86E-02	Detected
3rd week	7.60E-02	2.66E-02	1.85E-02	Detected
4th week	7.78E-02	2.48E-02	1.54E-02	Detected
March 2017				
1st week	1.11E-01	4.36E-02	3.55E-02	Detected
2nd week	9.44E-02	3.85E-02	2.52E-02	Detected
3rd week	9.47E-02	4.01E-02	2.73E-02	Detected
4th week	9.56E-02	3.03E-02	1.02E-02	Detected
April 2017				
1st week	1.18E-02	1.15E-02	1.94E-02	Detected
2nd week	3.97E-02	2.41E-02	2.37E-02	Detected
3rd week	1.35E-01	7.10E-02	6.05E-02	Detected
4th week	8.84E-02	3.74E-02	1.78E-02	Detected
May 2017				
1st week	7.97E-02	4.92E-02	6.08E-02	Detected
2nd week	1.66E-01	9.91E-02	8.88E-02	Detected
3rd week	6.38E-02	4.06E-02	4.14E-02	Detected
4th week	7.15E-02	3.01E-02	2.15E-02	Detected
June 2017				
1st week	1.06E-01	4.77E-02	3.86E-02	Detected
2nd week	2.53E-01	6.11E-02	1.97E-02	Detected
3rd week	1.98E-01	4.66E-02	1.58E-02	Detected
4th week	2.48E-02	2.08E-02	3.26E-02	Detected

Table 2-6: Weekly Specific Activity of ^{238}Pu (Bq/g) in Station A (Pre-HEPA) filters in 2017 (continued)

Sample Date	^{238}Pu Activity Bq/g	Unc. (2σ) Bq/g	MDC Bq/g	Status
July 2017				
1st week	5.74E-02	1.03E-01	2.25E-01	Detected
2nd week	5.70E-02	2.78E-02	2.81E-02	Detected
3rd week	7.11E-02	3.10E-02	2.32E-02	Detected
4th week	7.54E-02	2.31E-02	1.28E-02	Detected
August 2017				
1st week	9.09E-02	4.22E-02	3.37E-02	Detected
2nd week	5.41E-02	3.20E-02	3.83E-02	Detected
3rd week	2.82E-02	1.82E-02	2.00E-02	Detected
4th week	4.35E-02	2.27E-02	2.14E-02	Detected
September 2017				
1st week	2.14E-01	7.02E-02	4.81E-02	Detected
2nd week	3.33E-01	9.13E-02	4.79E-02	Detected
3rd week	1.99E-01	7.49E-02	5.03E-02	Detected
4th week	4.14E-02	2.63E-02	2.69E-02	Detected
October 2017				
1st week	2.02E-02	1.67E-02	2.25E-02	Detected
2nd week	3.43E-02	2.01E-02	2.20E-02	Detected
3rd week	1.25E-01	4.68E-02	3.84E-02	Detected
4th week	9.02E-02	2.65E-02	1.32E-02	Detected
November 2017				
1st week	4.96E-02	3.02E-02	3.86E-02	Detected
2nd week	1.45E-02	1.51E-02	2.73E-02	Detected
3rd week	2.32E-02	1.07E-02	7.95E-03	Detected
4th week	5.86E-02	2.86E-02	2.11E-02	Detected
December 2017				
1st week	5.17E-02	2.99E-02	3.59E-02	Detected
2nd week	5.92E-02	2.64E-02	2.45E-02	Detected
3rd week	3.53E-02	2.22E-02	2.48E-02	Detected
4th week	4.95E-02	2.49E-02	1.89E-02	Detected

Table 2-7: Monthly Activity concentrations of ^{241}Am (Bq/m^3) in Station B (Post-HEPA) filters in 2017

Radionuclides	Sample Date	^{241}Am Activity Bq/m^3	Unc.(2σ) Bq/m^3	MDC Bq/m^3	Status
^{241}Am	January	1.07E-05	1.97E-06	4.26E-07	Detected
	February	9.66E-06	1.87E-06	4.31E-07	Detected
	March	1.38E-05	3.26E-06	8.64E-07	Detected
	April	3.04E-06	9.56E-07	4.49E-07	Detected
	May	1.09E-05	1.94E-06	3.87E-07	Detected
	June	8.09E-06	1.67E-06	5.39E-07	Detected
	July	5.83E-06	1.34E-06	5.20E-07	Detected
	August	4.50E-06	1.20E-06	6.39E-07	Detected
	September	5.84E-06	1.27E-06	6.03E-07	Detected
	October	7.48E-06	1.50E-06	3.93E-07	Detected
	November	7.81E-06	1.50E-06	3.68E-07	Detected
	December	1.22E-05	2.09E-06	4.41E-07	Detected

Table 2-8: Monthly Activity concentrations of $^{239+240}Pu$ (Bq/m^3) in Station B (Post-HEPA) filters in 2017

Radionuclides	Sample Date	$^{239+240}Pu$ Activity Bq/m^3	Unc.(2σ) Bq/m^3	MDC Bq/m^3	Status
$^{239+240}Pu$	January	1.14E-06	4.89E-07	2.39E-07	Detected
	February	3.82E-07	3.07E-07	3.85E-07	Detected
	March	1.19E-06	5.29E-07	4.03E-07	Detected
	April	4.29E-07	3.09E-07	3.72E-07	Detected
	May	1.28E-06	5.56E-07	3.21E-07	Detected
	June	3.78E-07	2.99E-07	2.77E-07	Detected
	July	7.97E-07	4.76E-07	4.28E-07	Detected
	August	4.21E-07	3.07E-07	3.33E-07	Detected
	September	9.40E-07	4.49E-07	3.68E-07	Detected
	October	9.04E-07	4.28E-07	3.51E-07	Detected
	November	6.49E-07	3.60E-07	2.35E-07	Detected
	December	2.38E-06	7.47E-07	4.72E-07	Detected

Table 2-9: Monthly Activity concentrations of ^{238}Pu (Bq/m^3) in Station B (Post-HEPA) filters in 2017

Radionuclides	Sample Date	^{238}Pu Activity Bq/m^3	Unc.(2σ) Bq/m^3	MDC Bq/m^3	Status
^{238}Pu	January	-9.58E-09	1.49E-07	4.91E-07	Not detected
	February	-2.12E-08	1.20E-07	4.64E-07	Not detected
	March	8.24E-08	1.87E-07	4.51E-07	Not detected
	April	7.64E-08	1.73E-07	4.17E-07	Not detected
	May	-1.08E-08	1.70E-07	5.57E-07	Not detected
	June	4.45E-08	1.66E-07	4.61E-07	Not detected
	July	-9.01E-08	1.46E-07	5.62E-07	Detected
	August	-7.02E-08	1.14E-07	4.38E-07	Not detected
	September	3.77E-08	1.41E-07	3.91E-07	Not detected
	October	1.26E-07	1.86E-07	3.73E-07	Not detected
	November	3.76E-08	1.41E-07	3.90E-07	Not detected
	December	-1.24E-07	1.18E-07	5.20E-07	Not detected

Table 2-10: Monthly Specific Activity of ^{241}Am (Bq/g) in Station B (Post-HEPA) filters in 2017

Radionuclides	Sample Date	^{241}Am Activity Bq/g	Unc.(2σ) Bq/g	MDC Bq/g	Status
^{241}Am	January	3.12E+00	5.75E-01	1.24E-01	Detected
	February	1.99E+00	3.86E-01	8.88E-02	Detected
	March	2.93E+00	6.92E-01	1.84E-01	Detected
	April	4.70E-01	1.48E-01	6.94E-02	Detected
	May	1.21E+00	2.15E-01	4.28E-02	Detected
	June	9.47E-01	1.96E-01	6.31E-02	Detected
	July	6.78E-01	1.56E-01	6.04E-02	Detected
	August	6.71E-01	1.79E-01	9.54E-02	Detected
	September	1.07E+00	2.33E-01	1.10E-01	Detected
	October	1.63E+00	3.28E-01	8.58E-02	Detected
	November	2.19E+00	4.20E-01	1.03E-01	Detected
	December	6.21E+00	1.07E+00	2.25E-01	Detected

Table 2-11: Monthly Specific Activity of $^{239+240}$Pu (Bq/g) in Station B (Post-HEPA) filters in 2017

Radionuclides	Sample Date	$^{239+240}$Pu Activity Bq/g	Unc.(2σ) Bq/g	MDC Bq/g	Status
$^{239+240}$Pu	January	3.32E-01	1.43E-01	6.96E-02	Detected
	February	7.87E-02	6.33E-02	7.95E-02	Detected
	March	2.53E-01	1.12E-01	8.55E-02	Detected
	April	6.63E-02	4.77E-02	5.75E-02	Detected
	May	1.41E-01	6.15E-02	3.55E-02	Detected
	June	4.42E-02	3.50E-02	3.25E-02	Detected
	July	9.26E-02	5.53E-02	4.97E-02	Detected
	August	6.29E-02	4.59E-02	4.97E-02	Detected
	September	1.72E-01	8.22E-02	6.74E-02	Detected
	October	1.97E-01	9.36E-02	7.67E-02	Detected
	November	1.82E-01	1.01E-01	6.58E-02	Detected
	December	1.21E+00	3.82E-01	2.41E-01	Detected

Table 2-12: Monthly Specific Activity of ^{238}Pu (Bq/g) in Station B (Post-HEPA) filters in 2017

Radionuclides	Sample Date	^{238}Pu Activity Bq/g	Unc.(2σ) Bq/g	MDC Bq/g	Status
^{238}Pu	January	-2.79E-03	4.35E-02	1.43E-01	Not detected
	February	-4.38E-03	2.48E-02	9.56E-02	Not detected
	March	1.75E-02	3.97E-02	9.58E-02	Not detected
	April	1.18E-02	2.67E-02	6.44E-02	Not detected
	May	-1.20E-03	1.88E-02	6.16E-02	Not detected
	June	5.20E-03	1.95E-02	5.40E-02	Not detected
	July	-1.05E-02	1.70E-02	6.52E-02	Detected
	August	-1.05E-02	1.70E-02	6.53E-02	Not detected
	September	6.90E-03	2.58E-02	7.15E-02	Not detected
	October	2.75E-02	4.07E-02	8.15E-02	Not detected
	November	1.05E-02	3.95E-02	1.09E-01	Not detected
	December	-6.33E-02	6.05E-02	2.66E-01	Not detected

Table 2-13: Monthly Activity concentrations of Uranium Isotopes in Station A (Pre-HEPA) filters in 2017

Radionuclides	Sample Date	Activity Bq/m^3	Unc.(2σ) Bq/m^3	MDC Bq/m^3	Status
^{234}U	January	9.36E-07	5.05E-07	6.96E-07	Detected
	February	6.57E-07	3.45E-07	5.59E-07	Detected
	March	5.78E-07	3.28E-07	5.64E-07	Detected
	April	3.13E-07	3.19E-07	6.68E-07	Detected
	May	4.76E-07	2.50E-07	3.78E-07	Detected
	June	9.51E-07	4.30E-07	5.91E-07	Detected
	July	3.43E-07	3.62E-07	7.79E-07	Not detected
	August	2.20E-07	2.82E-07	6.18E-07	Not detected
	September	3.96E-07	3.78E-07	7.96E-07	Detected
	October	4.43E-07	2.97E-07	5.63E-07	Detected
	November	7.64E-07	3.27E-07	4.49E-07	Detected
	December	6.34E-07	3.01E-07	4.24E-07	Detected
^{235}U	January	6.09E-08	1.22E-07	2.83E-07	Not detected
	February	6.48E-08	1.30E-07	3.01E-07	Detected
	March	2.78E-07	2.57E-07	4.92E-07	Not detected
	April	1.05E-07	1.86E-07	4.20E-07	Not detected
	May	8.03E-08	1.77E-07	4.24E-07	Detected
	June	1.26E-07	3.01E-07	7.30E-07	Detected
	July	1.05E-07	2.55E-07	6.13E-07	Not detected
	August	1.69E-07	2.26E-07	4.78E-07	Not detected
	September	-1.39E-07	2.21E-07	7.01E-07	Not detected
	October	1.09E-07	2.19E-07	5.13E-07	Not detected
	November	2.06E-07	2.13E-07	4.16E-07	Not detected
	December	6.01E-08	1.47E-07	3.61E-07	Not detected
^{238}U	January	3.69E-07	2.77E-07	5.23E-07	Detected
	February	4.19E-07	2.71E-07	4.56E-07	Detected
	March	2.26E-07	2.70E-07	5.89E-07	Not detected
	April	1.13E-07	2.40E-07	5.68E-07	Not detected
	May	1.29E-07	2.30E-07	5.29E-07	Not detected
	June	1.35E-07	4.58E-07	1.11E-06	Detected
	July	1.70E-07	3.85E-07	9.11E-07	Detected
	August	1.37E-07	3.25E-07	7.71E-07	Not detected
	September	1.41E-07	3.51E-07	8.38E-07	Not detected
	October	3.31E-07	2.70E-07	5.40E-07	Not detected
	November	3.81E-07	3.10E-07	6.29E-07	Not detected
	December	3.15E-07	2.89E-07	5.95E-07	Not detected

Table 2-14: Monthly Specific Activity of Uranium Isotopes in Station A (Pre-HEPA) filters in 2017

Radionuclides	Sample Date	Activity Bq/g	Unc.(2σ) Bq/g	MDC Bq/g	Status
^{234}U	January	8.38E-03	4.52E-03	6.24E-03	Detected
	February	5.36E-03	2.81E-03	4.57E-03	Detected
	March	8.11E-03	4.60E-03	7.92E-03	Detected
	April	4.35E-03	4.43E-03	9.28E-03	Detected
	May	1.12E-02	5.88E-03	8.90E-03	Detected
	June	1.16E-02	5.27E-03	7.23E-03	Detected
	July	3.95E-03	4.18E-03	8.99E-03	Not detected
	August	3.07E-03	3.93E-03	8.61E-03	Not detected
	September	9.33E-03	8.90E-03	1.88E-02	Detected
	October	5.86E-03	3.93E-03	7.44E-03	Detected
	November	7.69E-03	3.29E-03	4.52E-03	Detected
	December	9.71E-03	4.60E-03	6.49E-03	Detected
^{235}U	January	5.45E-04	1.09E-03	2.54E-03	Not detected
	February	5.29E-04	1.06E-03	2.46E-03	Detected
	March	3.91E-03	3.61E-03	6.90E-03	Not detected
	April	1.46E-03	2.58E-03	5.84E-03	Not detected
	May	1.89E-03	4.17E-03	9.98E-03	Detected
	June	1.54E-03	3.69E-03	8.93E-03	Detected
	July	1.22E-03	2.94E-03	7.07E-03	Not detected
	August	2.36E-03	3.16E-03	6.67E-03	Not detected
	September	-3.29E-03	5.20E-03	1.65E-02	Not detected
	October	1.44E-03	2.90E-03	6.79E-03	Not detected
	November	2.08E-03	2.14E-03	4.19E-03	Not detected
	December	9.21E-04	2.26E-03	5.52E-03	Not detected
^{238}U	January	3.31E-03	2.48E-03	4.68E-03	Detected
	February	3.42E-03	2.21E-03	3.73E-03	Detected
	March	3.17E-03	3.78E-03	8.26E-03	Not detected
	April	1.57E-03	3.33E-03	7.89E-03	Not detected
	May	3.05E-03	5.40E-03	1.24E-02	Not detected
	June	1.65E-03	5.60E-03	1.36E-02	Detected
	July	1.96E-03	4.44E-03	1.05E-02	Detected
	August	1.91E-03	4.53E-03	1.08E-02	Not detected
	September	3.31E-03	8.29E-03	1.98E-02	Not detected
	October	4.38E-03	3.57E-03	7.15E-03	Not detected
	November	3.84E-03	3.12E-03	6.33E-03	Not detected
	December	4.82E-03	4.43E-03	9.11E-03	Not detected

Table 2-15: Monthly Activity concentrations of Uranium Isotopes in Station B (Post-HEPA) filters in 2017

Radionuclides	Sample Date	Activity Bq/m^3	Unc.(2σ) Bq/m^3	MDC Bq/m^3	Status
^{234}U	January	3.64E-07	3.13E-07	5.78E-07	Not detected
	February	6.45E-07	3.62E-07	4.00E-07	Detected
	March	1.22E-07	4.22E-07	1.04E-06	Detected
	April	3.11E-07	3.68E-07	7.84E-07	Not detected
	May	1.23E-07	4.28E-07	1.05E-06	Not detected
	June	7.67E-08	3.60E-07	9.01E-07	Not detected
	July	3.42E-07	3.25E-07	6.63E-07	Not detected
	August	2.72E-07	2.78E-07	5.69E-07	Detected
	September	2.80E-08	2.69E-07	6.89E-07	Not detected
	October	2.04E-08	2.48E-07	6.24E-07	Detected
	November	7.63E-08	1.97E-07	4.79E-07	Detected
	December	5.80E-08	2.18E-07	5.47E-07	Not detected
^{235}U	January	5.83E-07	3.27E-07	3.61E-07	Detected
	February	5.31E-08	2.80E-07	7.48E-07	Not detected
	March	1.50E-07	2.66E-07	6.02E-07	Not detected
	April	1.44E-07	2.90E-07	6.79E-07	Not detected
	May	-1.52E-07	3.05E-07	9.55E-07	Not detected
	June	1.42E-07	1.90E-07	3.48E-07	Not detected
	July	3.84E-08	2.30E-07	6.08E-07	Not detected
	August	-1.49E-07	2.12E-07	7.03E-07	Detected
	September	1.04E-07	2.09E-07	4.90E-07	Not detected
	October	-5.03E-08	1.42E-07	4.39E-07	Not detected
	November	-6.28E-08	1.26E-07	4.42E-07	Not detected
	December	3.59E-08	1.90E-07	5.05E-07	Not detected
^{238}U	January	-3.63E-08	2.98E-07	8.14E-07	Not detected
	February	8.58E-08	3.83E-07	9.62E-07	Not detected
	March	2.43E-07	4.58E-07	1.07E-06	Not detected
	April	3.11E-07	3.97E-07	8.72E-07	Not detected
	May	-5.32E-07	6.63E-07	1.80E-06	Not detected
	June	4.19E-07	3.85E-07	7.67E-07	Not detected
	July	-3.10E-08	2.83E-07	7.60E-07	Not detected
	August	2.41E-07	2.83E-07	6.05E-07	Not detected
	September	1.12E-07	2.97E-07	7.13E-07	Not detected
	October	-1.22E-07	2.37E-07	6.53E-07	Not detected
	November	1.27E-07	1.83E-07	4.01E-07	Not detected
	December	-2.02E-07	2.52E-07	7.64E-07	Not detected

Table 2-16: Monthly Specific Activity of Uranium Isotopes in Station B (Post-HEPA) filters in 2017

Radionuclides	Sample Date	Activity Bq/g	Unc.(2σ) Bq/g	MDC Bq/g	Status
^{234}U	January	1.06E-01	9.12E-02	1.69E-01	Not detected
	February	1.33E-01	7.46E-02	8.25E-02	Detected
	March	2.59E-02	8.96E-02	2.20E-01	Detected
	April	4.81E-02	5.68E-02	1.21E-01	Not detected
	May	1.36E-02	4.73E-02	1.16E-01	Not detected
	June	8.98E-03	4.21E-02	1.05E-01	Not detected
	July	3.97E-02	3.77E-02	7.70E-02	Not detected
	August	4.06E-02	4.15E-02	8.49E-02	Detected
	September	5.13E-03	4.93E-02	1.26E-01	Not detected
	October	4.46E-03	5.42E-02	1.36E-01	Detected
	November	2.14E-02	5.53E-02	1.34E-01	Detected
	December	2.97E-02	1.11E-01	2.80E-01	Not detected
^{235}U	January	1.70E-01	9.53E-02	1.05E-01	Detected
	February	1.09E-02	5.78E-02	1.54E-01	Not detected
	March	3.19E-02	5.66E-02	1.28E-01	Not detected
	April	2.23E-02	4.48E-02	1.05E-01	Not detected
	May	-1.68E-02	3.37E-02	1.06E-01	Not detected
	June	1.66E-02	2.22E-02	4.07E-02	Not detected
	July	4.46E-03	2.67E-02	7.06E-02	Not detected
	August	-2.23E-02	3.17E-02	1.05E-01	Detected
	September	1.91E-02	3.83E-02	8.96E-02	Not detected
	October	-1.10E-02	3.11E-02	9.58E-02	Not detected
	November	-1.76E-02	3.52E-02	1.24E-01	Not detected
	December	1.84E-02	9.70E-02	2.58E-01	Not detected
^{238}U	January	-1.06E-02	8.71E-02	2.37E-01	Not detected
	February	1.77E-02	7.89E-02	1.98E-01	Not detected
	March	5.15E-02	9.73E-02	2.27E-01	Not detected
	April	4.81E-02	6.14E-02	1.35E-01	Not detected
	May	-5.89E-02	7.34E-02	1.99E-01	Not detected
	June	4.91E-02	4.50E-02	8.98E-02	Not detected
	July	-3.60E-03	3.29E-02	8.83E-02	Not detected
	August	3.59E-02	4.22E-02	9.03E-02	Not detected
	September	2.05E-02	5.43E-02	1.31E-01	Not detected
	October	-2.66E-02	5.18E-02	1.42E-01	Not detected
	November	3.55E-02	5.11E-02	1.12E-01	Not detected
	December	-1.03E-01	1.29E-01	3.90E-01	Not detected

Table 2-17: Weekly Activity concentrations of ^{137}Cs (Bq/m^3) in Station A (Pre-HEPA) filters in 2017

Sample Date	^{137}Cs Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
January 2017				
1st week	4.49E-05	8.34E-05	2.80E-04	Not detected
2nd week	1.75E-05	1.08E-04	3.59E-04	Not detected
3rd week	2.05E-06	8.39E-05	2.80E-04	Not detected
4th week	1.48E-05	5.89E-05	1.97E-04	Not detected
February 2017				
1st week	1.95E-05	8.44E-05	2.81E-04	Not detected
2nd week	-1.80E-04	1.11E-04	3.72E-04	Not detected
3rd week	-1.41E-05	8.62E-05	2.88E-04	Not detected
4th week	0.00E+00	0.00E+00	0.00E+00	Not detected
March 2017				
1st week	6.74E-05	8.23E-05	2.73E-04	Not detected
2nd week	1.17E-04	8.54E-05	2.82E-04	Not detected
3rd week	4.08E-05	9.09E-05	3.02E-04	Not detected
4th week	2.99E-05	6.93E-05	2.30E-04	Not detected
April 2017				
1st week	1.46E-05	9.40E-05	3.13E-04	Not detected
2nd week	8.19E-05	1.26E-04	4.18E-04	Not detected
3rd week	1.01E-04	1.09E-04	3.59E-04	Not detected
4th week	8.05E-05	6.70E-05	2.21E-04	Not detected
May 2017				
1st week	7.27E-06	8.17E-05	2.72E-04	Not detected
2nd week	7.89E-05	1.03E-04	3.42E-04	Not detected
3rd week	-1.59E-04	1.07E-04	3.58E-04	Not detected
4th week	1.71E-04	7.08E-05	2.31E-04	Not detected
June 2017				
1st week	0.00E+00	0.00E+00	0.00E+00	Not detected
2nd week	9.88E-05	9.37E-05	3.10E-04	Not detected
3rd week	5.47E-05	9.11E-05	3.02E-04	Not detected
4th week	1.02E-04	1.19E-04	3.93E-04	Not detected

Table 2-17: Weekly Activity concentrations of ^{137}Cs (Bq/m^3) in Station A (Pre-HEPA) filters in 2017 (continued)

Sample Date	^{137}Cs Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
July 2017				
1st week	-6.35E-04	3.87E-04	1.31E-03	Not detected
2nd week	-1.18E-04	9.19E-05	3.10E-04	Not detected
3rd week	2.25E-05	8.84E-05	2.94E-04	Not detected
4th week	1.07E-04	6.01E-05	1.97E-04	Not detected
August 2017				
1st week	3.93E-05	9.02E-05	3.00E-04	Not detected
2nd week	-1.45E-03	1.13E-03	3.85E-03	Not detected
3rd week	-5.06E-04	1.12E-03	3.77E-03	Not detected
4th week	8.81E-04	7.58E-04	2.50E-03	Not detected
September 2017				
1st week	-1.47E-04	9.33E-05	3.15E-04	Not detected
2nd week	4.29E-05	1.12E-04	3.71E-04	Not detected
3rd week	2.60E-05	8.82E-05	2.94E-04	Not detected
4th week	9.71E-05	8.50E-05	2.81E-04	Not detected
October 2017				
1st week	1.64E-04	8.58E-05	2.81E-04	Not detected
2nd week	-1.74E-06	1.18E-04	3.94E-04	Not detected
3rd week	9.62E-05	8.77E-05	2.90E-04	Not detected
4th week	3.61E-05	7.76E-05	2.58E-04	Not detected
November 2017				
1st week	-2.66E-05	8.89E-05	2.97E-04	Not detected
2nd week	1.18E-04	1.10E-04	3.64E-04	Not detected
3rd week	9.25E-05	9.13E-05	3.02E-04	Not detected
4th week	8.00E-05	8.67E-05	2.87E-04	Not detected
December 2017				
1st week	-7.64E-05	9.28E-05	3.11E-04	Not detected
2nd week	8.68E-05	1.12E-04	3.70E-04	Not detected
3rd week	-4.65E-05	9.23E-05	3.09E-04	Not detected
4th week	3.71E-05	7.93E-05	2.63E-04	Not detected

Table 2-18: Weekly Activity concentrations of ^{40}K (Bq/m^3) in Station A (Pre-HEPA) filters in 2017

Sample Date	^{40}K Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
January 2017				
1st week	9.72E-05	9.95E-04	3.33E-03	Not detected
2nd week	1.61E-03	1.13E-03	3.84E-03	Not detected
3rd week	2.50E-05	1.04E-03	3.49E-03	Not detected
4th week	7.57E-04	6.90E-04	2.28E-03	Not detected
February 2017				
1st week	-1.31E-03	1.05E-03	3.58E-03	Not detected
2nd week	3.97E-04	1.06E-03	3.53E-03	Not detected
3rd week	-5.33E-04	1.04E-03	3.49E-03	Not detected
4th week	0.00E+00	0.00E+00	0.00E+00	Not detected
March 2017				
1st week	-4.32E-05	1.01E-03	3.39E-03	Not detected
2nd week	1.36E-03	1.03E-03	3.41E-03	Not detected
3rd week	-1.41E-03	1.17E-03	3.97E-03	Not detected
4th week	-6.14E-04	8.75E-04	2.95E-03	Not detected
April 2017				
1st week	-1.03E-03	1.18E-03	4.00E-03	Not detected
2nd week	1.19E-03	1.23E-03	4.07E-03	Not detected
3rd week	-1.56E-04	1.36E-03	4.58E-03	Not detected
4th week	3.05E-04	7.81E-04	2.61E-03	Not detected
May 2017				
1st week	-2.50E-04	1.04E-03	3.49E-03	Not detected
2nd week	4.89E-04	1.01E-03	3.36E-03	Not detected
3rd week	2.07E-05	1.04E-03	3.48E-03	Not detected
4th week	-4.75E-04	7.39E-04	2.49E-03	Not detected
June 2017				
1st week	0.00E+00	0.00E+00	0.00E+00	Not detected
2nd week	9.03E-04	1.16E-03	3.85E-03	Not detected
3rd week	-2.97E-04	1.14E-03	3.83E-03	Not detected
4th week	7.81E-04	1.41E-03	4.70E-03	Not detected

Table 2-18: Weekly Activity concentrations of ^{40}K (Bq/m^3) in Station A (Pre-HEPA) filters in 2017 (continued)

Sample Date	^{40}K Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
July 2017				
1st week	-5.04E-03	4.84E-03	1.64E-02	Not detected
2nd week	2.20E-04	1.08E-03	3.60E-03	Not detected
3rd week	2.06E-03	1.03E-03	3.34E-03	Not detected
4th week	-3.26E-04	7.61E-04	2.56E-03	Not detected
August 2017				
1st week	-4.77E-04	1.17E-03	3.92E-03	Not detected
2nd week	-1.45E-03	1.13E-03	3.85E-03	Not detected
3rd week	-5.06E-04	1.12E-03	3.77E-03	Not detected
4th week	8.81E-04	7.58E-04	2.50E-03	Not detected
September 2017				
1st week	-2.20E-03	1.17E-03	3.97E-03	Not detected
2nd week	-1.12E-04	1.08E-03	3.64E-03	Not detected
3rd week	6.11E-04	1.06E-03	3.53E-03	Not detected
4th week	-5.33E-04	8.78E-04	2.96E-03	Not detected
October 2017				
1st week	-2.10E-04	1.04E-03	3.49E-03	Not detected
2nd week	-1.66E-03	1.22E-03	4.13E-03	Not detected
3rd week	-2.01E-04	1.09E-03	3.67E-03	Not detected
4th week	1.10E-04	7.52E-04	2.52E-03	Not detected
November 2017				
1st week	-5.82E-04	1.11E-03	3.74E-03	Not detected
2nd week	6.19E-04	1.07E-03	3.57E-03	Not detected
3rd week	7.58E-04	1.13E-03	3.77E-03	Not detected
4th week	-1.57E-03	9.04E-04	3.06E-03	Not detected
December 2017				
1st week	5.56E-04	1.12E-03	3.72E-03	Not detected
2nd week	-9.75E-05	1.13E-03	3.78E-03	Not detected
3rd week	-1.02E-03	1.15E-03	3.87E-03	Not detected
4th week	-1.21E-03	8.17E-04	2.76E-03	Not detected

Table 2-19: Weekly Activity concentrations of ^{60}Co (Bq/m^3) in Station A (Pre-HEPA) filters in 2017

Sample Date	^{60}Co Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
January 2017				
1st week	3.94E-05	8.31E-05	2.80E-04	Not detected
2nd week	9.41E-05	8.95E-05	3.04E-04	Not detected
3rd week	3.38E-05	8.68E-05	2.93E-04	Not detected
4th week	3.45E-05	6.16E-05	2.08E-04	Not detected
February 2017				
1st week	-1.87E-04	9.19E-05	3.15E-04	Not detected
2nd week	-5.86E-05	9.06E-05	3.06E-04	Not detected
3rd week	3.73E-06	8.55E-05	2.87E-04	Not detected
4th week	0.00E+00	0.00E+00	0.00E+00	Not detected
March 2017				
1st week	-1.43E-04	8.81E-05	3.01E-04	Not detected
2nd week	-3.63E-05	8.49E-05	2.87E-04	Not detected
3rd week	-6.24E-05	9.79E-05	3.31E-04	Not detected
4th week	-3.61E-05	7.18E-05	2.42E-04	Not detected
April 2017				
1st week	1.22E-04	9.10E-05	3.00E-04	Not detected
2nd week	-9.33E-05	1.04E-04	3.52E-04	Not detected
3rd week	-6.50E-05	1.12E-04	3.80E-04	Not detected
4th week	-2.38E-05	6.76E-05	2.28E-04	Not detected
May 2017				
1st week	-1.06E-04	8.51E-05	2.89E-04	Not detected
2nd week	-1.23E-04	8.75E-05	2.98E-04	Not detected
3rd week	-2.43E-05	8.37E-05	2.82E-04	Not detected
4th week	-4.69E-05	5.99E-05	2.03E-04	Not detected
June 2017				
1st week	0.00E+00	0.00E+00	0.00E+00	Not detected
2nd week	-7.07E-05	1.05E-04	3.55E-04	Not detected
3rd week	-4.40E-05	9.68E-05	3.26E-04	Not detected
4th week	-1.46E-04	1.32E-04	4.47E-04	Not detected

Table 2-19: Weekly Activity concentrations of ^{60}Co (Bq/m^3) in Station A (Pre-HEPA) filters in 2017 (continued)

Sample Date	^{60}Co Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
July 2017				
1st week	-4.87E-04	4.06E-04	1.38E-03	Not detected
2nd week	8.86E-06	9.68E-05	3.24E-04	Not detected
3rd week	-9.44E-06	9.17E-05	3.08E-04	Not detected
4th week	1.92E-05	6.42E-05	2.15E-04	Not detected
August 2017				
1st week	-2.10E-04	9.89E-05	3.39E-04	Not detected
2nd week	9.17E-05	9.45E-05	3.13E-04	Not detected
3rd week	-4.59E-05	9.61E-05	3.24E-04	Not detected
4th week	1.37E-05	6.43E-05	2.15E-04	Not detected
September 2017				
1st week	3.53E-05	9.16E-05	3.06E-04	Not detected
2nd week	-1.88E-04	9.61E-05	3.29E-04	Not detected
3rd week	-6.81E-05	9.64E-05	3.26E-04	Not detected
4th week	1.11E-05	7.47E-05	2.50E-04	Not detected
October 2017				
1st week	-1.18E-04	9.52E-05	3.24E-04	Not detected
2nd week	-8.74E-05	1.02E-04	3.44E-04	Not detected
3rd week	-2.71E-04	1.00E-04	3.45E-04	Not detected
4th week	-6.79E-06	6.56E-05	2.21E-04	Not detected
November 2017				
1st week	-2.06E-04	9.33E-05	3.20E-04	Not detected
2nd week	-3.04E-05	9.29E-05	3.13E-04	Not detected
3rd week	-5.37E-07	9.20E-05	3.09E-04	Not detected
4th week	7.55E-06	7.49E-05	2.51E-04	Not detected
December 2017				
1st week	-1.52E-04	9.53E-05	3.25E-04	Not detected
2nd week	3.99E-05	9.29E-05	3.10E-04	Not detected
3rd week	-8.00E-05	9.68E-05	3.27E-04	Not detected
4th week	4.53E-05	6.49E-05	2.16E-04	Not detected

Table 2-20: Weekly Specific Activity of ^{137}Cs (Bq/g) in Station A (Pre-HEPA) filters in 2017

Sample Date	^{137}Cs Activity Bq/g	Unc. (2σ) Bq/g	MDC Bq/g	Status
January 2017				
1st week	3.56E-01	6.62E-01	2.22E+00	Not detected
2nd week	1.18E-01	7.27E-01	2.42E+00	Not detected
3rd week	2.75E-02	1.13E+00	3.76E+00	Not detected
4th week	1.45E-01	5.78E-01	1.93E+00	Not detected
February 2017				
1st week	1.50E-01	6.48E-01	2.16E+00	Not detected
2nd week	-1.65E+00	1.02E+00	3.42E+00	Not detected
3rd week	-1.22E-01	7.47E-01	2.49E+00	Not detected
4th week	0.00E+00	0.00E+00	0.00E+00	Not detected
March 2017				
1st week	1.03E+00	1.26E+00	4.18E+00	Not detected
2nd week	1.82E+00	1.33E+00	4.40E+00	Not detected
3rd week	6.84E-01	1.53E+00	5.07E+00	Not detected
4th week	3.30E-01	7.65E-01	2.54E+00	Not detected
April 2017				
1st week	1.09E-01	7.03E-01	2.34E+00	Not detected
2nd week	1.00E+00	1.54E+00	5.10E+00	Not detected
3rd week	2.93E+00	3.15E+00	1.04E+01	Not detected
4th week	1.72E+00	1.43E+00	4.73E+00	Not detected
May 2017				
1st week	1.95E-01	2.20E+00	7.32E+00	Not detected
2nd week	4.27E+00	5.58E+00	1.85E+01	Not detected
3rd week	-3.95E+00	2.64E+00	8.87E+00	Not detected
4th week	2.65E+00	1.10E+00	3.58E+00	Not detected
June 2017				
1st week	0.00E+00	0.00E+00	0.00E+00	Not detected
2nd week	1.13E+00	1.07E+00	3.54E+00	Not detected
3rd week	5.46E-01	9.09E-01	3.02E+00	Not detected
4th week	1.12E+00	1.30E+00	4.32E+00	Not detected

Table 2-20: Weekly Specific Activity of ^{137}Cs (Bq/g) in Station A (Pre-HEPA) filters in 2017 (continued)

Sample Date	^{137}Cs Activity Bq/g	Unc. (2σ) Bq/g	MDC Bq/g	Status
July 2017				
1st week	-2.01E+01	1.22E+01	4.13E+01	Not detected
2nd week	-1.43E+00	1.12E+00	3.76E+00	Not detected
3rd week	3.03E-01	1.19E+00	3.95E+00	Not detected
4th week	9.95E-01	5.59E-01	1.83E+00	Not detected
August 2017				
1st week	6.79E-01	1.56E+00	5.18E+00	Not detected
2nd week	-1.93E+01	1.51E+01	5.12E+01	Not detected
3rd week	-5.33E+00	1.18E+01	3.97E+01	Not detected
4th week	1.41E+01	1.21E+01	3.99E+01	Not detected
September 2017				
1st week	-3.36E+00	2.14E+00	7.22E+00	Not detected
2nd week	9.73E-01	2.53E+00	8.41E+00	Not detected
3rd week	7.47E-01	2.54E+00	8.44E+00	Not detected
4th week	2.11E+00	1.84E+00	6.09E+00	Not detected
October 2017				
1st week	2.29E+00	1.20E+00	3.94E+00	Not detected
2nd week	-2.15E-02	1.46E+00	4.86E+00	Not detected
3rd week	1.69E+00	1.54E+00	5.10E+00	Not detected
4th week	4.10E-01	8.81E-01	2.92E+00	Not detected
November 2017				
1st week	-4.40E-01	1.47E+00	4.91E+00	Not detected
2nd week	1.32E+00	1.24E+00	4.09E+00	Not detected
3rd week	4.39E-01	4.33E-01	1.43E+00	Not detected
4th week	1.51E+00	1.63E+00	5.40E+00	Not detected
December 2017				
1st week	-1.24E+00	1.51E+00	5.05E+00	Not detected
2nd week	9.88E-01	1.27E+00	4.21E+00	Not detected
3rd week	-6.91E-01	1.37E+00	4.60E+00	Not detected
4th week	7.31E-01	1.56E+00	5.18E+00	Not detected

Table 2-21: Weekly Specific Activity of ^{40}K (Bq/g) in Station A (Pre-HEPA) filters in 2017

Sample Date	^{40}K Activity Bq/g	Unc. (2σ) Bq/g	MDC Bq/g	Status
January 2017				
1st week	7.72E-01	7.91E+00	2.65E+01	Not detected
2nd week	1.08E+01	7.63E+00	2.58E+01	Not detected
3rd week	3.35E-01	1.40E+01	4.68E+01	Not detected
4th week	7.43E+00	6.77E+00	2.24E+01	Not detected
February 2017				
1st week	-1.01E+01	8.10E+00	2.75E+01	Not detected
2nd week	3.64E+00	9.72E+00	3.24E+01	Not detected
3rd week	-4.62E+00	8.97E+00	3.02E+01	Not detected
4th week	0.00E+00	0.00E+00	0.00E+00	Not detected
March 2017				
1st week	-6.62E-01	1.55E+01	5.20E+01	Not detected
2nd week	2.12E+01	1.61E+01	5.31E+01	Not detected
3rd week	-2.37E+01	1.96E+01	6.66E+01	Not detected
4th week	-6.78E+00	9.67E+00	3.26E+01	Not detected
April 2017				
1st week	-7.72E+00	8.85E+00	3.00E+01	Not detected
2nd week	1.45E+01	1.50E+01	4.96E+01	Not detected
3rd week	-4.54E+00	3.97E+01	1.33E+02	Not detected
4th week	6.53E+00	1.67E+01	5.58E+01	Not detected
May 2017				
1st week	-6.71E+00	2.79E+01	9.38E+01	Not detected
2nd week	2.64E+01	5.44E+01	1.81E+02	Not detected
3rd week	5.12E-01	2.58E+01	8.63E+01	Not detected
4th week	-7.36E+00	1.15E+01	3.86E+01	Not detected
June 2017				
1st week	0.00E+00	0.00E+00	0.00E+00	Not detected
2nd week	1.03E+01	1.32E+01	4.39E+01	Not detected
3rd week	-2.96E+00	1.14E+01	3.82E+01	Not detected
4th week	8.58E+00	1.55E+01	5.17E+01	Not detected

Table 2-21: Weekly Specific Activity of ^{40}K (Bq/g) in Station A (Pre-HEPA) filters in 2017 (continued)

Sample Date	^{40}K Activity Bq/g	Unc. (2σ) Bq/g	MDC Bq/g	Status
July 2017				
1st week	-1.59E+02	1.53E+02	5.18E+02	Not detected
2nd week	2.67E+00	1.31E+01	4.37E+01	Not detected
3rd week	2.77E+01	1.38E+01	4.49E+01	Not detected
4th week	-3.03E+00	7.07E+00	2.38E+01	Not detected
August 2017				
1st week	-8.24E+00	2.01E+01	6.76E+01	Not detected
2nd week	-1.93E+01	1.51E+01	5.12E+01	Not detected
3rd week	-5.33E+00	1.18E+01	3.97E+01	Not detected
4th week	1.41E+01	1.21E+01	3.99E+01	Not detected
September 2017				
1st week	-5.04E+01	2.67E+01	9.10E+01	Not detected
2nd week	-2.53E+00	2.46E+01	8.24E+01	Not detected
3rd week	1.75E+01	3.05E+01	1.02E+02	Not detected
4th week	-1.16E+01	1.91E+01	6.42E+01	Not detected
October 2017				
1st week	-2.94E+00	1.45E+01	4.89E+01	Not detected
2nd week	-2.05E+01	1.51E+01	5.10E+01	Not detected
3rd week	-3.53E+00	1.92E+01	6.46E+01	Not detected
4th week	1.25E+00	8.53E+00	2.86E+01	Not detected
November 2017				
1st week	-9.62E+00	1.84E+01	6.19E+01	Not detected
2nd week	6.96E+00	1.21E+01	4.02E+01	Not detected
3rd week	3.59E+00	5.38E+00	1.79E+01	Not detected
4th week	-2.95E+01	1.70E+01	5.76E+01	Not detected
December 2017				
1st week	9.02E+00	1.81E+01	6.03E+01	Not detected
2nd week	-1.11E+00	1.28E+01	4.30E+01	Not detected
3rd week	-1.51E+01	1.71E+01	5.76E+01	Not detected
4th week	-2.39E+01	1.61E+01	5.44E+01	Not detected

Table 2-22: Weekly Specific Activity of ^{60}Co (Bq/g) in Station A (Pre-HEPA) Filters in 2017

Sample Date	^{60}Co Activity Bq/g	Unc. (2σ) Bq/g	MDC Bq/g	Status
January 2017				
1st week	3.12E-01	6.60E-01	2.23E+00	Not detected
2nd week	6.33E-01	6.03E-01	2.04E+00	Not detected
3rd week	4.54E-01	1.16E+00	3.92E+00	Not detected
4th week	3.39E-01	6.04E-01	2.04E+00	Not detected
February 2017				
1st week	-1.44E+00	7.05E-01	2.42E+00	Not detected
2nd week	-5.39E-01	8.32E-01	2.81E+00	Not detected
3rd week	3.23E-02	7.41E-01	2.49E+00	Not detected
4th week	0.00E+00	0.00E+00	0.00E+00	Not detected
March 2017				
1st week	-2.20E+00	1.35E+00	4.61E+00	Not detected
2nd week	-5.67E-01	1.32E+00	4.47E+00	Not detected
3rd week	-1.05E+00	1.64E+00	5.55E+00	Not detected
4th week	-3.99E-01	7.93E-01	2.68E+00	Not detected
April 2017				
1st week	9.13E-01	6.81E-01	2.25E+00	Not detected
2nd week	-1.14E+00	1.27E+00	4.30E+00	Not detected
3rd week	-1.89E+00	3.27E+00	1.10E+01	Not detected
4th week	-5.10E-01	1.45E+00	4.88E+00	Not detected
May 2017				
1st week	-2.86E+00	2.28E+00	7.78E+00	Not detected
2nd week	-6.65E+00	4.73E+00	1.61E+01	Not detected
3rd week	-6.03E-01	2.07E+00	6.98E+00	Not detected
4th week	-7.26E-01	9.28E-01	3.14E+00	Not detected
June 2017				
1st week	0.00E+00	0.00E+00	0.00E+00	Not detected
2nd week	-8.07E-01	1.20E+00	4.05E+00	Not detected
3rd week	-4.39E-01	9.65E-01	3.26E+00	Not detected
4th week	-1.60E+00	1.45E+00	4.92E+00	Not detected

Table 2-22: Weekly Specific Activity of ^{60}Co (Bq/g) in Station A (Pre-HEPA) filters in 2017 (continued)

Sample Date	^{60}Co Activity Bq/g	Unc. (2σ) Bq/g	MDC Bq/g	Status
July 2017				
1st week	-1.54E+01	1.28E+01	4.36E+01	Not detected
2nd week	1.08E-01	1.17E+00	3.94E+00	Not detected
3rd week	-1.27E-01	1.23E+00	4.14E+00	Not detected
4th week	1.79E-01	5.97E-01	2.00E+00	Not detected
August 2017				
1st week	-3.63E+00	1.71E+00	5.85E+00	Not detected
2nd week	1.22E+00	1.26E+00	4.17E+00	Not detected
3rd week	-4.83E-01	1.01E+00	3.41E+00	Not detected
4th week	2.19E-01	1.03E+00	3.43E+00	Not detected
September 2017				
1st week	8.09E-01	2.10E+00	7.02E+00	Not detected
2nd week	-4.26E+00	2.18E+00	7.47E+00	Not detected
3rd week	-1.96E+00	2.77E+00	9.37E+00	Not detected
4th week	2.40E-01	1.62E+00	5.43E+00	Not detected
October 2017				
1st week	-1.66E+00	1.33E+00	4.54E+00	Not detected
2nd week	-1.08E+00	1.25E+00	4.25E+00	Not detected
3rd week	-4.76E+00	1.77E+00	6.07E+00	Not detected
4th week	-7.71E-02	7.45E-01	2.50E+00	Not detected
November 2017				
1st week	-3.41E+00	1.54E+00	5.29E+00	Not detected
2nd week	-3.42E-01	1.05E+00	3.52E+00	Not detected
3rd week	-2.55E-03	4.37E-01	1.47E+00	Not detected
4th week	1.42E-01	1.41E+00	4.73E+00	Not detected
December 2017				
1st week	-2.46E+00	1.55E+00	5.27E+00	Not detected
2nd week	4.54E-01	1.06E+00	3.53E+00	Not detected
3rd week	-1.19E+00	1.44E+00	4.87E+00	Not detected
4th week	8.92E-01	1.28E+00	4.25E+00	Not detected

Table 2-23: Monthly Activity concentrations of ^{137}Cs (Bq/m^3) in Station B (Post-HEPA) filters in 2017

Radionuclides	Sample Date	Activity Bq/m^3	Unc.(2σ) Bq/m^3	MDC Bq/m^3	Status
^{137}Cs	January	2.44E-05	1.77E-05	5.85E-05	Not detected
	February	-2.24E-05	2.65E-05	8.88E-05	Not detected
	March	1.55E-05	2.34E-05	7.75E-05	Not detected
	April	-1.72E-05	1.98E-05	6.64E-05	Not detected
	May	3.37E-06	2.35E-05	7.83E-05	Not detected
	June	5.56E-05	2.39E-05	7.79E-05	Not detected
	July	2.85E-05	2.33E-05	7.69E-05	Not detected
	August	2.86E-06	2.00E-05	6.65E-05	Not detected
	September	-3.40E-06	2.51E-05	8.39E-05	Not detected
	October	9.22E-06	2.03E-05	6.74E-05	Not detected
	November	2.61E-05	2.05E-05	6.75E-05	Not detected
	December	-3.46E-05	2.13E-05	7.17E-05	Not detected

Table 2-24: Monthly Activity concentrations of ^{40}K (Bq/m^3) in Station B (Post-HEPA) filters in 2017

Radionuclides	Sample Date	Activity Bq/m^3	Unc.(2σ) Bq/m^3	MDC Bq/m^3	Status
^{40}K	January	-1.58E-05	2.23E-04	7.48E-04	Not detected
	February	1.33E-04	2.41E-04	8.03E-04	Not detected
	March	1.75E-04	2.28E-04	7.57E-04	Not detected
	April	1.11E-06	2.35E-04	7.87E-04	Not detected
	May	1.41E-04	2.25E-04	7.48E-04	Not detected
	June	-3.58E-04	3.16E-04	1.07E-03	Not detected
	July	-2.60E-04	3.04E-04	1.03E-03	Not detected
	August	5.11E-05	2.40E-04	8.03E-04	Not detected
	September	-1.18E-04	2.59E-04	8.71E-04	Not detected
	October	-2.73E-04	2.51E-04	8.51E-04	Not detected
	November	-3.02E-04	2.68E-04	9.07E-04	Not detected
	December	7.37E-06	2.49E-04	8.34E-04	Not detected

Table 2-25: Monthly Activity concentrations of ^{60}Co (Bq/m^3) in Station B (Post-HEPA) filters in 2017

Radionuclides	Sample Date	Activity Bq/m^3	Unc.(2σ) Bq/m^3	MDC Bq/m^3	Status
^{60}Co	January	-3.43E-06	1.84E-05	6.20E-05	Not detected
	February	-7.85E-06	2.08E-05	7.00E-05	Not detected
	March	9.67E-06	1.92E-05	6.41E-05	Not detected
	April	-2.40E-05	2.02E-05	6.88E-05	Not detected
	May	-2.29E-05	1.98E-05	6.71E-05	Not detected
	June	1.64E-05	2.50E-05	8.33E-05	Not detected
	July	-1.81E-05	2.72E-05	9.19E-05	Not detected
	August	-3.74E-05	2.16E-05	7.39E-05	Not detected
	September	-3.10E-05	2.26E-05	7.71E-05	Not detected
	October	-2.08E-05	2.17E-05	7.34E-05	Not detected
	November	-1.86E-05	2.17E-05	7.34E-05	Not detected
	December	-1.71E-05	2.06E-05	6.99E-05	Not detected

Table 2-26: Monthly Specific Activity of ^{137}Cs (Bq/g) in Station B (Post-HEPA) filters in 2017

Radionuclides	Sample Date	Activity Bq/g	Unc.(2σ) Bq/g	MDC Bq/g	Status
^{137}Cs	January	7.10E+00	5.17E+00	1.70E+01	Not detected
	February	-4.61E+00	5.47E+00	1.83E+01	Not detected
	March	3.30E+00	4.97E+00	1.65E+01	Not detected
	April	-2.66E+00	3.05E+00	1.03E+01	Not detected
	May	3.72E-01	2.60E+00	8.66E+00	Not detected
	June	6.50E+00	2.80E+00	9.12E+00	Not detected
	July	3.31E+00	2.71E+00	8.94E+00	Not detected
	August	4.27E-01	2.98E+00	9.93E+00	Not detected
	September	-6.21E-01	4.60E+00	1.54E+01	Not detected
	October	2.01E+00	4.43E+00	1.47E+01	Not detected
	November	7.30E+00	5.73E+00	1.89E+01	Not detected
	December	-1.01E+01	6.19E+00	2.09E+01	Not detected

Table 2-27: Monthly Specific Activity of ^{40}K (Bq/g) in Station B (Post-HEPA) filters in 2017

Radionuclides	Sample Date	Activity Bq/g	Unc.(2σ) Bq/g	MDC Bq/g	Status
^{40}K	January	-4.62E+00	6.50E+01	2.18E+02	Not detected
	February	2.75E+01	4.97E+01	1.66E+02	Not detected
	March	3.71E+01	4.84E+01	1.61E+02	Not detected
	April	1.71E-01	3.63E+01	1.22E+02	Not detected
	May	1.56E+01	2.49E+01	8.28E+01	Not detected
	June	-4.19E+01	3.70E+01	1.25E+02	Not detected
	July	-3.03E+01	3.53E+01	1.19E+02	Not detected
	August	7.62E+00	3.58E+01	1.20E+02	Not detected
	September	-2.15E+01	4.74E+01	1.59E+02	Not detected
	October	-5.97E+01	5.49E+01	1.86E+02	Not detected
	November	-8.46E+01	7.50E+01	2.54E+02	Not detected
	December	2.15E+00	7.25E+01	2.43E+02	Not detected

Table 2-28: Monthly Specific Activity of ^{60}Co (Bq/g) in Station B (Post-HEPA) filters in 2017

Radionuclides	Sample Date	Activity Bq/g	Unc.(2σ) Bq/g	MDC Bq/g	Status
^{60}Co	January	-9.99E-01	5.37E+00	1.81E+01	Not detected
	February	-1.62E+00	4.28E+00	1.44E+01	Not detected
	March	2.05E+00	4.08E+00	1.36E+01	Not detected
	April	-3.71E+00	3.13E+00	1.06E+01	Not detected
	May	-2.54E+00	2.19E+00	7.43E+00	Not detected
	June	1.92E+00	2.93E+00	9.75E+00	Not detected
	July	-2.10E+00	3.16E+00	1.07E+01	Not detected
	August	-5.58E+00	3.23E+00	1.10E+01	Not detected
	September	-5.68E+00	4.14E+00	1.41E+01	Not detected
	October	-4.53E+00	4.73E+00	1.60E+01	Not detected
	November	-5.21E+00	6.07E+00	2.06E+01	Not detected
	December	-4.97E+00	6.01E+00	2.04E+01	Not detected

CHAPTER 3

Ambient Air Monitoring

Ambient air monitoring essentially means the monitoring of "the air around us". Ambient air monitoring networks are an important part of a facility's environmental monitoring program. They monitor for both routine and unforeseen releases, verify that the facility is in compliance with the public radiological dose limits and are used to assess impacts to the environment over time. Additionally, they can also provide a precautionary measure in the event of accidental releases of radioactivity. The overall effectiveness of an air-monitoring network is dependent on the number and placement of samplers, flow rates and sampling times of the samplers, and analytical methods used to measure radionuclides in the air. 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. These monitoring stations are located at: (1) Onsite, which is 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. Additionally, three new sets of high-volume air samplers were installed following the 2014 underground radiation release event and are located at: (1) Carlsbad (behind the CEMRC facility), (2) south side of Loving, and (3) east side of the WIPP facility near the WIPP. The ambient air monitoring sites nearest the WIPP facility are located in the most prevalent wind directions from the facility, whereas the ambient air monitoring sites in Loving and Carlsbad are to provide additional information to area residents in the event of a future radiation release event and to maintain public assurance since Loving and Carlsbad are the two nearest communities surrounding the WIPP.

The program is designed to detect radioactive materials in the air in case of an emergency response situation. 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.

The radionuclides of greatest concern in the WIPP are $^{239+240}$Pu and ^{241}Am, which account for more than 99% of the total radioactivity slated for disposal within the repository. According to current estimates, the WIPP repository will contain approximately 1.56×104 kg of Pu isotopes and 336 kg of ^{241}Am (DOE, 2018). In this context, the variation in concentrations of these radionuclides in the WIPP environment is important not only because they are the main components of the WIPP wastes, but also because of their global background activity. Since the first nuclear test in New Mexico in 1945, approximately 11 PBq of $^{239+240}$Pu has been injected into the atmosphere (Perkins and Thomas 1980; UNSCEAR, 2000). In addition, 0.6 PBq of ^{238}Pu were released over the south Pacific in the high-altitude destruction of the SNAP-9A satellite

power source in 1964 (Hardy et al., 1973; Krey, 1968). Most of the global fallout was deposited in the northern hemisphere, the majority of which was deposited in the middle latitudes.

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 indicating their global origin (UNSCEAR, 2000). At present, almost all plutonium being introduced into the atmosphere can be found in the surface soils or oceans. Depending on meteorological conditions, physiochemical properties of soil, and human activity, plutonium can migrate vertically with various rates, can be transported into plants, or can become re-suspended into the air with eroded soil particles. These aerosols 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.

Atmospheric concentration of Plutonium in the Northern Hemisphere

Plutonium is not naturally present in measurable quantities in the ambient air. With few exceptions, nuclear weapon testing was by far the main source of plutonium in ambient air, but the amount of plutonium remaining in the atmosphere today from these tests is small because most of the radioactivity has been deposited on the ground as fallout (Lee et al., 1998; Harley, 1980, Perkins and Thomas, 1980). Concentrations of plutonium in surface air were not systematically monitored from 1959 to 1964 during the period of the heaviest contributions from global fallout. The ^{90}Sr global fallout pattern is similar to that of plutonium isotopes, with an average $^{239+240}$Pu to ^{90}Sr global activity ratio of about 0.025 (decay corrected to 2000) based on the normalized production rate for ^{90}Sr and plutonium isotopes in nuclear explosions (UNSCEAR, 2000). The $^{239+240}$Pu to ^{90}Sr ratio method (Bennett 1978) is generally utilized to make good estimates of the plutonium concentrations in air.

The current concentration of $^{239+240}$Pu in ambient air is about ~1000 times lower than levels measured during the early 1960s and 1970s. During these decades, plutonium concentrations in surface air were highly variable for several reasons, including continued contributions from weapons testing and the recycling of deposited plutonium back into the atmosphere via re-suspension of contaminant soil. Furthermore, the fallout radionuclides were not deposited evenly over the earth and are known to vary with latitude, being highest in the middle latitudes of the northern hemisphere. The measurement of soil inventories has shown that the weapons fallout tended to deposit in areas with abundant rainfall. This heterogeneity is due to the fact that wet deposition more effectively removed the radioactive particles from the atmosphere than dry deposition (Hardy et al., 1973). The Chernobyl accident in April 1986 released about 70 TBq of the plutonium isotopes which increased the concentration of $^{239+240}$Pu in surface air during 1986-1987, especially in Europe, and contributed slightly to the plutonium

global inventory (UNSCEAR 2000). However, following a peak in 1986, the concentrations of $^{239+240}$Pu are shown to have continuously decreased. In order to establish an environmental baseline of $^{239+240}$Pu deposition, time-series data of plutonium are important as they provide information about the factors that control the past and present concentrations of plutonium in the atmosphere. Such data are also important in understanding the long-term history of plutonium in the environment.

While the current atmospheric plutonium data and those collected during the era of above-ground nuclear weapons testing both show springtime peaks, the causes for the cycles are likely quite different. Studies conducted prior to the end of the atmospheric weapons testing showed that the seasonal cycle of plutonium concentrations (highest in spring and lowest in summer) is associated with enhanced transport of radioactive aerosols from the stratosphere to the troposphere. However, after the cessation of nuclear weapons testing in 1980 and with a comparatively small additional input from the Chernobyl, most of the plutonium in the air today is associated with re-suspension soil, which is contaminated from weapons fallout. As mentioned earlier, re-suspension is considered to be the predominant mechanism for maintaining the small residual plutonium in the surface air samples. The importance of re-suspension as a mechanism for recycling plutonium back into the atmosphere has been discussed in many publications (Rosner et al., 1997; Arimoto et al., 2005). The general discussion on transuranic re-suspension has been thoroughly reviewed by Sehmel (1987). On the other hand, Nicholson (1988) has reviewed re-suspension of radionuclides, including plutonium in contaminated areas, which are usually arid or semiarid regions. The re-suspension is dependent on current meteorological conditions. Windy, dry days can increase the soil re-suspension, whereas precipitation (rain or snow) can wash particulate matter out of the air and decreases the rate of re-suspension.

An important finding of these earlier studies was that the activity of Pu and the concentration of Al in aerosols were correlated and this was driven by the re-suspension of dust particles contaminated with radioactive fallout from past nuclear weapons tests. Similar results were found for Am and Al. Related studies of soils collected on and near the WIPP site have shown that correlations exist among Al and both naturally-occurring and bomb-derived radionuclides including $^{239+240}$Pu (Kirchner et al., 2002). Here we briefly review the methods used for the ambient aerosol studies and then summarize some recent results, highlighting the continuing efforts to evaluate potential releases from the WIPP.

Sampling Locations

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/ETM glass fiber filters (Pall German Laboratory, Ann Arbor, MI, pore size 1µm). A typical sampling period lasts for about three to four weeks depending on the levels of particulate matter that accumulates on the filters. These samplers are operated to maximize particulate loading without impacting airflow, if flow volume drops down to 0.99 m^3/min filters are changed. Filter change outs also occur in the event of a power outage or if a sampler stops due to some mechanical issue. Each filter is weighed before and after sampling to determine the weight of aerosol material collected on the filters. Actinide analyses were performed on each individual filter by the CEMRC. As shown in Figure 3-2, the sampling height of each aerosol station is ~5 m from the ground.

Following the underground radiation release event of 2014, the CEMRC added three additional high-volume sampling stations to provide additional information to area residents in the event of a future radiation release. The new sampling stations are located in : (1) Carlsbad, behind the CEMRC facility, about 56 km northwest of the WIPP site; (2) on the south side of Loving, about 47 km southwest of the WIPP facility, and (3) on the east side of the WIPP facility near the WIPP meteorological station, about 0.3 km east of the WIPP facility. These sampling locations are shown in Figure 3-3. Aerosol samples are currently only collected from two sites (Loving and Carlsbad). The third high-volume sampling station located on the east side of the WIPP was not fully deployed until the summer of 2017.

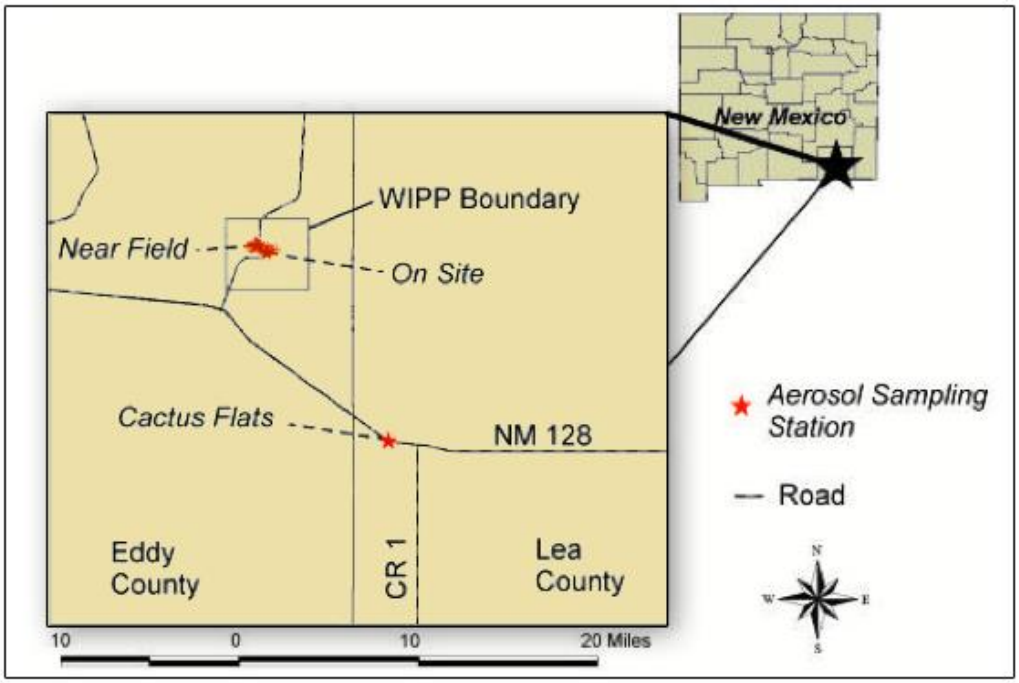


Figure 3-1: Ambient Aerosol Sampling Locations (Prior to Radiation Release 2014)

Figure 3-2: Typical WIPP Site High Volume Air Sampling Station

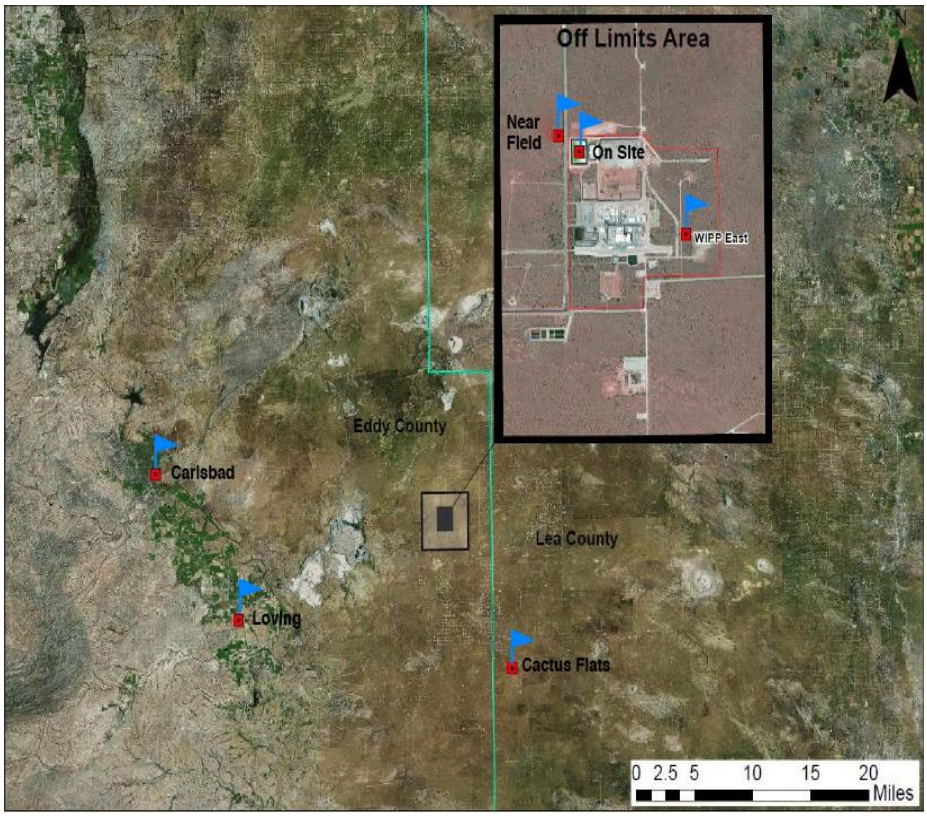


Figure 3-3: Ambient Aerosol Sampling Locations (Post Radiation Release)

Sample Preparation

The high-volume samples are analyzed for selected radionuclides, including ^{238}Pu, $^{239+240}Pu$, ^{241}Am, and recently ^{235}U, ^{234}U, and ^{238}U following six hours of heating in a muffle furnace at 500° C to drive off organics. Once heated in the muffle furnace, each filter is then digested with a strong acid mixture of HCl+HF+$HClO_4$ to aid in the complete decomposition of silica. Samples are then treated with conc. $HClO_4$ and HNO_3 for the removal of fluoride ions. The inside walls of the beaker are rinsed carefully with HNO_3 to gather residual HF and evaporation is repeated to ensure that all residual HF is removed from the matrix. The residues are then dissolved in 1.0 M HCl for subsequent radionuclide separation and analysis. The acid digestates of the filter composite samples are then split into two fractions. One fraction is analyzed by gamma spectroscopy for ^{40}K, ^{60}Co, and ^{137}Cs. The other fraction is 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, Eichrom, 100-200 mesh), while TRU chromatography columns are used 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 five days. Gamma-emitting nuclides in the air filters are measured using a high purity germanium detector, HpGe (Canberra) for 48 hours.

Data Reporting

The activities of the actinides and gamma radionuclides in the aerosol samples are reported as activity concentration (Bq/m^3) and specific activity (Bq/g). Activity concentration is calculated as the activity of radionuclides detected in Becquerels (Bq) divided by the volume of air in cubic meters, while specific activity is calculated as the nuclides activity divided by the aerosol mass in grams collected on the filter.

Results and Discussion

The CEMRC detected trace levels of ^{241}Am and $^{239+240}Pu$ at two sampling locations (Onsite and Near Field) in February 2014 immediately following the February 14, 2014, underground radiation release event at the WIPP. No radioactivity was detected at the Cactus Flats Station located approximately 19 km southeast of the WIPP facility. 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 (shown in Figures 3-4 and 3-5). The levels detected were very low and localized; no radiation-related health effects among local workers or the public are expected. 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. A week after the event the airborne radioactive particulate levels at these stations had decreased by a factor of 100, and two weeks later the levels at these stations

were back to the pre-release levels and sometimes not even detectable, demonstrating no long-term environmental impacts remain from the 2014 underground radiation release event at the WIPP.

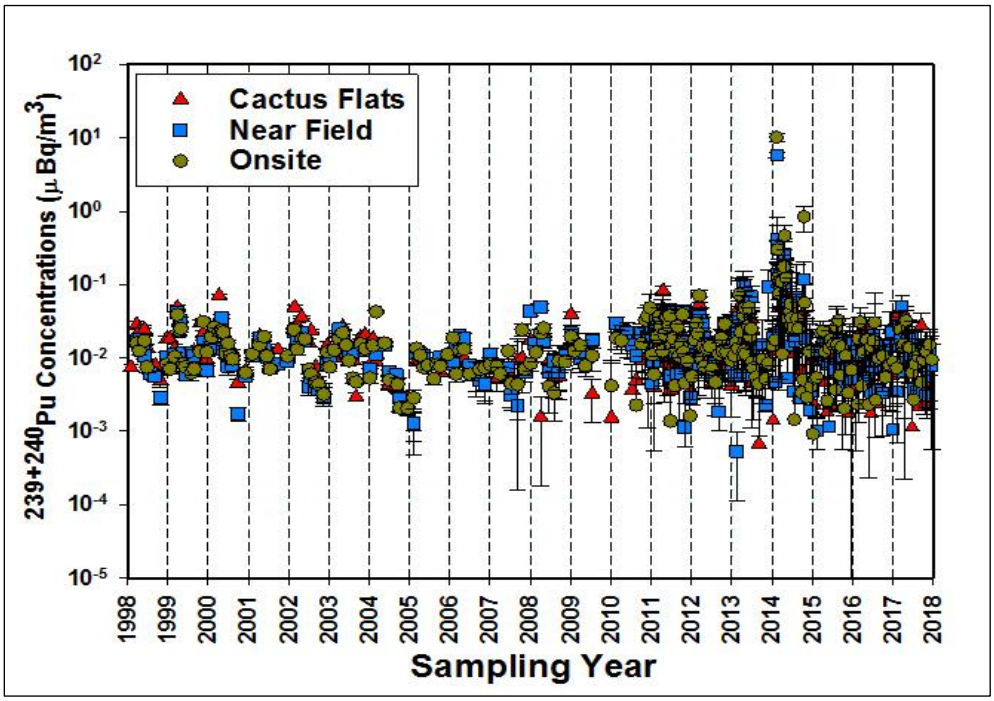


Figure 3-4: The Pre- and Post-radiological event $^{239+240}$Pu concentrations in ambient air at three stations in the vicinity of the WIPP site

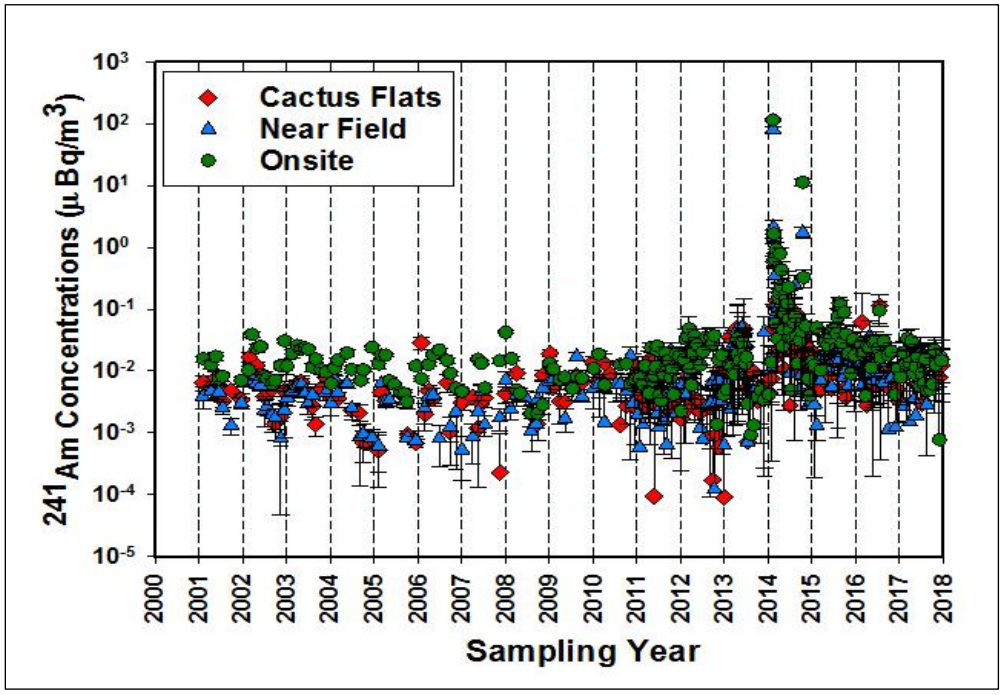


Figure 3-5: The Pre- and Post-radiological event ^{241}Am concentrations in ambient air at three stations in the vicinity of the WIPP site

The concentrations of $^{239+240}$Pu, ^{241}Am and ^{238}Pu measured in the ambient air filters during 2017 are listed in Tables 3-1 to 3-3 (Onsite Station), Tables 3-4 to 3-6 (Near Field Station) and Tables 3-7 to 3-9 (Cactus Flats Station). The ^{241}Am and $^{239+240}$Pu concentrations slightly above minimum detectable levels were detected in a few ambient air samples collected around WIPP in 2017 and are attributed to the re-suspension of contaminated soil dust plus the local precipitation to some extent. Studies conducted prior to the end of atmospheric weapons testing showed that Pu activities varied seasonally, being highest in spring and summer because of the enhanced springtime transportation of radioactive aerosols from the stratosphere to the troposphere. However, with the cessation of nuclear weapons tests and considering the residence time of Pu in the atmosphere is on the order of a year, the stratospheric deposition of radionuclides, including Pu, is no longer a dominant factor for the Pu concentration in air. Additionally, the Chernobyl nuclear power plant accident that occurred in April 1986 did not bring significant amounts of Pu to this area. Therefore, re-suspension is believed to be the main source of Pu in the aerosol samples around the WIPP.

The WIPP's historical ambient air monitoring data also indicate frequent detection of $^{239+240}$Pu and ^{241}Am in ambient aerosol samples collected on filters around the WIPP (Figures 3-4 and 3-5). 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 the WIPP, there is a potential local source of anthropogenic (human-caused) 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 collected from the Gnome site (CEMRC, 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 detected activity levels, 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 primarily represent redistributed global fallout.

The $^{239+240}$Pu specific activity (activity per unit mass aerosol collected) was in the range of 0.00-0.0.56 mBq/g at the Onsite station, 0.00-1.05 mBq/g at the Near Field station and 0.0-0.92 mBq/g at the Cactus Flats station, while that of ^{241}Am was in the range of 0.02-0.61 mBq/g at the Onsite station, 0.0-0.69 mBq/g at the Near Field station and 0.0-0.68 mBq/g at the Cactus Flats station. The aerosol mass loadings recorded in these sampling stations varied in the range from 0.52-2.17 g at Onsite, 0.49-1.61 g at Near Field, and 0.44-2.04 g at Cactus Flats. Furthermore, the mass loadings at all stations tend to track one another remarkably well as shown in Figures 3-6 and 3-7. The specific activity of $^{239+240}$Pu, ^{241}Am, and ^{238}Pu measured in the ambient air filters during 2017 are listed in Tables 3-10 to 3-12 (Onsite Station), Tables 3-13 to 3-15 (Near Field Station) and Tables 3-16 to 3-18 (Cactus Flats Station).

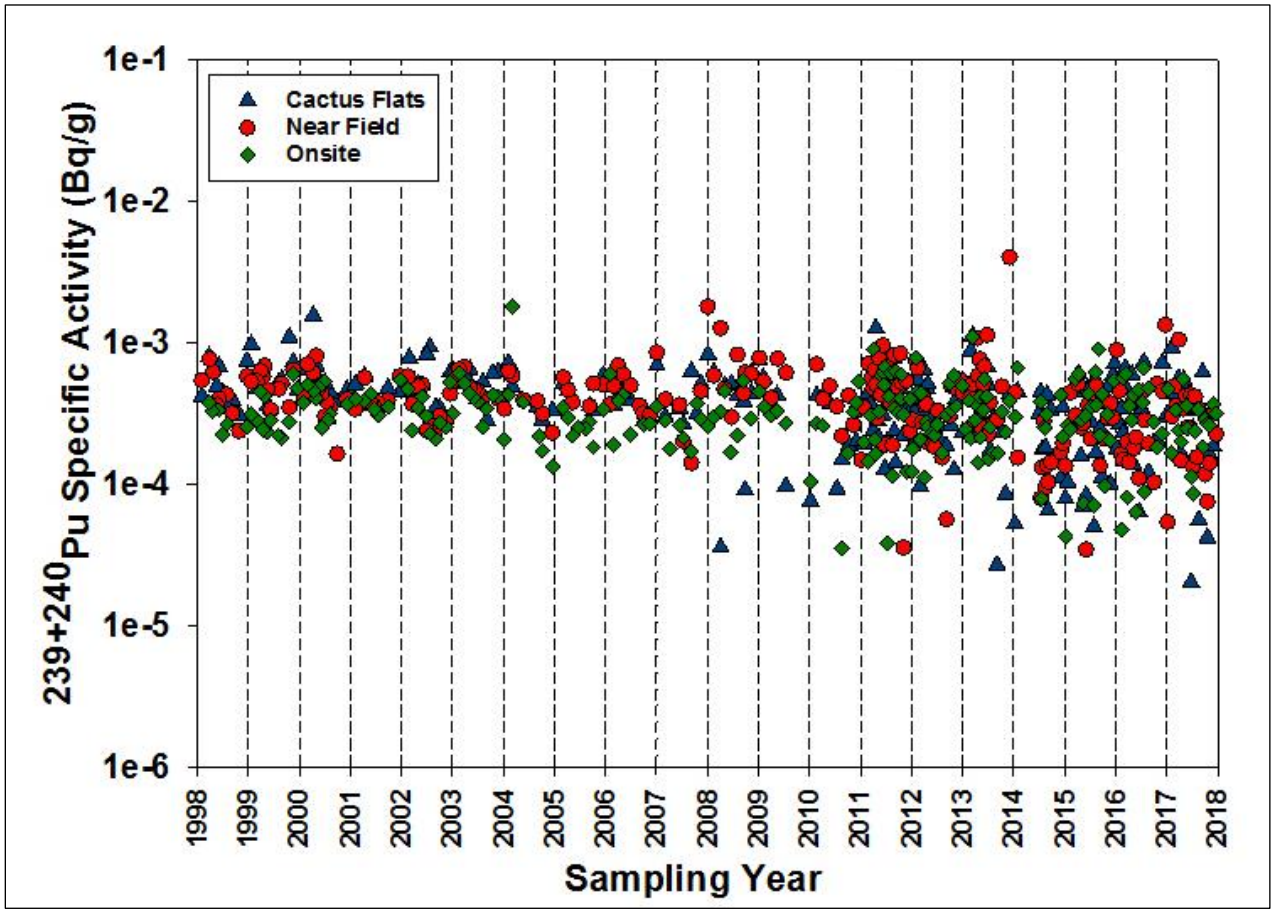


Figure 3-6: The Pre- and Post-radiological event $^{239+240}$Pu specific activity in ambient air at three stations in the vicinity of the WIPP site

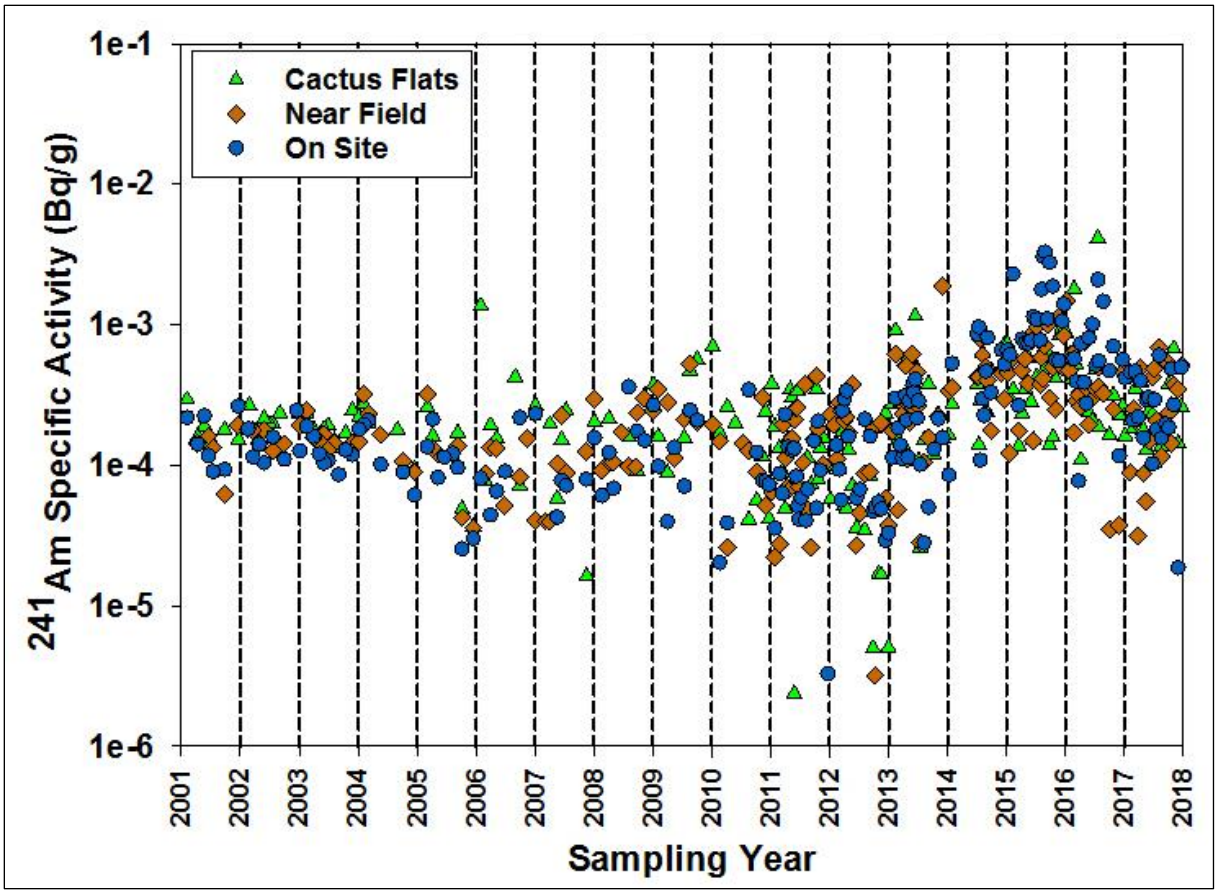


Figure 3-7: The Pre- and Post-radiological event ^{241}Am specific activity in ambient air at three stations in the vicinity of the WIPP site

Ambient Air Uranium Concentrations

Uranium is comprised of naturally occurring radionuclides found in the environment. Uranium occurs naturally in all rocks and soil with typical background levels ranging from approximately 2 to 4 mg/kg (Ahrens 1965, Wedepohl 1968). Thus, the detection of uranium in ambient air is normal. Natural sources of uranium in ambient air include re-suspended soil, volcanic eruptions (ATSDR 1999; Kuroda et al. 1984), and airborne particulates from coal and fuel combustion. The concentrations of uranium isotopes measured in the ambient air in the WIPP vicinity are listed in Table 3-19 (Onsite Station), Table 3-20 (Near Field Station) and Table 3-21 (Cactus Flats Station). The isotopes of uranium were detected at all sample locations. The highest concentrations detected were 4.40E-6 Bq/m^3 for ^{234}U and 4.30E-6 Bq/m^3 for ^{238}U measured at the Onsite sampling station. The concentrations detected between the Onsite location and distant locations were not statistically different. The specific activity of uranium isotopes measured in the ambient air filters during 2017 are listed in Table 3-22 (Onsite Station), Table 3-23 (Near Field Station) and Table 3-24 (Cactus Flats Station).

Uranium ratios are used to determine the type of uranium present in the environment. Natural uranium has a $^{235}U/^{238}U$ ratio of 0.00725, and $^{234}U/^{238}U$ ratio of 1.0. The average annual $^{234}U/^{238}U$ ratios of 1.03±0.05 at the Onsite Station, 1.05±0.04 at the Near Field station, and 1.04±0.02 at the Cactus Flats station are consistent with naturally occurring uranium. The uranium concentrations in the ambient air samples collected around the WIPP site since 2011 are shown in Figures 3-8 and 3-9.

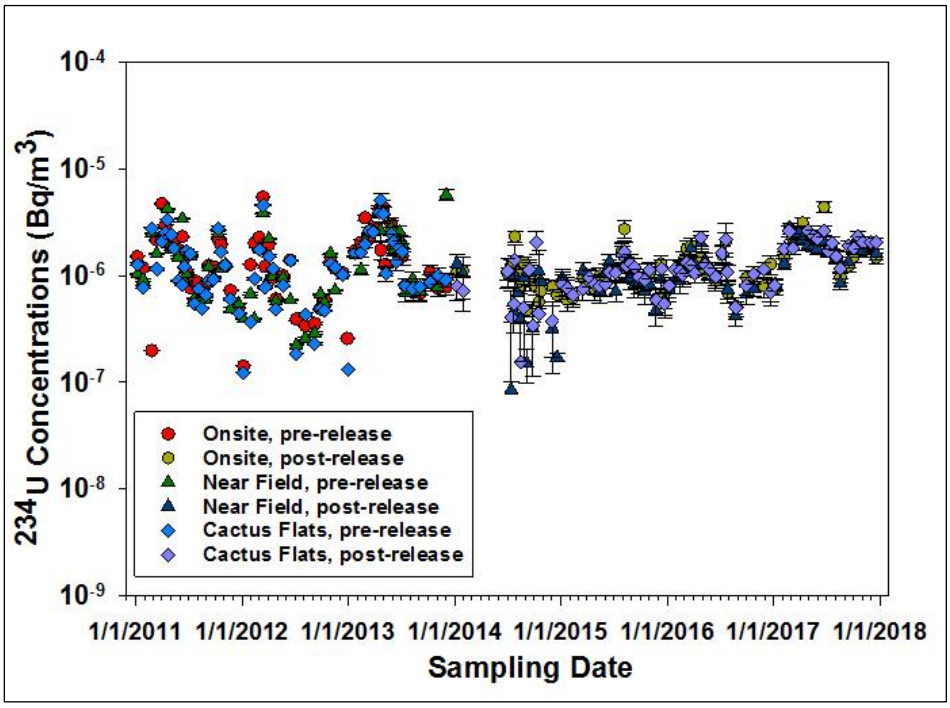


Figure 3-8: The Pre- and Post-radiological event ^{234}U concentrations in ambient air at three stations in the vicinity of the WIPP site

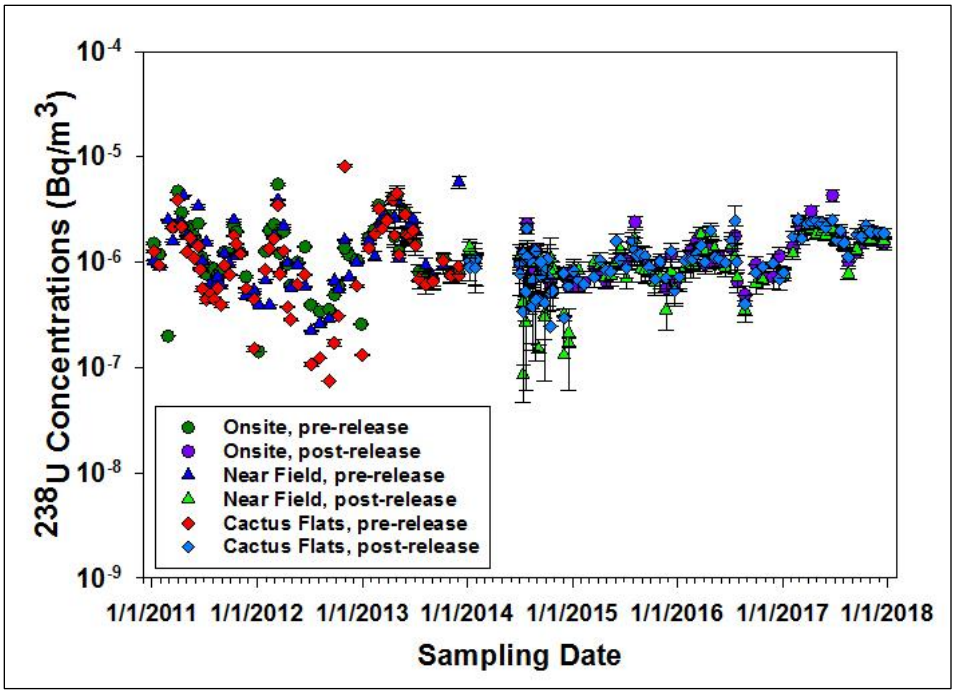


Figure 3-9: The Pre- and Post-radiological event ^{238}U concentrations in ambient air at three stations in the vicinity of the WIPP site

Ambient Air Gamma Radionuclide Concentrations

There were no measurable concentrations of ^{137}Cs or ^{60}Co in any of the ambient air filter samples collected following the radiation release event. However, ^{40}K was detected in a few ambient air 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 air samples before and after the radiological event at WIPP are shown in Figures 3-10 through 3-18.

Additionally, there was no increase in gamma radionuclide concentrations that can be attributed to the February 14, 2014, underground radiation recent release event. The individual concentrations of these radionuclides measured in three aerosol stations are listed in Table 3-25 (Onsite Station), Table 3-26 (Near Field Station) and Table 3-27 (Cactus Flats Station). The individual, specific activity of these radionuclides in these three monitoring stations are summarized in Table 3-28 (Onsite Station), Table 3-29 (Near Field Station) and Table 3-30 (Cactus Flats Station).

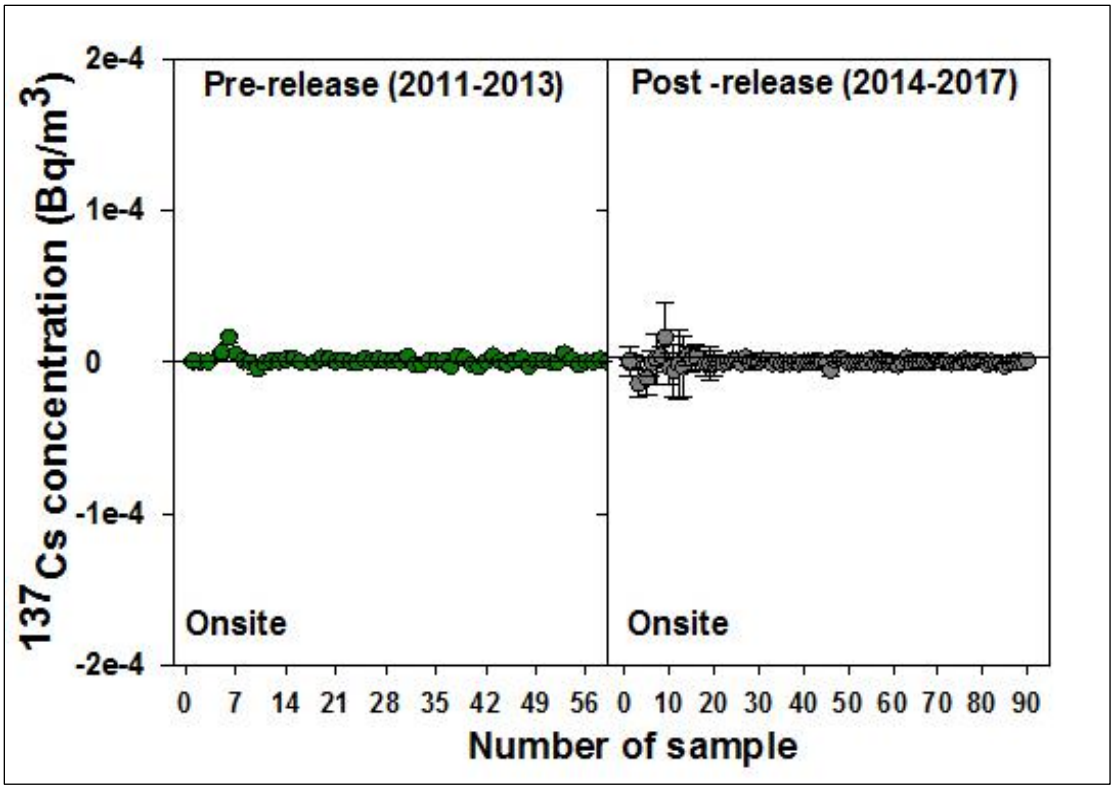


Figure 3-10: The Pre- and Post-release event ^{137}Cs concentrations in ambient air at Onsite station

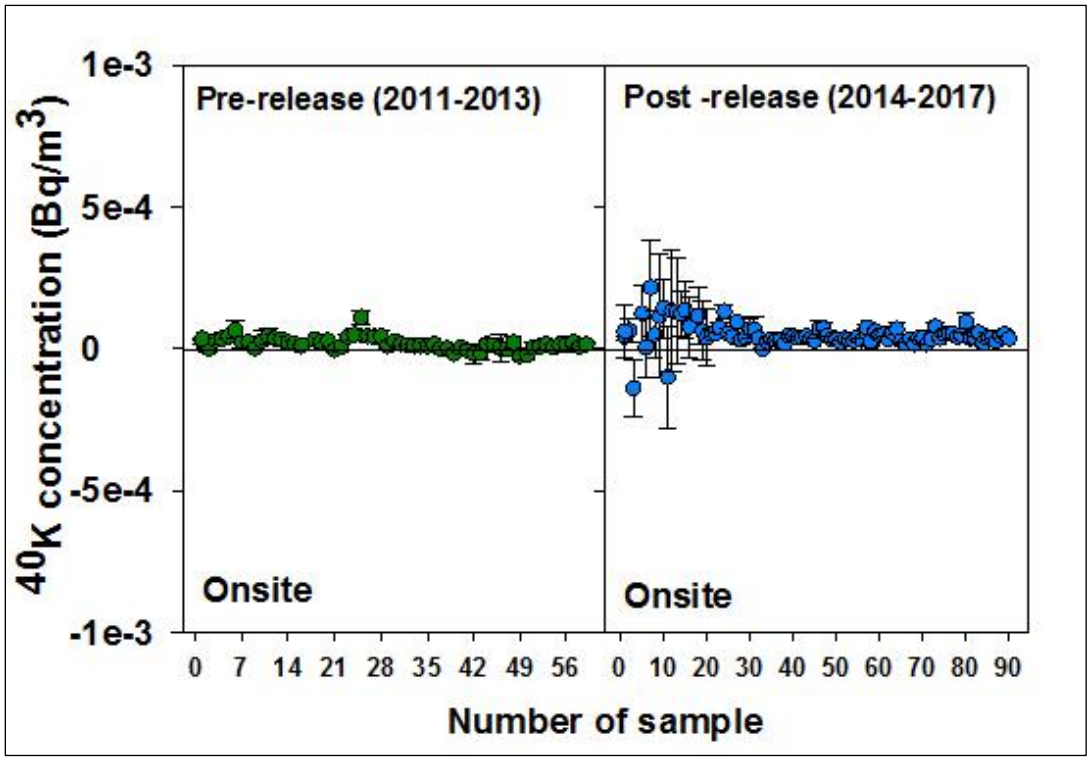


Figure 3-11: The Pre- and Post-radiological event ^{40}K concentrations in ambient air at Onsite station

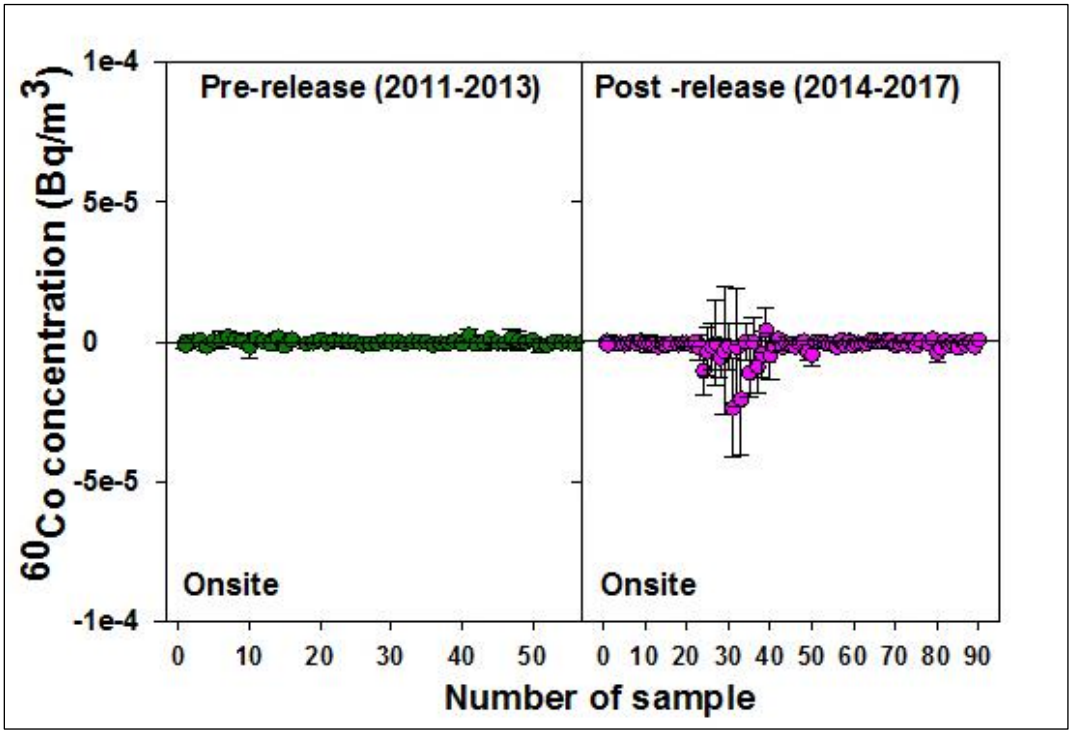


Figure 3-12: The Pre- and Post-radiological event ^{60}Co concentrations in ambient air at Onsite station

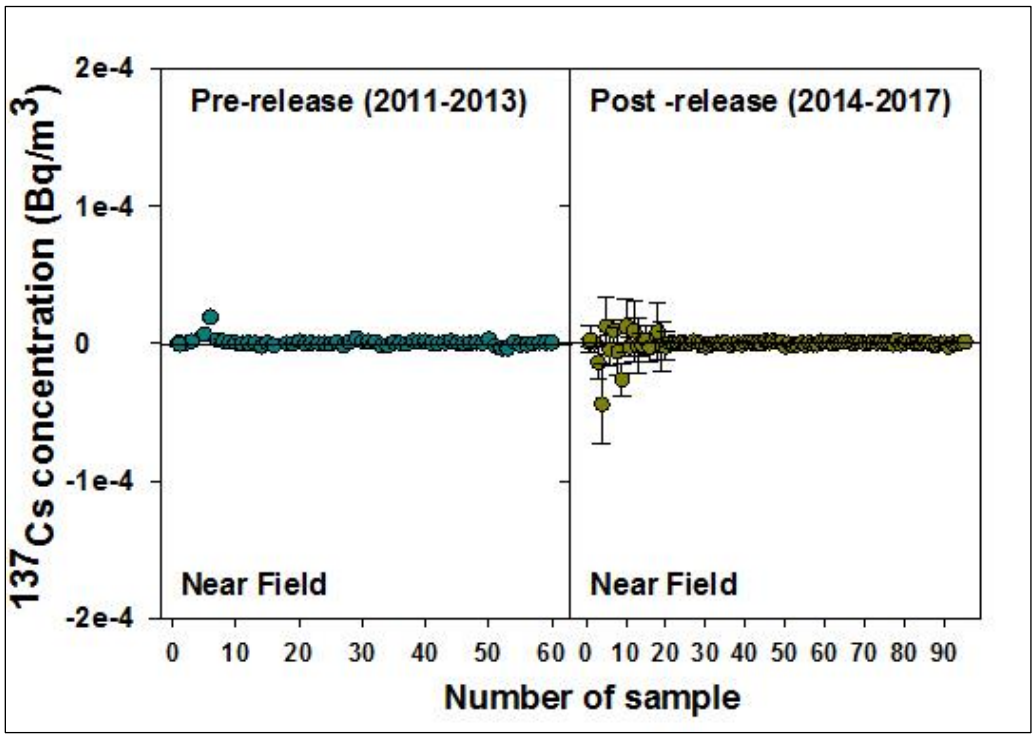


Figure 3-13: The Pre- and Post-radiological event ^{137}Cs concentrations in ambient air at Near Field station

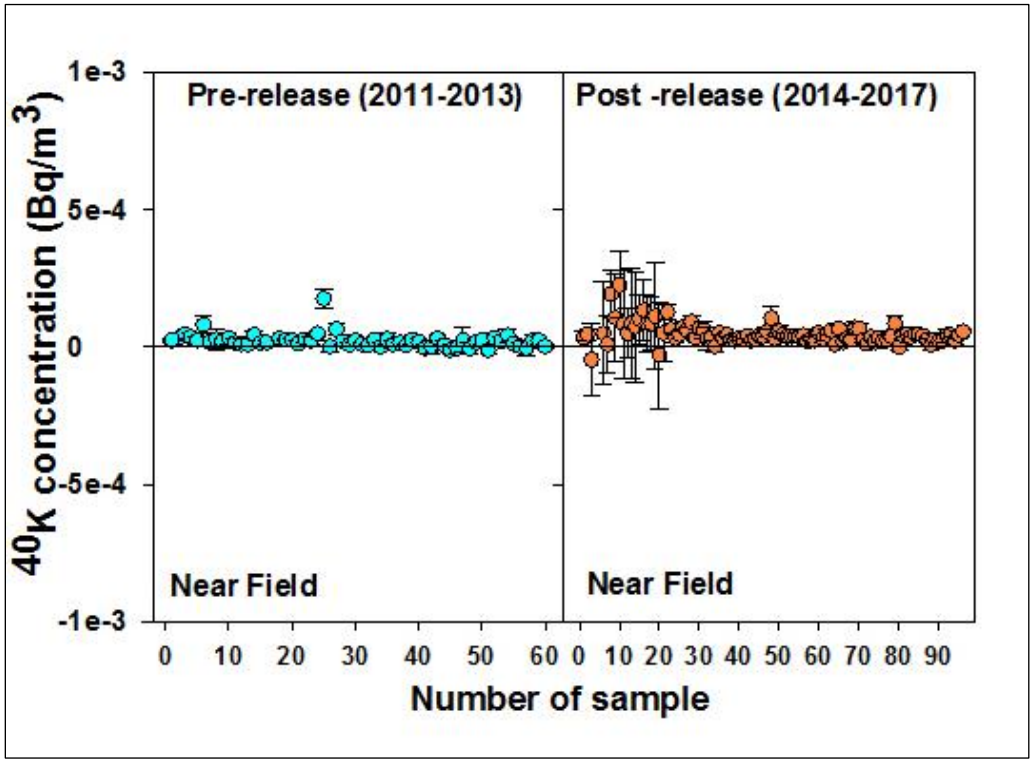


Figure 3-14: The Pre- and Post-radiological event ^{40}K concentrations in ambient air at Near Field station

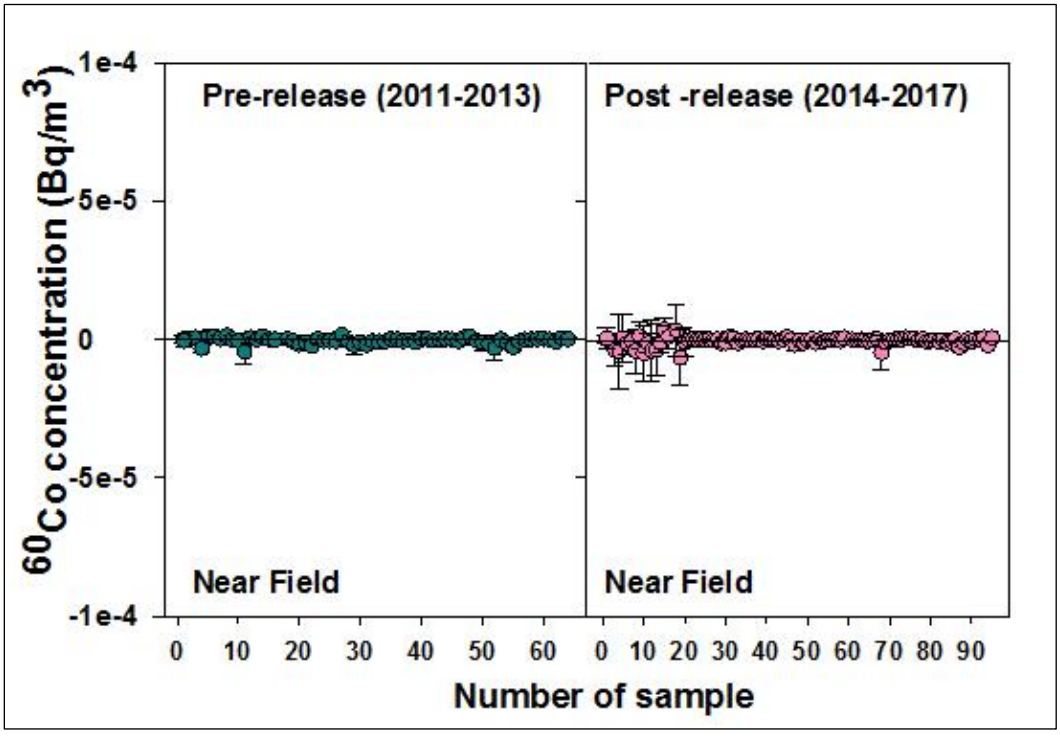


Figure 3-15: The Pre- and Post-radiological event ^{60}Co concentrations in ambient air at Near Field station

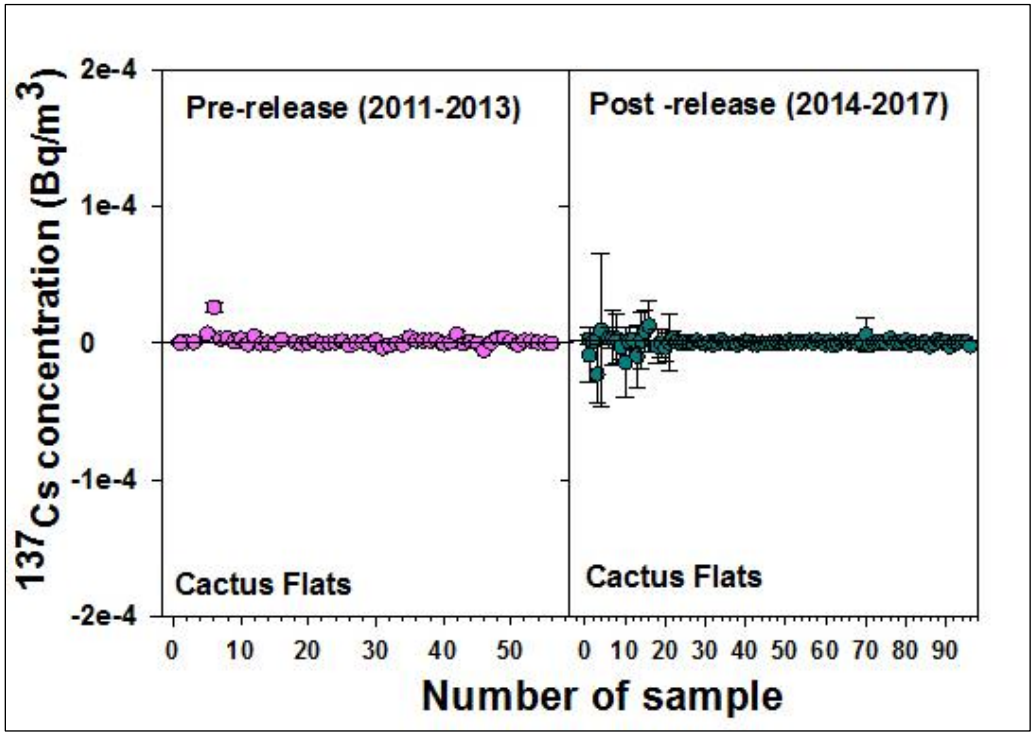


Figure 3-16: The Pre- and Post-radiological event ^{137}Cs concentrations in ambient air at Cactus Flats station

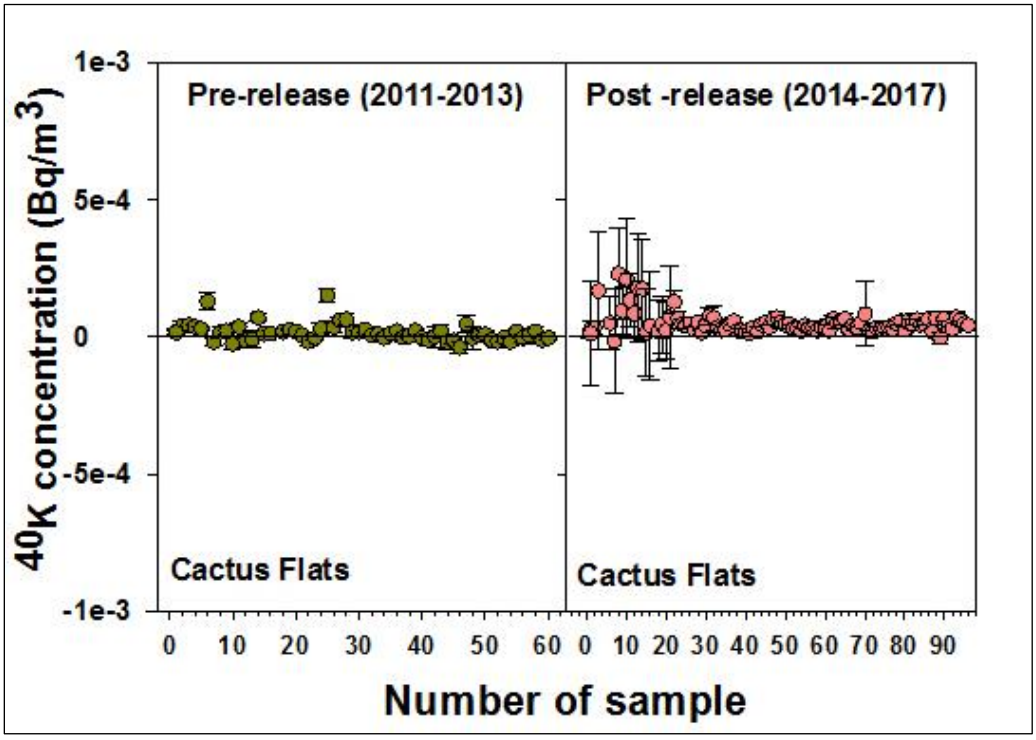


Figure 3-17: The Pre- and Post-radiological event ^{40}K concentrations in ambient air at Cactus Flats station

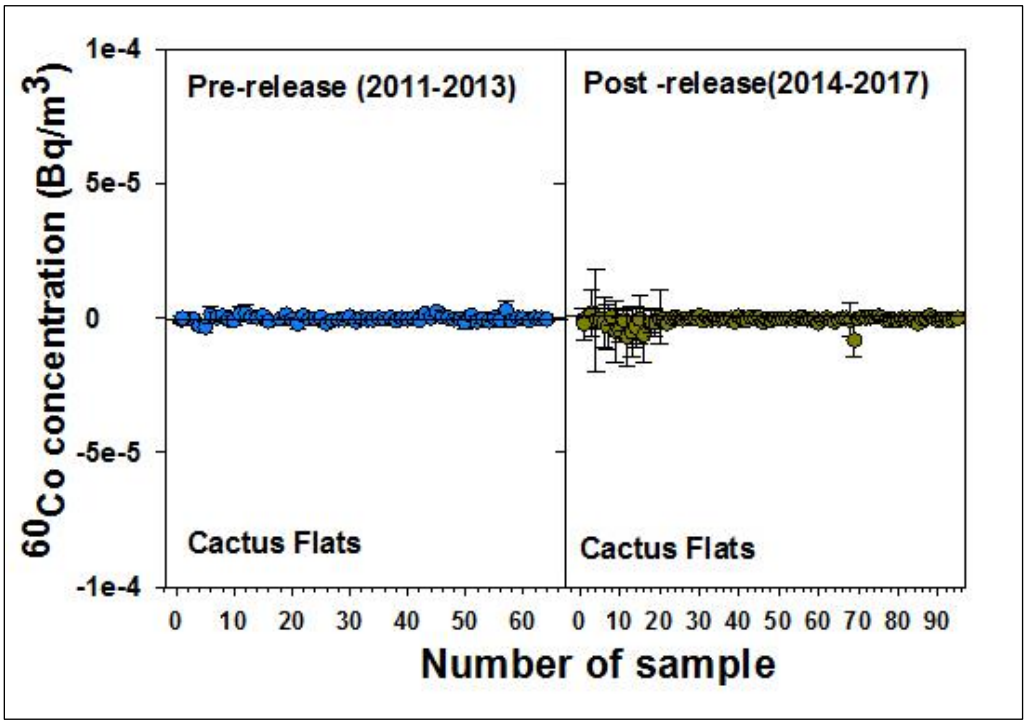


Figure 3-18: The Pre- and Post-radiological event ^{60}Co concentrations in ambient air at Cactus Flats station

Radionuclides Concentrations at Carlsbad and Loving Air Monitoring Stations

The CEMRC began sampling at these two stations in May of 2015. The concentrations of $^{239+240}$Pu, ^{238}Pu, and ^{241}Am measured are listed in Tables 3-31 (Loving) and 3-32 (Carlsbad) and are shown in Figures 3-19 through 3-21 (Loving) and Figures 3-22 through 3-24 (Carlsbad). The levels of $^{239+240}$Pu, ^{238}Pu and ^{241}Am at these monitoring stations are consistent with the normal background levels usually measured in the WIPP vicinity. The corresponding specific activity (activity per gram of dust) is summarized in Tables 3-33 and 3-34. The isotopes of uranium were detected at both sample locations. The concentrations of uranium isotopes measured are listed in Tables 3-35 (Loving) and 3-36 (Carlsbad) and are shown in Figures 3-25 and 3-26 (Loving) and Figures 3-27 and 3-28 (Carlsbad). The levels detected were similar to those measured at other sample locations around the WIPP. The average annual ^{234}U/^{238}U ratios of 1.05±0.04 at the Loving Station and 1.04±0.05 at the Carlsbad station are consistent with naturally occurring uranium. The specific activity of uranium isotopes measured in the ambient air filters during 2017 is listed in Tables 3-37 (Loving) and 3-38 (Carlsbad).

Gamma emitting radionuclides (^{137}Cs or ^{60}Co) were not detected in any of the ambient air filter samples collected in 2017. However, ^{40}K was detected in a few ambient air filter samples.

The activity concentrations of these gamma radionuclides measured are listed in Tables 3-39 (Loving) and 3-40 (Carlsbad) and shown in Figures 3-29 through 3-31 (Loving) and Figures 3-32 through 3-34 (Carlsbad). The corresponding specific activity values are summarized in Tables 3-41 (Loving) and 3-42 (Carlsbad).

Radionuclides Concentrations at WIPP EAST Tower Air Monitoring Stations

As mentioned earlier, the CEMRC expanded its air-monitoring network following the radiation release event at the WIPP in 2014. During the calendar year 2017, a new air monitoring station was deployed on the east side of the WIPP facility near the WIPP meteorological station, about 0.3 km east of the WIPP facility. The CEMRC began sampling at this station in September of 2017. The concentrations of $^{239+240}$Pu, ^{238}Pu, and ^{241}Am measured are listed in Table 3-43 and are shown in Figures 3-35 through 3-37. The levels of $^{239+240}$Pu, ^{238}Pu, and ^{241}Am at these monitoring stations are consistent with the normal background levels usually measured in the WIPP vicinity. The corresponding specific activity (activity per gram of dust) is summarized in Table 3-44. The uranium isotopes were detected at this sampling location. The concentrations of uranium isotopes measured are listed in Table 3-45 and are shown in Figures 3-38 and 3-39. The levels detected were similar to those measured at other sample locations around the WIPP. The specific activity of uranium isotopes measured in the ambient air filters during 2017 is listed in Table 3-46.

Gamma radionuclides (^{137}Cs or ^{60}Co) were not detected in any of the ambient air filter samples collected in 2017. However, ^{40}K was detected in two ambient air filter samples. The activity concentrations of these gamma radionuclides measured are listed in Table 3-47 and shown in Figures 3-40 through 3-42. The corresponding specific activity values are summarized in Table 3-48.

Conclusion

The source and level of plutonium and americium in and around the WIPP environment prior to the arrival of TRU waste and after the WIPP became operational were compared to assess if there is any evidence of an increase in radionuclides activity concentrations in the region that could be attributed to releases from the WIPP. The CEMRC's ambient air monitoring data shows that, except for the brief detection of americium and plutonium in the nearby monitoring stations (Onsite and Near Field), there is no persist contamination and no lasting increase in radiological contaminants near the WIPP that can be attributed to the 2014 radiation release. The WIPP's historical ambient air data indicates that fallout in the vicinity of the WIPP is mainly from global nuclear weapons testing. Although transport of contaminants from the Gnome site to the WIPP remains a possibility during high wind seasons, the activity and atomic ratio measurements indicates that deposited plutonium and americium in the air mainly results from global fallout. Re-suspension of soil particles which are contaminated from weapons fallout

continues to be considered the predominant source of plutonium in the environment surrounding the WIPP area.

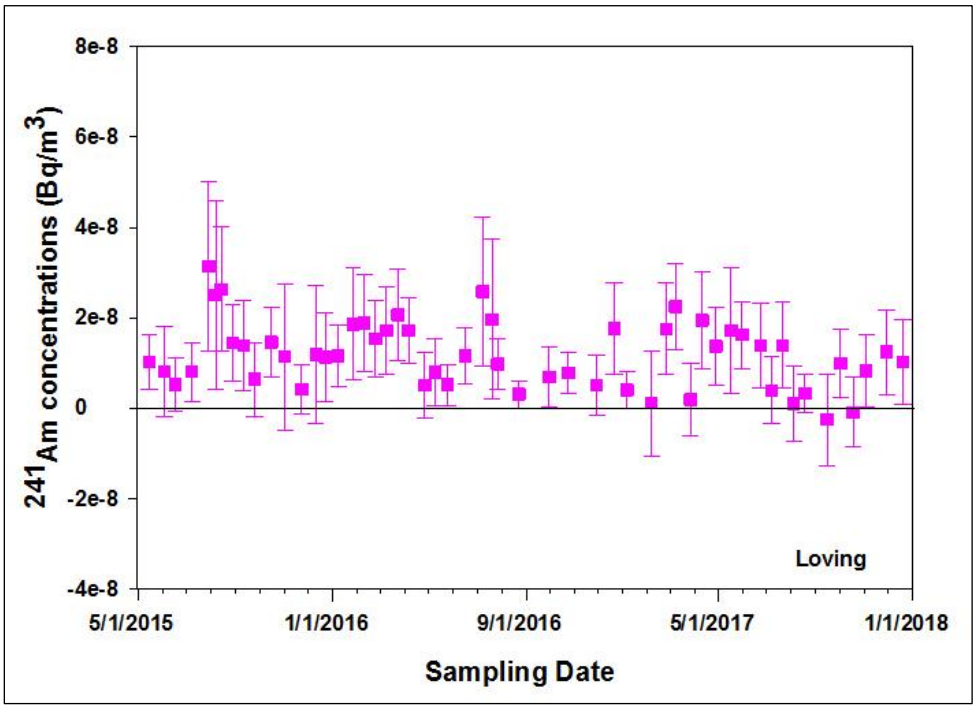


Figure 3-19: The ^{241}Am concentrations in ambient air at Loving station in 2015-2017

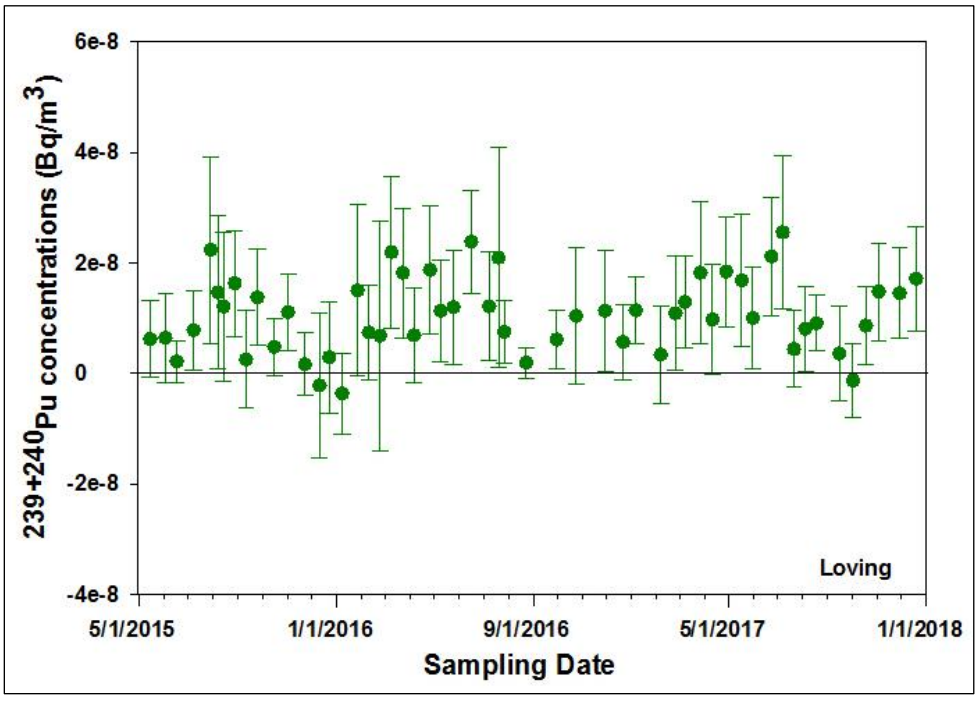


Figure 3-20: The $^{239+240}$Pu concentrations in ambient air at Loving station in 2015-2017

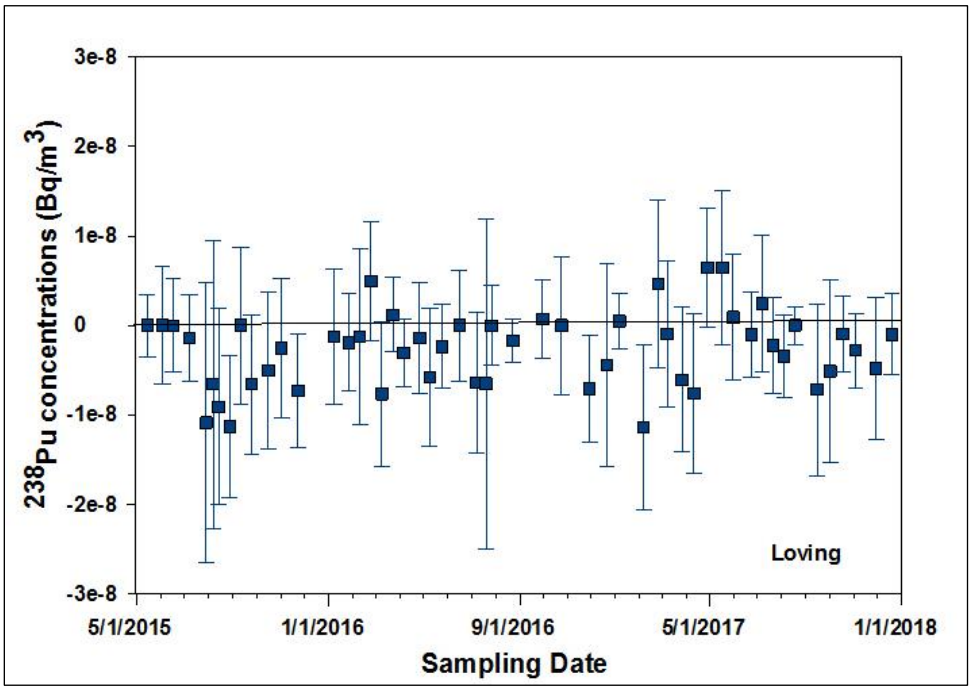


Figure 3-21: The ^{238}Pu concentrations in ambient air at Loving station in 2015-2017

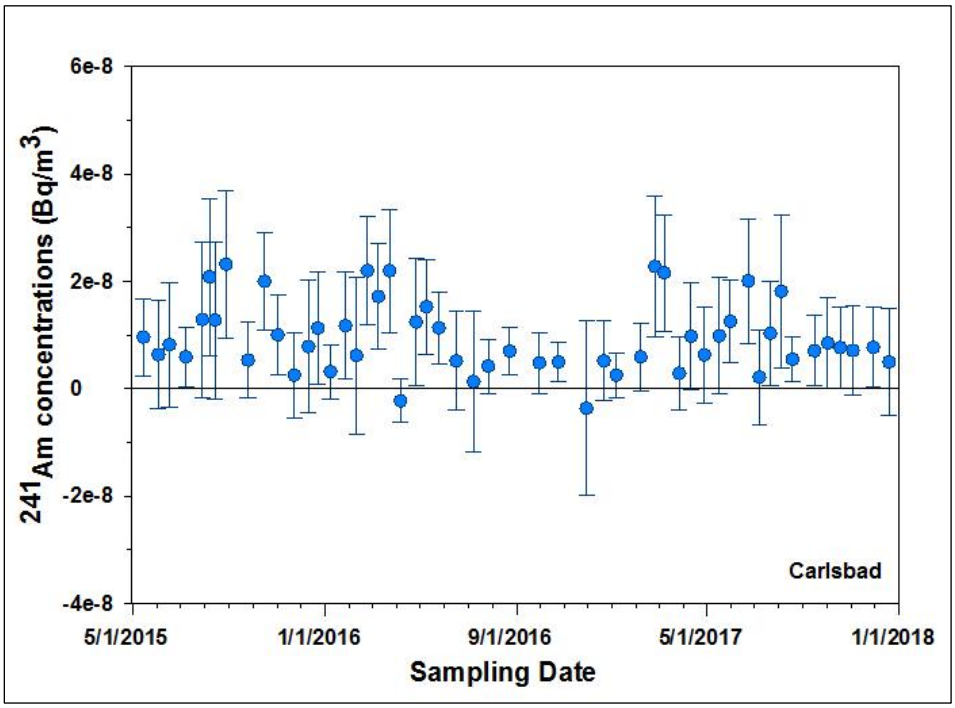


Figure 3-22: The ^{241}Am concentrations in ambient air at Carlsbad station in 2015-2017

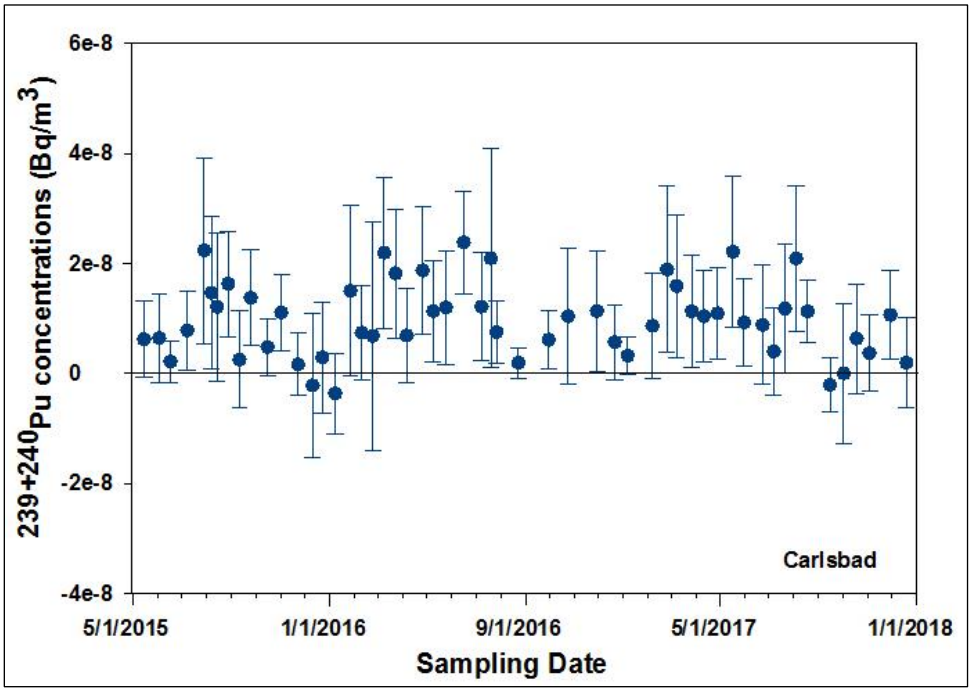


Figure 3-23: The $^{239+240}$Pu concentrations in ambient air at Carlsbad station in 2015-2017

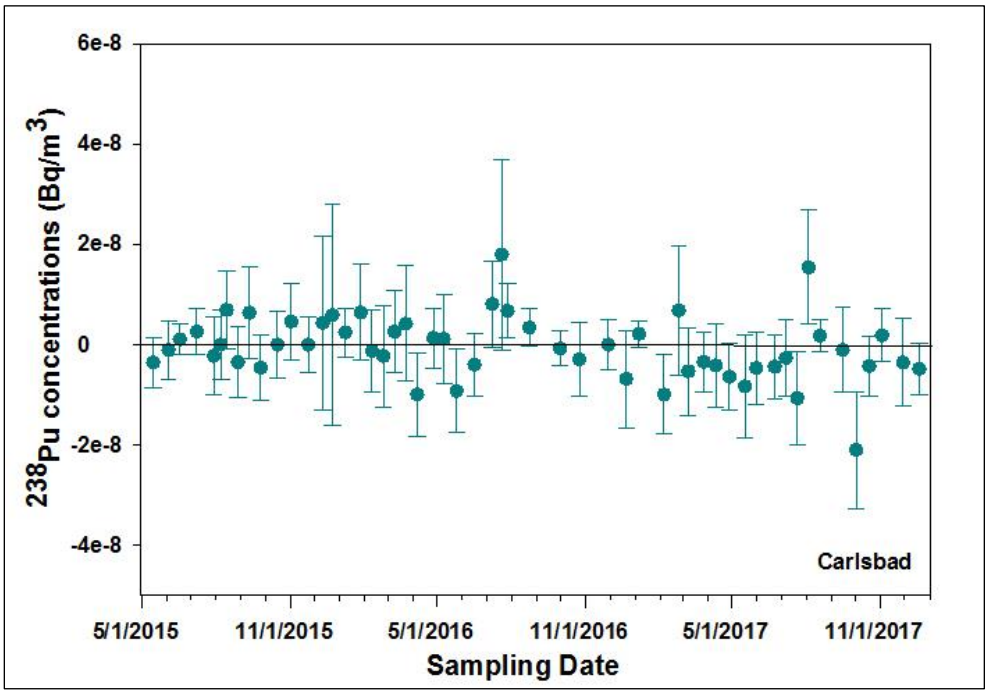


Figure 3-24: The ^{238}Pu concentrations in ambient air at Carlsbad station in 2015-2017

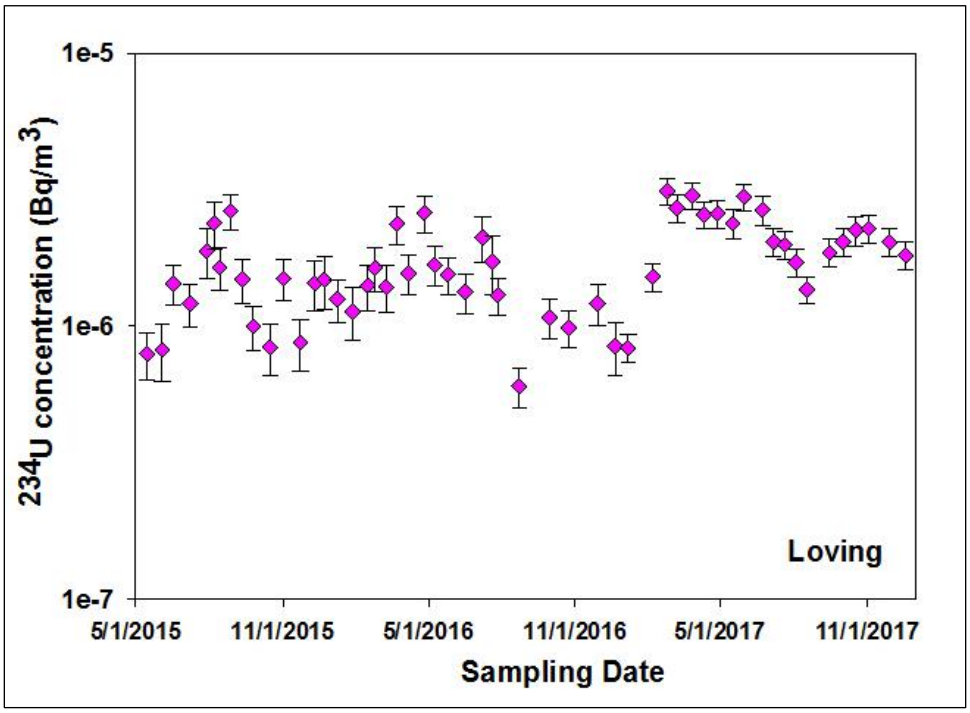


Figure 3-25: The ^{234}U concentrations in ambient air at Loving station in 2015-2017

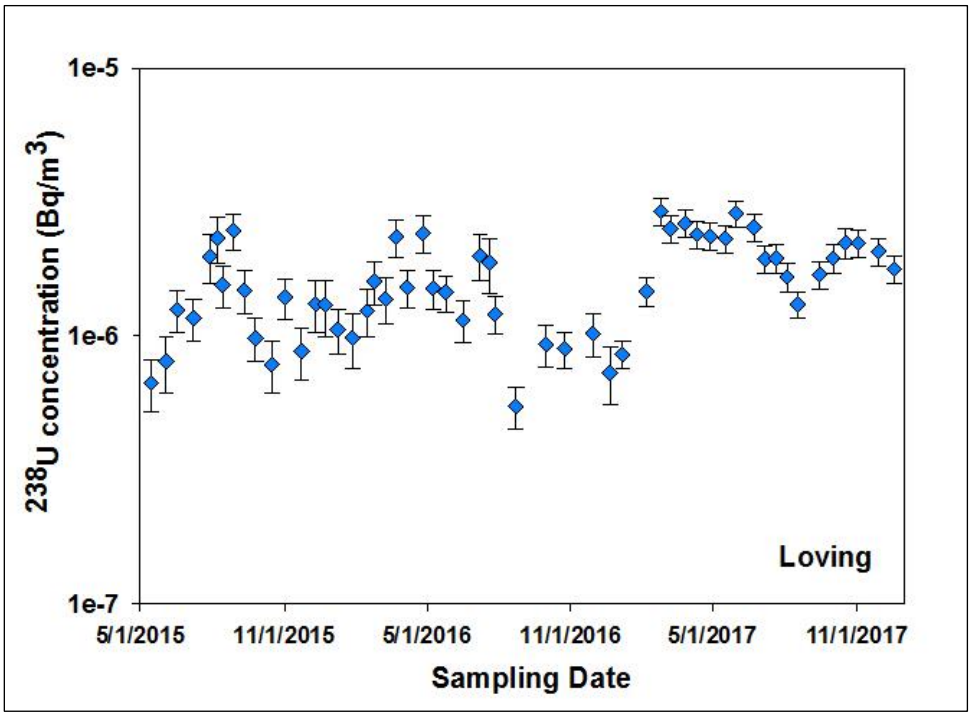


Figure 3-26: The ^{238}U concentrations in ambient air at Loving station in 2015-2017

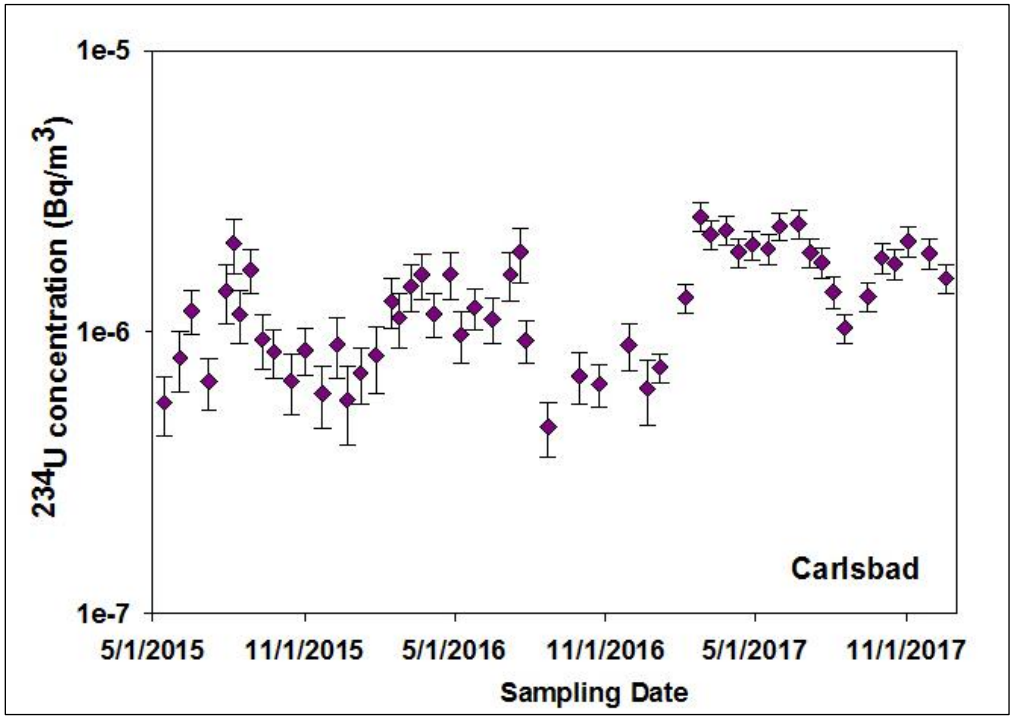


Figure 3-27: The ^{234}U concentrations in ambient air at Carlsbad station in 2015-2017

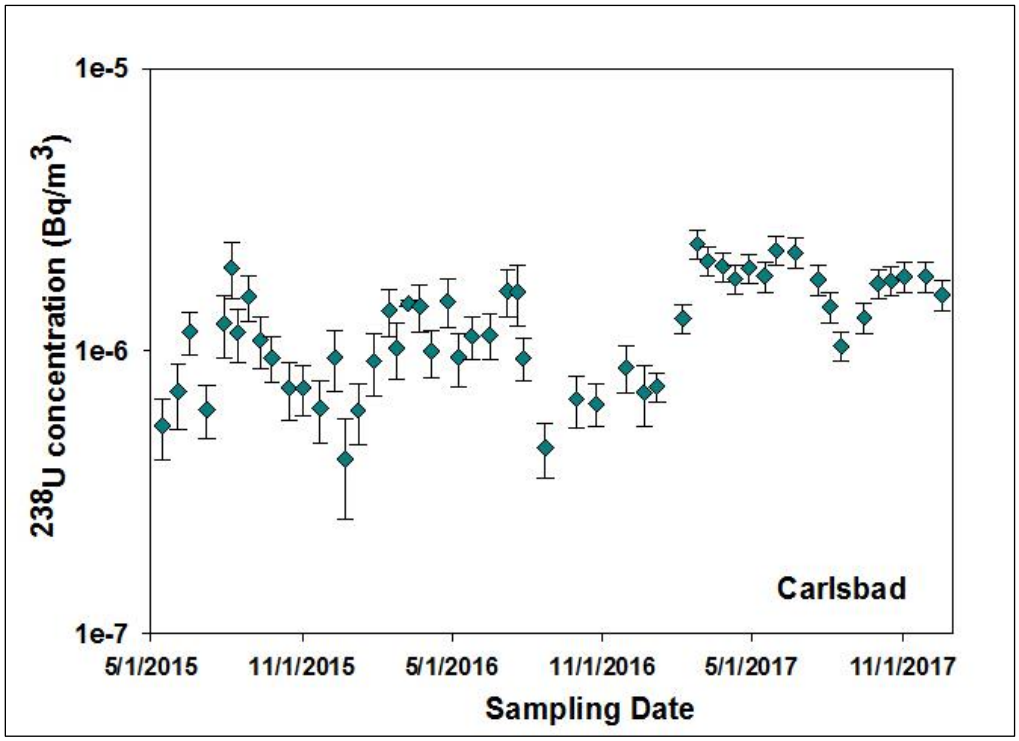


Figure 3-28: The ^{238}U concentrations in ambient air at Carlsbad station in 2015-2017

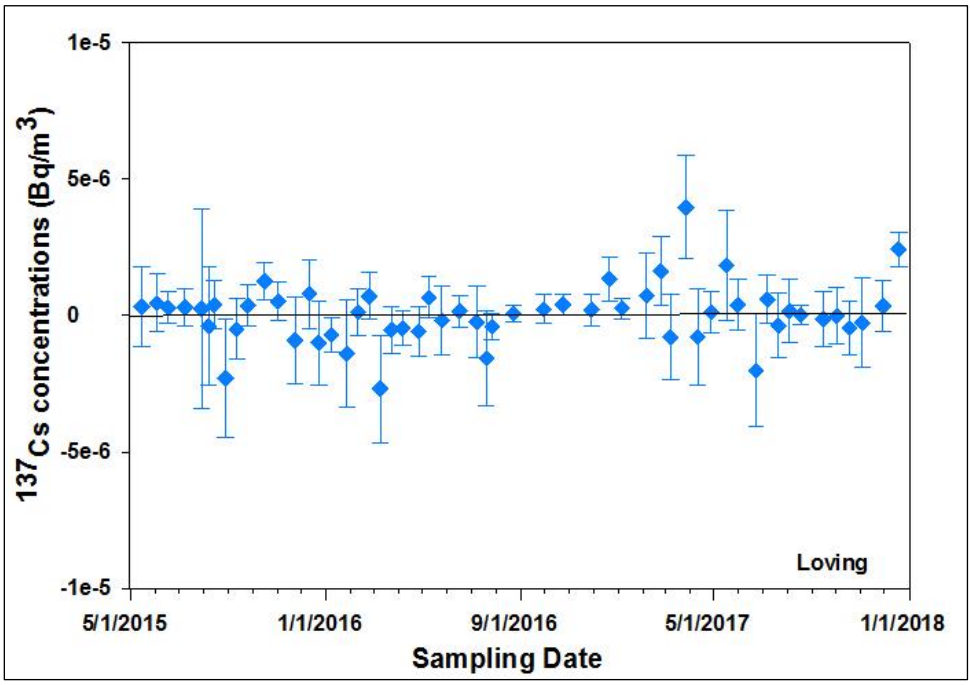


Figure 3-29: The ^{137}Cs concentrations in ambient air at Loving station in 2015-2017

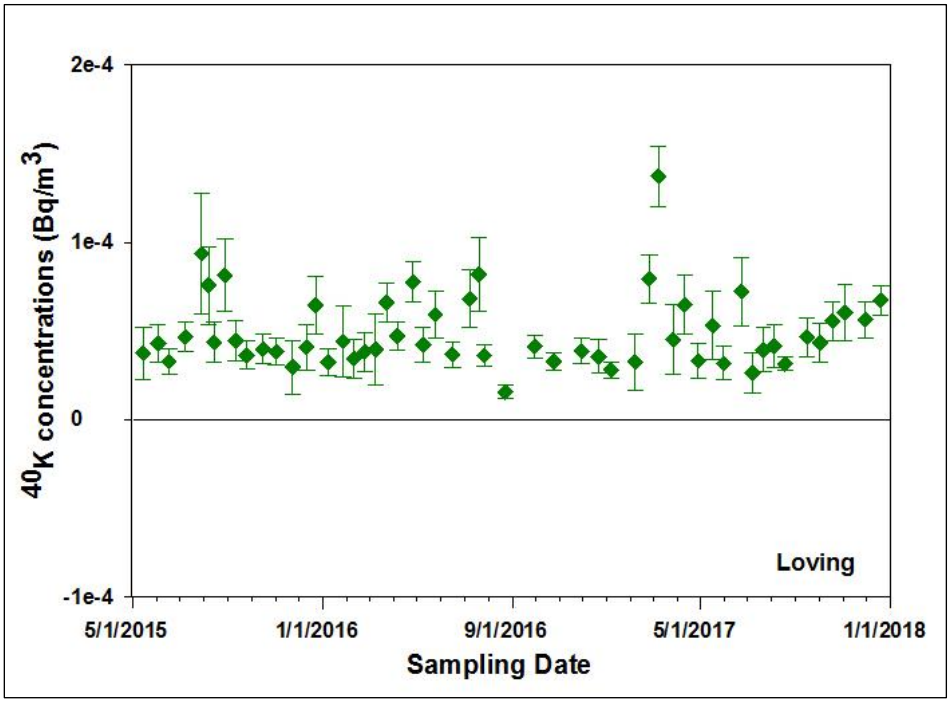


Figure 3-30: The ^{40}K concentrations in ambient air at Loving station in 2015-2017

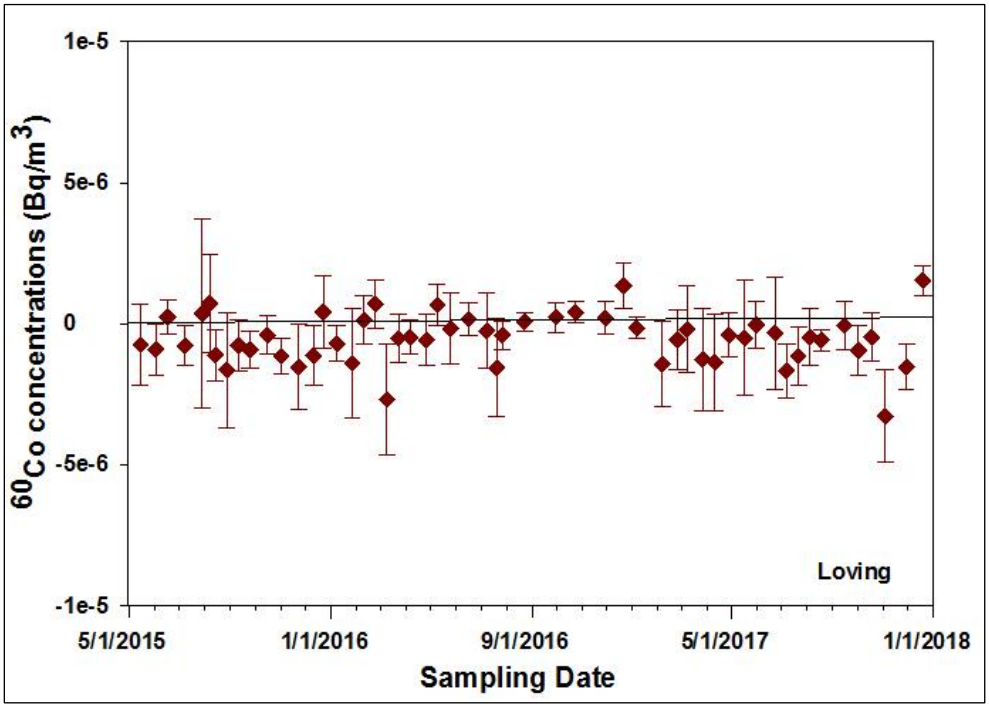


Figure 3-31: The ^{60}Co concentrations in ambient air at Loving station in 2015-2017

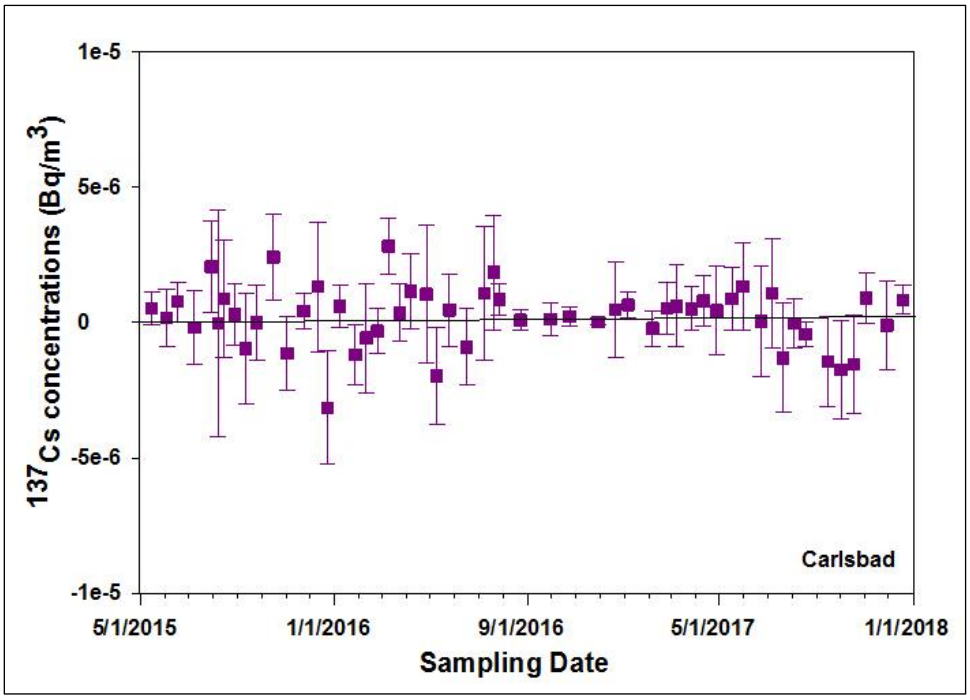


Figure 3-32: The ^{137}Cs concentrations in ambient air at Carlsbad station in 2015-2017

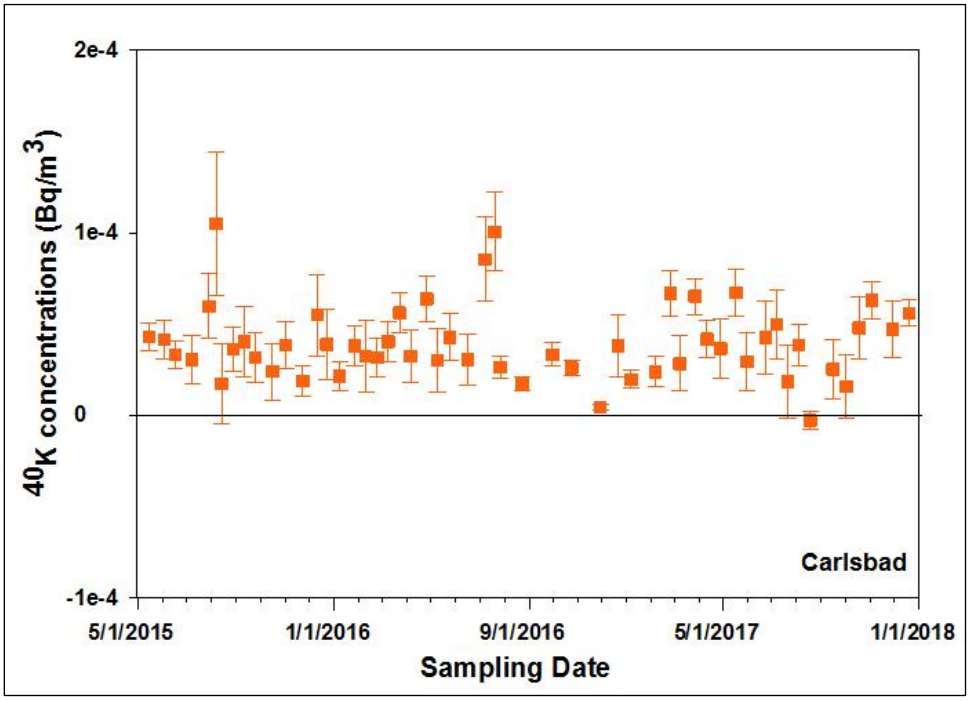


Figure 3-33: The ^{40}K concentrations in ambient air at Carlsbad station in 2015-2017

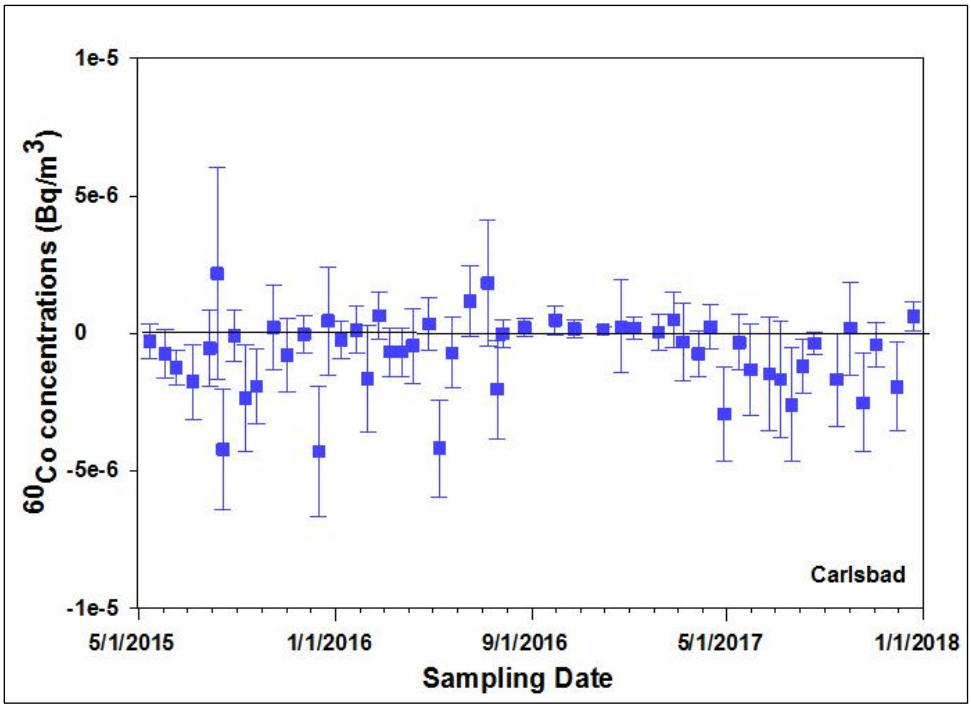


Figure 3-34: The ^{60}Co concentrations in ambient air at Carlsbad station in 2015-2017

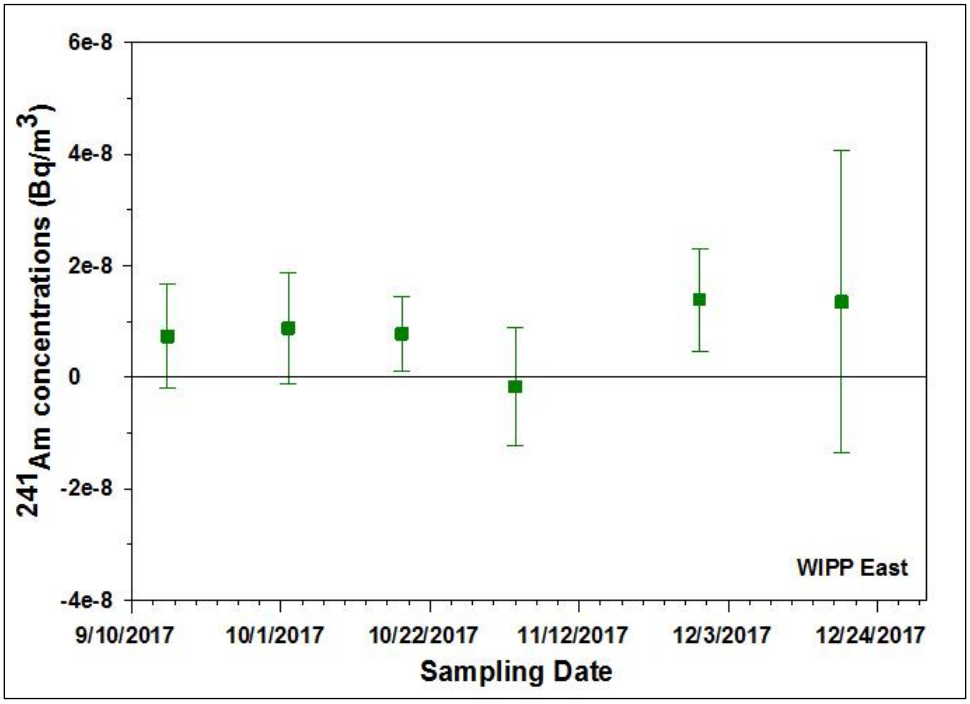


Figure 3-35: The ^{241}Am concentrations in ambient air at WIPP east station in 2017

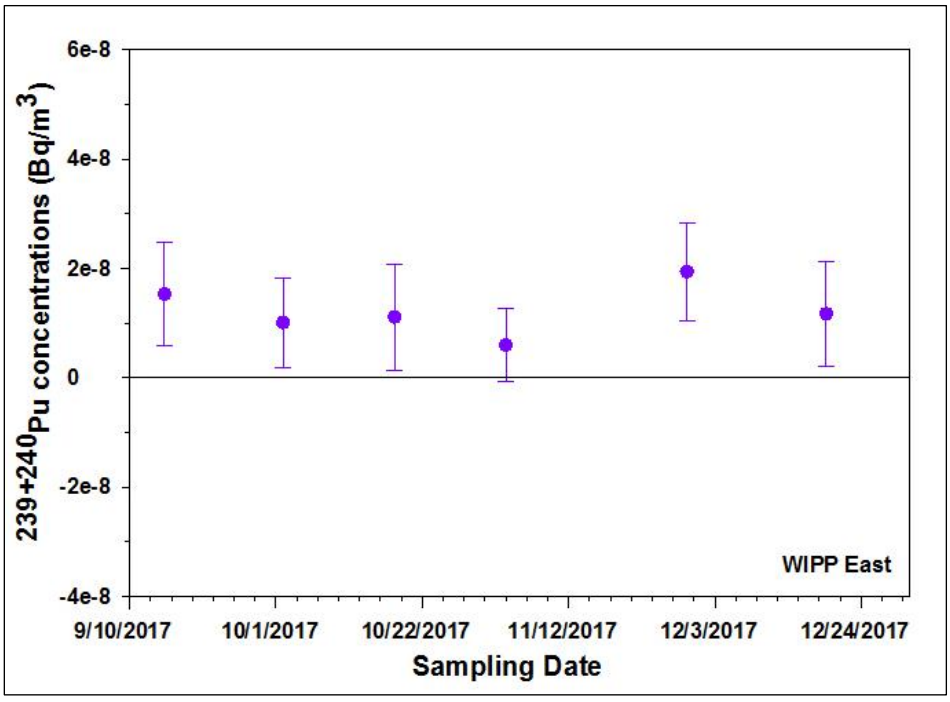


Figure 3-36: The $^{239+240}$Pu concentrations in ambient air at WIPP east station in 2017

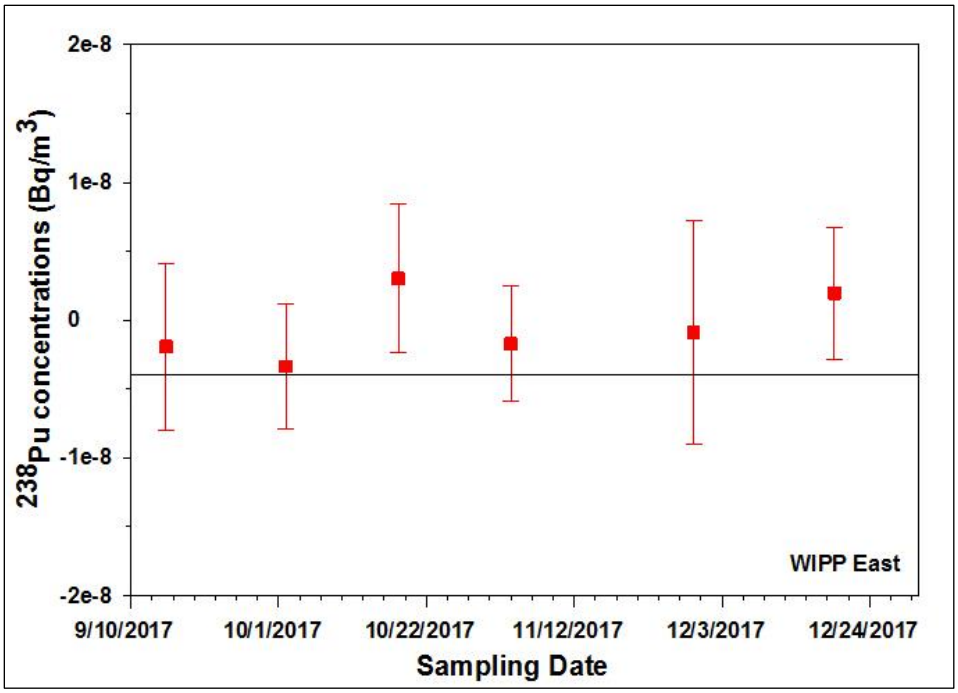


Figure 3-37: The ^{238}Pu concentrations in ambient air at WIPP east station in 2017

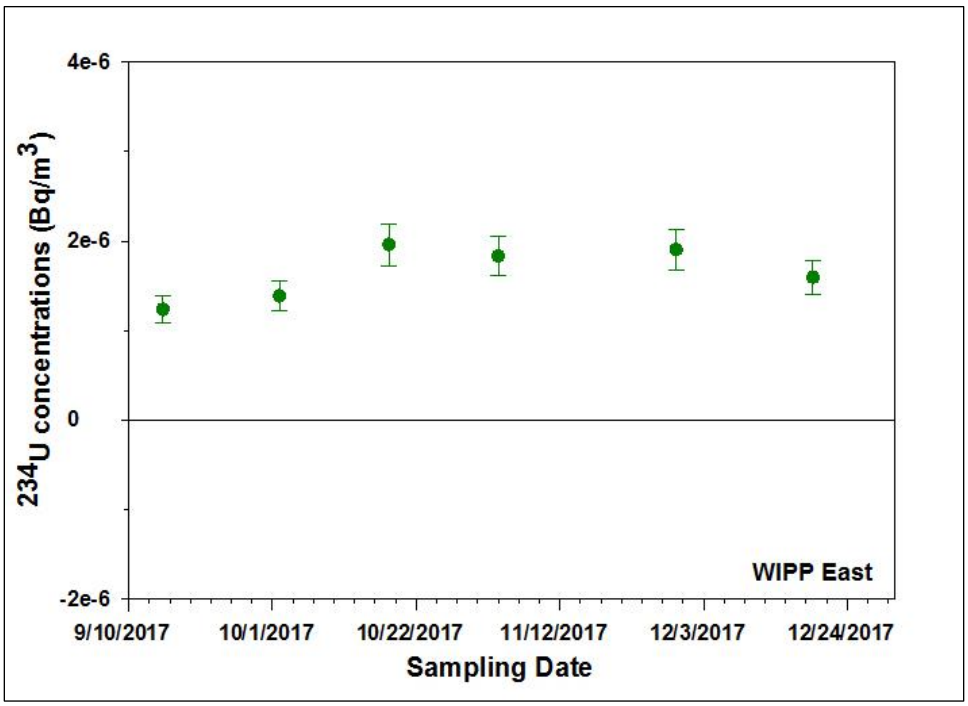


Figure 3-38: The ^{234}U concentrations in ambient air at WIPP east station in 2017

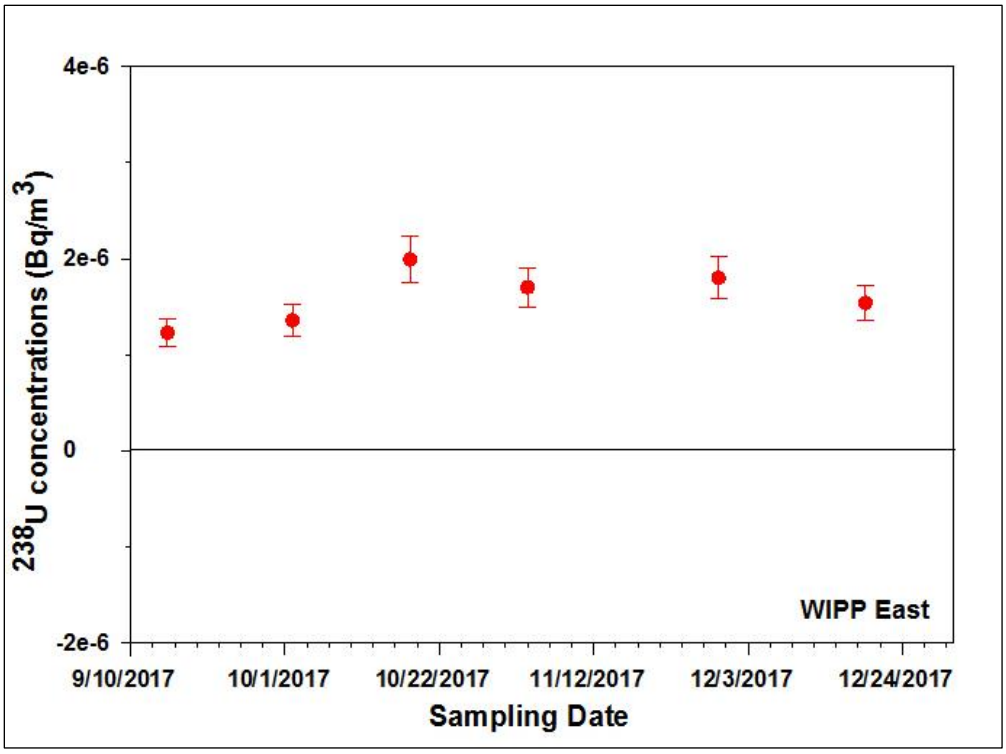


Figure 3-39: The ^{238}U concentrations in ambient air at WIPP east station in 2017

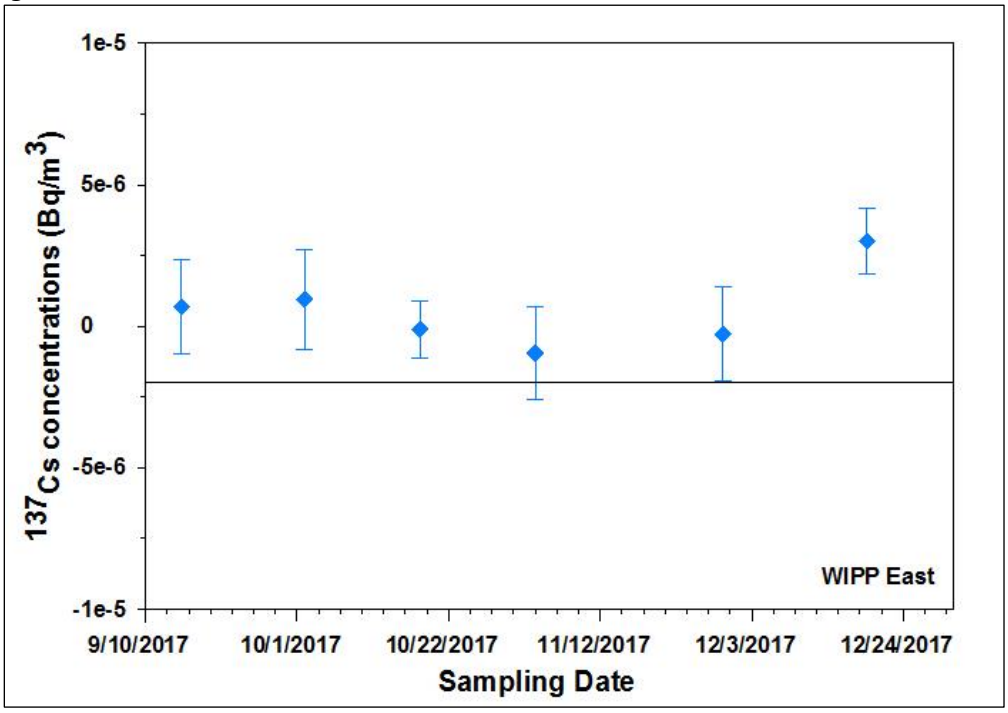


Figure 3-40: The ^{137}Cs concentrations in ambient air at WIPP east station in 2017

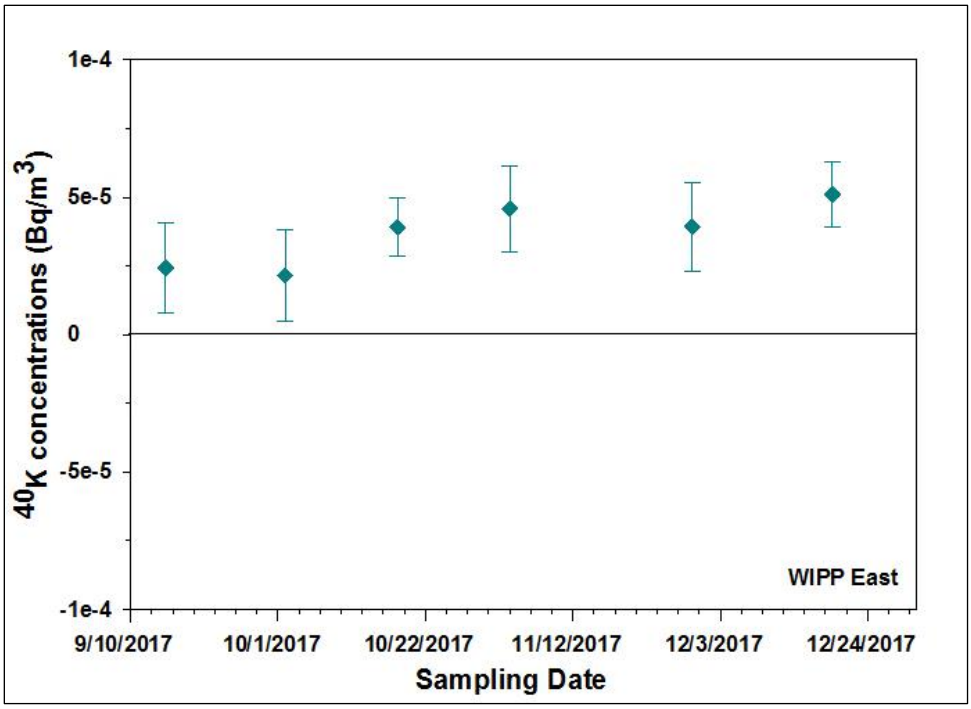


Figure 3-41: The ^{40}K concentrations in ambient air at WIPP east station in 2017

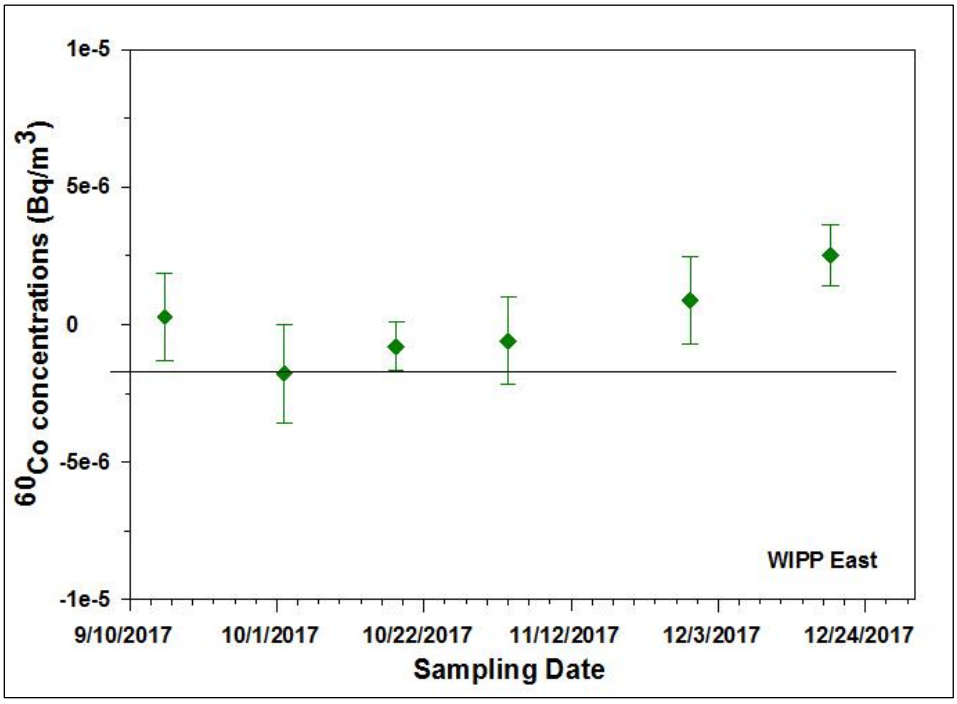


Figure 3-42: The ^{60}Co concentrations in ambient air at WIPP east station in 2017

Table 3-1: Activity concentrations of ^{241}Am in the filter samples collected from Onsite Station

Radionuclides	Sample Date 2017	Activity Bq/m^3	Unc.(2σ) Bq/m^3	MDC Bq/m^3	Status
^{241}Am	Jan. 6 – Feb. 6	7.91E-09	5.08E-09	8.76E-09	Not detected
	Feb. 6 – Feb. 24	2.00E-08	1.05E-08	1.73E-08	Detected
	Feb. 24 – Mar. 8	1.29E-08	9.75E-09	1.65E-08	Not detected
	Mar. 8 – Mar. 27	3.35E-08	1.25E-08	1.60E-08	Detected
	Mar. 27 – Apr. 11	1.34E-08	8.62E-09	1.34E-08	Not detected
	Apr. 11 – Apr. 28	3.06E-08	1.65E-08	2.27E-08	Detected
	Apr. 28 – May 17	9.11E-09	1.19E-08	2.66E-08	Not detected
	May 17 – May 31	1.15E-08	1.20E-08	2.55E-08	Not detected
	May 31 – June 23	1.72E-08	1.04E-08	1.84E-08	Not detected
	June 23 – July 7	5.66E-09	2.88E-08	7.21E-08	Not detected
	July 7 – July 21	9.12E-09	1.07E-08	2.29E-08	Not detected
	July 21 – Aug. 4	6.19E-09	8.95E-09	1.96E-08	Not detected
	Aug. 4 – Aug. 18	1.55E-08	9.66E-09	1.54E-08	Detected
	Aug. 18 - Sep. 15	4.80E-09	4.80E-09	1.02E-08	Not detected
	Sep. 15 – Oct. 2	4.96E-09	1.38E-08	3.32E-08	Not detected
	Oct. 2 – Oct. 18	6.11E-09	9.72E-09	2.23E-08	Not detected
	Oct. 18 – Nov. 3	2.19E-08	1.31E-08	2.12E-08	Detected
	Nov. 3 – Nov. 29	1.25E-08	9.11E-09	1.67E-08	Not detected
	Nov. 29 – Dec. 19	7.77E-10	7.77E-09	1.98E-08	Not detected
	Dec. 19 – Jan. 8	1.47E-08	8.13E-09	1.16E-08	Detected

Table 3-2: Activity concentrations of $^{239+240}Pu$ in the filter samples collected from Onsite Station

Radionuclides	Sample Date 2017	Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
$^{239+240}Pu$	Jan. 6 – Feb. 6	8.83E-09	6.67E-09	1.13E-08	Not detected
	Feb. 6 – Feb. 24	7.20E-09	4.87E-09	7.20E-09	Not detected
	Feb. 24 – Mar. 8	-1.34E-09	8.00E-09	2.32E-08	Not detected
	Mar. 8 – Mar. 27	2.40E-08	1.16E-08	1.12E-08	Detected
	Mar. 27 – Apr. 11	1.44E-08	1.52E-08	3.26E-08	Not detected
	Apr. 11 – Apr. 28	1.53E-08	1.38E-08	2.68E-08	Not detected
	Apr. 28 – May 17	3.23E-08	1.13E-08	7.91E-09	Detected
	May 17 – May 31	1.41E-08	8.49E-09	1.01E-08	Detected
	May 31 – June 23	1.39E-08	9.39E-09	1.62E-08	Not detected

Table 3-2: Activity concentrations of $^{239+240}$Pu in the filter samples collected from Onsite Station (continued)

Radionuclides	Sample Date 2017	Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
$^{239+240}$Pu	June 23 – July 7	6.25E-09	2.50E-08	6.30E-08	Not detected
	July 7 – July 21	2.67E-09	6.54E-09	1.60E-08	Not detected
	July 21 – Aug. 4	8.16E-09	1.02E-08	2.19E-08	Not detected
	Aug. 4 – Aug. 18	-4.88E-09	7.75E-09	2.46E-08	Not detected
	Aug. 18 - Sep. 15	1.04E-08	5.05E-09	6.89E-09	Detected
	Sep. 15 – Oct. 2	4.64E-09	6.19E-09	1.31E-08	Not detected
	Oct. 2 – Oct. 18	9.49E-09	7.58E-09	1.10E-08	Not detected
	Oct. 18 – Nov. 3	1.20E-08	1.03E-08	2.00E-08	Not detected
	Nov. 3 – Nov. 29	1.21E-08	1.06E-08	2.06E-08	Not detected
	Nov. 29 – Dec. 19	1.52E-08	9.46E-09	1.43E-08	Detected
	Dec. 19 – Jan. 8	9.42E-09	1.01E-08	2.11E-08	Not detected

Table 3-3: Activity concentrations of ^{238}Pu in the filter samples collected from Onsite Station

Radionuclides	Sample Date 2017	Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
^{238}Pu	Jan. 6 – Feb. 6	-5.61E-09	5.83E-09	1.88E-08	Not detected
	Feb. 6 – Feb. 24	-1.20E-09	4.80E-09	1.35E-08	Not detected
	Feb. 24 – Mar. 8	-1.34E-09	8.00E-09	2.32E-08	Not detected
	Mar. 8 – Mar. 27	-1.20E-09	7.20E-09	2.09E-08	Not detected
	Mar. 27 – Apr. 11	2.39E-09	6.76E-09	1.68E-08	Not detected
	Apr. 11 – Apr. 28	3.66E-16	6.15E-09	1.84E-08	Not detected
	Apr. 28 – May 17	-2.56E-09	7.42E-09	2.09E-08	Not detected
	May 17 – May 31	-5.39E-09	8.90E-09	2.64E-08	Not detected
	May 31 – June 23	-4.65E-09	6.18E-09	1.98E-08	Not detected
	June 23 – July 7	-1.56E-08	1.88E-08	6.30E-08	Not detected
	July 7 – July 21	-2.67E-09	9.30E-09	2.68E-08	Not detected
	July 21 – Aug. 4	-8.16E-09	9.62E-09	2.97E-08	Not detected
	Aug. 4 – Aug. 18	-4.88E-09	7.75E-09	2.46E-08	Not detected
	Aug. 18 - Sep. 15	-2.61E-09	3.26E-09	1.02E-08	Not detected
	Sep. 15 – Oct. 2	-2.79E-09	9.27E-09	2.53E-08	Not detected
	Oct. 2 – Oct. 18	8.35E-09	6.78E-09	8.73E-09	Not detected
	Oct. 18 – Nov. 3	-5.98E-09	5.67E-09	2.00E-08	Not detected
	Nov. 3 – Nov. 29	3.29E-09	5.81E-09	1.31E-08	Not detected
	Nov. 29 – Dec. 19	0.00E+00	5.73E-09	1.61E-08	Not detected
	Dec. 19 – Jan. 8	-4.20E-09	6.65E-09	2.11E-08	Not detected

Table 3-4: Activity concentrations of ^{241}Am in the filter samples collected from Near Field station

Radionuclides	Sample Date 2017	Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
^{241}Am	Jan. 6 – Feb. 6	-6.08E-10	5.29E-09	1.43E-08	Not detected
	Feb. 6 – Feb. 24	2.64E-09	1.04E-08	2.56E-08	Not detected
	Feb. 24 – Mar. 8	1.41E-08	1.46E-08	3.11E-08	Not detected
	Mar. 8 – Mar. 27	1.10E-08	9.40E-09	1.92E-08	Not detected
	Mar. 27 – Apr. 11	1.50E-09	1.31E-08	3.37E-08	Not detected
	Apr. 11 – Apr. 28	2.09E-08	1.09E-08	1.48E-08	Detected
	Apr. 28 – May 17	3.42E-09	7.27E-09	1.72E-08	Not detected
	May 17 – May 31	1.91E-09	8.99E-09	2.25E-08	Not detected
	May 31 – June 23	6.36E-09	8.47E-09	1.87E-08	Not detected
	June 23 – July 7	1.89E-08	1.04E-08	1.48E-08	Detected
	July 7 – July 21	1.36E-08	1.02E-08	1.83E-08	Not detected
	July 21 – Aug. 4	6.30E-09	1.03E-08	2.36E-08	Not detected
	Aug. 4 – Aug. 18	1.57E-08	8.81E-09	9.70E-09	Detected
	Aug. 18 - Sep. 15	2.89E-09	4.13E-09	9.29E-09	Not detected
	Sep. 15 – Oct. 2	1.31E-08	7.70E-09	1.04E-08	Detected
	Oct. 2 – Oct. 18	6.90E-09	1.26E-08	2.94E-08	Not detected
	Oct. 18 – Nov. 3	5.91E-09	1.03E-08	2.34E-08	Not detected
	Nov. 3 – Nov. 29	1.47E-08	7.70E-09	6.76E-09	Detected
	Nov. 29 – Dec. 19	1.39E-08	8.33E-09	1.29E-08	Detected
	Dec. 19 – Jan. 8	1.80E-08	1.37E-08	2.31E-08	Not detected

Table 3-5: Activity concentrations of $^{239+240}Pu$ in the filter samples collected from Near Field Station

Radionuclides	Sample Date 2017	Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
$^{239+240}Pu$	Jan. 6 – Feb. 6	1.05E-09	5.53E-09	1.47E-08	Not detected
	Feb. 6 – Feb. 24	8.90E-09	8.22E-09	1.58E-08	Not detected
	Feb. 24 – Mar. 8	2.74E-08	1.52E-08	2.14E-08	Detected
	Mar. 8 – Mar. 27	1.89E-08	1.04E-08	1.75E-08	Detected
	Mar. 27 – Apr. 11	5.01E-08	1.93E-08	2.79E-08	Detected
	Apr. 11 – Apr. 28	6.20E-09	7.19E-09	1.46E-08	Not detected
	Apr. 28 – May 17	1.33E-08	8.69E-09	1.41E-08	Not detected
	May 17 – May 31	1.48E-08	1.00E-08	1.67E-08	Not detected
	May 31 – June 23	1.07E-08	6.80E-09	8.33E-09	Detected
	June 23 – July 7	1.92E-08	1.15E-08	1.79E-08	Detected
	July 7 – July 21	3.71E-09	9.62E-09	2.33E-08	Not detected
	July 21 – Aug. 4	1.26E-08	9.58E-09	1.62E-08	Not detected
	Aug. 4 – Aug. 18	3.52E-09	7.78E-09	1.86E-08	Not detected

Table 3-5: Activity concentrations of $^{239+240}$Pu in the filter samples collected from Near Field Station (continued)

Radionuclides	Sample Date 2017	Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
$^{239+240}$Pu	Aug. 18 - Sep. 15	8.62E-09	4.98E-09	7.87E-09	Detected
	Sep. 15 – Oct. 2	0.00E+00	7.40E-09	2.01E-08	Not detected
	Oct. 2 – Oct. 18	3.47E-09	8.51E-09	2.08E-08	Not detected
	Oct. 18 – Nov. 3	3.09E-09	6.85E-09	1.63E-08	Not detected
	Nov. 3 – Nov. 29	5.49E-09	6.37E-09	1.29E-08	Not detected
	Nov. 29 – Dec. 19	1.26E-08	9.96E-09	1.83E-08	Not detected
	Dec. 19 – Jan. 8	7.91E-09	7.34E-09	1.40E-08	Not detected

Table 3-6: Activity concentrations of ^{238}Pu in the filter samples collected from Near Field Station

Radionuclides	Sample Date 2017	Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
^{238}Pu	Jan. 6 – Feb. 6	-7.31E-09	9.62E-09	2.85E-08	Not detected
	Feb. 6 – Feb. 24	-1.98E-09	7.95E-09	2.23E-08	Not detected
	Feb. 24 – Mar. 8	-4.56E-09	8.07E-09	2.65E-08	Not detected
	Mar. 8 – Mar. 27	8.23E-10	3.67E-09	9.85E-09	Not detected
	Mar. 27 – Apr. 11	4.55E-09	7.22E-09	1.60E-08	Not detected
	Apr. 11 – Apr. 28	-9.29E-09	8.04E-09	2.63E-08	Not detected
	Apr. 28 – May 17	-3.56E-09	7.13E-09	2.09E-08	Not detected
	May 17 – May 31	-2.12E-09	8.99E-09	2.49E-08	Not detected
	May 31 – June 23	8.05E-09	5.73E-09	6.60E-09	Detected
	June 23 – July 7	-7.89E-09	8.18E-09	2.65E-08	Not detected
	July 7 – July 21	-4.57E-09	5.13E-09	1.81E-08	Not detected
	July 21 – Aug. 4	-9.49E-09	8.32E-09	2.80E-08	Not detected
	Aug. 4 – Aug. 18	0.00E+00	7.49E-09	2.06E-08	Not detected
	Aug. 18 - Sep. 15	0.00E+00	2.86E-09	7.87E-09	Not detected
	Sep. 15 – Oct. 2	-4.28E-09	8.53E-09	2.51E-08	Not detected
	Oct. 2 – Oct. 18	-3.47E-09	8.51E-09	2.75E-08	Not detected
	Oct. 18 – Nov. 3	-7.22E-09	7.48E-09	2.42E-08	Not detected
	Nov. 3 – Nov. 29	-9.18E-09	6.92E-09	2.33E-08	Not detected
	Nov. 29 – Dec. 19	3.15E-09	6.31E-09	1.48E-08	Not detected
	Dec. 19 – Jan. 8	-4.41E-09	6.85E-09	2.08E-08	Not detected

Table 3-7: Activity concentrations of ^{241}Am in the filter samples collected from Cactus Flats Station

Radionuclides	Sample Date 2017	Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
^{241}Am	Jan. 6 – Feb. 6	3.18E-09	3.20E-09	6.32E-09	Not detected
	Feb. 6 – Feb. 24	8.30E-09	1.26E-08	2.84E-08	Not detected
	Feb. 24 – Mar. 8	1.04E-08	1.22E-08	2.61E-08	Not detected
	Mar. 8 – Mar. 27	2.08E-08	9.04E-09	9.60E-09	Detected
	Mar. 27 – Apr. 11	2.19E-08	1.06E-08	1.25E-08	Detected
	Apr. 11 – Apr. 28	2.12E-08	9.06E-09	7.87E-09	Detected
	Apr. 28 – May 17	1.21E-08	8.47E-09	1.52E-08	Not detected
	May 17 – May 31	5.92E-09	8.40E-09	1.86E-08	Not detected
	May 31 – June 23	1.23E-08	8.62E-09	1.54E-08	Not detected
	June 23 – July 7	1.29E-08	9.19E-09	1.51E-08	Not detected
	July 7 – July 21	2.99E-09	1.04E-08	2.54E-08	Not detected
	July 21 – Aug. 4	-1.07E-09	1.33E-08	3.42E-08	Not detected
	Aug. 4 – Aug. 18	1.62E-08	1.09E-08	1.89E-08	Not detected
	Aug. 18 - Sep. 15	5.23E-09	4.80E-09	9.75E-09	Not detected
	Sep. 15 – Oct. 2	-5.47E-09	9.53E-09	2.79E-08	Not detected
	Oct. 2 – Oct. 18	1.34E-08	8.32E-09	1.26E-08	Detected
	Oct. 18 – Nov. 3	1.50E-08	1.30E-08	2.58E-08	Not detected
	Nov. 3 – Nov. 29	1.88E-08	1.27E-08	2.13E-08	Not detected
	Nov. 29 – Dec. 19	7.77E-09	9.96E-09	2.18E-08	Not detected
	Dec. 19 – Jan. 8	1.26E-08	9.46E-09	1.66E-08	Not detected

Table 3-8: Activity concentrations of $^{239+240}Pu$ in the filter samples collected from Cactus Flats Station

Radionuclides	Sample Date 2017	Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
$^{239+240}Pu$	Jan. 6 – Feb. 6	6.21E-09	4.41E-09	6.78E-09	Not detected
	Feb. 6 – Feb. 24	3.69E-08	2.21E-08	3.66E-08	Detected
	Feb. 24 – Mar. 8	2.50E-08	1.49E-08	2.21E-08	Detected
	Mar. 8 – Mar. 27	2.88E-08	1.27E-08	1.63E-08	Detected
	Mar. 27 – Apr. 11	2.94E-08	1.50E-08	2.36E-08	Detected
	Apr. 11 – Apr. 28	8.91E-09	8.69E-09	1.72E-08	Not detected
	Apr. 28 – May 17	3.71E-08	1.29E-08	1.25E-08	Detected
	May 17 – May 31	2.09E-08	1.21E-08	1.74E-08	Detected
	May 31 – June 23	1.72E-08	9.18E-09	1.14E-08	Detected
	June 23 – July 7	1.12E-09	1.25E-08	3.17E-08	Not detected
	July 7 – July 21	7.08E-09	9.50E-09	2.06E-08	Not detected
	July 21 – Aug. 4	1.32E-08	1.04E-08	1.92E-08	Not detected

Table 3-8: Activity concentrations of $^{239+240}$Pu in the filter samples collected from Cactus Flats Station (continued)

Radionuclides	Sample Date 2017	Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
$^{239+240}$Pu	Aug. 4 – Aug. 18	-8.10E-09	1.11E-08	3.26E-08	Not detected
	Aug. 18 - Sep. 15	2.13E-09	4.87E-09	1.16E-08	Not detected
	Sep. 15 – Oct. 2	2.79E-08	1.25E-08	1.52E-08	Detected
	Oct. 2 – Oct. 18	-1.27E-09	9.21E-09	2.56E-08	Not detected
	Oct. 18 – Nov. 3	2.35E-09	1.33E-08	3.31E-08	Not detected
	Nov. 3 – Nov. 29	4.50E-09	1.17E-08	2.82E-08	Not detected
	Nov. 29 – Dec. 19	1.00E-08	8.05E-09	1.45E-08	Not detected
	Dec. 19 – Jan. 8	-1.91E-09	1.01E-08	2.69E-08	Not detected

Table 3-9: Activity concentrations of ^{238}Pu in the filter samples collected from Cactus Flats Station

Radionuclides	Sample Date 2017	Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
^{238}Pu	Jan. 6 – Feb. 6	1.13E-09	2.77E-09	6.78E-09	Not detected
	Feb. 6 – Feb. 24	-1.94E-09	2.02E-08	5.32E-08	Not detected
	Feb. 24 – Mar. 8	4.69E-09	1.21E-08	2.94E-08	Not detected
	Mar. 8 – Mar. 27	-6.17E-09	7.70E-09	2.42E-08	Not detected
	Mar. 27 – Apr. 11	-1.05E-08	7.88E-09	2.76E-08	Not detected
	Apr. 11 – Apr. 28	4.95E-09	6.58E-09	1.40E-08	Not detected
	Apr. 28 – May 17	8.83E-10	6.38E-09	1.67E-08	Not detected
	May 17 – May 31	1.23E-09	8.88E-09	2.32E-08	Not detected
	May 31 – June 23	0.00E+00	5.40E-09	1.51E-08	Not detected
	June 23 – July 7	-1.91E-08	1.15E-08	3.70E-08	Not detected
	July 7 – July 21	-9.41E-09	8.24E-09	2.77E-08	Not detected
	July 21 – Aug. 4	0.00E+00	5.40E-09	1.55E-08	Not detected
	Aug. 4 – Aug. 18	-1.39E-08	1.28E-08	3.80E-08	Not detected
	Aug. 18 - Sep. 15	-8.51E-10	2.08E-09	6.74E-09	Not detected
	Sep. 15 – Oct. 2	-8.58E-09	8.63E-09	2.73E-08	Not detected
	Oct. 2 – Oct. 18	-2.55E-09	8.81E-09	2.56E-08	Not detected
	Oct. 18 – Nov. 3	-1.30E-08	1.31E-08	3.86E-08	Not detected
	Nov. 3 – Nov. 29	-1.50E-08	1.14E-08	3.82E-08	Not detected
	Nov. 29 – Dec. 19	1.82E-09	5.78E-09	1.45E-08	Not detected
	Dec. 19 – Jan. 8	-1.53E-08	9.89E-09	3.14E-08	Not detected

Table 3-10: Specific activity of ^{241}Am in the filter samples collected from Onsite Station

Radionuclides	Sample Date 2017	Activity Bq/g	Unc.(2σ) Bq/g	MDC Bq/g	Status
^{241}Am	Jan. 6 – Feb. 6	4.20E-04	2.70E-04	4.65E-04	Not detected
	Feb. 6 – Feb. 24	4.61E-04	2.41E-04	3.99E-04	Detected
	Feb. 24 – Mar. 8	2.10E-04	1.58E-04	2.69E-04	Not detected
	Mar. 8 – Mar. 27	4.67E-04	1.74E-04	2.23E-04	Detected
	Mar. 27 – Apr. 11	2.21E-04	1.43E-04	2.23E-04	Not detected
	Apr. 11 – Apr. 28	4.01E-04	2.16E-04	2.97E-04	Detected
	Apr. 28 – May 17	1.57E-04	2.04E-04	4.58E-04	Not detected
	May 17 – May 31	2.93E-04	3.06E-04	6.52E-04	Not detected
	May 31 – June 23	3.05E-04	1.84E-04	3.26E-04	Not detected
	June 23 – July 7	1.02E-04	5.21E-04	1.30E-03	Not detected
	July 7 – July 21	2.93E-04	3.45E-04	7.36E-04	Not detected
	July 21 – Aug. 4	1.80E-04	2.60E-04	5.69E-04	Not detected
	Aug. 4 – Aug. 18	6.07E-04	3.77E-04	6.00E-04	Detected
	Aug. 18 - Sep. 15	1.56E-04	1.56E-04	3.30E-04	Not detected
	Sep. 15 – Oct. 2	1.97E-04	5.50E-04	1.32E-03	Not detected
	Oct. 2 – Oct. 18	1.85E-04	2.95E-04	6.76E-04	Not detected
	Oct. 18 – Nov. 3	4.89E-04	2.92E-04	4.74E-04	Detected
	Nov. 3 – Nov. 29	2.69E-04	1.96E-04	3.60E-04	Not detected
	Nov. 29 – Dec. 19	1.87E-05	1.87E-04	4.77E-04	Not detected
	Dec. 19 – Jan. 8	5.00E-04	2.77E-04	3.93E-04	Detected

Table 3-11: Specific activity of $^{239+240}Pu$ in the filter samples collected from Onsite Station

Radionuclides	Sample Date 2017	Activity Bq/g	Unc. (2σ) Bq/g	MDC Bq/g	Status
$^{239+240}Pu$	Jan. 6 – Feb. 6	4.69E-04	3.54E-04	6.00E-04	Not detected
	Feb. 6 – Feb. 24	1.66E-04	1.12E-04	1.66E-04	Not detected
	Feb. 24 – Mar. 8	-2.17E-05	1.30E-04	3.77E-04	Not detected
	Mar. 8 – Mar. 27	3.34E-04	1.61E-04	1.55E-04	Detected
	Mar. 27 – Apr. 11	2.38E-04	2.52E-04	5.40E-04	Not detected
	Apr. 11 – Apr. 28	2.00E-04	1.81E-04	3.50E-04	Not detected
	Apr. 28 – May 17	5.57E-04	1.95E-04	1.36E-04	Detected
	May 17 – May 31	3.59E-04	2.17E-04	2.57E-04	Detected
	May 31 – June 23	2.47E-04	1.67E-04	2.87E-04	Not detected
	June 23 – July 7	1.13E-04	4.52E-04	1.14E-03	Not detected
	July 7 – July 21	8.59E-05	2.10E-04	5.14E-04	Not detected

Table 3-11: Specific activity of $^{239+240}Pu$ in the filter samples collected from Onsite Station (continued)

Radionuclides	Sample Date 2017	Activity Bq/g	Unc. (2σ) Bq/g	MDC Bq/g	Status
$^{239+240}Pu$	July 21 – Aug. 4	2.37E-04	2.95E-04	6.37E-04	Not detected
	Aug. 4 – Aug. 18	-1.91E-04	3.03E-04	9.61E-04	Not detected
	Aug. 18 - Sep. 15	3.38E-04	1.64E-04	2.23E-04	Detected
	Sep. 15 – Oct. 2	1.84E-04	2.46E-04	5.21E-04	Not detected
	Oct. 2 – Oct. 18	2.88E-04	2.30E-04	3.34E-04	Not detected
	Oct. 18 – Nov. 3	2.68E-04	2.30E-04	4.48E-04	Not detected
	Nov. 3 – Nov. 29	2.60E-04	2.28E-04	4.44E-04	Not detected
	Nov. 29 – Dec. 19	3.65E-04	2.28E-04	3.43E-04	Detected
	Dec. 19 – Jan. 8	3.20E-04	3.45E-04	7.18E-04	Not detected

Table 3-12: Specific activity of ^{238}Pu in the filter samples collected from Onsite Station

Radionuclides	Sample Date 2017	Activity Bq/g	Unc. (2σ) Bq/g	MDC Bq/g	Status
^{238}Pu	Jan. 6 – Feb. 6	-2.98E-04	3.09E-04	9.99E-04	Not detected
	Feb. 6 – Feb. 24	-2.77E-05	1.11E-04	3.11E-04	Not detected
	Feb. 24 – Mar. 8	-2.17E-05	1.30E-04	3.77E-04	Not detected
	Mar. 8 – Mar. 27	-1.67E-05	1.00E-04	2.91E-04	Not detected
	Mar. 27 – Apr. 11	3.96E-05	1.12E-04	2.79E-04	Not detected
	Apr. 11 – Apr. 28	4.79E-12	8.04E-05	2.41E-04	Not detected
	Apr. 28 – May 17	-4.40E-05	1.28E-04	3.60E-04	Not detected
	May 17 – May 31	-1.38E-04	2.27E-04	6.74E-04	Not detected
	May 31 – June 23	-8.25E-05	1.10E-04	3.51E-04	Not detected
	June 23 – July 7	-2.82E-04	3.40E-04	1.14E-03	Not detected
	July 7 – July 21	-8.59E-05	2.99E-04	8.62E-04	Not detected
	July 21 – Aug. 4	-2.37E-04	2.79E-04	8.62E-04	Not detected
	Aug. 4 – Aug. 18	-1.91E-04	3.03E-04	9.61E-04	Not detected
	Aug. 18 - Sep. 15	-8.45E-05	1.06E-04	3.31E-04	Not detected
	Sep. 15 – Oct. 2	-1.11E-04	3.68E-04	1.01E-03	Not detected
	Oct. 2 – Oct. 18	2.53E-04	2.06E-04	2.65E-04	Not detected
	Oct. 18 – Nov. 3	-1.34E-04	1.27E-04	4.48E-04	Not detected
	Nov. 3 – Nov. 29	7.09E-05	1.25E-04	2.83E-04	Not detected
	Nov. 29 – Dec. 19	0.00E+00	1.38E-04	3.87E-04	Not detected
	Dec. 19 – Jan. 8	-1.43E-04	2.26E-04	7.18E-04	Not detected

Table 3-13: Specific activity of ^{241}Am in the filter samples collected from Near Field Station

Radionuclides	Sample Date 2017	Activity Bq/g	Unc. (2σ) Bq/g	MDC Bq/g	Status
^{241}Am	Jan. 6 – Feb. 6	-3.14E-05	2.73E-04	7.38E-04	Not detected
	Feb. 6 – Feb. 24	8.92E-05	3.52E-04	8.64E-04	Not detected
	Feb. 24 – Mar. 8	2.54E-04	2.61E-04	5.57E-04	Not detected
	Mar. 8 – Mar. 27	2.10E-04	1.80E-04	3.68E-04	Not detected
	Mar. 27 – Apr. 11	3.16E-05	2.75E-04	7.08E-04	Not detected
	Apr. 11 – Apr. 28	4.97E-04	2.59E-04	3.50E-04	Detected
	Apr. 28 – May 17	8.71E-05	1.85E-04	4.37E-04	Not detected
	May 17 – May 31	5.51E-05	2.59E-04	6.47E-04	Not detected
	May 31 – Jun 23	1.49E-04	1.99E-04	4.39E-04	Not detected
	June 23 – July 7	4.22E-04	2.33E-04	3.30E-04	Detected
	July 7 – July 21	4.87E-04	3.64E-04	6.54E-04	Not detected
	July 21 – Aug. 4	2.09E-04	3.43E-04	7.82E-04	Not detected
	Aug. 4 – Aug. 18	6.94E-04	3.89E-04	4.29E-04	Detected
	Aug. 18 - Sep. 15	1.15E-04	1.64E-04	3.68E-04	Not detected
	Sep. 15 – Oct. 2	5.50E-04	3.24E-04	4.40E-04	Detected
	Oct. 2 – Oct. 18	2.34E-04	4.28E-04	9.95E-04	Not detected
	Oct. 18 – Nov. 3	1.44E-04	2.50E-04	5.70E-04	Not detected
	Nov. 3 – Nov. 29	3.77E-04	1.98E-04	1.74E-04	Detected
	Nov. 29 – Dec. 19	3.46E-04	2.07E-04	3.22E-04	Detected
	Dec. 19 – Jan. 8	5.15E-04	3.92E-04	6.60E-04	Not detected

Table 3-14: Specific activity of $^{239+240}Pu$ in the filter samples collected from Near Field Station

Radionuclides	Sample Date 2017	Activity Bq/g	Unc. (2σ) Bq/g	MDC Bq/g	Status
$^{239+240}Pu$	Jan. 6 – Feb. 6	5.39E-05	2.85E-04	7.58E-04	Not detected
	Feb. 6 – Feb. 24	3.01E-04	2.78E-04	5.33E-04	Not detected
	Feb. 24 – Mar. 8	4.91E-04	2.72E-04	3.85E-04	Detected
	Mar. 8 – Mar. 27	3.61E-04	2.00E-04	3.35E-04	Detected
	Mar. 27 – Apr. 11	1.05E-03	4.05E-04	5.86E-04	Detected
	Apr. 11 – Apr. 28	1.47E-04	1.71E-04	3.47E-04	Not detected
	Apr. 28 – May 17	3.40E-04	2.21E-04	3.60E-04	Not detected
	May 17 – May 31	4.26E-04	2.89E-04	4.82E-04	Not detected
	May 31 – June 23	2.52E-04	1.59E-04	1.95E-04	Detected
	June 23 – July 7	4.29E-04	2.56E-04	3.99E-04	Detected
	July 7 – July 21	1.33E-04	3.44E-04	8.31E-04	Not detected
	July 21 – Aug. 4	4.17E-04	3.18E-04	5.36E-04	Not detected
	Aug. 4 – Aug. 18	1.56E-04	3.44E-04	8.20E-04	Not detected
	Aug. 18 - Sep. 15	3.41E-04	1.97E-04	3.12E-04	Detected

Table 3-14: Specific activity of $^{239+240}$Pu in the filter samples collected from Near Field Station (continued)

Radionuclides	Sample Date 2017	Activity Bq/g	Unc. (2σ) Bq/g	MDC Bq/g	Status
	Sep. 15 – Oct. 2	0.00E+00	3.12E-04	8.46E-04	Not detected
	Oct. 2 – Oct. 18	1.17E-04	2.88E-04	7.05E-04	Not detected
	Oct. 18 – Nov. 3	7.52E-05	1.67E-04	3.97E-04	Not detected
	Nov. 3 – Nov. 29	1.41E-04	1.64E-04	3.32E-04	Not detected
	Nov. 29 – Dec. 19	3.13E-04	2.48E-04	4.55E-04	Not detected
	Dec. 19 – Jan. 8	2.26E-04	2.10E-04	4.00E-04	Not detected

Table 3-15: Specific activity of ^{238}Pu in the filter samples collected from Near Field Station

Radionuclides	Sample Date 2017	Activity Bq/g	Unc. (2σ) Bq/g	MDC Bq/g	Status
^{238}Pu	Jan. 6 – Feb. 6	-3.77E-04	4.96E-04	1.47E-03	Not detected
	Feb. 6 – Feb. 24	-6.71E-05	2.69E-04	7.54E-04	Not detected
	Feb. 24 – Mar. 8	-8.19E-05	1.45E-04	4.75E-04	Not detected
	Mar. 8 – Mar. 27	1.58E-05	7.02E-05	1.89E-04	Not detected
	Mar. 27 – Apr. 11	9.57E-05	1.52E-04	3.37E-04	Not detected
	Apr. 11 – Apr. 28	-2.21E-04	1.91E-04	6.25E-04	Not detected
	Apr. 28 – May 17	-9.07E-05	1.82E-04	5.33E-04	Not detected
	May 17 – May 31	-6.09E-05	2.59E-04	7.16E-04	Not detected
	May 31 – June 23	1.89E-04	1.34E-04	1.55E-04	Detected
	June 23 – July 7	-1.76E-04	1.83E-04	5.92E-04	Not detected
	July 7 – July 21	-1.63E-04	1.83E-04	6.48E-04	Not detected
	July 21 – Aug. 4	-3.15E-04	2.76E-04	9.28E-04	Not detected
	Aug. 4 – Aug. 18	0.00E+00	3.31E-04	9.10E-04	Not detected
	Aug. 18 - Sep. 15	0.00E+00	1.14E-04	3.12E-04	Not detected
	Sep. 15 – Oct. 2	-1.80E-04	3.59E-04	1.06E-03	Not detected
	Oct. 2 – Oct. 18	-1.17E-04	2.88E-04	9.33E-04	Not detected
	Oct. 18 – Nov. 3	-1.76E-04	1.82E-04	5.89E-04	Not detected
	Nov. 3 – Nov. 29	-2.36E-04	1.78E-04	5.98E-04	Not detected
	Nov. 29 – Dec. 19	7.84E-05	1.57E-04	3.69E-04	Not detected
	Dec. 19 – Jan. 8	-1.26E-04	1.96E-04	5.93E-04	Not detected

Table 3-16: Specific activity of ^{241}Am in the filter samples collected from Cactus Flats Station

Radionuclides	Sample Date 2017	Activity Bq/g	Unc. (2σ) Bq/g	MDC Bq/g	Status
^{241}Am	Jan. 6 – Feb. 6	1.62E-04	1.62E-04	3.21E-04	Not detected
	Feb. 6 – Feb. 24	2.07E-04	3.13E-04	7.08E-04	Not detected
	Feb. 24 – Mar. 8	1.81E-04	2.13E-04	4.55E-04	Not detected
	Mar. 8 – Mar. 27	3.52E-04	1.53E-04	1.62E-04	Detected
	Mar. 27 – Apr. 11	4.20E-04	2.04E-04	2.41E-04	Detected
	Apr. 11 – Apr. 28	3.92E-04	1.68E-04	1.46E-04	Detected
	Apr. 28 – May 17	1.78E-04	1.25E-04	2.24E-04	Not detected
	May 17 – May 31	1.29E-04	1.82E-04	4.03E-04	Not detected
	May 31 – June 23	2.40E-04	1.68E-04	3.01E-04	Not detected
	June 23 – July 7	2.31E-04	1.65E-04	2.71E-04	Not detected
	July 7 – July 21	1.05E-04	3.65E-04	8.95E-04	Not detected
	July 21 – Aug. 4	-2.79E-05	3.48E-04	8.93E-04	Not detected
	Aug. 4 – Aug. 18	5.64E-04	3.80E-04	6.56E-04	Not detected
	Aug. 18 - Sep. 15	1.37E-04	1.26E-04	2.55E-04	Not detected
	Sep. 15 – Oct. 2	-1.21E-04	2.11E-04	6.19E-04	Not detected
	Oct. 2 – Oct. 18	3.78E-04	2.34E-04	3.56E-04	Detected
	Oct. 18 – Nov. 3	2.67E-04	2.30E-04	4.59E-04	Not detected
	Nov. 3 – Nov. 29	6.76E-04	4.58E-04	7.67E-04	Not detected
	Nov. 29 – Dec. 19	1.43E-04	1.83E-04	4.00E-04	Not detected
	Dec. 19 – Jan. 8	2.61E-04	1.97E-04	3.45E-04	Not detected

Table 3-17: Specific activity of $^{239+240}Pu$ in the filter samples collected from Cactus Flats Station

Radionuclides	Sample Date 2017	Activity Bq/g	Unc. (2σ) Bq/g	MDC Bq/g	Status
$^{239+240}Pu$	Jan. 6 – Feb. 6	3.16E-04	2.24E-04	3.45E-04	Not detected
	Feb. 6 – Feb. 24	9.20E-04	5.51E-04	9.12E-04	Detected
	Feb. 24 – Mar. 8	4.36E-04	2.61E-04	3.85E-04	Detected
	Mar. 8 – Mar. 27	4.87E-04	2.15E-04	2.76E-04	Detected
	Mar. 27 – Apr. 11	5.65E-04	2.89E-04	4.53E-04	Detected
	Apr. 11 – Apr. 28	1.65E-04	1.61E-04	3.19E-04	Not detected
	Apr. 28 – May 17	5.48E-04	1.91E-04	1.84E-04	Detected
	May 17 – May 31	4.55E-04	2.62E-04	3.78E-04	Detected
	May 31 – June 23	3.35E-04	1.79E-04	2.24E-04	Detected
	June 23 – July 7	2.01E-05	2.24E-04	5.69E-04	Not detected
	July 7 – July 21	2.49E-04	3.34E-04	7.24E-04	Not detected
	July 21 – Aug. 4	3.45E-04	2.71E-04	5.00E-04	Not detected
	Aug. 4 – Aug. 18	-2.82E-04	3.87E-04	1.13E-03	Not detected
	Aug. 18 - Sep. 15	5.56E-05	1.27E-04	3.04E-04	Not detected

Table 3-17: Specific activity of $^{239+240}$Pu in the filter samples collected from Cactus Flats Station (continued)

Radionuclides	Sample Date 2017	Activity Bq/g	Unc. (2σ) Bq/g	MDC Bq/g	Status
$^{239+240}$Pu	Sep. 15 – Oct. 2	6.19E-04	2.77E-04	3.36E-04	Detected
	Oct. 2 – Oct. 18	-3.58E-05	2.59E-04	7.21E-04	Not detected
	Oct. 18 – Nov. 3	4.17E-05	2.36E-04	5.88E-04	Not detected
	Nov. 3 – Nov. 29	1.62E-04	4.20E-04	1.02E-03	Not detected
	Nov. 29 – Dec. 19	1.84E-04	1.48E-04	2.66E-04	Not detected
	Dec. 19 – Jan. 8	-3.96E-05	2.10E-04	5.59E-04	Not detected

Table 3-18: Specific activity of ^{238}Pu in the filter samples collected from Cactus Flats Station

Radionuclides	Sample Date 2017	Activity Bq/g	Unc. (2σ) Bq/g	MDC Bq/g	Status
^{238}Pu	Jan. 6 – Feb. 6	5.75E-05	1.41E-04	3.45E-04	Not detected
	Feb. 6 – Feb. 24	-4.84E-05	5.04E-04	1.33E-03	Not detected
	Feb. 24 – Mar. 8	8.20E-05	2.12E-04	5.14E-04	Not detected
	Mar. 8 – Mar. 27	-1.04E-04	1.30E-04	4.08E-04	Not detected
	Mar. 27 – Apr. 11	-2.03E-04	1.51E-04	5.30E-04	Not detected
	Apr. 11 – Apr. 28	9.16E-05	1.22E-04	2.59E-04	Not detected
	Apr. 28 – May. 17	1.30E-05	9.41E-05	2.46E-04	Not detected
	May. 17 – May 31	2.68E-05	1.93E-04	5.03E-04	Not detected
	May 31 – Jun 23	0.00E+00	1.06E-04	2.95E-04	Not detected
	Jun 23 – Jul. 7	-3.43E-04	2.06E-04	6.63E-04	Not detected
	Jul. 7 – Jul. 21	-3.31E-04	2.90E-04	9.75E-04	Not detected
	Jul.21 – Aug. 4	0.00E+00	1.41E-04	4.05E-04	Not detected
	Aug. 4 – Aug. 18	-4.85E-04	4.45E-04	1.32E-03	Not detected
	Aug. 18 - Sep. 15	-2.23E-05	5.45E-05	1.76E-04	Not detected
	Sep. 15 – Oct. 2	-1.90E-04	1.91E-04	6.05E-04	Not detected
	Oct. 2 – Oct. 18	-7.18E-05	2.48E-04	7.21E-04	Not detected
	Oct. 18 – Nov. 3	-2.30E-04	2.33E-04	6.86E-04	Not detected
	Nov. 3 – Nov. 29	-5.38E-04	4.08E-04	1.37E-03	Not detected
	Nov. 29 – Dec. 19	3.35E-05	1.06E-04	2.66E-04	Not detected
	Dec. 19 – Jan. 8	-3.17E-04	2.06E-04	6.52E-04	Not detected

Table 3-19: Activity concentrations of uranium isotopes (^{234}U, ^{235}U and ^{238}U) in the filter samples collected from Onsite station

Radionuclides	Sample Date 2017	Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
^{234}U	Jan. 6 – Feb. 6	7.45E-07	8.79E-08	1.17E-08	Detected
	Feb. 6 – Feb. 24	1.49E-06	1.84E-07	1.91E-08	Detected
	Feb. 24 – Mar. 8	2.82E-06	3.27E-07	3.54E-08	Detected
	Mar. 8 – Mar. 27	2.21E-06	2.60E-07	2.65E-08	Detected
	Mar. 27 – Apr. 11	2.37E-06	2.80E-07	3.17E-08	Detected
	Apr. 11 – Apr. 28	3.14E-06	3.83E-07	5.37E-08	Detected
	Apr. 28 – May 17	2.34E-06	2.75E-07	2.11E-08	Detected
	May 17 – May 31	2.07E-06	2.56E-07	3.17E-08	Detected
	May 31 – June 23	2.31E-06	2.63E-07	2.30E-08	Detected
	June 23 – July 7	4.40E-06	5.28E-07	5.49E-08	Detected
	July 7 – July 21	1.74E-06	2.07E-07	2.95E-08	Detected
	July 21 – Aug. 4	1.77E-06	2.19E-07	3.83E-08	Detected
	Aug. 4 – Aug. 18	1.48E-06	1.80E-07	3.05E-08	Detected
	Aug. 18 - Sep. 15	9.68E-07	1.13E-07	9.04E-09	Detected
	Sep. 15 – Oct. 2	1.23E-06	1.48E-07	1.73E-08	Detected
	Oct. 2 – Oct. 18	1.50E-06	1.82E-07	3.02E-08	Detected
	Oct. 18 – Nov. 3	1.92E-06	2.30E-07	2.92E-08	Detected
	Nov. 3 – Nov. 29	1.70E-06	2.10E-07	3.64E-08	Detected
	Nov. 29 – Dec. 19	1.92E-06	2.30E-07	2.20E-08	Detected
	Dec. 19 – Jan. 8	1.48E-06	1.78E-07	2.23E-08	Detected
^{235}U	Jan. 6 – Feb. 6	3.37E-08	9.78E-09	8.62E-09	Detected
	Feb. 6 – Feb. 24	6.84E-08	2.27E-08	2.10E-08	Detected
	Feb. 24 – Mar. 8	1.14E-07	3.15E-08	2.62E-08	Detected
	Mar. 8 – Mar. 27	9.60E-08	2.55E-08	1.60E-08	Detected
	Mar. 27 – Apr. 11	1.18E-07	3.11E-08	2.43E-08	Detected
	Apr. 11 – Apr. 28	1.46E-07	4.26E-08	3.01E-08	Detected
	Apr. 28 – May 17	7.49E-08	2.39E-08	2.61E-08	Detected
	May 17 – May 31	1.11E-07	3.28E-08	2.33E-08	Detected
	May 31 – June 23	1.03E-07	2.41E-08	1.29E-08	Detected
	June 23 – July 7	2.18E-07	6.83E-08	7.31E-08	Detected
	July 7 – July 21	7.85E-08	2.31E-08	1.65E-08	Detected
	July 21 – Aug. 4	8.95E-08	2.81E-08	2.15E-08	Detected
	Aug. 4 – Aug. 18	8.71E-08	2.59E-08	2.34E-08	Detected
	Aug. 18 - Sep. 15	4.98E-08	1.24E-08	8.33E-09	Detected
	Sep. 15 – Oct. 2	6.03E-08	1.89E-08	1.80E-08	Detected
	Oct. 2 – Oct. 18	6.96E-08	2.26E-08	2.37E-08	Detected

Table 3-19: Activity concentrations of uranium isotopes (^{234}U, ^{235}U and ^{238}U) in the filter samples collected from Onsite station (continued)

Radionuclides	Sample Date 2017	Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
^{235}U	Oct. 18 – Nov. 3	8.65E-08	2.55E-08	2.07E-08	Detected
	Nov. 3 – Nov. 29	7.56E-08	2.48E-08	2.63E-08	Detected
	Nov. 29 – Dec. 19	1.05E-07	2.70E-08	1.62E-08	Detected
	Dec. 19 – Jan. 8	7.35E-08	2.25E-08	2.45E-08	Detected
^{238}U	Jan. 6 – Feb. 6	7.56E-07	8.90E-08	1.80E-08	Detected
	Feb. 6 – Feb. 24	1.41E-06	1.75E-07	3.06E-08	Detected
	Feb. 24 – Mar. 8	2.46E-06	2.88E-07	5.47E-08	Detected
	Mar. 8 – Mar. 27	2.11E-06	2.49E-07	2.53E-08	Detected
	Mar. 27 – Apr. 11	2.20E-06	2.61E-07	4.06E-08	Detected
	Apr. 11 – Apr. 28	3.05E-06	3.75E-07	5.53E-08	Detected
	Apr. 28 – May 17	2.20E-06	2.61E-07	2.25E-08	Detected
	May 17 – May 31	1.90E-06	2.39E-07	4.29E-08	Detected
	May 31 – June 23	2.21E-06	2.53E-07	2.36E-08	Detected
	June 23 – July 7	4.30E-06	5.18E-07	9.36E-08	Detected
	July 7 – July 21	1.73E-06	2.06E-07	3.04E-08	Detected
	July 21 – Aug. 4	1.90E-06	2.34E-07	3.95E-08	Detected
	Aug. 4 – Aug. 18	1.46E-06	1.78E-07	3.91E-08	Detected
	Aug. 18 - Sep. 15	1.03E-06	1.19E-07	1.26E-08	Detected
	Sep. 15 – Oct. 2	1.23E-06	1.48E-07	2.67E-08	Detected
	Oct. 2 – Oct. 18	1.52E-06	1.85E-07	4.33E-08	Detected
	Oct. 18 – Nov. 3	1.90E-06	2.29E-07	3.63E-08	Detected
	Nov. 3 – Nov. 29	1.66E-06	2.04E-07	3.53E-08	Detected
	Nov. 29 – Dec. 19	1.82E-06	2.18E-07	2.56E-08	Detected
	Dec. 19 – Jan. 8	1.50E-06	1.80E-07	2.51E-08	Detected

Table 3-20: Activity concentrations of uranium isotopes (^{234}U, ^{235}U and ^{238}U) in the filter samples collected from Near Field Station

Radionuclides	Sample Date 2017	Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
^{234}U	Jan. 6 – Feb. 6	8.35E-07	1.00E-07	1.20E-08	Detected
	Feb. 6 – Feb. 24	1.30E-06	1.56E-07	2.15E-08	Detected
	Feb. 24 – Mar. 8	2.82E-06	3.27E-07	2.82E-08	Detected
	Mar. 8 – Mar. 27	1.95E-06	2.30E-07	2.18E-08	Detected
	Mar. 27 – Apr. 11	2.54E-06	2.96E-07	2.95E-08	Detected
	Apr. 11 – Apr. 28	2.18E-06	2.62E-07	2.22E-08	Detected
	Apr. 28 – May 17	1.94E-06	2.30E-07	2.58E-08	Detected
	May 17 – May 31	1.92E-06	2.41E-07	4.17E-08	Detected
	May 31 – June 23	1.79E-06	2.06E-07	1.95E-08	Detected
	June 23 – July 7	2.11E-06	2.54E-07	3.35E-08	Detected
	July 7 – July 21	1.73E-06	2.07E-07	2.47E-08	Detected
	July 21 – Aug. 4	1.79E-06	2.23E-07	3.02E-08	Detected
	Aug. 4 – Aug. 18	1.48E-06	1.84E-07	3.30E-08	Detected
	Aug. 18 - Sep. 15	8.44E-07	1.00E-07	8.65E-09	Detected
	Sep. 15 – Oct. 2	1.35E-06	1.63E-07	2.47E-08	Detected
	Oct. 2 – Oct. 18	1.89E-06	2.32E-07	3.56E-08	Detected
	Oct. 18 – Nov. 3	2.09E-06	2.53E-07	2.92E-08	Detected
	Nov. 3 – Nov. 29	1.69E-06	2.08E-07	2.26E-08	Detected
	Nov. 29 – Dec. 19	1.93E-06	2.28E-07	2.58E-08	Detected
	Dec. 19 – Jan. 8	1.62E-06	1.91E-07	1.86E-08	Detected
^{235}U	Jan. 6 – Feb. 6	3.75E-08	1.15E-08	9.78E-09	Detected
	Feb. 6 – Feb. 24	7.20E-08	2.02E-08	1.36E-08	Detected
	Feb. 24 – Mar. 8	1.31E-07	3.34E-08	2.31E-08	Detected
	Mar. 8 – Mar. 27	9.59E-08	2.48E-08	1.90E-08	Detected
	Mar. 27 – Apr. 11	1.27E-07	3.16E-08	2.09E-08	Detected
	Apr. 11 – Apr. 28	9.88E-08	2.80E-08	1.89E-08	Detected
	Apr. 28 – May 17	1.17E-07	2.84E-08	1.83E-08	Detected
	May 17 – May 31	7.26E-08	2.96E-08	4.05E-08	Detected
	May 31 – June 23	9.53E-08	2.26E-08	1.23E-08	Detected
	June 23 – July 7	1.17E-07	3.10E-08	1.56E-08	Detected
	July 7 – July 21	8.01E-08	2.55E-08	2.63E-08	Detected
	July 21 – Aug. 4	4.25E-08	2.17E-08	3.22E-08	Detected
	Aug. 4 – Aug. 18	9.33E-08	2.80E-08	2.35E-08	Detected
	Aug. 18 - Sep. 15	3.60E-08	1.05E-08	7.34E-09	Detected
	Sep. 15 – Oct. 2	6.23E-08	1.94E-08	1.50E-08	Detected
	Oct. 2 – Oct. 18	7.85E-08	2.77E-08	2.97E-08	Detected
	Oct. 18 – Nov. 3	1.04E-07	3.01E-08	2.38E-08	Detected

Table 3-20: Activity concentrations of uranium isotopes (^{234}U, ^{235}U and ^{238}U) in the filter samples collected from Near Field Station (continued)

Radionuclides	Sample Date 2017	Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
^{235}U	Nov. 3 – Nov. 29	1.07E-07	2.90E-08	2.35E-08	Detected
	Nov. 29 – Dec. 19	8.97E-08	2.42E-08	1.55E-08	Detected
	Dec. 19 – Jan. 8	7.56E-08	2.13E-08	1.81E-08	Detected
^{238}U	Jan. 6 – Feb. 6	7.71E-07	9.34E-08	1.58E-08	Detected
	Feb. 6 – Feb. 24	1.21E-06	1.47E-07	2.05E-08	Detected
	Feb. 24 – Mar. 8	2.52E-06	2.95E-07	3.72E-08	Detected
	Mar. 8 – Mar. 27	1.80E-06	2.14E-07	1.94E-08	Detected
	Mar. 27 – Apr. 11	2.26E-06	2.66E-07	3.66E-08	Detected
	Apr. 11 – Apr. 28	2.05E-06	2.48E-07	3.89E-08	Detected
	Apr. 28 – May 17	1.86E-06	2.22E-07	2.67E-08	Detected
	May 17 – May 31	1.94E-06	2.43E-07	5.90E-08	Detected
	May 31 – June 23	1.81E-06	2.09E-07	2.53E-08	Detected
	Jun 23 – July 7	2.05E-06	2.46E-07	3.82E-08	Detected
	July 7 – July 21	1.67E-06	2.02E-07	3.92E-08	Detected
	July 21 – Aug. 4	1.70E-06	2.12E-07	4.79E-08	Detected
	Aug. 4 – Aug. 18	1.49E-06	1.85E-07	4.10E-08	Detected
	Aug. 18 - Sep. 15	7.80E-07	9.32E-08	1.21E-08	Detected
	Sep. 15 – Oct. 2	1.32E-06	1.59E-07	2.56E-08	Detected
	Oct. 2 – Oct. 18	1.77E-06	2.20E-07	4.96E-08	Detected
	Oct. 18 – Nov. 3	2.03E-06	2.48E-07	3.47E-08	Detected
	Nov. 3 – Nov. 29	1.63E-06	2.01E-07	3.47E-08	Detected
	Nov. 29 – Dec. 19	1.90E-06	2.25E-07	3.20E-08	Detected
	Dec. 19 – Jan. 8	1.59E-06	1.87E-07	1.96E-08	Detected

Table 3-21: Activity concentrations of uranium isotopes (^{234}U, ^{235}U and ^{238}U) in the filter samples collected from Cactus Flats Station

Radionuclides	Sample Date 2017	Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
^{234}U	Jan. 6 – Feb. 6	8.12E-07	9.60E-08	9.53E-09	Detected
	Feb. 6 – Feb. 24	1.81E-06	2.12E-07	1.82E-08	Detected
	Feb. 24 – Mar. 8	2.64E-06	3.09E-07	3.46E-08	Detected
	Mar. 8 – Mar. 27	1.80E-06	2.10E-07	2.00E-08	Detected
	Mar. 27 – Apr. 11	2.57E-07	3.06E-07	2.77E-08	Detected
	Apr. 11 – Apr. 28	2.10E-08	2.92E-07	2.40E-08	Not detected
	Apr. 28 – May 17	2.62E-06	3.02E-07	1.39E-08	Detected
	May 17 – May 31	2.38E-06	2.84E-07	3.48E-08	Detected
	May 31 – June 23	2.20E-06	2.54E-07	2.16E-08	Detected
	June 23 – July 7	2.64E-06	3.11E-07	3.36E-08	Detected
	July 7 – July 21	1.71E-06	2.02E-07	2.03E-08	Detected
	July 21 – Aug. 4	2.04E-06	2.56E-07	3.15E-08	Detected
	Aug. 4 – Aug. 18	1.53E-06	1.85E-07	2.45E-08	Detected
	Aug. 18 - Sep. 15	1.18E-06	1.35E-07	8.30E-09	Detected
	Sep. 15 – Oct. 2	1.91E-06	2.22E-07	2.48E-08	Detected
	Oct. 2 – Oct. 18	1.81E-06	2.19E-07	2.95E-08	Detected
	Oct. 18 – Nov. 3	2.33E-06	2.76E-07	2.24E-08	Detected
	Nov. 3 – Nov. 29	2.04E-06	2.58E-07	4.58E-08	Detected
	Nov. 29 – Dec. 19	2.06E-06	2.43E-07	3.05E-08	Detected
	Dec. 19 – Jan. 8	2.04E-06	2.39E-07	2.24E-08	Detected
^{235}U	Jan. 6 – Feb. 6	3.74E-08	1.05E-08	7.03E-09	Detected
	Feb. 6 – Feb. 24	8.37E-08	2.24E-08	1.43E-08	Detected
	Feb. 24 – Mar. 8	1.33E-07	3.40E-08	1.62E-08	Detected
	Mar. 8 – Mar. 27	7.34E-08	2.06E-08	1.74E-08	Detected
	Mar. 27 – Apr. 11	1.26E-07	3.26E-08	2.26E-08	Detected
	Apr. 11 – Apr. 28	1.39E-07	3.05E-08	1.70E-08	Detected
	Apr. 28 – May. 17	1.22E-07	2.80E-08	1.13E-08	Detected
	May. 17 – May 31	1.07E-07	3.09E-08	2.67E-08	Detected
	May 31 – Jun 23	8.62E-08	2.30E-08	1.98E-08	Detected
	Jun 23 – Jul. 7	1.56E-07	3.71E-08	2.02E-08	Detected
	Jul. 7 – Jul. 21	7.58E-08	2.30E-08	2.11E-08	Detected
	Jul.21 – Aug. 4	1.01E-07	3.31E-08	3.28E-08	Detected
	Aug. 4 – Aug. 18	7.93E-08	2.39E-08	2.00E-08	Detected
	Aug. 18 - Sep. 15	5.54E-08	1.27E-08	6.53E-09	Detected
	Sep. 15 – Oct. 2	9.70E-08	2.49E-08	1.50E-08	Detected
	Oct. 2 – Oct. 18	8.89E-08	2.56E-08	1.78E-08	Detected
	Oct. 18 – Nov. 3	1.16E-07	3.01E-08	1.17E-08	Detected

Table 3-21: Activity concentrations of uranium isotopes (^{234}U, ^{235}U and ^{238}U) in the filter samples collected from Cactus Flats Station (continued)

Radionuclides	Sample Date 2017	Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
^{235}U	Nov. 3 – Nov. 29	9.00E-08	3.18E-08	2.77E-08	Detected
	Nov. 29 – Dec. 19	8.26E-08	2.46E-08	2.61E-08	Detected
	Dec. 19 – Jan. 8	1.01E-07	2.51E-08	1.14E-08	Detected
^{238}U	Jan. 6 – Feb. 6	7.94E-07	9.39E-08	1.16E-08	Detected
	Feb. 6 – Feb. 24	1.76E-06	2.06E-07	1.52E-08	Detected
	Feb. 24 – Mar. 8	2.54E-06	2.99E-07	3.16E-08	Detected
	Mar. 8 – Mar. 27	1.67E-06	1.95E-07	2.08E-08	Detected
	Mar. 27 – Apr. 11	2.32E-06	2.74E-07	3.29E-08	Detected
	Apr. 11 – Apr. 28	2.35E-06	2.71E-07	2.83E-08	Detected
	Apr. 28 – May 17	2.47E-06	2.87E-07	2.10E-08	Detected
	May 17 – May 31	2.34E-06	2.81E-07	4.56E-08	Detected
	May 31 – June 23	2.14E-06	2.46E-07	2.80E-08	Detected
	June 23 – July 7	2.52E-06	2.98E-07	3.84E-08	Detected
	July 7 – July 21	1.64E-06	1.94E-07	3.11E-08	Detected
	July 21 – Aug. 4	2.01E-06	2.51E-07	4.83E-08	Detected
	Aug. 4 – Aug. 18	1.53E-06	1.85E-07	2.92E-08	Detected
	Aug. 18 - Sep. 15	1.13E-06	1.29E-07	1.08E-08	Detected
	Sep. 15 – Oct. 2	1.85E-06	2.17E-07	3.24E-08	Detected
	Oct. 2 – Oct. 18	1.73E-06	2.09E-07	3.37E-08	Detected
	Oct. 18 – Nov. 3	2.24E-06	2.66E-07	4.29E-08	Detected
	Nov. 3 – Nov. 29	1.94E-06	2.47E-07	4.74E-08	Detected
	Nov. 29 – Dec. 19	1.95E-06	2.31E-07	4.53E-08	Detected
	Dec. 19 – Jan. 8	1.89E-06	2.22E-07	2.97E-08	Detected

Table 3-22: Specific activity of uranium isotopes (^{234}U, ^{235}U and ^{238}U) in the filter samples collected from Onsite Station

Radionuclides	Sample Date 2017	Activity Bq/g	Unc. (2σ) Bq/g	MDC Bq/g	Status
^{234}U	Jan. 6 – Feb. 6	3.96E-02	4.67E-03	6.19E-04	Detected
	Feb. 6 – Feb. 24	3.44E-02	4.25E-03	4.42E-04	Detected
	Feb. 24 – Mar. 8	4.58E-02	5.32E-03	5.75E-04	Detected
	Mar. 8 – Mar. 27	3.08E-02	3.62E-03	3.69E-04	Detected
	Mar. 27 – Apr. 11	3.93E-02	4.63E-03	5.25E-04	Detected
	Apr. 11 – Apr. 28	4.10E-02	5.01E-03	7.02E-04	Detected
	Apr. 28 – May 17	4.02E-02	4.74E-03	3.64E-04	Detected
	May 17 – May 31	5.29E-02	6.54E-03	8.08E-04	Detected
	May 31 – June 23	4.10E-02	4.67E-03	4.07E-04	Detected
	June 23 – July 7	7.95E-02	9.54E-03	9.91E-04	Detected
	July 7 – July 21	5.60E-02	6.67E-03	9.48E-04	Detected
	July 21 – Aug. 4	5.14E-02	6.37E-03	1.11E-03	Detected
	Aug. 4 – Aug. 18	5.76E-02	7.03E-03	1.19E-03	Detected
	Aug. 18 - Sep. 15	3.14E-02	3.67E-03	2.93E-04	Detected
	Sep. 15 – Oct. 2	4.89E-02	5.90E-03	6.88E-04	Detected
	Oct. 2 – Oct. 18	4.55E-02	5.53E-03	9.15E-04	Detected
	Oct. 18 – Nov. 3	4.30E-02	5.15E-03	6.53E-04	Detected
	Nov. 3 – Nov. 29	3.67E-02	4.52E-03	7.85E-04	Detected
	Nov. 29 – Dec. 19	4.62E-02	5.52E-03	5.30E-04	Detected
	Dec. 19 – Jan. 8	5.02E-02	6.04E-03	7.57E-04	Detected
^{235}U	Jan. 6 – Feb. 6	1.79E-03	5.19E-04	4.57E-04	Detected
	Feb. 6 – Feb. 24	1.58E-03	5.25E-04	4.84E-04	Detected
	Feb. 24 – Mar. 8	1.86E-03	5.11E-04	4.25E-04	Detected
	Mar. 8 – Mar. 27	1.34E-03	3.55E-04	2.23E-04	Detected
	Mar. 27 – Apr. 11	1.96E-03	5.15E-04	4.03E-04	Detected
	Apr. 11 – Apr. 28	1.90E-03	5.57E-04	3.94E-04	Detected
	Apr. 28 – May. 17	1.29E-03	4.12E-04	4.49E-04	Detected
	May. 17 – May 31	2.84E-03	8.35E-04	5.95E-04	Detected
	May 31 – Jun 23	1.83E-03	4.27E-04	2.28E-04	Detected
	Jun 23 – Jul. 7	3.93E-03	1.23E-03	1.32E-03	Detected
	Jul. 7 – Jul. 21	2.52E-03	7.41E-04	5.32E-04	Detected
	Jul.21 – Aug. 4	2.60E-03	8.15E-04	6.24E-04	Detected
	Aug. 4 – Aug. 18	3.40E-03	1.01E-03	9.13E-04	Detected
	Aug. 18 - Sep. 15	1.62E-03	4.03E-04	2.70E-04	Detected
	Sep. 15 – Oct. 2	2.39E-03	7.51E-04	7.17E-04	Detected
	Oct. 2 – Oct. 18	2.11E-03	6.85E-04	7.20E-04	Detected

Table 3-22: Specific activity of uranium isotopes (^{234}U, ^{235}U and ^{238}U) in the filter samples collected from Onsite Station (continued)

Radionuclides	Sample Date 2017	Activity Bq/g	Unc. (2σ) Bq/g	MDC Bq/g	Status
^{235}U	Oct. 18 – Nov. 3	1.94E-03	5.70E-04	4.63E-04	Detected
	Nov. 3 – Nov. 29	1.63E-03	5.34E-04	5.66E-04	Detected
	Nov. 29 – Dec. 19	2.53E-03	6.51E-04	3.91E-04	Detected
	Dec. 19 – Jan. 8	2.50E-03	7.65E-04	8.35E-04	Detected
^{238}U	Jan. 6 – Feb. 6	4.01E-02	4.72E-03	9.58E-04	Detected
	Feb. 6 – Feb. 24	3.24E-02	4.04E-03	7.06E-04	Detected
	Feb. 24 – Mar. 8	3.99E-02	4.68E-03	8.88E-04	Detected
	Mar. 8 – Mar. 27	2.94E-02	3.46E-03	3.52E-04	Detected
	Mar. 27 – Apr. 11	3.64E-02	4.32E-03	6.73E-04	Detected
	Apr. 11 – Apr. 28	3.99E-02	4.90E-03	7.23E-04	Detected
	Apr. 28 – May. 17	3.79E-02	4.50E-03	3.88E-04	Detected
	May. 17 – May 31	4.86E-02	6.08E-03	1.09E-03	Detected
	May 31 – Jun 23	3.92E-02	4.49E-03	4.19E-04	Detected
	Jun 23 – Jul. 7	7.76E-02	9.36E-03	1.69E-03	Detected
	Jul. 7 – Jul. 21	5.55E-02	6.61E-03	9.77E-04	Detected
	Jul.21 – Aug. 4	5.51E-02	6.79E-03	1.15E-03	Detected
	Aug. 4 – Aug. 18	5.69E-02	6.96E-03	1.53E-03	Detected
	Aug. 18 - Sep. 15	3.33E-02	3.87E-03	4.09E-04	Detected
	Sep. 15 – Oct. 2	4.89E-02	5.90E-03	1.06E-03	Detected
	Oct. 2 – Oct. 18	4.60E-02	5.60E-03	1.31E-03	Detected
	Oct. 18 – Nov. 3	4.25E-02	5.12E-03	8.12E-04	Detected
	Nov. 3 – Nov. 29	3.57E-02	4.40E-03	7.60E-04	Detected
	Nov. 29 – Dec. 19	4.38E-02	5.25E-03	6.17E-04	Detected
	Dec. 19 – Jan. 8	5.10E-02	6.12E-03	8.54E-04	Detected

Table 3-23: Specific activity of uranium isotopes (^{234}U, ^{235}U and ^{238}U) in the filter samples collected from Near Field Station

Radionuclides	Sample Date 2017	Activity Bq/g	Unc. (2σ) Bq/g	MDC Bq/g	Status
^{234}U	Jan. 6 – Feb. 6	4.30E-02	5.16E-03	6.19E-04	Detected
	Feb. 6 – Feb. 24	4.39E-02	5.29E-03	7.29E-04	Detected
	Feb. 24 – Mar. 8	5.06E-02	5.87E-03	5.06E-04	Detected
	Mar. 8 – Mar. 27	3.73E-02	4.40E-03	4.17E-04	Detected
	Mar. 27 – Apr. 11	5.33E-02	6.22E-03	6.20E-04	Detected
	Apr. 11 – Apr. 28	5.18E-02	6.22E-03	5.27E-04	Detected
	Apr. 28 – May 17	4.93E-02	5.85E-03	6.57E-04	Detected
	May 17 – May 31	5.53E-02	6.93E-03	1.20E-03	Detected
	May 31 – June 23	4.19E-02	4.83E-03	4.57E-04	Detected
	June 23 – July 7	4.73E-02	5.67E-03	7.48E-04	Detected
	July 7 – July 21	6.18E-02	7.41E-03	8.81E-04	Detected
	July 21 – Aug. 4	5.95E-02	7.38E-03	1.00E-03	Detected
	Aug. 4 – Aug. 18	6.53E-02	8.12E-03	1.46E-03	Detected
	Aug. 18 - Sep. 15	3.34E-02	3.97E-03	3.43E-04	Detected
	Sep. 15 – Oct. 2	5.67E-02	6.85E-03	1.04E-03	Detected
	Oct. 2 – Oct. 18	6.39E-02	7.84E-03	1.21E-03	Detected
	Oct. 18 – Nov. 3	5.08E-02	6.16E-03	7.09E-04	Detected
	Nov. 3 – Nov. 29	4.35E-02	5.33E-03	5.80E-04	Detected
	Nov. 29 – Dec. 19	4.80E-02	5.68E-03	6.41E-04	Detected
	Dec. 19 – Jan. 8	4.62E-02	5.45E-03	5.31E-04	Detected
^{235}U	Jan. 6 – Feb. 6	1.93E-03	5.92E-04	5.04E-04	Detected
	Feb. 6 – Feb. 24	2.44E-03	6.83E-04	4.60E-04	Detected
	Feb. 24 – Mar. 8	2.36E-03	6.00E-04	4.14E-04	Detected
	Mar. 8 – Mar. 27	1.84E-03	4.74E-04	3.64E-04	Detected
	Mar. 27 – Apr. 11	2.67E-03	6.65E-04	4.40E-04	Detected
	Apr. 11 – Apr. 28	2.35E-03	6.64E-04	4.48E-04	Detected
	Apr. 28 – May 17	2.97E-03	7.24E-04	4.66E-04	Detected
	May 17 – May 31	2.09E-03	8.53E-04	1.17E-03	Detected
	May 31 – June 23	2.24E-03	5.30E-04	2.88E-04	Detected
	June 23 – July 7	2.61E-03	6.93E-04	3.49E-04	Detected
	July 7 – July 21	2.86E-03	9.12E-04	9.42E-04	Detected
	July 21 – Aug. 4	1.41E-03	7.20E-04	1.07E-03	Detected
	Aug. 4 – Aug. 18	4.12E-03	1.24E-03	1.04E-03	Detected
	Aug. 18 - Sep. 15	1.43E-03	4.16E-04	2.91E-04	Detected
	Sep. 15 – Oct. 2	2.62E-03	8.19E-04	6.31E-04	Detected
	Oct. 2 – Oct. 18	2.66E-03	9.40E-04	1.01E-03	Detected

Table 3-23: Specific activity of uranium isotopes (^{234}U, ^{235}U and ^{238}U) in the filter samples collected from Near Field Station (continued)

Radionuclides	Sample Date 2017	Activity Bq/g	Unc. (2σ) Bq/g	MDC Bq/g	Status
^{235}U	Oct. 18 – Nov. 3	2.54E-03	7.33E-04	5.79E-04	Detected
	Nov. 3 – Nov. 29	2.74E-03	7.45E-04	6.04E-04	Detected
	Nov. 29 – Dec. 19	2.23E-03	6.01E-04	3.87E-04	Detected
	Dec. 19 – Jan. 8	2.16E-03	6.07E-04	5.17E-04	Detected
^{238}U	Jan. 6 – Feb. 6	3.98E-02	4.82E-03	8.14E-04	Detected
	Feb. 6 – Feb. 24	4.09E-02	4.97E-03	6.92E-04	Detected
	Feb. 24 – Mar. 8	4.53E-02	5.30E-03	6.68E-04	Detected
	Mar. 8 – Mar. 27	3.45E-02	4.09E-03	3.72E-04	Detected
	Mar. 27 – Apr. 11	4.74E-02	5.60E-03	7.70E-04	Detected
	Apr. 11 – Apr. 28	4.87E-02	5.88E-03	9.23E-04	Detected
	Apr. 28 – May 17	4.73E-02	5.65E-03	6.80E-04	Detected
	May 17 – May 31	5.58E-02	7.01E-03	1.70E-03	Detected
	May 31 – June 23	4.25E-02	4.90E-03	5.93E-04	Detected
	June 23 – July 7	4.58E-02	5.50E-03	8.55E-04	Detected
	July 7 – July 21	5.98E-02	7.21E-03	1.40E-03	Detected
	July 21 – Aug. 4	5.64E-02	7.04E-03	1.59E-03	Detected
	Aug. 4 – Aug. 18	6.57E-02	8.16E-03	1.81E-03	Detected
	Aug. 18 - Sep. 15	3.09E-02	3.69E-03	4.80E-04	Detected
	Sep. 15 – Oct. 2	5.54E-02	6.71E-03	1.08E-03	Detected
	Oct. 2 – Oct. 18	6.01E-02	7.46E-03	1.68E-03	Detected
	Oct. 18 – Nov. 3	4.94E-02	6.03E-03	8.45E-04	Detected
	Nov. 3 – Nov. 29	4.19E-02	5.15E-03	8.92E-04	Detected
	Nov. 29 – Dec. 19	4.73E-02	5.61E-03	7.96E-04	Detected
	Dec. 19 – Jan. 8	4.54E-02	5.35E-03	5.61E-04	Detected

Table 3-24: Specific activity of uranium isotopes (^{234}U, ^{235}U and ^{238}U) in the filter samples collected from Cactus Flats Station

Radionuclides	Sample Date 2017	Activity Bq/g	Unc. (2σ) Bq/g	MDC Bq/g	Status
^{234}U	Jan. 6 – Feb. 6	4.13E-02	4.88E-03	4.85E-04	Detected
	Feb. 6 – Feb. 24	4.51E-02	5.28E-03	4.52E-04	Detected
	Feb. 24 – Mar. 8	4.61E-02	5.40E-03	6.04E-04	Detected
	Mar. 8 – Mar. 27	3.04E-02	3.55E-03	3.38E-04	Detected
	Mar. 27 – Apr. 11	4.93E-03	5.88E-03	5.32E-04	Detected
	Apr. 11 – Apr. 28	3.89E-04	5.41E-03	4.44E-04	Not detected
	Apr. 28 – May 17	3.86E-02	4.46E-03	2.05E-04	Detected
	May 17 – May 31	5.16E-02	6.17E-03	7.55E-04	Detected
	May 31 – June 23	4.31E-02	4.97E-03	4.22E-04	Detected
	June 23 – July 7	4.74E-02	5.58E-03	6.02E-04	Detected
	July 7 – July 21	6.04E-02	7.12E-03	7.15E-04	Detected
	July 21 – Aug. 4	5.33E-02	6.67E-03	8.21E-04	Detected
	Aug. 4 – Aug. 18	5.31E-02	6.44E-03	8.53E-04	Detected
	Aug. 18 - Sep. 15	3.08E-02	3.52E-03	2.17E-04	Detected
	Sep. 15 – Oct. 2	4.23E-02	4.92E-03	5.49E-04	Detected
	Oct. 2 – Oct. 18	5.09E-02	6.15E-03	8.29E-04	Detected
	Oct. 18 – Nov. 3	4.14E-02	4.90E-03	3.98E-04	Detected
	Nov. 3 – Nov. 29	7.33E-02	9.27E-03	1.65E-03	Detected
	Nov. 29 – Dec. 19	3.79E-02	4.47E-03	5.61E-04	Detected
	Dec. 19 – Jan. 8	4.24E-02	4.96E-03	4.65E-04	Detected
^{235}U	Jan. 6 – Feb. 6	1.90E-03	5.33E-04	3.57E-04	Detected
	Feb. 6 – Feb. 24	2.08E-03	5.58E-04	3.57E-04	Detected
	Feb. 24 – Mar. 8	2.32E-03	5.93E-04	2.83E-04	Detected
	Mar. 8 – Mar. 27	1.24E-03	3.49E-04	2.95E-04	Detected
	Mar. 27 – Apr. 11	2.43E-03	6.26E-04	4.34E-04	Detected
	Apr. 11 – Apr. 28	2.57E-03	5.65E-04	3.15E-04	Detected
	Apr. 28 – May 17	1.80E-03	4.12E-04	1.67E-04	Detected
	May 17 – May 31	2.33E-03	6.71E-04	5.80E-04	Detected
	May 31 – June 23	1.68E-03	4.50E-04	3.86E-04	Detected
	June 23 – July 7	2.79E-03	6.65E-04	3.63E-04	Detected
	July 7 – July 21	2.67E-03	8.08E-04	7.43E-04	Detected
	July 21 – Aug. 4	2.64E-03	8.64E-04	8.55E-04	Detected
	Aug. 4 – Aug. 18	2.76E-03	8.31E-04	6.96E-04	Detected
	Aug. 18 - Sep. 15	1.45E-03	3.31E-04	1.71E-04	Detected
	Sep. 15 – Oct. 2	2.15E-03	5.51E-04	3.32E-04	Detected
	Oct. 2 – Oct. 18	2.50E-03	7.21E-04	5.00E-04	Detected

Table 3-24: Specific activity of uranium isotopes (^{234}U, ^{235}U and ^{238}U) in the filter samples collected from Cactus Flats Station (continued)

Radionuclides	Sample Date 2017	Activity Bq/g	Unc. (2σ) Bq/g	MDC Bq/g	Status
^{235}U	Oct. 18 – Nov. 3	2.06E-03	5.34E-04	2.07E-04	Detected
	Nov. 3 – Nov. 29	3.24E-03	1.15E-03	9.96E-04	Detected
	Nov. 29 – Dec. 19	1.52E-03	4.53E-04	4.79E-04	Detected
	Dec. 19 – Jan. 8	2.10E-03	5.21E-04	2.38E-04	Detected
^{238}U	Jan. 6 – Feb. 6	4.04E-02	4.78E-03	5.89E-04	Detected
	Feb. 6 – Feb. 24	4.38E-02	5.14E-03	3.80E-04	Detected
	Feb. 24 – Mar. 8	4.44E-02	5.21E-03	5.51E-04	Detected
	Mar. 8 – Mar. 27	2.82E-02	3.30E-03	3.52E-04	Detected
	Mar. 27 – Apr. 11	4.45E-02	5.27E-03	6.33E-04	Detected
	Apr. 11 – Apr. 28	4.36E-02	5.02E-03	5.24E-04	Detected
	Apr. 28 – May. 17	3.64E-02	4.23E-03	3.09E-04	Detected
	May. 17 – May 31	5.09E-02	6.09E-03	9.90E-04	Detected
	May 31 – Jun 23	4.18E-02	4.82E-03	5.48E-04	Detected
	Jun 23 – Jul. 7	4.52E-02	5.35E-03	6.88E-04	Detected
	Jul. 7 – Jul. 21	5.76E-02	6.84E-03	1.10E-03	Detected
	Jul.21 – Aug. 4	5.24E-02	6.55E-03	1.26E-03	Detected
	Aug. 4 – Aug. 18	5.31E-02	6.44E-03	1.02E-03	Detected
	Aug. 18 - Sep. 15	2.95E-02	3.37E-03	2.82E-04	Detected
	Sep. 15 – Oct. 2	4.09E-02	4.80E-03	7.19E-04	Detected
	Oct. 2 – Oct. 18	4.86E-02	5.88E-03	9.48E-04	Detected
	Oct. 18 – Nov. 3	3.98E-02	4.73E-03	7.63E-04	Detected
	Nov. 3 – Nov. 29	6.98E-02	8.89E-03	1.71E-03	Detected
	Nov. 29 – Dec. 19	3.58E-02	4.25E-03	8.32E-04	Detected
	Dec. 19 – Jan. 8	3.94E-02	4.63E-03	6.17E-04	Detected

Table 3-25: Activity concentrations of gamma emitting isotopes (^{137}Cs, ^{60}Co and ^{40}K) in the filter samples collected from Onsite Station

Radionuclides	Sample Date 2017	Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
^{137}Cs	Jan. 6 – Feb. 6	4.77E-07	9.09E-07	3.01E-06	Not detected
	Feb. 6 – Feb. 24	6.43E-07	1.59E-06	5.26E-06	Not detected
	Feb. 24 – Mar. 8	-3.36E-07	1.25E-06	4.15E-06	Not detected
	Mar. 8 – Mar. 27	3.17E-07	6.28E-07	2.08E-06	Not detected
	Mar. 27 – Apr. 11	-2.05E-07	8.09E-07	2.69E-06	Not detected
	Apr. 11 – Apr. 28	1.70E-06	1.02E-06	3.36E-06	Not detected
	Apr. 28 – May 17	2.59E-07	1.62E-06	5.37E-06	Not detected
	May 17 – May 31	2.63E-07	9.26E-07	3.07E-06	Not detected
	May 31 – June 23	1.32E-06	9.26E-07	3.05E-06	Not detected
	June 23 – July 7	1.11E-06	3.30E-06	1.09E-05	Not detected
	July 7 – July 21	-1.18E-06	1.19E-06	3.96E-06	Not detected
	July 21 – Aug. 4	6.96E-07	1.18E-06	3.90E-06	Not detected
	Aug. 4 – Aug. 18	-3.84E-07	1.15E-06	3.80E-06	Not detected
	Aug. 18 - Sep. 15	-6.22E-07	8.27E-07	2.75E-06	Not detected
	Sep. 15 – Oct. 2	-2.30E-06	1.71E-06	5.70E-06	Not detected
	Oct. 2 – Oct. 18	-2.15E-07	9.97E-07	3.31E-06	Not detected
	Oct. 18 – Nov. 3	2.74E-07	7.96E-07	2.65E-06	Not detected
	Nov. 3 – Nov. 29	1.92E-07	9.30E-07	3.08E-06	Not detected
	Nov. 29 – Dec. 19	-9.87E-08	9.22E-07	3.06E-06	Not detected
	Dec. 19 – Jan. 8	1.17E-06	6.50E-07	2.13E-06	Not detected
^{60}Co	Jan. 6 – Feb. 6	-1.24E-06	9.01E-07	3.04E-06	Not detected
	Feb. 6 – Feb. 24	-7.30E-07	1.52E-06	5.10E-06	Not detected
	Feb. 24 – Mar. 8	3.81E-07	9.91E-07	3.29E-06	Not detected
	Mar. 8 – Mar. 27	-9.94E-07	6.50E-07	2.19E-06	Not detected
	Mar. 27 – Apr. 11	5.76E-07	8.07E-07	2.67E-06	Not detected
	Apr. 11 – Apr. 28	-1.44E-06	1.04E-06	3.50E-06	Not detected
	Apr. 28 – May 17	4.39E-07	1.59E-06	5.28E-06	Not detected
	May 17 – May 31	-6.58E-07	9.98E-07	3.34E-06	Not detected
	May 31 – June 23	9.63E-07	8.03E-07	2.65E-06	Not detected
	June 23 – July 7	-3.96E-06	2.95E-06	9.91E-06	Not detected
	July 7 – July 21	-2.29E-06	1.05E-06	3.54E-06	Not detected
	July 21 – Aug. 4	4.37E-07	1.03E-06	3.42E-06	Not detected
	Aug. 4 – Aug. 18	-1.18E-06	9.97E-07	3.35E-06	Not detected
	Aug. 18 - Sep. 15	-3.52E-07	8.24E-07	2.76E-06	Not detected
	Sep. 15 – Oct. 2	-2.19E-06	1.70E-06	5.71E-06	Not detected
	Oct. 2 – Oct. 18	3.38E-07	8.49E-07	2.82E-06	Not detected

Table 3-25: Activity concentrations of gamma emitting isotopes (^{137}Cs, ^{60}Co and ^{40}K) in the filter samples collected from Onsite Station (continued)

Radionuclides	Sample Date 2017	Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
^{60}Co	Oct. 18 – Nov. 3	-1.00E-06	8.29E-07	2.78E-06	Not detected
	Nov. 3 – Nov. 29	-1.80E-07	7.94E-07	2.65E-06	Not detected
	Nov. 29 – Dec. 19	-1.67E-06	8.07E-07	2.72E-06	Not detected
	Dec. 19 – Jan. 8	6.88E-07	5.69E-07	1.88E-06	Not detected
^{40}K	Jan. 6 – Feb. 6	1.74E-05	8.94E-06	2.93E-05	Not detected
	Feb. 6 – Feb. 24	3.33E-05	1.50E-05	4.90E-05	Not detected
	Feb. 24 – Mar. 8	7.85E-05	1.28E-05	3.83E-05	Detected
	Mar. 8 – Mar. 27	3.71E-05	7.72E-06	2.48E-05	Detected
	Mar. 27 – Apr. 11	5.36E-05	1.03E-05	3.28E-05	Detected
	Apr. 11 – Apr. 28	5.44E-05	1.29E-05	4.15E-05	Detected
	Apr. 28 – May 17	5.35E-05	1.54E-05	4.95E-05	Detected
	May 17 – May 31	4.14E-05	1.17E-05	3.75E-05	Detected
	May 31 – June 23	4.99E-05	1.02E-05	3.05E-05	Detected
	June 23 – July 7	9.49E-05	3.46E-05	1.11E-04	Not detected
	July 7 – July 21	3.70E-05	1.22E-05	3.88E-05	Not detected
	July 21 – Aug. 4	3.76E-05	1.25E-05	3.97E-05	Not detected
	Aug. 4 – Aug. 18	5.77E-05	1.21E-05	3.65E-05	Detected
	Aug. 18 - Sep. 15	2.00E-05	7.83E-06	2.54E-05	Not detected
	Sep. 15 – Oct. 2	3.85E-05	1.59E-05	5.17E-05	Not detected
	Oct. 2 – Oct. 18	3.94E-05	1.06E-05	3.31E-05	Detected
	Oct. 18 – Nov. 3	2.66E-05	1.03E-05	3.36E-05	Not detected
	Nov. 3 – Nov. 29	4.56E-05	1.00E-05	3.04E-05	Detected
	Nov. 29 – Dec. 19	5.24E-05	1.02E-05	3.01E-05	Detected
	Dec. 19 – Jan. 8	3.73E-05	7.54E-06	2.24E-05	Detected

Table 3-26: Activity concentrations of gamma emitting isotopes (^{137}Cs, ^{60}Co and ^{40}K) in the filter samples collected from Near Field Station

Radionuclides	Sample Date 2017	Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
^{137}Cs	Jan. 6 – Feb. 6	3.13E-07	4.79E-07	1.58E-06	Not detected
	Feb. 6 – Feb. 24	-7.04E-07	6.58E-07	2.19E-06	Not detected
	Feb. 24 – Mar. 8	2.35E-06	2.33E-06	7.69E-06	Not detected
	Mar. 8 – Mar. 27	-6.86E-07	6.30E-07	2.10E-06	Not detected
	Mar. 27 – Apr. 11	6.44E-07	8.18E-07	2.70E-06	Not detected
	Apr. 11 – Apr. 28	1.51E-06	8.96E-07	2.94E-06	Not detected
	Apr. 28 – May 17	4.30E-07	7.44E-07	2.46E-06	Not detected
	May 17 – May 31	3.18E-07	9.24E-07	3.06E-06	Not detected
	May 31 – June 23	1.59E-07	1.65E-06	5.46E-06	Not detected
	Jun 23 – July 7	1.18E-06	1.23E-06	4.06E-06	Not detected
	July 7 – July 21	4.64E-07	9.72E-07	3.22E-06	Not detected
	July 21 – Aug. 4	-1.20E-06	2.19E-06	7.29E-06	Not detected
	Aug. 4 – Aug. 18	-1.13E-06	2.17E-06	7.22E-06	Not detected
	Aug. 18 - Sep. 15	-1.83E-07	4.69E-07	1.56E-06	Not detected
	Sep. 15 – Oct. 2	3.40E-08	1.85E-06	6.14E-06	Not detected
	Oct. 2 – Oct. 18	-2.61E-06	2.42E-06	8.09E-06	Not detected
	Oct. 18 – Nov. 3	1.78E-07	8.20E-07	2.72E-06	Not detected
	Nov. 3 – Nov. 29	-3.13E-07	1.65E-06	5.49E-06	Not detected
	Nov. 29 – Dec. 19	6.31E-07	1.64E-06	5.42E-06	Not detected
	Dec. 19 – Jan. 8	9.81E-07	5.33E-07	1.75E-06	Not detected
^{60}Co	Jan. 6 – Feb. 6	4.67E-07	3.96E-07	1.31E-06	Not detected
	Feb. 6 – Feb. 24	-4.15E-07	6.61E-07	2.21E-06	Not detected
	Feb. 24 – Mar. 8	4.45E-07	2.29E-06	7.63E-06	Not detected
	Mar. 8 – Mar. 27	-1.50E-06	6.25E-07	2.12E-06	Not detected
	Mar. 27 – Apr. 11	-1.03E-06	8.46E-07	2.84E-06	Not detected
	Apr. 11 – Apr. 28	-3.95E-07	7.65E-07	2.56E-06	Not detected
	Apr. 28 – May. 17	-1.31E-06	7.96E-07	2.68E-06	Not detected
	May. 17 – May 31	-2.71E-07	9.92E-07	3.31E-06	Not detected
	May 31 – Jun 23	-2.33E-06	1.68E-06	5.64E-06	Not detected
	Jun 23 – Jul. 7	-1.22E-06	1.09E-06	3.66E-06	Not detected
	Jul. 7 – Jul. 21	1.87E-07	1.02E-06	3.38E-06	Not detected
	Jul.21 – Aug. 4	-5.26E-06	2.28E-06	7.72E-06	Not detected
	Aug. 4 – Aug. 18	-2.49E-06	2.16E-06	7.25E-06	Not detected
	Aug. 18 - Sep. 15	-1.44E-08	3.95E-07	1.32E-06	Not detected
	Sep. 15 – Oct. 2	-1.41E-06	1.78E-06	5.99E-06	Not detected
	Oct. 2 – Oct. 18	1.58E-07	2.30E-06	7.67E-06	Not detected

Table 3-26: Activity concentrations of gamma emitting isotopes (^{137}Cs, ^{60}Co and ^{40}K) in the filter samples collected from Near Field Station (continued)

Radionuclides	Sample Date 2017	Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
^{60}Co	Oct. 18 – Nov. 3	1.52E-07	8.64E-07	2.87E-06	Not detected
	Nov. 3 – Nov. 29	1.32E-06	1.56E-06	5.17E-06	Not detected
	Nov. 29 – Dec. 19	-4.02E-06	1.68E-06	5.68E-06	Not detected
	Dec. 19 – Jan. 8	1.15E-06	5.46E-07	1.78E-06	Not detected
^{40}K	Jan. 6 – Feb. 6	2.60E-05	5.14E-06	1.59E-05	Detected
	Feb. 6 – Feb. 24	3.70E-05	8.10E-06	2.60E-05	Detected
	Feb. 24 – Mar. 8	8.64E-05	2.32E-05	7.42E-05	Detected
	Mar. 8 – Mar. 27	-9.98E-07	7.33E-06	2.44E-05	Not detected
	Mar. 27 – Apr. 11	4.28E-05	1.05E-05	3.38E-05	Detected
	Apr. 11 – Apr. 28	4.66E-05	9.48E-06	2.93E-05	Detected
	Apr. 28 – May 17	3.74E-05	9.40E-06	3.00E-05	Detected
	May 17 – May 31	4.67E-05	1.18E-05	3.77E-05	Detected
	May 31 – June 23	4.58E-05	1.60E-05	5.17E-05	Not detected
	June 23 – July 7	3.97E-05	1.34E-05	4.25E-05	Not detected
	July 7 – July 21	2.58E-05	1.23E-05	4.03E-05	Not detected
	July 21 – Aug. 4	7.97E-06	2.24E-05	7.47E-05	Not detected
	Aug. 4 – Aug. 18	2.56E-05	2.08E-05	6.86E-05	Not detected
	Aug. 18 - Sep. 15	2.12E-05	5.00E-06	1.54E-05	Detected
	Sep. 15 – Oct. 2	2.33E-05	1.82E-05	5.99E-05	Not detected
	Oct. 2 – Oct. 18	4.20E-05	2.22E-05	7.28E-05	Not detected
	Oct. 18 – Nov. 3	4.32E-05	1.05E-05	3.35E-05	Detected
	Nov. 3 – Nov. 29	2.36E-05	1.64E-05	5.41E-05	Not detected
	Nov. 29 – Dec. 19	4.38E-05	1.52E-05	4.93E-05	Not detected
	Dec. 19 – Jan. 8	5.56E-05	7.49E-06	2.21E-05	Detected

Table 3-27: Activity concentrations of gamma emitting isotopes (^{137}Cs, ^{60}Co and ^{40}K) in the filter samples collected from Cactus Flats Station

Radionuclides	Sample Date 2017	Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
^{137}Cs	Jan. 6 – Feb. 6	1.05E-07	9.16E-07	3.04E-06	Not detected
	Feb. 6 – Feb. 24	3.17E-07	8.31E-07	2.75E-06	Not detected
	Feb. 24 – Mar. 8	8.85E-07	9.98E-07	3.30E-06	Not detected
	Mar. 8 – Mar. 27	2.19E-06	1.48E-06	4.86E-06	Not detected
	Mar. 27 – Apr. 11	-1.30E-06	2.04E-06	6.78E-06	Not detected
	Apr. 11 – Apr. 28	7.34E-07	1.69E-06	5.59E-06	Not detected
	Apr. 28 – May 17	-5.03E-07	1.68E-06	5.59E-06	Not detected
	May 17 – May 31	1.51E-07	2.06E-06	6.85E-06	Not detected
	May 31 – June 23	4.14E-07	9.30E-07	3.08E-06	Not detected
	June 23 – July 7	-2.36E-06	2.17E-06	7.25E-06	Not detected
	July 7 – July 21	4.37E-08	9.10E-07	3.02E-06	Not detected
	July 21 – Aug. 4	2.39E-06	2.11E-06	6.96E-06	Not detected
	Aug. 4 – Aug. 18	6.40E-07	2.05E-06	6.79E-06	Not detected
	Aug. 18 - Sep. 15	8.94E-07	8.29E-07	2.74E-06	Not detected
	Sep. 15 – Oct. 2	-2.45E-06	2.06E-06	6.89E-06	Not detected
	Oct. 2 – Oct. 18	5.01E-07	8.29E-07	2.74E-06	Not detected
	Oct. 18 – Nov. 3	6.79E-07	2.00E-06	6.62E-06	Not detected
	Nov. 3 – Nov. 29	9.68E-07	1.39E-06	4.58E-06	Not detected
	Nov. 29 – Dec. 19	7.05E-07	7.34E-07	2.42E-06	Not detected
	Dec. 19 – Jan. 8	-2.06E-06	1.31E-06	4.40E-06	Not detected
^{60}Co	Jan. 6 – Feb. 6	4.28E-07	8.58E-07	2.85E-06	Not detected
	Feb. 6 – Feb. 24	-1.47E-06	7.13E-07	2.40E-06	Not detected
	Feb. 24 – Mar. 8	-1.37E-06	1.02E-06	3.42E-06	Not detected
	Mar. 8 – Mar. 27	-1.31E-06	1.43E-06	4.79E-06	Not detected
	Mar. 27 – Apr. 11	-1.76E-06	1.91E-06	6.43E-06	Not detected
	Apr. 11 – Apr. 28	-4.09E-07	1.62E-06	5.40E-06	Not detected
	Apr. 28 – May 17	-8.08E-07	1.67E-06	5.57E-06	Not detected
	May 17 – May 31	-1.96E-07	2.04E-06	6.81E-06	Not detected
	May 31 – June 23	-8.12E-07	8.47E-07	2.84E-06	Not detected
	June 23 – July 7	-3.95E-06	2.17E-06	7.34E-06	Not detected
	July 7 – July 21	-3.92E-07	9.56E-07	3.19E-06	Not detected
	July 21 – Aug. 4	1.05E-07	2.07E-06	6.91E-06	Not detected
	Aug. 4 – Aug. 18	1.81E-06	2.02E-06	6.69E-06	Not detected
	Aug. 18 - Sep. 15	-1.43E-07	8.41E-07	2.81E-06	Not detected
	Sep. 15 – Oct. 2	-1.76E-06	2.02E-06	6.78E-06	Not detected
	Oct. 2 – Oct. 18	-9.09E-07	8.78E-07	2.94E-06	Not detected

Table 3-27: Activity concentrations of gamma emitting isotopes (^{137}Cs, ^{60}Co and ^{40}K) in the filter samples collected from Cactus Flats Station (continued)

Radionuclides	Sample Date 2017	Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
^{60}Co	Oct. 18 – Nov. 3	-4.34E-07	1.97E-06	6.57E-06	Not detected
	Nov. 3 – Nov. 29	-1.67E-06	1.22E-06	4.09E-06	Not detected
	Nov. 29 – Dec. 19	-7.66E-07	7.69E-07	2.58E-06	Not detected
	Dec. 19 – Jan. 8	1.37E-07	1.13E-06	3.80E-06	Not detected
^{40}K	Jan. 6 – Feb. 6	2.84E-05	8.85E-06	2.85E-05	Not detected
	Feb. 6 – Feb. 24	4.89E-05	8.65E-06	2.62E-05	Detected
	Feb. 24 – Mar. 8	5.67E-05	1.25E-05	4.02E-05	Detected
	Mar. 8 – Mar. 27	2.59E-05	1.50E-05	4.92E-05	Not detected
	Mar. 27 – Apr. 11	5.96E-05	1.96E-05	6.33E-05	Not detected
	Apr. 11 – Apr. 28	4.54E-05	1.72E-05	5.57E-05	Not detected
	Apr. 28 – May 17	6.24E-05	1.62E-05	5.16E-05	Detected
	May 17 – May 31	4.42E-05	2.05E-05	6.70E-05	Not detected
	May 31 – June 23	4.68E-05	1.02E-05	3.10E-05	Detected
	June 23 – July 7	6.50E-05	2.07E-05	6.68E-05	Not detected
	July 7 – July 21	1.69E-05	1.17E-05	3.85E-05	Not detected
	July 21 – Aug. 4	6.75E-05	2.00E-05	6.41E-05	Detected
	Aug. 4 – Aug. 18	-2.32E-06	2.07E-05	6.91E-05	Not detected
	Aug. 18 - Sep. 15	6.49E-05	7.38E-06	2.12E-05	Detected
	Sep. 15 – Oct. 2	3.66E-05	1.95E-05	6.38E-05	Not detected
	Oct. 2 – Oct. 18	2.91E-05	1.04E-05	3.38E-05	Not detected
	Oct. 18 – Nov. 3	7.11E-05	1.89E-05	6.04E-05	Detected
	Nov. 3 – Nov. 29	6.06E-05	1.47E-05	4.53E-05	Detected
	Nov. 29 – Dec. 19	4.78E-05	9.53E-06	2.99E-05	Detected
	Dec. 19 – Jan. 8	4.14E-05	1.14E-05	3.62E-05	Detected

Table 3-28: Specific activity of gamma emitting isotopes (^{137}Cs, ^{60}Co and ^{40}K) in the filter samples collected from Onsite Station

Radionuclides	Sample Date 2017	Activity Bq/g	Unc. (2σ) Bq/g	MDC Bq/g	Status
^{137}Cs	Jan. 6 – Feb. 6	2.26E-02	4.31E-02	1.43E-01	Not detected
	Feb. 6 – Feb. 24	1.54E-02	3.81E-02	1.26E-01	Not detected
	Feb. 24 – Mar. 8	-5.64E-03	2.10E-02	6.97E-02	Not detected
	Mar. 8 – Mar. 27	4.82E-03	9.53E-03	3.16E-02	Not detected
	Mar. 27 – Apr. 11	-3.40E-03	1.34E-02	4.45E-02	Not detected
	Apr. 11 – Apr. 28	2.22E-02	1.34E-02	4.39E-02	Not detected
	Apr. 28 – May 17	4.46E-03	2.79E-02	9.25E-02	Not detected
	May 17 – May 31	6.70E-03	2.36E-02	7.83E-02	Not detected
	May 31 – June 23	2.34E-02	1.64E-02	5.41E-02	Not detected
	June 23 – July 7	2.00E-02	5.96E-02	1.97E-01	Not detected
	July 7 – July 21	-3.78E-02	3.82E-02	1.27E-01	Not detected
	July 21 – Aug. 4	2.02E-02	3.42E-02	1.13E-01	Not detected
	Aug. 4 – Aug. 18	-1.50E-02	4.47E-02	1.49E-01	Not detected
	Aug. 18 - Sep. 15	-2.02E-02	2.68E-02	8.93E-02	Not detected
	Sep. 15 – Oct. 2	-9.13E-02	6.78E-02	2.26E-01	Not detected
	Oct. 2 – Oct. 18	-6.53E-03	3.03E-02	1.00E-01	Not detected
	Oct. 18 – Nov. 3	6.14E-03	1.78E-02	5.92E-02	Not detected
	Nov. 3 – Nov. 29	4.13E-03	2.00E-02	6.63E-02	Not detected
	Nov. 29 – Dec. 19	-2.37E-03	2.22E-02	7.36E-02	Not detected
	Dec. 19 – Jan. 8	3.98E-02	2.21E-02	7.25E-02	Not detected
^{60}Co	Jan. 6 – Feb. 6	-5.87E-02	4.27E-02	1.44E-01	Not detected
	Feb. 6 – Feb. 24	-1.75E-02	3.65E-02	1.22E-01	Not detected
	Feb. 24 – Mar. 8	6.40E-03	1.67E-02	5.53E-02	Not detected
	Mar. 8 – Mar. 27	-1.51E-02	9.88E-03	3.32E-02	Not detected
	Mar. 27 – Apr. 11	9.54E-03	1.34E-02	4.43E-02	Not detected
	Apr. 11 – Apr. 28	-1.89E-02	1.36E-02	4.57E-02	Not detected
	Apr. 28 – May 17	7.55E-03	2.73E-02	9.10E-02	Not detected
	May 17 – May 31	-1.68E-02	2.55E-02	8.52E-02	Not detected
	May 31 – June 23	1.71E-02	1.43E-02	4.70E-02	Not detected
	June 23 – July 7	-7.16E-02	5.33E-02	1.79E-01	Not detected
	July 7 – July 21	-7.36E-02	3.37E-02	1.14E-01	Not detected
	July 21 – Aug. 4	1.27E-02	2.99E-02	9.94E-02	Not detected
	Aug. 4 – Aug. 18	-4.59E-02	3.89E-02	1.31E-01	Not detected
	Aug. 18 - Sep. 15	-1.14E-02	2.67E-02	8.94E-02	Not detected
	Sep. 15 – Oct. 2	-8.72E-02	6.74E-02	2.27E-01	Not detected
	Oct. 2 – Oct. 18	1.03E-02	2.57E-02	8.55E-02	Not detected

Table 3-28: Specific activity of gamma emitting isotopes (^{137}Cs, ^{60}Co and ^{40}K) in the filter samples collected from Onsite Station (continued)

Radionuclides	Sample Date 2017	Activity Bq/g	Unc. (2σ) Bq/g	MDC Bq/g	Status
^{60}Co	Oct. 18 – Nov. 3	-2.24E-02	1.85E-02	6.22E-02	Not detected
	Nov. 3 – Nov. 29	-3.87E-03	1.71E-02	5.70E-02	Not detected
	Nov. 29 – Dec. 19	-4.03E-02	1.94E-02	6.55E-02	Not detected
	Dec. 19 – Jan. 8	2.34E-02	1.94E-02	6.39E-02	Not detected
^{40}K	Jan. 6 – Feb. 6	8.24E-01	4.24E-01	1.39E+00	Not detected
	Feb. 6 – Feb. 24	7.99E-01	3.60E-01	1.18E+00	Not detected
	Feb. 24 – Mar. 8	1.32E+00	2.15E-01	6.44E-01	Detected
	Mar. 8 – Mar. 27	5.64E-01	1.17E-01	3.76E-01	Detected
	Mar. 27 – Apr. 11	8.88E-01	1.70E-01	5.44E-01	Detected
	Apr. 11 – Apr. 28	7.11E-01	1.68E-01	5.42E-01	Detected
	Apr. 28 – May 17	9.21E-01	2.66E-01	8.52E-01	Detected
	May 17 – May 31	1.06E+00	2.98E-01	9.56E-01	Detected
	May 31 – June 23	8.86E-01	1.81E-01	5.42E-01	Detected
	June 23 – July 7	1.71E+00	6.25E-01	2.00E+00	Not detected
	July 7 – July 21	1.19E+00	3.92E-01	1.25E+00	Not detected
	July 21 – Aug. 4	1.09E+00	3.63E-01	1.15E+00	Not detected
	Aug. 4 – Aug. 18	2.25E+00	4.73E-01	1.42E+00	Detected
	Aug. 18 - Sep. 15	6.47E-01	2.54E-01	8.25E-01	Not detected
	Sep. 15 – Oct. 2	1.53E+00	6.31E-01	2.05E+00	Not detected
	Oct. 2 – Oct. 18	1.20E+00	3.21E-01	1.00E+00	Detected
	Oct. 18 – Nov. 3	5.95E-01	2.31E-01	7.52E-01	Not detected
	Nov. 3 – Nov. 29	9.82E-01	2.15E-01	6.54E-01	Detected
	Nov. 29 – Dec. 19	1.26E+00	2.44E-01	7.25E-01	Detected
	Dec. 19 – Jan. 8	1.27E+00	2.56E-01	7.60E-01	Detected

Table 3-29: Specific activity of gamma emitting isotopes (^{137}Cs, ^{60}Co and ^{40}K) in the filter samples collected from Near Field Station

Radionuclides	Sample Date 2017	Activity Bq/g	Unc. (2σ) Bq/g	MDC Bq/g	Status
^{137}Cs	Jan. 6 – Feb. 6	1.61E-02	2.47E-02	8.17E-02	Not detected
	Feb. 6 – Feb. 24	-2.38E-02	2.22E-02	7.42E-02	Not detected
	Feb. 24 – Mar. 8	4.22E-02	4.18E-02	1.38E-01	Not detected
	Mar. 8 – Mar. 27	-1.31E-02	1.21E-02	4.02E-02	Not detected
	Mar. 27 – Apr. 11	1.35E-02	1.72E-02	5.68E-02	Not detected
	Apr. 11 – Apr. 28	3.58E-02	2.13E-02	6.99E-02	Not detected
	Apr. 28 – May 17	1.10E-02	1.90E-02	6.27E-02	Not detected
	May 17 – May 31	9.14E-03	2.66E-02	8.81E-02	Not detected
	May 31 – June 23	3.74E-03	3.86E-02	1.28E-01	Not detected
	June 23 – July 7	2.63E-02	2.75E-02	9.08E-02	Not detected
	July 7 – July 21	1.66E-02	3.47E-02	1.15E-01	Not detected
	July 21 – Aug. 4	-3.98E-02	7.26E-02	2.42E-01	Not detected
	Aug. 4 – Aug. 18	-4.99E-02	9.58E-02	3.19E-01	Not detected
	Aug. 18 - Sep. 15	-7.27E-03	1.86E-02	6.17E-02	Not detected
	Sep. 15 – Oct. 2	1.43E-03	7.79E-02	2.58E-01	Not detected
	Oct. 2 – Oct. 18	-8.84E-02	8.21E-02	2.74E-01	Not detected
	Oct. 18 – Nov. 3	4.32E-03	1.99E-02	6.61E-02	Not detected
	Nov. 3 – Nov. 29	-8.03E-03	4.24E-02	1.41E-01	Not detected
	Nov. 29 – Dec. 19	1.57E-02	4.07E-02	1.35E-01	Not detected
	Dec. 19 – Jan. 8	2.80E-02	1.52E-02	5.00E-02	Not detected
^{60}Co	Jan. 6 – Feb. 6	2.41E-02	2.04E-02	6.74E-02	Not detected
	Feb. 6 – Feb. 24	-1.40E-02	2.23E-02	7.48E-02	Not detected
	Feb. 24 – Mar. 8	7.98E-03	4.11E-02	1.37E-01	Not detected
	Mar. 8 – Mar. 27	-2.88E-02	1.20E-02	4.06E-02	Not detected
	Mar. 27 – Apr. 11	-2.16E-02	1.78E-02	5.97E-02	Not detected
	Apr. 11 – Apr. 28	-9.38E-03	1.82E-02	6.07E-02	Not detected
	Apr. 28 – May 17	-3.35E-02	2.03E-02	6.82E-02	Not detected
	May 17 – May 31	-7.81E-03	2.86E-02	9.53E-02	Not detected
	May 31 – June 23	-5.46E-02	3.93E-02	1.32E-01	Not detected
	June 23 – July 7	-2.72E-02	2.44E-02	8.18E-02	Not detected
	July 7 – July 21	6.69E-03	3.63E-02	1.21E-01	Not detected
	July 21 – Aug. 4	-1.75E-01	7.56E-02	2.56E-01	Not detected
	Aug. 4 – Aug. 18	-1.10E-01	9.52E-02	3.20E-01	Not detected
	Aug. 18 - Sep. 15	-5.71E-04	1.57E-02	5.22E-02	Not detected
	Sep. 15 – Oct. 2	-5.93E-02	7.51E-02	2.52E-01	Not detected
	Oct. 2 – Oct. 18	5.36E-03	7.80E-02	2.60E-01	Not detected

Table 3-29: Specific activity of gamma emitting isotopes (^{137}Cs, ^{60}Co and ^{40}K) in the filter samples collected from Near Field Station (continued)

Radionuclides	Sample Date 2017	Activity Bq/g	Unc. (2σ) Bq/g	MDC Bq/g	Status
	Oct. 18 – Nov. 3	3.71E-03	2.10E-02	6.99E-02	Not detected
	Nov. 3 – Nov. 29	3.38E-02	4.01E-02	1.33E-01	Not detected
	Nov. 29 – Dec. 19	-1.00E-01	4.17E-02	1.41E-01	Not detected
	Dec. 19 – Jan. 8	3.30E-02	1.56E-02	5.10E-02	Not detected
^{40}K	Jan. 6 – Feb. 6	1.34E+00	2.65E-01	8.18E-01	Detected
	Feb. 6 – Feb. 24	1.25E+00	2.74E-01	8.81E-01	Detected
	Feb. 24 – Mar. 8	1.55E+00	4.16E-01	1.33E+00	Detected
	Mar. 8 – Mar. 27	-1.91E-02	1.40E-01	4.67E-01	Not detected
	Mar. 27 – Apr. 11	9.00E-01	2.20E-01	7.11E-01	Detected
	Apr. 11 – Apr. 28	1.11E+00	2.25E-01	6.97E-01	Detected
	Apr. 28 – May 17	9.53E-01	2.40E-01	7.65E-01	Detected
	May 17 – May 31	1.35E+00	3.40E-01	1.08E+00	Detected
	May 31 – June 23	1.07E+00	3.75E-01	1.21E+00	Not detected
	June 23 – July 7	8.88E-01	2.99E-01	9.51E-01	Not detected
	July 7 – July 21	9.21E-01	4.41E-01	1.44E+00	Not detected
	July 21 – Aug. 4	2.64E-01	7.44E-01	2.48E+00	Not detected
	Aug. 4 – Aug. 18	1.13E+00	9.18E-01	3.03E+00	Not detected
	Aug. 18 - Sep. 15	8.41E-01	1.98E-01	6.09E-01	Detected
	Sep. 15 – Oct. 2	9.79E-01	7.64E-01	2.52E+00	Not detected
	Oct. 2 – Oct. 18	1.42E+00	7.53E-01	2.47E+00	Not detected
	Oct. 18 – Nov. 3	1.05E+00	2.56E-01	8.14E-01	Detected
	Nov. 3 – Nov. 29	6.05E-01	4.22E-01	1.39E+00	Not detected
	Nov. 29 – Dec. 19	1.09E+00	3.79E-01	1.23E+00	Not detected
	Dec. 19 – Jan. 8	1.59E+00	2.14E-01	6.31E-01	Detected

Table 3-30: Specific activity of gamma emitting isotopes (^{137}Cs, ^{60}Co and ^{40}K) in the filter samples collected from Cactus Flats Station

Radionuclides	Sample Date 2017	Activity Bq/g	Unc. (2σ) Bq/g	MDC Bq/g	Status
^{137}Cs	Jan. 6 – Feb. 6	4.74E-03	4.16E-02	1.38E-01	Not detected
	Feb. 6 – Feb. 24	8.24E-03	2.16E-02	7.15E-02	Not detected
	Feb. 24 – Mar. 8	1.62E-02	1.83E-02	6.03E-02	Not detected
	Mar. 8 – Mar. 27	4.04E-02	2.74E-02	9.00E-02	Not detected
	Mar. 27 – Apr. 11	-2.50E-02	3.91E-02	1.30E-01	Not detected
	Apr. 11 – Apr. 28	1.36E-02	3.13E-02	1.04E-01	Not detected
	Apr. 28 – May 17	-7.42E-03	2.48E-02	8.24E-02	Not detected
	May 17 – May 31	3.28E-03	4.48E-02	1.49E-01	Not detected
	May 31 – June 23	8.09E-03	1.82E-02	6.01E-02	Not detected
	June 23 – July 7	-4.24E-02	3.90E-02	1.30E-01	Not detected
	July 7 – July 21	1.54E-03	3.20E-02	1.06E-01	Not detected
	July 21 – Aug. 4	6.23E-02	5.50E-02	1.81E-01	Not detected
	Aug. 4 – Aug. 18	2.23E-02	7.13E-02	2.36E-01	Not detected
	Aug. 18 - Sep. 15	2.34E-02	2.17E-02	7.15E-02	Not detected
	Sep. 15 – Oct. 2	-5.43E-02	4.58E-02	1.53E-01	Not detected
	Oct. 2 – Oct. 18	1.41E-02	2.33E-02	7.71E-02	Not detected
	Oct. 18 – Nov. 3	1.21E-02	3.55E-02	1.18E-01	Not detected
	Nov. 3 – Nov. 29	3.48E-02	4.98E-02	1.65E-01	Not detected
	Nov. 29 – Dec. 19	1.30E-02	1.35E-02	4.45E-02	Not detected
	Dec. 19 – Jan. 8	-4.28E-02	2.72E-02	9.14E-02	Not detected
^{60}Co	Jan. 6 – Feb. 6	1.94E-02	3.90E-02	1.29E-01	Not detected
	Feb. 6 – Feb. 24	-3.81E-02	1.85E-02	6.23E-02	Not detected
	Feb. 24 – Mar. 8	-2.50E-02	1.86E-02	6.25E-02	Not detected
	Mar. 8 – Mar. 27	-2.42E-02	2.64E-02	8.86E-02	Not detected
	Mar. 27 – Apr. 11	-3.38E-02	3.68E-02	1.24E-01	Not detected
	Apr. 11 – Apr. 28	-7.57E-03	2.99E-02	1.00E-01	Not detected
	Apr. 28 – May 17	-1.19E-02	2.46E-02	8.22E-02	Not detected
	May 17 – May 31	-4.26E-03	4.43E-02	1.48E-01	Not detected
	May 31 – June 23	-1.59E-02	1.66E-02	5.54E-02	Not detected
	June 23 – July 7	-7.08E-02	3.90E-02	1.32E-01	Not detected
	July 7 – July 21	-1.38E-02	3.37E-02	1.12E-01	Not detected
	July 21 – Aug. 4	2.75E-03	5.41E-02	1.80E-01	Not detected
	Aug. 4 – Aug. 18	6.28E-02	7.03E-02	2.33E-01	Not detected
	Aug. 18 - Sep. 15	-3.74E-03	2.20E-02	7.34E-02	Not detected
	Sep. 15 – Oct. 2	-3.91E-02	4.48E-02	1.50E-01	Not detected
	Oct. 2 – Oct. 18	-2.56E-02	2.47E-02	8.28E-02	Not detected

Table 3-30: Specific activity of gamma emitting isotopes (^{137}Cs, ^{60}Co and ^{40}K) in the filter samples collected from Cactus Flats Station (continued)

Radionuclides	Sample Date 2017	Activity Bq/g	Unc. (2σ) Bq/g	MDC Bq/g	Status
^{60}Co	Oct. 18 – Nov. 3	-7.72E-03	3.49E-02	1.17E-01	Not detected
	Nov. 3 – Nov. 29	-6.01E-02	4.38E-02	1.47E-01	Not detected
	Nov. 29 – Dec. 19	-1.41E-02	1.42E-02	4.74E-02	Not detected
	Dec. 19 – Jan. 8	2.85E-03	2.36E-02	7.89E-02	Not detected
^{40}K	Jan. 6 – Feb. 6	1.29E+00	4.01E-01	1.29E+00	Not detected
	Feb. 6 – Feb. 24	1.27E+00	2.25E-01	6.83E-01	Detected
	Feb. 24 – Mar. 8	1.04E+00	2.29E-01	7.36E-01	Detected
	Mar. 8 – Mar. 27	4.79E-01	2.78E-01	9.11E-01	Not detected
	Mar. 27 – Apr. 11	1.15E+00	3.77E-01	1.22E+00	Not detected
	Apr. 11 – Apr. 28	8.41E-01	3.18E-01	1.03E+00	Not detected
	Apr. 28 – May 17	9.20E-01	2.38E-01	7.60E-01	Detected
	May 17 – May 31	9.59E-01	4.45E-01	1.45E+00	Not detected
	May 31 – June 23	9.14E-01	2.00E-01	6.07E-01	Detected
	June 23 – July 7	1.17E+00	3.71E-01	1.20E+00	Not detected
	July 7 – July 21	5.95E-01	4.12E-01	1.35E+00	Not detected
	July 21 – Aug. 4	1.76E+00	5.21E-01	1.67E+00	Detected
	Aug. 4 – Aug. 18	-8.07E-02	7.20E-01	2.40E+00	Not detected
	Aug. 18 - Sep. 15	1.70E+00	1.93E-01	5.54E-01	Detected
	Sep. 15 – Oct. 2	8.13E-01	4.32E-01	1.41E+00	Not detected
	Oct. 2 – Oct. 18	8.20E-01	2.94E-01	9.52E-01	Not detected
	Oct. 18 – Nov. 3	1.26E+00	3.36E-01	1.07E+00	Detected
	Nov. 3 – Nov. 29	2.18E+00	5.28E-01	1.63E+00	Detected
	Nov. 29 – Dec. 19	8.79E-01	1.75E-01	5.50E-01	Detected
	Dec. 19 – Jan. 8	8.61E-01	2.37E-01	7.52E-01	Detected

Table 3-31: Activity concentrations of ^{241}Am, $^{239+240}Pu$ and ^{238}Pu in the filter samples collected from Loving Station

Radionuclides	Sample Date 2017	Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
^{241}Am	Jan. 6 – Feb. 6	4.03E-09	4.13E-09	8.44E-09	Not detected
	Feb. 6 – Feb. 24	1.08E-09	1.17E-08	2.95E-08	Not detected
	Feb. 24 – Mar. 8	1.76E-08	1.02E-08	1.16E-08	Detected
	Mar. 8 – Mar. 27	2.25E-08	9.60E-09	1.00E-08	Detected
	Mar. 27 – Apr. 11	1.90E-09	8.04E-09	2.02E-08	Not detected
	Apr. 11 – Apr. 28	1.95E-08	1.08E-08	1.78E-08	Detected
	Apr. 28 – May 17	1.37E-08	8.55E-09	1.41E-08	Not detected
	May 17 – May 31	1.73E-08	1.39E-08	2.67E-08	Not detected
	May 31 – June 23	1.62E-08	7.42E-09	5.69E-09	Detected
	June 23 – July 7	1.39E-08	9.41E-09	1.57E-08	Not detected
	July 7 – July 21	3.93E-09	7.38E-09	1.71E-08	Not detected
	July 21 – Aug. 4	1.39E-08	9.47E-09	1.58E-08	Not detected
	Aug. 4 – Aug. 18	9.99E-10	8.26E-09	2.13E-08	Not detected
	Aug. 18 - Sep. 15	3.23E-09	4.27E-09	9.46E-09	Not detected
	Sep. 15 – Oct. 2	-2.50E-09	1.01E-08	2.67E-08	Not detected
	Oct. 2 – Oct. 18	1.00E-08	7.58E-09	1.28E-08	Not detected
	Oct. 18 – Nov. 3	-9.33E-10	7.74E-09	2.09E-08	Not detected
	Nov. 3 – Nov. 29	8.26E-09	8.12E-09	1.66E-08	Not detected
	Nov. 29 – Dec. 19	1.24E-08	9.32E-09	1.77E-08	Not detected
	Dec. 19 – Jan. 8	1.02E-08	9.39E-09	1.94E-08	Not detected
$^{239+240}Pu$	Jan. 6 – Feb. 6	1.14E-08	6.00E-09	9.04E-09	Detected
	Feb. 6 – Feb. 24	3.40E-09	8.76E-09	2.13E-08	Not detected
	Feb. 24 – Mar. 8	1.09E-08	1.03E-08	1.86E-08	Not detected
	Mar. 8 – Mar. 27	1.29E-08	8.33E-09	1.19E-08	Detected
	Mar. 27 – Apr. 11	1.82E-08	1.28E-08	2.29E-08	Not detected
	Apr. 11 – Apr. 28	9.73E-09	9.96E-09	2.04E-08	Not detected
	Apr. 28 – May 17	1.84E-08	9.96E-09	1.46E-08	Detected
	May 17 – May 31	1.68E-08	1.20E-08	2.06E-08	Not detected
	May 31 – June 23	1.00E-08	9.18E-09	1.83E-08	Not detected
	June 23 – July 7	2.12E-08	1.06E-08	1.27E-08	Detected
	July 7 – July 21	2.55E-08	1.39E-08	2.12E-08	Detected
	July 21 – Aug. 4	4.39E-09	6.96E-09	1.54E-08	Not detected
	Aug. 4 – Aug. 18	8.11E-09	7.73E-09	1.39E-08	Not detected
	Aug. 18 - Sep. 15	9.11E-09	5.08E-09	8.16E-09	Detected
	Sep. 15 – Oct. 2	3.59E-09	8.61E-09	2.08E-08	Not detected
	Oct. 2 – Oct. 18	-1.28E-09	6.77E-09	2.03E-08	Not detected

Table 3-31: Activity concentrations of ^{241}Am, $^{239+240}Pu$ and ^{238}Pu in the filter samples collected from Loving Station (continued)

Radionuclides	Sample Date 2017	Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
$^{239+240}Pu$	Oct. 18 – Nov. 3	8.65E-09	6.98E-09	1.15E-08	Not detected
	Nov. 3 – Nov. 29	1.48E-08	8.83E-09	1.31E-08	Detected
	Nov. 29 – Dec. 19	1.45E-08	8.12E-09	8.97E-09	Detected
	Dec. 19 – Jan. 8	1.72E-08	9.46E-09	1.21E-08	Detected
^{238}Pu	Jan. 6 – Feb. 6	5.19E-10	3.12E-09	8.23E-09	Not detected
	Feb. 6 – Feb. 24	-1.14E-08	9.18E-09	2.99E-08	Not detected
	Feb. 24 – Mar. 8	4.65E-09	9.31E-09	2.18E-08	Not detected
	Mar. 8 – Mar. 27	-9.89E-10	8.19E-09	2.22E-08	Not detected
	Mar. 27 – Apr. 11	-6.08E-09	8.09E-09	2.59E-08	Not detected
	Apr. 11 – Apr. 28	-7.59E-09	8.97E-09	2.76E-08	Not detected
	Apr. 28 – May 17	6.46E-09	6.69E-09	1.30E-08	Not detected
	May 17 – May 31	6.48E-09	8.64E-09	1.83E-08	Not detected
	May 31 – June 23	9.11E-10	7.04E-09	1.83E-08	Not detected
	June 23 – July 7	-1.05E-09	4.73E-09	1.49E-08	Not detected
	July 7 – July 21	2.43E-09	7.70E-09	1.93E-08	Not detected
	July 21 – Aug. 4	-2.20E-09	5.38E-09	1.74E-08	Not detected
	Aug. 4 – Aug. 18	-3.47E-09	4.65E-09	1.63E-08	Not detected
	Aug. 18 - Sep. 15	0.00E+00	2.13E-09	6.11E-09	Not detected
	Sep. 15 – Oct. 2	-7.17E-09	9.61E-09	2.93E-08	Not detected
	Oct. 2 – Oct. 18	-5.12E-09	1.02E-08	3.01E-08	Not detected
	Oct. 18 – Nov. 3	-9.56E-10	4.29E-09	1.35E-08	Not detected
	Nov. 3 – Nov. 29	-2.78E-09	4.16E-09	1.48E-08	Not detected
	Nov. 29 – Dec. 19	-4.84E-09	7.98E-09	2.37E-08	Not detected
	Dec. 19 – Jan. 8	-1.01E-09	4.52E-09	1.43E-08	Not detected

Table 3-32: Activity concentrations of ^{241}Am, $^{239+240}Pu$ and ^{238}Pu in the filter samples collected from Carlsbad Station

Radionuclides	Sample Date 2017	Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
^{241}Am	Jan. 6 – Feb. 6	2.50E-09	4.10E-09	9.36E-09	Not detected
	Feb. 6 – Feb. 24	5.96E-09	6.36E-09	1.30E-08	Not detected
	Feb. 24 – Mar. 8	2.28E-08	1.31E-08	2.01E-08	Detected
	Mar. 8 – Mar. 27	2.16E-08	1.08E-08	1.63E-08	Detected
	Mar. 27 – Apr. 11	2.85E-09	6.85E-09	1.65E-08	Not detected
	Apr. 11 – Apr. 28	9.77E-09	9.99E-09	2.09E-08	Not detected
	Apr. 28 – May 17	6.34E-09	8.97E-09	2.02E-08	Not detected
	May 17 – May 31	9.84E-09	1.08E-08	2.31E-08	Not detected
	May 31 – June 23	1.26E-08	7.77E-09	1.24E-08	Detected
	June 23 – July 7	2.01E-08	1.16E-08	1.89E-08	Detected
	July 7 – July 21	2.19E-09	8.78E-09	2.20E-08	Not detected
	July 21 – Aug. 4	1.03E-08	9.71E-09	1.93E-08	Not detected
	Aug. 4 – Aug. 18	1.81E-08	1.43E-08	2.63E-08	Not detected
	Aug. 18 - Sep. 15	5.51E-09	4.27E-09	7.94E-09	Not detected
	Sep. 15 – Oct. 2	7.08E-09	6.53E-09	1.25E-08	Not detected
	Oct. 2 – Oct. 18	8.54E-09	8.46E-09	1.72E-08	Not detected
	Oct. 18 – Nov. 3	7.66E-09	7.47E-09	1.48E-08	Not detected
	Nov. 3 – Nov. 29	7.13E-09	8.26E-09	1.78E-08	Not detected
	Nov. 29 – Dec. 19	7.70E-09	7.49E-09	1.49E-08	Not detected
	Dec. 19 – Jan. 8	5.00E-09	1.00E-08	2.35E-08	Not detected
$^{239+240}Pu$	Jan. 6 – Feb. 6	3.23E-09	3.42E-09	6.46E-09	Not detected
	Feb. 6 – Feb. 24	8.69E-09	9.68E-09	1.97E-08	Not detected
	Feb. 24 – Mar. 8	1.89E-08	1.51E-08	2.72E-08	Not detected
	Mar. 8 – Mar. 27	1.59E-08	1.31E-08	2.61E-08	Not detected
	Mar. 27 – Apr. 11	1.13E-08	1.01E-08	1.97E-08	Not detected
	Apr. 11 – Apr. 28	1.04E-08	8.38E-09	1.47E-08	Not detected
	Apr. 28 – May 17	1.09E-08	8.26E-09	1.45E-08	Not detected
	May 17 – May 31	2.21E-08	1.38E-08	2.20E-08	Detected
	May 31 – June 23	9.32E-09	7.98E-09	1.48E-08	Not detected
	June 23 – July 7	8.85E-09	1.09E-08	2.35E-08	Not detected
	July 7 – July 21	4.00E-09	8.00E-09	1.87E-08	Not detected
	July 21 – Aug. 4	1.18E-08	1.16E-08	2.40E-08	Not detected
	Aug. 4 – Aug. 18	2.09E-08	1.32E-08	2.35E-08	Not detected
	Aug. 18 - Sep. 15	1.13E-08	5.76E-09	9.07E-09	Detected
	Sep. 15 – Oct. 2	-2.04E-09	4.99E-09	1.62E-08	Not detected
	Oct. 2 – Oct. 18	0.00E+00	1.28E-08	3.29E-08	Not detected

Table 3-32: Activity concentrations of ^{241}Am, $^{239+240}Pu$ and ^{238}Pu in the filter samples collected from Carlsbad Station (continued)

Radionuclides	Sample Date 2017	Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
	Oct. 18 – Nov. 3	6.37E-09	9.96E-09	2.26E-08	Not detected
	Nov. 3 – Nov. 29	3.71E-09	6.96E-09	1.62E-08	Not detected
	Nov. 29 – Dec. 19	1.07E-08	8.05E-09	1.41E-08	Not detected
	Dec. 19 – Jan. 8	1.94E-09	8.26E-09	2.07E-08	Not detected
^{238}Pu	Jan. 6 – Feb. 6	2.15E-09	2.64E-09	4.98E-09	Not detected
	Feb. 6 – Feb. 24	-9.96E-09	7.91E-09	2.78E-08	Not detected
	Feb. 24 – Mar. 8	6.87E-09	1.29E-08	2.99E-08	Not detected
	Mar. 8 – Mar. 27	-5.31E-09	8.76E-09	2.61E-08	Not detected
	Mar. 27 – Apr. 11	-3.39E-09	5.99E-09	1.97E-08	Not detected
	Apr. 11 – Apr. 28	-4.16E-09	8.31E-09	2.45E-08	Not detected
	Apr. 28 – May 17	-6.41E-09	6.63E-09	2.15E-08	Not detected
	May 17 – May 31	-8.30E-09	1.04E-08	3.25E-08	Not detected
	May 31 – June 23	-4.65E-09	7.20E-09	2.19E-08	Not detected
	June 23 – July 7	-4.42E-09	6.27E-09	2.08E-08	Not detected
	July 7 – July 21	-2.66E-09	7.54E-09	2.32E-08	Not detected
	July 21 – Aug. 4	-1.07E-08	9.18E-09	2.92E-08	Not detected
	Aug. 4 – Aug. 18	1.54E-08	1.14E-08	2.07E-08	Not detected
	Aug. 18 - Sep. 15	1.81E-09	3.14E-09	7.17E-09	Not detected
	Sep. 15 – Oct. 2	-1.02E-09	8.37E-09	2.29E-08	Not detected
	Oct. 2 – Oct. 18	-2.10E-08	1.17E-08	3.84E-08	Not detected
	Oct. 18 – Nov. 3	-4.25E-09	6.02E-09	2.00E-08	Not detected
	Nov. 3 – Nov. 29	1.86E-09	5.25E-09	1.31E-08	Not detected
	Nov. 29 – Dec. 19	-3.57E-09	8.76E-09	2.44E-08	Not detected
	Dec. 19 – Jan. 8	-4.85E-09	5.16E-09	1.82E-08	Not detected

Table 3-33: Specific activity of ^{241}Am, $^{239+240}Pu$ and ^{238}Pu in the filter samples collected from Loving Station

Radionuclides	Sample Date 2017	Activity Bq/g	Unc. (2σ) Bq/g	MDC Bq/g	Status
^{241}Am	Jan. 6 – Feb. 6	1.48E-04	1.51E-04	3.09E-04	Not detected
	Feb. 6 – Feb. 24	2.34E-05	2.52E-04	6.40E-04	Not detected
	Feb. 24 – Mar. 8	1.94E-04	1.13E-04	1.29E-04	Detected
	Mar. 8 – Mar. 27	2.46E-04	1.05E-04	1.10E-04	Detected
	Mar. 27 – Apr. 11	2.35E-05	9.94E-05	2.50E-04	Not detected
	Apr. 11 – Apr. 28	2.77E-04	1.54E-04	2.53E-04	Detected
	Apr. 28 – May 17	1.81E-04	1.13E-04	1.86E-04	Not detected
	May 17 – May 31	3.28E-04	2.65E-04	5.08E-04	Not detected
	May 31 – June 23	1.81E-04	8.24E-05	6.32E-05	Detected
	June 23 – July 7	1.88E-04	1.27E-04	2.12E-04	Not detected
	July 7 – July 21	8.21E-05	1.54E-04	3.57E-04	Not detected
	July 21 – Aug. 4	3.10E-04	2.11E-04	3.52E-04	Not detected
	Aug. 4 – Aug. 18	2.57E-05	2.12E-04	5.48E-04	Not detected
	Aug. 18 - Sep. 15	5.75E-05	7.62E-05	1.69E-04	Not detected
	Sep. 15 – Oct. 2	-5.72E-05	2.32E-04	6.10E-04	Not detected
	Oct. 2 – Oct. 18	2.06E-04	1.56E-04	2.63E-04	Not detected
	Oct. 18 – Nov. 3	-1.71E-05	1.41E-04	3.83E-04	Not detected
	Nov. 3 – Nov. 29	1.21E-04	1.19E-04	2.44E-04	Not detected
	Nov. 29 – Dec. 19	2.08E-04	1.56E-04	2.96E-04	Not detected
	Dec. 19 – Jan. 8	1.77E-04	1.62E-04	3.35E-04	Not detected
$^{239+240}Pu$	Jan. 6 – Feb. 6	4.19E-04	2.20E-04	3.31E-04	Detected
	Feb. 6 – Feb. 24	7.38E-05	1.90E-04	4.62E-04	Not detected
	Feb. 24 – Mar. 8	1.20E-04	1.14E-04	2.06E-04	Not detected
	Mar. 8 – Mar. 27	1.41E-04	9.11E-05	1.30E-04	Detected
	Mar. 27 – Apr. 11	2.25E-04	1.58E-04	2.83E-04	Not detected
	Apr. 11 – Apr. 28	1.38E-04	1.42E-04	2.90E-04	Not detected
	Apr. 28 – May 17	2.44E-04	1.32E-04	1.94E-04	Detected
	May 17 – May 31	3.20E-04	2.28E-04	3.91E-04	Not detected
	May 31 – June 23	1.11E-04	1.02E-04	2.03E-04	Not detected
	June 23 – July 7	2.87E-04	1.44E-04	1.72E-04	Detected
	July 7 – July 21	5.33E-04	2.89E-04	4.42E-04	Detected
	July 21 – Aug. 4	9.78E-05	1.55E-04	3.44E-04	Not detected
	Aug. 4 – Aug. 18	2.09E-04	1.99E-04	3.59E-04	Not detected
	Aug. 18 - Sep. 15	1.62E-04	9.07E-05	1.45E-04	Detected
	Sep. 15 – Oct. 2	8.21E-05	1.97E-04	4.77E-04	Not detected
	Oct. 2 – Oct. 18	-2.63E-05	1.39E-04	4.18E-04	Not detected

Table 3-33: Specific activity of ^{241}Am, $^{239+240}Pu$ and ^{238}Pu in the filter samples collected from Loving Station (continued)

Radionuclides	Sample Date 2017	Activity Bq/g	Unc. (2σ) Bq/g	MDC Bq/g	Status
$^{239+240}Pu$	Oct. 18 – Nov. 3	1.58E-04	1.28E-04	2.11E-04	Not detected
	Nov. 3 – Nov. 29	2.18E-04	1.30E-04	1.92E-04	Detected
	Nov. 29 – Dec. 19	2.43E-04	1.36E-04	1.50E-04	Detected
	Dec. 19 – Jan. 8	2.97E-04	1.64E-04	2.10E-04	Detected
^{238}Pu	Jan. 6 – Feb. 6	1.90E-05	1.14E-04	3.02E-04	Not detected
	Feb. 6 – Feb. 24	-2.46E-04	1.99E-04	6.49E-04	Not detected
	Feb. 24 – Mar. 8	5.13E-05	1.03E-04	2.41E-04	Not detected
	Mar. 8 – Mar. 27	-1.08E-05	8.95E-05	2.43E-04	Not detected
	Mar. 27 – Apr. 11	-7.52E-05	1.00E-04	3.20E-04	Not detected
	Apr. 11 – Apr. 28	-1.08E-04	1.28E-04	3.93E-04	Not detected
	Apr. 28 – May 17	8.56E-05	8.85E-05	1.72E-04	Not detected
	May 17 – May 31	1.23E-04	1.64E-04	3.48E-04	Not detected
	May 31 – June 23	1.01E-05	7.83E-05	2.03E-04	Not detected
	June 23 – July 7	-1.43E-05	6.40E-05	2.02E-04	Not detected
	July 7 – July 21	5.08E-05	1.61E-04	4.02E-04	Not detected
	July 21 – Aug. 4	-4.89E-05	1.20E-04	3.88E-04	Not detected
	Aug. 4 – Aug. 18	-8.93E-05	1.20E-04	4.19E-04	Not detected
	Aug. 18 - Sep. 15	0.00E+00	3.79E-05	1.09E-04	Not detected
	Sep. 15 – Oct. 2	-1.64E-04	2.20E-04	6.70E-04	Not detected
	Oct. 2 – Oct. 18	-1.05E-04	2.10E-04	6.18E-04	Not detected
	Oct. 18 – Nov. 3	-1.75E-05	7.84E-05	2.47E-04	Not detected
	Nov. 3 – Nov. 29	-4.09E-05	6.12E-05	2.17E-04	Not detected
	Nov. 29 – Dec. 19	-8.08E-05	1.33E-04	3.96E-04	Not detected
	Dec. 19 – Jan. 8	-1.75E-05	7.81E-05	2.47E-04	Not detected

Table 3-34: Specific activity of ^{241}Am, $^{239+240}Pu$ and ^{238}Pu in the filter samples collected from Carlsbad Station

Radionuclides	Sample Date 2017	Activity Bq/g	Unc. (2σ) Bq/g	MDC Bq/g	Status
^{241}Am	Jan. 6 – Feb. 6	1.44E-04	2.36E-04	5.39E-04	Not detected
	Feb. 6 – Feb. 24	2.07E-04	2.21E-04	4.51E-04	Not detected
	Feb. 24 – Mar. 8	3.77E-04	2.17E-04	3.32E-04	Detected
	Mar. 8 – Mar. 27	3.44E-04	1.72E-04	2.60E-04	Detected
	Mar. 27 – Apr. 11	6.41E-05	1.54E-04	3.72E-04	Not detected
	Apr. 11 – Apr. 28	2.14E-04	2.19E-04	4.58E-04	Not detected
	Apr. 28 – May 17	1.32E-04	1.87E-04	4.20E-04	Not detected
	May 17 – May 31	2.64E-04	2.90E-04	6.21E-04	Not detected
	May 31 – June 23	2.06E-04	1.27E-04	2.04E-04	Detected
	June 23 – July 7	3.52E-04	2.03E-04	3.32E-04	Detected
	July 7 – July 21	4.92E-05	1.97E-04	4.94E-04	Not detected
	July 21 – Aug. 4	2.86E-04	2.69E-04	5.36E-04	Not detected
	Aug. 4 – Aug. 18	5.93E-04	4.67E-04	8.62E-04	Not detected
	Aug. 18 - Sep. 15	1.52E-04	1.18E-04	2.19E-04	Not detected
	Sep. 15 – Oct. 2	2.85E-04	2.63E-04	5.02E-04	Not detected
	Oct. 2 – Oct. 18	2.17E-04	2.15E-04	4.39E-04	Not detected
	Oct. 18 – Nov. 3	1.86E-04	1.81E-04	3.59E-04	Not detected
	Nov. 3 – Nov. 29	1.50E-04	1.73E-04	3.74E-04	Not detected
	Nov. 29 – Dec. 19	1.79E-04	1.74E-04	3.46E-04	Not detected
	Dec. 19 – Jan. 8	1.18E-04	2.37E-04	5.57E-04	Not detected
$^{239+240}Pu$	Jan. 6 – Feb. 6	1.86E-04	1.97E-04	3.72E-04	Not detected
	Feb. 6 – Feb. 24	3.01E-04	3.36E-04	6.84E-04	Not detected
	Feb. 24 – Mar. 8	3.13E-04	2.50E-04	4.50E-04	Not detected
	Mar. 8 – Mar. 27	2.53E-04	2.08E-04	4.15E-04	Not detected
	Mar. 27 – Apr. 11	2.54E-04	2.28E-04	4.43E-04	Not detected
	Apr. 11 – Apr. 28	2.28E-04	1.84E-04	3.21E-04	Not detected
	Apr. 28 – May 17	2.28E-04	1.72E-04	3.03E-04	Not detected
	May 17 – May 31	5.95E-04	3.71E-04	5.90E-04	Detected
	May 31 – June 23	1.53E-04	1.31E-04	2.42E-04	Not detected
	June 23 – July 7	1.55E-04	1.91E-04	4.13E-04	Not detected
	July 7 – July 21	8.96E-05	1.79E-04	4.20E-04	Not detected
	July 21 – Aug. 4	3.28E-04	3.23E-04	6.67E-04	Not detected
	Aug. 4 – Aug. 18	6.85E-04	4.33E-04	7.68E-04	Not detected
	Aug. 18 - Sep. 15	3.11E-04	1.58E-04	2.50E-04	Detected
	Sep. 15 – Oct. 2	-8.19E-05	2.01E-04	6.50E-04	Not detected
	Oct. 2 – Oct. 18	0.00E+00	3.25E-04	8.38E-04	Not detected

Table 3-34: Specific activity of ^{241}Am, $^{239+240}$Pu and ^{238}Pu in the filter samples collected from Carlsbad Station (continued)

Radionuclides	Sample Date 2017	Activity Bq/g	Unc. (2σ) Bq/g	MDC Bq/g	Status
$^{239+240}$Pu	Oct. 18 – Nov. 3	1.55E-04	2.42E-04	5.49E-04	Not detected
	Nov. 3 – Nov. 29	7.80E-05	1.46E-04	3.40E-04	Not detected
	Nov. 29 – Dec. 19	2.47E-04	1.87E-04	3.28E-04	Not detected
	Dec. 19 – Jan. 8	4.60E-05	1.96E-04	4.90E-04	Not detected
^{238}Pu	Jan. 6 – Feb. 6	1.24E-04	1.52E-04	2.87E-04	Not detected
	Feb. 6 – Feb. 24	-3.46E-04	2.75E-04	9.66E-04	Not detected
	Feb. 24 – Mar. 8	1.14E-04	2.14E-04	4.95E-04	Not detected
	Mar. 8 – Mar. 27	-8.45E-05	1.39E-04	4.15E-04	Not detected
	Mar. 27 – Apr. 11	-7.62E-05	1.35E-04	4.43E-04	Not detected
	Apr. 11 – Apr. 28	-9.11E-05	1.82E-04	5.36E-04	Not detected
	Apr. 28 – May 17	-1.33E-04	1.38E-04	4.48E-04	Not detected
	May 17 – May 31	-2.23E-04	2.79E-04	8.74E-04	Not detected
	May 31 – June 23	-7.64E-05	1.18E-04	3.59E-04	Not detected
	June 23 – July 7	-7.76E-05	1.10E-04	3.65E-04	Not detected
	July 7 – July 21	-5.98E-05	1.69E-04	5.20E-04	Not detected
	July 21 – Aug. 4	-2.96E-04	2.55E-04	8.11E-04	Not detected
	Aug. 4 – Aug. 18	5.04E-04	3.72E-04	6.79E-04	Not detected
	Aug. 18 - Sep. 15	4.98E-05	8.63E-05	1.97E-04	Not detected
	Sep. 15 – Oct. 2	-4.09E-05	3.37E-04	9.20E-04	Not detected
	Oct. 2 – Oct. 18	-5.35E-04	2.98E-04	9.77E-04	Not detected
	Oct. 18 – Nov. 3	-1.03E-04	1.46E-04	4.86E-04	Not detected
	Nov. 3 – Nov. 29	3.90E-05	1.10E-04	2.74E-04	Not detected
	Nov. 29 – Dec. 19	-8.27E-05	2.03E-04	5.65E-04	Not detected
	Dec. 19 – Jan. 8	-1.15E-04	1.22E-04	4.31E-04	Not detected

Table 3-35: Activity concentrations of uranium isotopes (^{234}U, ^{235}U and ^{238}U) in the filter samples collected from Loving Station

Radionuclides	Sample Date 2017	Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
^{234}U	Jan. 6 – Feb. 6	8.33E-07	1.00E-07	1.44E-08	Detected
	Feb. 6 – Feb. 24	1.52E-06	1.80E-07	1.65E-08	Detected
	Feb. 24 – Mar. 8	3.13E-06	3.60E-07	3.44E-08	Detected
	Mar. 8 – Mar. 27	2.72E-06	3.14E-07	1.28E-08	Detected
	Mar. 27 – Apr. 11	3.02E-06	3.46E-07	2.28E-08	Detected
	Apr. 11 – Apr. 28	2.57E-06	2.98E-07	2.45E-08	Detected
	Apr. 28 – May 17	2.59E-06	3.02E-07	2.27E-08	Detected
	May 17 – May 31	2.38E-06	2.85E-07	3.74E-08	Detected
	May 31 – June 23	2.99E-06	3.35E-07	2.61E-08	Detected
	June 23 – July 7	2.67E-06	3.17E-07	3.57E-08	Detected
	July 7 – July 21	2.04E-06	2.45E-07	2.26E-08	Detected
	July 21 – Aug. 4	1.99E-06	2.40E-07	2.38E-08	Detected
	Aug. 4 – Aug. 18	1.72E-06	2.03E-07	2.07E-08	Detected
	Aug. 18 - Sep. 15	1.37E-06	1.54E-07	1.07E-08	Detected
	Sep. 15 – Oct. 2	1.86E-06	2.18E-07	2.42E-08	Detected
	Oct. 2 – Oct. 18	2.05E-06	2.42E-07	2.86E-08	Detected
	Oct. 18 – Nov. 3	2.25E-06	2.81E-07	4.28E-08	Detected
	Nov. 3 – Nov. 29	2.28E-06	2.72E-07	2.61E-08	Detected
	Nov. 29 – Dec. 19	2.04E-06	2.41E-07	2.35E-08	Detected
	Dec. 19 – Jan. 8	1.82E-06	2.16E-07	2.90E-08	Detected
^{235}U	Jan. 6 – Feb. 6	4.03E-08	1.19E-08	1.07E-08	Detected
	Feb. 6 – Feb. 24	7.13E-08	2.01E-08	1.08E-08	Detected
	Feb. 24 – Mar. 8	1.32E-07	3.36E-08	2.55E-08	Detected
	Mar. 8 – Mar. 27	1.27E-07	2.98E-08	1.57E-08	Detected
	Mar. 27 – Apr. 11	1.08E-07	2.74E-08	1.30E-08	Detected
	Apr. 11 – Apr. 28	1.27E-07	3.00E-08	1.62E-08	Detected
	Apr. 28 – May 17	1.02E-07	2.60E-08	1.22E-08	Detected
	May 17 – May 31	1.02E-07	3.09E-08	2.86E-08	Detected
	May 31 – June 23	1.43E-07	2.93E-08	1.48E-08	Detected
	June 23 – July 7	1.40E-07	3.54E-08	2.07E-08	Detected
	July 7 – July 21	1.07E-07	3.07E-08	3.01E-08	Detected
	July 21 – Aug. 4	1.32E-07	3.51E-08	3.18E-08	Detected
	Aug. 4 – Aug. 18	1.12E-07	2.77E-08	1.25E-08	Detected
	Aug. 18 - Sep. 15	7.10E-08	1.47E-08	6.43E-09	Detected
	Sep. 15 – Oct. 2	8.30E-08	2.28E-08	1.72E-08	Detected
	Oct. 2 – Oct. 18	9.84E-08	2.63E-08	1.67E-08	Detected

Table 3-35: Activity concentrations of uranium isotopes (^{234}U, ^{235}U and ^{238}U) in the filter samples collected from Loving Station (continued)

Radionuclides	Sample Date 2017	Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
^{235}U	Oct. 18 – Nov. 3	7.97E-08	2.80E-08	2.40E-08	Detected
	Nov. 3 – Nov. 29	1.43E-07	3.45E-08	2.89E-08	Detected
	Nov. 29 – Dec. 19	1.20E-07	2.88E-08	1.82E-08	Detected
	Dec. 19 – Jan. 8	7.98E-08	2.39E-08	2.55E-08	Detected
^{238}U	Jan. 6 – Feb. 6	8.55E-07	1.02E-07	1.28E-08	Detected
	Feb. 6 – Feb. 24	1.47E-06	1.74E-07	2.11E-08	Detected
	Feb. 24 – Mar. 8	2.92E-06	3.36E-07	3.05E-08	Detected
	Mar. 8 – Mar. 27	2.52E-06	2.93E-07	2.38E-08	Detected
	Mar. 27 – Apr. 11	2.64E-06	3.05E-07	3.63E-08	Detected
	Apr. 11 – Apr. 28	2.40E-06	2.80E-07	4.58E-08	Detected
	Apr. 28 – May 17	2.37E-06	2.77E-07	1.84E-08	Detected
	May 17 – May 31	2.32E-06	2.78E-07	4.79E-08	Detected
	May 31 – June 23	2.87E-06	3.23E-07	3.28E-08	Detected
	June 23 – July 7	2.55E-06	3.04E-07	4.48E-08	Detected
	July 7 – July 21	1.94E-06	2.34E-07	3.85E-08	Detected
	July 21 – Aug. 4	1.96E-06	2.37E-07	4.07E-08	Detected
	Aug. 4 – Aug. 18	1.67E-06	1.99E-07	3.26E-08	Detected
	Aug. 18 - Sep. 15	1.31E-06	1.49E-07	1.32E-08	Detected
	Sep. 15 – Oct. 2	1.70E-06	2.01E-07	2.69E-08	Detected
	Oct. 2 – Oct. 18	1.95E-06	2.32E-07	3.59E-08	Detected
	Oct. 18 – Nov. 3	2.23E-06	2.78E-07	4.41E-08	Detected
	Nov. 3 – Nov. 29	2.22E-06	2.66E-07	2.95E-08	Detected
	Nov. 29 – Dec. 19	2.07E-06	2.44E-07	2.45E-08	Detected
	Dec. 19 – Jan. 8	1.78E-06	2.12E-07	3.05E-08	Detected

Table 3-36: Activity concentrations of uranium isotopes (^{234}U, ^{235}U and ^{238}U) in the filter samples collected from Carlsbad Station

Radionuclides	Sample Date 2017	Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
^{234}U	Jan. 6 – Feb. 6	7.49E-07	8.93E-08	1.11E-08	Detected
	Feb. 6 – Feb. 24	1.33E-06	1.56E-07	1.74E-08	Detected
	Feb. 24 – Mar. 8	2.57E-06	2.99E-07	2.86E-08	Detected
	Mar. 8 – Mar. 27	2.22E-06	2.61E-07	1.69E-08	Detected
	Mar. 27 – Apr. 11	2.30E-06	2.71E-07	2.29E-08	Detected
	Apr. 11 – Apr. 28	1.92E-06	2.27E-07	2.95E-08	Detected
	Apr. 28 – May 17	2.05E-06	2.42E-07	2.44E-08	Detected
	May 17 – May 31	1.98E-06	2.41E-07	3.45E-08	Detected
	May 31 – June 23	2.37E-06	2.68E-07	2.31E-08	Detected
	June 23 – July 7	2.42E-06	2.94E-07	3.60E-08	Detected
	July 7 – July 21	1.92E-06	2.29E-07	2.14E-08	Detected
	July 21 – Aug. 4	1.77E-06	2.13E-07	3.08E-08	Detected
	Aug. 4 – Aug. 18	1.39E-06	1.72E-07	3.25E-08	Detected
	Aug. 18 - Sep. 15	1.03E-06	1.20E-07	9.43E-09	Detected
	Sep. 15 – Oct. 2	1.34E-06	1.61E-07	2.11E-08	Detected
	Oct. 2 – Oct. 18	1.84E-06	2.21E-07	2.97E-08	Detected
	Oct. 18 – Nov. 3	1.76E-06	2.13E-07	2.96E-08	Detected
	Nov. 3 – Nov. 29	2.11E-06	2.54E-07	2.46E-08	Detected
	Nov. 29 – Dec. 19	1.91E-06	2.30E-07	2.34E-08	Detected
	Dec. 19 – Jan. 8	1.55E-06	1.86E-07	2.48E-08	Detected
^{235}U	Jan. 6 – Feb. 6	2.74E-08	9.18E-09	8.58E-09	Detected
	Feb. 6 – Feb. 24	6.07E-08	1.77E-08	1.43E-08	Detected
	Feb. 24 – Mar. 8	1.08E-07	2.96E-08	2.22E-08	Detected
	Mar. 8 – Mar. 27	8.83E-08	2.41E-08	1.57E-08	Detected
	Mar. 27 – Apr. 11	1.19E-07	3.08E-08	2.38E-08	Detected
	Apr. 11 – Apr. 28	7.58E-08	2.33E-08	2.43E-08	Detected
	Apr. 28 – May 17	9.39E-08	2.47E-08	1.54E-08	Detected
	May 17 – May 31	7.47E-08	2.57E-08	2.45E-08	Detected
	May 31 – June 23	1.14E-07	2.49E-08	9.39E-09	Detected
	June 23 – July 7	1.08E-07	3.35E-08	3.56E-08	Detected
	July 7 – July 21	2.36E-06	2.82E-07	2.64E-08	Detected
	July 21 – Aug. 4	9.79E-08	2.71E-08	1.43E-08	Detected
	Aug. 4 – Aug. 18	9.89E-08	2.74E-08	1.82E-08	Detected
	Aug. 18 - Sep. 15	4.52E-08	1.15E-08	6.96E-09	Detected
	Sep. 15 – Oct. 2	6.17E-08	1.93E-08	1.85E-08	Detected
	Oct. 2 – Oct. 18	9.15E-08	2.57E-08	1.72E-08	Detected

Table 3-36: Activity concentrations of uranium isotopes (^{234}U, ^{235}U and ^{238}U) in the filter samples collected from Carlsbad Station (continued)

Radionuclides	Sample Date 2017	Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
^{235}U	Oct. 18 – Nov. 3	5.96E-08	2.32E-08	3.17E-08	Detected
	Nov. 3 – Nov. 29	1.22E-07	3.16E-08	2.40E-08	Detected
	Nov. 29 – Dec. 19	1.01E-07	2.71E-08	1.73E-08	Detected
	Dec. 19 – Jan. 8	8.26E-08	2.34E-08	2.25E-08	Detected
^{238}U	Jan. 6 – Feb. 6	7.49E-07	8.93E-08	1.25E-08	Detected
	Feb. 6 – Feb. 24	1.31E-06	1.54E-07	2.23E-08	Detected
	Feb. 24 – Mar. 8	2.40E-06	2.79E-07	3.24E-08	Detected
	Mar. 8 – Mar. 27	2.08E-06	2.46E-07	1.99E-08	Detected
	Mar. 27 – Apr. 11	2.00E-06	2.38E-07	3.52E-08	Detected
	Apr. 11 – Apr. 28	1.80E-06	2.14E-07	2.93E-08	Detected
	Apr. 28 – May 17	1.97E-06	2.33E-07	2.08E-08	Detected
	May 17 – May 31	1.85E-06	2.26E-07	4.29E-08	Detected
	May 31 – June 23	2.28E-06	2.58E-07	2.37E-08	Detected
	June 23 – July 7	2.24E-06	2.73E-07	3.88E-08	Detected
	July 7 – July 21	1.23E-07	2.87E-08	1.94E-08	Detected
	July 21 – Aug. 4	1.79E-06	2.16E-07	3.52E-08	Detected
	Aug. 4 – Aug. 18	1.44E-06	1.78E-07	3.34E-08	Detected
	Aug. 18 - Sep. 15	1.04E-06	1.21E-07	1.10E-08	Detected
	Sep. 15 – Oct. 2	1.31E-06	1.58E-07	2.73E-08	Detected
	Oct. 2 – Oct. 18	1.74E-06	2.10E-07	3.45E-08	Detected
	Oct. 18 – Nov. 3	1.78E-06	2.15E-07	3.49E-08	Detected
	Nov. 3 – Nov. 29	1.84E-06	2.24E-07	2.60E-08	Detected
	Nov. 29 – Dec. 19	1.84E-06	2.22E-07	3.18E-08	Detected
	Dec. 19 – Jan. 8	1.58E-06	1.89E-07	2.37E-08	Detected

Table 3-37: Specific activity of uranium isotopes (^{234}U, ^{235}U and ^{238}U) in the filter samples collected from Loving Station

Radionuclides	Sample Date 2017	Activity Bq/g	Unc. (2σ) Bq/g	MDC Bq/g	Status
^{234}U	Jan. 6 – Feb. 6	3.06E-02	3.68E-03	5.28E-04	Detected
	Feb. 6 – Feb. 24	3.29E-02	3.90E-03	3.57E-04	Detected
	Feb. 24 – Mar. 8	3.46E-02	3.97E-03	3.80E-04	Detected
	Mar. 8 – Mar. 27	2.97E-02	3.43E-03	1.40E-04	Detected
	Mar. 27 – Apr. 11	3.73E-02	4.28E-03	2.82E-04	Detected
	Apr. 11 – Apr. 28	3.66E-02	4.24E-03	3.48E-04	Detected
	Apr. 28 – May 17	3.43E-02	3.99E-03	3.00E-04	Detected
	May 17 – May 31	4.53E-02	5.41E-03	7.11E-04	Detected
	May 31 – June 23	3.32E-02	3.73E-03	2.90E-04	Detected
	June 23 – July 7	3.61E-02	4.29E-03	4.83E-04	Detected
	July 7 – July 21	4.26E-02	5.11E-03	4.71E-04	Detected
	July 21 – Aug. 4	4.43E-02	5.35E-03	5.31E-04	Detected
	Aug. 4 – Aug. 18	4.42E-02	5.23E-03	5.32E-04	Detected
	Aug. 18 - Sep. 15	2.44E-02	2.75E-03	1.90E-04	Detected
	Sep. 15 – Oct. 2	4.26E-02	5.00E-03	5.54E-04	Detected
	Oct. 2 – Oct. 18	4.21E-02	4.97E-03	5.88E-04	Detected
	Oct. 18 – Nov. 3	4.12E-02	5.13E-03	7.82E-04	Detected
	Nov. 3 – Nov. 29	3.35E-02	4.00E-03	3.84E-04	Detected
	Nov. 29 – Dec. 19	3.41E-02	4.02E-03	3.93E-04	Detected
	Dec. 19 – Jan. 8	3.04E-02	3.61E-03	4.84E-04	Detected
^{235}U	Jan. 6 – Feb. 6	1.48E-03	4.38E-04	3.91E-04	Detected
	Feb. 6 – Feb. 24	1.55E-03	4.35E-04	2.34E-04	Detected
	Feb. 24 – Mar. 8	1.46E-03	3.71E-04	2.82E-04	Detected
	Mar. 8 – Mar. 27	1.39E-03	3.26E-04	1.72E-04	Detected
	Mar. 27 – Apr. 11	1.33E-03	3.39E-04	1.60E-04	Detected
	Apr. 11 – Apr. 28	1.81E-03	4.26E-04	2.30E-04	Detected
	Apr. 28 – May 17	1.36E-03	3.44E-04	1.62E-04	Detected
	May 17 – May 31	1.93E-03	5.88E-04	5.45E-04	Detected
	May 31 – June 23	1.59E-03	3.26E-04	1.65E-04	Detected
	June 23 – July 7	1.90E-03	4.79E-04	2.81E-04	Detected
	July 7 – July 21	2.24E-03	6.41E-04	6.28E-04	Detected
	July 21 – Aug. 4	2.94E-03	7.81E-04	7.08E-04	Detected
	Aug. 4 – Aug. 18	2.89E-03	7.13E-04	3.22E-04	Detected
	Aug. 18 - Sep. 15	1.27E-03	2.61E-04	1.15E-04	Detected
	Sep. 15 – Oct. 2	1.90E-03	5.22E-04	3.94E-04	Detected
	Oct. 2 – Oct. 18	2.02E-03	5.40E-04	3.43E-04	Detected

Table 3-37: Specific activity of uranium isotopes (^{234}U, ^{235}U and ^{238}U) in the filter samples collected from Loving Station (continued)

Radionuclides	Sample Date 2017	Activity Bq/g	Unc. (2σ) Bq/g	MDC Bq/g	Status
^{235}U	Oct. 18 – Nov. 3	1.46E-03	5.12E-04	4.38E-04	Detected
	Nov. 3 – Nov. 29	2.11E-03	5.07E-04	4.25E-04	Detected
	Nov. 29 – Dec. 19	2.01E-03	4.81E-04	3.04E-04	Detected
	Dec. 19 – Jan. 8	1.33E-03	3.99E-04	4.26E-04	Detected
^{238}U	Jan. 6 – Feb. 6	3.13E-02	3.75E-03	4.69E-04	Detected
	Feb. 6 – Feb. 24	3.18E-02	3.78E-03	4.58E-04	Detected
	Feb. 24 – Mar. 8	3.22E-02	3.71E-03	3.36E-04	Detected
	Mar. 8 – Mar. 27	2.76E-02	3.20E-03	2.60E-04	Detected
	Mar. 27 – Apr. 11	3.27E-02	3.77E-03	4.49E-04	Detected
	Apr. 11 – Apr. 28	3.42E-02	3.98E-03	6.52E-04	Detected
	Apr. 28 – May 17	3.13E-02	3.67E-03	2.44E-04	Detected
	May 17 – May 31	4.41E-02	5.28E-03	9.11E-04	Detected
	May 31 – June 23	3.19E-02	3.59E-03	3.65E-04	Detected
	June 23 – July 7	3.46E-02	4.12E-03	6.06E-04	Detected
	July 7 – July 21	4.06E-02	4.88E-03	8.03E-04	Detected
	July 21 – Aug. 4	4.35E-02	5.27E-03	9.07E-04	Detected
	Aug. 4 – Aug. 18	4.28E-02	5.12E-03	8.39E-04	Detected
	Aug. 18 - Sep. 15	2.34E-02	2.65E-03	2.36E-04	Detected
	Sep. 15 – Oct. 2	3.89E-02	4.59E-03	6.16E-04	Detected
	Oct. 2 – Oct. 18	4.02E-02	4.76E-03	7.38E-04	Detected
	Oct. 18 – Nov. 3	4.08E-02	5.09E-03	8.06E-04	Detected
	Nov. 3 – Nov. 29	3.27E-02	3.90E-03	4.34E-04	Detected
	Nov. 29 – Dec. 19	3.46E-02	4.07E-03	4.09E-04	Detected
	Dec. 19 – Jan. 8	2.97E-02	3.54E-03	5.10E-04	Detected

Table 3-38: Specific activity of uranium isotopes (^{234}U, ^{235}U and ^{238}U) in the filter samples collected from Carlsbad Station

Radionuclides	Sample Date 2017	Activity Bq/g	Unc. (2σ) Bq/g	MDC Bq/g	Status
^{234}U	Jan. 6 – Feb. 6	4.31E-02	5.15E-03	6.37E-04	Detected
	Feb. 6 – Feb. 24	4.61E-02	5.42E-03	6.05E-04	Detected
	Feb. 24 – Mar. 8	4.26E-02	4.95E-03	4.73E-04	Detected
	Mar. 8 – Mar. 27	3.53E-02	4.15E-03	2.69E-04	Detected
	Mar. 27 – Apr. 11	5.17E-02	6.09E-03	5.14E-04	Detected
	Apr. 11 – Apr. 28	4.21E-02	4.98E-03	6.45E-04	Detected
	Apr. 28 – May 17	4.26E-02	5.03E-03	5.08E-04	Detected
	May 17 – May 31	5.31E-02	6.47E-03	9.28E-04	Detected
	May 31 – June 23	3.89E-02	4.40E-03	3.79E-04	Detected
	June 23 – July 7	4.25E-02	5.15E-03	6.31E-04	Detected
	July 7 – July 21	4.30E-02	5.14E-03	4.80E-04	Detected
	July 21 – Aug. 4	4.90E-02	5.92E-03	8.54E-04	Detected
	Aug. 4 – Aug. 18	4.56E-02	5.64E-03	1.06E-03	Detected
	Aug. 18 - Sep. 15	2.85E-02	3.30E-03	2.60E-04	Detected
	Sep. 15 – Oct. 2	5.40E-02	6.47E-03	8.51E-04	Detected
	Oct. 2 – Oct. 18	4.68E-02	5.62E-03	7.56E-04	Detected
	Oct. 18 – Nov. 3	4.26E-02	5.18E-03	7.19E-04	Detected
	Nov. 3 – Nov. 29	4.43E-02	5.34E-03	5.17E-04	Detected
	Nov. 29 – Dec. 19	4.42E-02	5.32E-03	5.44E-04	Detected
	Dec. 19 – Jan. 8	3.68E-02	4.40E-03	5.87E-04	Detected
^{235}U	Jan. 6 – Feb. 6	1.58E-03	5.29E-04	4.94E-04	Detected
	Feb. 6 – Feb. 24	2.11E-03	6.13E-04	4.95E-04	Detected
	Feb. 24 – Mar. 8	1.79E-03	4.90E-04	3.67E-04	Detected
	Mar. 8 – Mar. 27	1.40E-03	3.83E-04	2.51E-04	Detected
	Mar. 27 – Apr. 11	2.67E-03	6.91E-04	5.34E-04	Detected
	Apr. 11 – Apr. 28	1.66E-03	5.09E-04	5.32E-04	Detected
	Apr. 28 – May 17	1.95E-03	5.14E-04	3.20E-04	Detected
	May 17 – May 31	2.01E-03	6.89E-04	6.59E-04	Detected
	May 31 – June 23	1.88E-03	4.09E-04	1.54E-04	Detected
	June 23 – July 7	1.89E-03	5.88E-04	6.24E-04	Detected
	July 7 – July 21	5.30E-02	6.33E-03	5.92E-04	Detected
	July 21 – Aug. 4	2.72E-03	7.52E-04	3.98E-04	Detected
	Aug. 4 – Aug. 18	3.24E-03	8.97E-04	5.96E-04	Detected
	Aug. 18 - Sep. 15	1.24E-03	3.18E-04	1.92E-04	Detected
	Sep. 15 – Oct. 2	2.48E-03	7.78E-04	7.43E-04	Detected

Table 3-38: Specific activity of uranium isotopes (^{234}U, ^{235}U and ^{238}U) in the filter samples collected from Carlsbad Station (continued)

Radionuclides	Sample Date 2017	Activity Bq/g	Unc. (2σ) Bq/g	MDC Bq/g	Status
^{235}U	Oct. 2 – Oct. 18	2.33E-03	6.54E-04	4.39E-04	Detected
	Oct. 18 – Nov. 3	1.45E-03	5.64E-04	7.71E-04	Detected
	Nov. 3 – Nov. 29	2.56E-03	6.63E-04	5.04E-04	Detected
	Nov. 29 – Dec. 19	2.34E-03	6.29E-04	4.01E-04	Detected
^{238}U	Jan. 6 – Feb. 6	4.31E-02	5.15E-03	7.22E-04	Detected
	Feb. 6 – Feb. 24	4.53E-02	5.34E-03	7.75E-04	Detected
	Feb. 24 – Mar. 8	3.96E-02	4.62E-03	5.35E-04	Detected
	Mar. 8 – Mar. 27	3.31E-02	3.91E-03	3.17E-04	Detected
	Mar. 27 – Apr. 11	4.48E-02	5.34E-03	7.90E-04	Detected
	Apr. 11 – Apr. 28	3.94E-02	4.68E-03	6.42E-04	Detected
	Apr. 28 – May 17	4.10E-02	4.85E-03	4.34E-04	Detected
	May 17 – May 31	4.96E-02	6.07E-03	1.15E-03	Detected
	May 31 – June 23	3.74E-02	4.24E-03	3.89E-04	Detected
	June 23 – July 7	3.93E-02	4.79E-03	6.81E-04	Detected
	July 7 – July 21	2.75E-03	6.43E-04	4.36E-04	Detected
	July 21 – Aug. 4	4.98E-02	6.00E-03	9.78E-04	Detected
	Aug. 4 – Aug. 18	4.70E-02	5.82E-03	1.09E-03	Detected
	Aug. 18 - Sep. 15	2.87E-02	3.33E-03	3.02E-04	Detected
	Sep. 15 – Oct. 2	5.28E-02	6.36E-03	1.10E-03	Detected
	Oct. 2 – Oct. 18	4.43E-02	5.35E-03	8.80E-04	Detected
	Oct. 18 – Nov. 3	4.32E-02	5.23E-03	8.47E-04	Detected
	Nov. 3 – Nov. 29	3.85E-02	4.70E-03	5.46E-04	Detected
	Nov. 29 – Dec. 19	4.28E-02	5.16E-03	7.37E-04	Detected
	Dec. 19 – Jan. 8	3.75E-02	4.46E-03	5.62E-04	Detected

Table 3-39: Activity concentrations of gamma emitting isotopes (^{137}Cs, ^{60}Co and ^{40}K) in the filter samples collected from Loving Station

Radionuclides	Sample Date 2017	Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
^{137}Cs	Jan. 6 – Feb. 6	2.77E-07	3.78E-07	1.25E-06	Not detected
	Feb. 6 – Feb. 24	7.38E-07	1.56E-06	5.15E-06	Not detected
	Feb. 24 – Mar. 8	1.63E-06	1.27E-06	4.19E-06	Not detected
	Mar. 8 – Mar. 27	-7.88E-07	1.57E-06	5.21E-06	Not detected
	Mar. 27 – Apr. 11	3.96E-06	1.90E-06	6.21E-06	Not detected
	Apr. 11 – Apr. 28	-7.82E-07	1.78E-06	5.93E-06	Not detected
	Apr. 28 – May 17	1.28E-07	7.39E-07	2.45E-06	Not detected
	May 17 – May 31	1.84E-06	2.01E-06	6.65E-06	Not detected
	May 31 – June 23	3.92E-07	9.41E-07	3.11E-06	Not detected
	June 23 – July 7	-2.02E-06	2.07E-06	6.89E-06	Not detected
	July 7 – July 21	5.95E-07	8.85E-07	2.93E-06	Not detected
	July 21 – Aug. 4	-3.60E-07	1.17E-06	3.88E-06	Not detected
	Aug. 4 – Aug. 18	1.68E-07	1.16E-06	3.84E-06	Not detected
	Aug. 18 - Sep. 15	1.49E-08	3.60E-07	1.19E-06	Not detected
	Sep. 15 – Oct. 2	-1.23E-07	1.01E-06	3.36E-06	Not detected
	Oct. 2 – Oct. 18	-5.25E-09	1.02E-06	3.37E-06	Not detected
	Oct. 18 – Nov. 3	-4.55E-07	1.01E-06	3.35E-06	Not detected
	Nov. 3 – Nov. 29	-2.72E-07	1.64E-06	5.44E-06	Not detected
	Nov. 29 – Dec. 19	3.58E-07	9.37E-07	3.10E-06	Not detected
	Dec. 19 – Jan. 8	2.43E-06	6.31E-07	2.04E-06	detected
^{60}Co	Jan. 6 – Feb. 6	-1.43E-07	3.90E-07	1.30E-06	Not detected
	Feb. 6 – Feb. 24	-1.44E-06	1.51E-06	5.07E-06	Not detected
	Feb. 24 – Mar. 8	-5.68E-07	1.06E-06	3.53E-06	Not detected
	Mar. 8 – Mar. 27	-2.06E-07	1.53E-06	5.12E-06	Not detected
	Mar. 27 – Apr. 11	-1.27E-06	1.83E-06	6.13E-06	Not detected
	Apr. 11 – Apr. 28	-1.37E-06	1.71E-06	5.74E-06	Not detected
	Apr. 28 – May 17	-4.00E-07	7.72E-07	2.58E-06	Not detected
	May 17 – May 31	-5.01E-07	2.06E-06	6.89E-06	Not detected
	May 31 – June 23	-4.21E-08	8.23E-07	2.74E-06	Not detected
	June 23 – July 7	-3.35E-07	2.01E-06	6.70E-06	Not detected
	July 7 – July 21	-1.66E-06	9.55E-07	3.22E-06	Not detected
	July 21 – Aug. 4	-1.15E-06	1.02E-06	3.42E-06	Not detected
	Aug. 4 – Aug. 18	-4.81E-07	1.01E-06	3.38E-06	Not detected
	Aug. 18 - Sep. 15	-5.87E-07	3.87E-07	1.30E-06	Not detected
	Sep. 15 – Oct. 2	-5.92E-08	8.72E-07	2.91E-06	Not detected
	Oct. 2 – Oct. 18	-9.35E-07	8.94E-07	3.00E-06	Not detected

Table 3-39: Activity concentrations of gamma emitting isotopes (^{137}Cs, ^{60}Co and ^{40}K) in the filter samples collected from Loving Station (continued)

Radionuclides	Sample Date 2017	Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
^{60}Co	Oct. 18 – Nov. 3	-4.78E-07	8.53E-07	2.85E-06	Not detected
	Nov. 3 – Nov. 29	-3.28E-06	1.64E-06	5.56E-06	Not detected
	Nov. 29 – Dec. 19	-1.54E-06	8.17E-07	2.75E-06	Not detected
	Dec. 19 – Jan. 8	1.53E-06	5.35E-07	1.73E-06	Not detected
^{40}K	Jan. 6 – Feb. 6	2.79E-05	4.71E-06	1.50E-05	Detected
	Feb. 6 – Feb. 24	3.25E-05	1.57E-05	5.14E-05	Not detected
	Feb. 24 – Mar. 8	7.94E-05	1.35E-05	4.08E-05	Detected
	Mar. 8 – Mar. 27	1.37E-04	1.69E-05	5.01E-05	Detected
	Mar. 27 – Apr. 11	4.51E-05	1.95E-05	6.34E-05	Not detected
	Apr. 11 – Apr. 28	6.48E-05	1.67E-05	5.33E-05	Detected
	Apr. 28 – May 17	3.32E-05	9.67E-06	3.11E-05	Detected
	May 17 – May 31	5.30E-05	1.94E-05	6.27E-05	Not detected
	May 31 – June 23	3.18E-05	9.40E-06	3.03E-05	Detected
	June 23 – July 7	7.22E-05	1.93E-05	6.15E-05	Detected
	July 7 – July 21	2.63E-05	1.12E-05	3.65E-05	Not detected
	July 21 – Aug. 4	3.93E-05	1.24E-05	3.94E-05	Not detected
	Aug. 4 – Aug. 18	4.14E-05	1.24E-05	3.90E-05	Detected
	Aug. 18 - Sep. 15	3.14E-05	3.75E-06	1.08E-05	Detected
	Sep. 15 – Oct. 2	4.66E-05	1.09E-05	3.35E-05	Detected
	Oct. 2 – Oct. 18	4.33E-05	1.09E-05	3.37E-05	Detected
	Oct. 18 – Nov. 3	5.57E-05	1.09E-05	3.25E-05	Detected
	Nov. 3 – Nov. 29	6.04E-05	1.56E-05	4.96E-05	Detected
	Nov. 29 – Dec. 19	5.64E-05	1.02E-05	2.98E-05	Detected
	Dec. 19 – Jan. 8	6.73E-05	8.17E-06	1.97E-05	Detected

Table 3-40: Activity concentrations of gamma emitting isotopes (^{137}Cs, ^{60}Co and ^{40}K) in the filter samples collected from Carlsbad Station

Radionuclides	Sample Date 2017	Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
^{137}Cs	Jan. 6 – Feb. 6	6.54E-07	4.81E-07	1.58E-06	Not detected
	Feb. 6 – Feb. 24	-2.08E-07	6.57E-07	2.18E-06	Not detected
	Feb. 24 – Mar. 8	5.23E-07	9.71E-07	3.22E-06	Not detected
	Mar. 8 – Mar. 27	6.08E-07	1.51E-06	4.99E-06	Not detected
	Mar. 27 – Apr. 11	5.05E-07	8.03E-07	2.66E-06	Not detected
	Apr. 11 – Apr. 28	8.06E-07	9.53E-07	3.15E-06	Not detected
	Apr. 28 – May 17	4.41E-07	1.65E-06	5.48E-06	Not detected
	May 17 – May 31	8.71E-07	1.15E-06	3.81E-06	Not detected
	May 31 – June 23	1.34E-06	1.62E-06	5.36E-06	Not detected
	June 23 – July 7	4.01E-08	2.03E-06	6.73E-06	Not detected
	July 7 – July 21	1.08E-06	2.03E-06	6.71E-06	Not detected
	July 21 – Aug. 4	-1.31E-06	2.02E-06	6.73E-06	Not detected
	Aug. 4 – Aug. 18	-3.17E-08	9.17E-07	3.04E-06	Not detected
	Aug. 18 - Sep. 15	-4.27E-07	4.61E-07	1.53E-06	Not detected
	Sep. 15 – Oct. 2	-1.45E-06	1.67E-06	5.57E-06	Not detected
	Oct. 2 – Oct. 18	-1.74E-06	1.82E-06	6.07E-06	Not detected
	Oct. 18 – Nov. 3	-1.55E-06	1.82E-06	6.07E-06	Not detected
	Nov. 3 – Nov. 29	9.00E-07	9.26E-07	3.06E-06	Not detected
	Nov. 29 – Dec. 19	-1.05E-07	1.64E-06	5.46E-06	Not detected
	Dec. 19 – Jan. 8	8.39E-07	5.37E-07	1.77E-06	Not detected
^{60}Co	Jan. 6 – Feb. 6	1.83E-07	3.96E-07	1.31E-06	Not detected
	Feb. 6 – Feb. 24	3.83E-08	6.75E-07	2.25E-06	Not detected
	Feb. 24 – Mar. 8	4.81E-07	9.96E-07	3.30E-06	Not detected
	Mar. 8 – Mar. 27	-3.16E-07	1.40E-06	4.70E-06	Not detected
	Mar. 27 – Apr. 11	-7.42E-07	8.14E-07	2.73E-06	Not detected
	Apr. 11 – Apr. 28	2.25E-07	8.08E-07	2.68E-06	Not detected
	Apr. 28 – May 17	-2.94E-06	1.71E-06	5.78E-06	Not detected
	May 17 – May 31	-3.33E-07	1.01E-06	3.39E-06	Not detected
	May 31 – June 23	-1.33E-06	1.66E-06	5.58E-06	Not detected
	June 23 – July 7	-1.48E-06	2.07E-06	6.95E-06	Not detected
	July 7 – July 21	-1.68E-06	2.10E-06	7.04E-06	Not detected
	July 21 – Aug. 4	-2.60E-06	2.06E-06	6.94E-06	Not detected
	Aug. 4 – Aug. 18	-1.20E-06	9.93E-07	3.33E-06	Not detected
	Aug. 18 - Sep. 15	-3.56E-07	4.07E-07	1.36E-06	Not detected
	Sep. 15 – Oct. 2	-1.69E-06	1.69E-06	5.67E-06	Not detected
	Oct. 2 – Oct. 18	1.80E-07	1.69E-06	5.63E-06	Not detected

Table 3-40: Activity concentrations of gamma emitting isotopes (^{137}Cs, ^{60}Co and ^{40}K) in the filter samples collected from Carlsbad Station (continued)

Radionuclides	Sample Date 2017	Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
^{60}Co	Oct. 18 – Nov. 3	-2.53E-06	1.79E-06	6.05E-06	Not detected
	Nov. 3 – Nov. 29	-4.13E-07	8.09E-07	2.70E-06	Not detected
	Nov. 29 – Dec. 19	-1.95E-06	1.61E-06	5.43E-06	Not detected
	Dec. 19 – Jan. 8	6.19E-07	5.50E-07	1.82E-06	Not detected
^{40}K	Jan. 6 – Feb. 6	1.97E-05	5.04E-06	1.60E-05	Detected
	Feb. 6 – Feb. 24	2.37E-05	8.27E-06	2.70E-05	Not detected
	Feb. 24 – Mar. 8	6.67E-05	1.25E-05	3.98E-05	Detected
	Mar. 8 – Mar. 27	2.82E-05	1.52E-05	4.97E-05	Not detected
	Mar. 27 – Apr. 11	6.52E-05	9.85E-06	3.11E-05	Detected
	Apr. 11 – Apr. 28	4.18E-05	1.03E-05	3.18E-05	Detected
	Apr. 28 – May 17	3.65E-05	1.64E-05	5.36E-05	Not detected
	May 17 – May 31	6.73E-05	1.28E-05	3.81E-05	Detected
	May 31 – June 23	2.93E-05	1.59E-05	5.22E-05	Not detected
	June 23 – July 7	4.27E-05	2.03E-05	6.65E-05	Not detected
	July 7 – July 21	4.98E-05	1.93E-05	6.25E-05	Not detected
	July 21 – Aug. 4	1.84E-05	2.00E-05	6.62E-05	Not detected
	Aug. 4 – Aug. 18	3.84E-05	1.15E-05	3.70E-05	Detected
	Aug. 18 - Sep. 15	-2.84E-06	4.62E-06	1.54E-05	Not detected
	Sep. 15 – Oct. 2	2.52E-05	1.65E-05	5.43E-05	Not detected
	Oct. 2 – Oct. 18	1.59E-05	1.75E-05	5.80E-05	Not detected
	Oct. 18 – Nov. 3	4.78E-05	1.68E-05	5.42E-05	Not detected
	Nov. 3 – Nov. 29	6.30E-05	1.03E-05	2.91E-05	Detected
	Nov. 29 – Dec. 19	4.73E-05	1.57E-05	5.08E-05	Not detected
	Dec. 19 – Jan. 8	5.59E-05	7.19E-06	2.10E-05	Detected

Table 3-41: Specific activity of gamma emitting isotopes (^{137}Cs, ^{60}Co and ^{40}K) in the filter samples collected from Loving Station

Radionuclides	Sample Date 2017	Activity Bq/g	Unc. (2σ) Bq/g	MDC Bq/g	Status
^{137}Cs	Jan. 6 – Feb. 6	9.05E-03	1.24E-02	4.09E-02	Not detected
	Feb. 6 – Feb. 24	1.66E-02	3.50E-02	1.16E-01	Not detected
	Feb. 24 – Mar. 8	1.83E-02	1.43E-02	4.71E-02	Not detected
	Mar. 8 – Mar. 27	-9.43E-03	1.88E-02	6.24E-02	Not detected
	Mar. 27 – Apr. 11	4.90E-02	2.34E-02	7.68E-02	Not detected
	Apr. 11 – Apr. 28	-1.11E-02	2.54E-02	8.43E-02	Not detected
	Apr. 28 – May 17	1.70E-03	9.79E-03	3.25E-02	Not detected
	May 17 – May 31	3.51E-02	3.83E-02	1.26E-01	Not detected
	May 31 – June 23	4.36E-03	1.05E-02	3.46E-02	Not detected
	June 23 – July 7	-2.73E-02	2.80E-02	9.32E-02	Not detected
	July 7 – July 21	1.24E-02	1.85E-02	6.10E-02	Not detected
	July 21 – Aug. 4	-8.01E-03	2.60E-02	8.65E-02	Not detected
	Aug. 4 – Aug. 18	4.31E-03	2.98E-02	9.88E-02	Not detected
	Aug. 18 - Sep. 15	2.65E-04	6.41E-03	2.13E-02	Not detected
	Sep. 15 – Oct. 2	-2.81E-03	2.32E-02	7.68E-02	Not detected
	Oct. 2 – Oct. 18	-1.08E-04	2.09E-02	6.92E-02	Not detected
	Oct. 18 – Nov. 3	-8.32E-03	1.84E-02	6.12E-02	Not detected
	Nov. 3 – Nov. 29	-3.99E-03	2.41E-02	7.99E-02	Not detected
	Nov. 29 – Dec. 19	5.99E-03	1.57E-02	5.18E-02	Not detected
	Dec. 19 – Jan. 8	4.20E-02	1.09E-02	3.52E-02	Detected
^{60}Co	Jan. 6 – Feb. 6	-4.67E-03	1.28E-02	4.27E-02	Not detected
	Feb. 6 – Feb. 24	-3.23E-02	3.39E-02	1.14E-01	Not detected
	Feb. 24 – Mar. 8	-6.38E-03	1.19E-02	3.96E-02	Not detected
	Mar. 8 – Mar. 27	-2.47E-03	1.84E-02	6.13E-02	Not detected
	Mar. 27 – Apr. 11	-1.57E-02	2.26E-02	7.58E-02	Not detected
	Apr. 11 – Apr. 28	-1.94E-02	2.43E-02	8.17E-02	Not detected
	Apr. 28 – May 17	-5.30E-03	1.02E-02	3.42E-02	Not detected
	May 17 – May 31	-9.53E-03	3.92E-02	1.31E-01	Not detected
	May 31 – June 23	-4.68E-04	9.14E-03	3.04E-02	Not detected
	June 23 – July 7	-4.53E-03	2.71E-02	9.06E-02	Not detected
	July 7 – July 21	-3.47E-02	1.99E-02	6.71E-02	Not detected
	July 21 – Aug. 4	-2.55E-02	2.27E-02	7.62E-02	Not detected
	Aug. 4 – Aug. 18	-1.24E-02	2.60E-02	8.70E-02	Not detected
	Aug. 18 - Sep. 15	-1.05E-02	6.90E-03	2.32E-02	Not detected
	Sep. 15 – Oct. 2	-1.35E-03	2.00E-02	6.65E-02	Not detected
	Oct. 2 – Oct. 18	-1.92E-02	1.84E-02	6.16E-02	Not detected

Table 3-41: Specific activity of gamma emitting isotopes (^{137}Cs, ^{60}Co and ^{40}K) in the filter samples collected from Loving Station (continued)

Radionuclides	Sample Date 2017	Activity Bq/g	Unc. (2σ) Bq/g	MDC Bq/g	Status
^{60}Co	Oct. 18 – Nov. 3	-8.74E-03	1.56E-02	5.21E-02	Not detected
	Nov. 3 – Nov. 29	-4.82E-02	2.42E-02	8.17E-02	Not detected
	Nov. 29 – Dec. 19	-2.58E-02	1.37E-02	4.60E-02	Not detected
	Dec. 19 – Jan. 8	2.64E-02	9.25E-03	2.99E-02	Not detected
^{40}K	Jan. 6 – Feb. 6	9.15E-01	1.54E-01	4.90E-01	Detected
	Feb. 6 – Feb. 24	7.32E-01	3.54E-01	1.16E+00	Not detected
	Feb. 24 – Mar. 8	8.93E-01	1.52E-01	4.59E-01	Detected
	Mar. 8 – Mar. 27	1.64E+00	2.02E-01	6.00E-01	Detected
	Mar. 27 – Apr. 11	5.58E-01	2.41E-01	7.85E-01	Not detected
	Apr. 11 – Apr. 28	9.22E-01	2.38E-01	7.59E-01	Detected
	Apr. 28 – May 17	4.39E-01	1.28E-01	4.12E-01	Detected
	May 17 – May 31	1.01E+00	3.68E-01	1.19E+00	Not detected
	May 31 – June 23	3.53E-01	1.05E-01	3.36E-01	Detected
	June 23 – July 7	9.77E-01	2.60E-01	8.32E-01	Detected
	July 7 – July 21	5.48E-01	2.34E-01	7.61E-01	Not detected
	July 21 – Aug. 4	8.74E-01	2.77E-01	8.77E-01	Not detected
	Aug. 4 – Aug. 18	1.07E+00	3.18E-01	1.00E+00	Detected
	Aug. 18 - Sep. 15	5.59E-01	6.68E-02	1.92E-01	Detected
	Sep. 15 – Oct. 2	1.06E+00	2.50E-01	7.66E-01	Detected
	Oct. 2 – Oct. 18	8.89E-01	2.24E-01	6.93E-01	Detected
	Oct. 18 – Nov. 3	1.02E+00	1.99E-01	5.94E-01	Detected
	Nov. 3 – Nov. 29	8.88E-01	2.29E-01	7.30E-01	Detected
	Nov. 29 – Dec. 19	9.42E-01	1.71E-01	4.99E-01	Detected
	Dec. 19 – Jan. 8	1.16E+00	1.41E-01	3.40E-01	Detected

Table 3-42: Specific activity of gamma emitting isotopes (^{137}Cs, ^{60}Co and ^{40}K) in the filter samples collected from Carlsbad Station

Radionuclides	Sample Date 2017	Activity Bq/g	Unc. (2σ) Bq/g	MDC Bq/g	Status
^{137}Cs	Jan. 6 – Feb. 6	3.36E-02	2.48E-02	8.15E-02	Not detected
	Feb. 6 – Feb. 24	-7.51E-03	2.37E-02	7.87E-02	Not detected
	Feb. 24 – Mar. 8	8.83E-03	1.64E-02	5.43E-02	Not detected
	Mar. 8 – Mar. 27	1.06E-02	2.62E-02	8.66E-02	Not detected
	Mar. 27 – Apr. 11	1.13E-02	1.80E-02	5.96E-02	Not detected
	Apr. 11 – Apr. 28	1.76E-02	2.09E-02	6.89E-02	Not detected
	Apr. 28 – May 17	9.18E-03	3.44E-02	1.14E-01	Not detected
	May 17 – May 31	2.34E-02	3.10E-02	1.02E-01	Not detected
	May 31 – June 23	2.19E-02	2.66E-02	8.79E-02	Not detected
	June 23 – July 7	7.02E-04	3.56E-02	1.18E-01	Not detected
	July 7 – July 21	2.43E-02	4.55E-02	1.51E-01	Not detected
	July 21 – Aug. 4	-3.63E-02	5.61E-02	1.87E-01	Not detected
	Aug. 4 – Aug. 18	-1.04E-03	3.00E-02	9.96E-02	Not detected
	Aug. 18 - Sep. 15	-1.18E-02	1.27E-02	4.22E-02	Not detected
	Sep. 15 – Oct. 2	-5.83E-02	6.72E-02	2.24E-01	Not detected
	Oct. 2 – Oct. 18	-4.43E-02	4.64E-02	1.55E-01	Not detected
	Oct. 18 – Nov. 3	-3.77E-02	4.43E-02	1.47E-01	Not detected
	Nov. 3 – Nov. 29	1.89E-02	1.94E-02	6.41E-02	Not detected
	Nov. 29 – Dec. 19	-2.44E-03	3.82E-02	1.27E-01	Not detected
	Dec. 19 – Jan. 8	1.99E-02	1.27E-02	4.18E-02	Not detected
^{60}Co	Jan. 6 – Feb. 6	9.39E-03	2.04E-02	6.76E-02	Not detected
	Feb. 6 – Feb. 24	1.38E-03	2.43E-02	8.10E-02	Not detected
	Feb. 24 – Mar. 8	8.13E-03	1.68E-02	5.58E-02	Not detected
	Mar. 8 – Mar. 27	-5.48E-03	2.44E-02	8.15E-02	Not detected
	Mar. 27 – Apr. 11	-1.67E-02	1.83E-02	6.13E-02	Not detected
	Apr. 11 – Apr. 28	4.93E-03	1.77E-02	5.88E-02	Not detected
	Apr. 28 – May 17	-6.11E-02	3.57E-02	1.20E-01	Not detected
	May 17 – May 31	-8.96E-03	2.73E-02	9.10E-02	Not detected
	May 31 – June 23	-2.19E-02	2.73E-02	9.15E-02	Not detected
	June 23 – July 7	-2.60E-02	3.63E-02	1.22E-01	Not detected
	July 7 – July 21	-3.76E-02	4.71E-02	1.58E-01	Not detected
	July 21 – Aug. 4	-7.23E-02	5.73E-02	1.93E-01	Not detected
	Aug. 4 – Aug. 18	-3.92E-02	3.25E-02	1.09E-01	Not detected
	Aug. 18 - Sep. 15	-9.79E-03	1.12E-02	3.75E-02	Not detected
	Sep. 15 – Oct. 2	-6.81E-02	6.78E-02	2.28E-01	Not detected
	Oct. 2 – Oct. 18	4.59E-03	4.30E-02	1.43E-01	Not detected

Table 3-42: Specific activity of gamma emitting isotopes (^{137}Cs, ^{60}Co and ^{40}K) in the filter samples collected from Carlsbad Station (continued)

Radionuclides	Sample Date 2017	Activity Bq/g	Unc. (2σ) Bq/g	MDC Bq/g	Status
^{60}Co	Oct. 18 – Nov. 3	-6.14E-02	4.36E-02	1.47E-01	Not detected
	Nov. 3 – Nov. 29	-8.67E-03	1.70E-02	5.67E-02	Not detected
	Nov. 29 – Dec. 19	-4.53E-02	3.74E-02	1.26E-01	Not detected
	Dec. 19 – Jan. 8	1.46E-02	1.30E-02	4.31E-02	Not detected
^{40}K	Jan. 6 – Feb. 6	1.01E+00	2.60E-01	8.21E-01	Detected
	Feb. 6 – Feb. 24	8.56E-01	2.98E-01	9.72E-01	Not detected
	Feb. 24 – Mar. 8	1.13E+00	2.10E-01	6.72E-01	Detected
	Mar. 8 – Mar. 27	4.90E-01	2.63E-01	8.63E-01	Not detected
	Mar. 27 – Apr. 11	1.46E+00	2.21E-01	6.98E-01	Detected
	Apr. 11 – Apr. 28	9.15E-01	2.25E-01	6.97E-01	Detected
	Apr. 28 – May 17	7.60E-01	3.42E-01	1.12E+00	Not detected
	May 17 – May 31	1.81E+00	3.45E-01	1.02E+00	Detected
	May 31 – June 23	4.81E-01	2.61E-01	8.57E-01	Not detected
	June 23 – July 7	7.48E-01	3.57E-01	1.17E+00	Not detected
	July 7 – July 21	1.12E+00	4.32E-01	1.40E+00	Not detected
	July 21 – Aug. 4	5.12E-01	5.55E-01	1.84E+00	Not detected
	Aug. 4 – Aug. 18	1.26E+00	3.77E-01	1.21E+00	Detected
	Aug. 18 - Sep. 15	-7.82E-02	1.27E-01	4.24E-01	Not detected
	Sep. 15 – Oct. 2	1.01E+00	6.64E-01	2.18E+00	Not detected
	Oct. 2 – Oct. 18	4.05E-01	4.47E-01	1.48E+00	Not detected
	Oct. 18 – Nov. 3	1.16E+00	4.07E-01	1.32E+00	Not detected
	Nov. 3 – Nov. 29	1.32E+00	2.16E-01	6.12E-01	Detected
	Nov. 29 – Dec. 19	1.10E+00	3.65E-01	1.18E+00	Not detected
	Dec. 19 – Jan. 8	1.32E+00	1.70E-01	4.96E-01	Detected

Table 3-43: Activity concentrations of ^{241}Am, $^{239+240}Pu$ and ^{238}Pu in the filter samples collected from East Tower Station

Radionuclides	Sample Date 2017	Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
^{241}Am	Sep. 15 – Oct. 2	7.31E-09	9.34E-09	2.07E-08	Not detected
	Oct. 2 – Oct. 18	8.81E-09	9.96E-09	2.15E-08	Not detected
	Oct. 18 – Nov. 3	7.82E-09	6.77E-09	1.23E-08	Not detected
	Nov. 3 – Nov. 29	-1.72E-09	1.06E-08	2.75E-08	Not detected
	Nov. 29 – Dec. 19	1.39E-08	9.18E-09	1.64E-08	Not detected
	Dec. 19 – Jan. 8	1.36E-08	2.72E-08	6.37E-08	Not detected
$^{239+240}Pu$	Sep. 15 – Oct. 2	1.53E-08	9.56E-09	1.52E-08	Detected
	Oct. 2 – Oct. 18	1.01E-08	8.20E-09	1.35E-08	Not detected
	Oct. 18 – Nov. 3	1.11E-08	9.73E-09	1.90E-08	Not detected
	Nov. 3 – Nov. 29	6.00E-09	6.67E-09	1.36E-08	Not detected
	Nov. 29 – Dec. 19	1.94E-08	8.90E-09	8.19E-09	Detected
	Dec. 19 – Jan. 8	1.17E-08	9.60E-09	1.84E-08	Not detected
^{238}Pu	Sep. 15 – Oct. 2	-1.92E-09	6.07E-09	1.80E-08	Not detected
	Oct. 2 – Oct. 18	-3.36E-09	4.50E-09	1.58E-08	Not detected
	Oct. 18 – Nov. 3	3.03E-09	5.36E-09	1.21E-08	Not detected
	Nov. 3 – Nov. 29	-1.72E-09	4.21E-09	1.36E-08	Not detected
	Nov. 29 – Dec. 19	-8.83E-10	8.12E-09	2.17E-08	Not detected
	Dec. 19 – Jan. 8	1.95E-09	4.78E-09	1.17E-08	Not detected

Table 3-44: Specific activity of ^{241}Am, $^{239+240}Pu$ and ^{238}Pu in the filter samples collected from East Tower Station

Radionuclides	Sample Date 2017	Activity Bq/g	Unc. (2σ) Bq/g	MDC Bq/g	Status
^{241}Am	Sep. 15 – Oct. 2	3.26E-04	4.17E-04	9.24E-04	Not detected
	Oct. 2 – Oct. 18	3.43E-04	3.87E-04	8.38E-04	Not detected
	Oct. 18 – Nov. 3	1.93E-04	1.68E-04	3.03E-04	Not detected
	Nov. 3 – Nov. 29	-4.24E-05	2.62E-04	6.81E-04	Not detected
	Nov. 29 – Dec. 19	3.44E-04	2.27E-04	4.05E-04	Not detected
	Dec. 19 – Jan. 8	3.64E-04	7.29E-04	1.71E-03	Not detected
$^{239+240}Pu$	Sep. 15 – Oct. 2	6.85E-04	4.26E-04	6.79E-04	Detected
	Oct. 2 – Oct. 18	3.93E-04	3.19E-04	5.25E-04	Not detected
	Oct. 18 – Nov. 3	2.75E-04	2.41E-04	4.70E-04	Not detected
	Nov. 3 – Nov. 29	1.48E-04	1.65E-04	3.37E-04	Not detected
	Nov. 29 – Dec. 19	4.80E-04	2.20E-04	2.03E-04	Detected
	Dec. 19 – Jan. 8	3.14E-04	2.58E-04	4.92E-04	Not detected

Table 3-44: Specific activity of ^{241}Am, $^{239+240}$Pu and ^{238}Pu in the filter samples collected from East Tower Station (continued)

Radionuclides	Sample Date 2017	Activity Bq/g	Unc. (2σ) Bq/g	MDC Bq/g	Status
^{238}Pu	Sep. 15 – Oct. 2	-8.56E-05	2.71E-04	8.05E-04	Not detected
	Oct. 2 – Oct. 18	-1.31E-04	1.75E-04	6.14E-04	Not detected
	Oct. 18 – Nov. 3	7.51E-05	1.33E-04	3.00E-04	Not detected
	Nov. 3 – Nov. 29	-4.24E-05	1.04E-04	3.37E-04	Not detected
	Nov. 29 – Dec. 19	-2.18E-05	2.01E-04	5.36E-04	Not detected
	Dec. 19 – Jan. 8	5.23E-05	1.28E-04	3.14E-04	Not detected

Table 3-45: Activity concentrations of uranium isotopes (^{234}U, ^{235}U and ^{238}U) in the filter samples collected from East Tower Station

Radionuclides	Sample Date 2017	Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
^{234}U	Sep. 15 – Oct. 2	1.24E-06	1.51E-07	2.66E-08	Detected
	Oct. 2 – Oct. 18	1.39E-06	1.69E-07	2.61E-08	Detected
	Oct. 18 – Nov. 3	1.96E-06	2.34E-07	3.30E-08	Detected
	Nov. 3 – Nov. 29	1.84E-06	2.19E-07	2.46E-08	Detected
	Nov. 29 – Dec. 19	1.91E-06	2.27E-07	3.35E-08	Detected
	Dec. 19 – Jan. 8	1.60E-06	1.89E-07	1.73E-08	Detected
^{235}U	Sep. 15 – Oct. 2	6.05E-08	2.00E-08	2.34E-08	Detected
	Oct. 2 – Oct. 18	5.77E-08	2.00E-08	1.94E-08	Detected
	Oct. 18 – Nov. 3	1.09E-07	2.92E-08	2.52E-08	Detected
	Nov. 3 – Nov. 29	9.18E-08	2.47E-08	1.26E-08	Detected
	Nov. 29 – Dec. 19	1.08E-07	2.71E-08	1.58E-08	Detected
	Dec. 19 – Jan. 8	6.79E-08	1.98E-08	1.60E-08	Detected
^{238}U	Sep. 15 – Oct. 2	1.23E-06	1.49E-07	2.80E-08	Detected
	Oct. 2 – Oct. 18	1.36E-06	1.66E-07	3.13E-08	Detected
	Oct. 18 – Nov. 3	1.99E-06	2.38E-07	3.09E-08	Detected
	Nov. 3 – Nov. 29	1.70E-06	2.04E-07	3.26E-08	Detected
	Nov. 29 – Dec. 19	1.80E-06	2.15E-07	2.90E-08	Detected
	Dec. 19 – Jan. 8	1.54E-06	1.82E-07	2.42E-08	Detected

Table 3-46: Specific activity of uranium isotopes (^{234}U, ^{235}U and ^{238}U) in the filter samples collected from East Tower Station

Radionuclides	Sample Date 2017	Activity Bq/g	Unc. (2σ) Bq/g	MDC Bq/g	Status
^{234}U	Sep. 15 – Oct. 2	5.53E-02	6.72E-03	1.19E-03	Detected
	Oct. 2 – Oct. 18	5.39E-02	6.59E-03	1.02E-03	Detected
	Oct. 18 – Nov. 3	4.85E-02	5.80E-03	8.17E-04	Detected
	Nov. 3 – Nov. 29	4.54E-02	5.41E-03	6.07E-04	Detected
	Nov. 29 – Dec. 19	4.72E-02	5.62E-03	8.28E-04	Detected
	Dec. 19 – Jan. 8	4.28E-02	5.06E-03	4.64E-04	Detected
^{235}U	Sep. 15 – Oct. 2	2.70E-03	8.92E-04	1.04E-03	Detected
	Oct. 2 – Oct. 18	2.24E-03	7.78E-04	7.54E-04	Detected
	Oct. 18 – Nov. 3	2.69E-03	7.22E-04	6.24E-04	Detected
	Nov. 3 – Nov. 29	2.27E-03	6.11E-04	3.11E-04	Detected
	Nov. 29 – Dec. 19	2.67E-03	6.71E-04	3.91E-04	Detected
	Dec. 19 – Jan. 8	1.82E-03	5.30E-04	4.28E-04	Detected
^{238}U	Sep. 15 – Oct. 2	5.49E-02	6.66E-03	1.25E-03	Detected
	Oct. 2 – Oct. 18	5.28E-02	6.47E-03	1.22E-03	Detected
	Oct. 18 – Nov. 3	4.93E-02	5.88E-03	7.64E-04	Detected
	Nov. 3 – Nov. 29	4.21E-02	5.04E-03	8.05E-04	Detected
	Nov. 29 – Dec. 19	4.45E-02	5.33E-03	7.18E-04	Detected
	Dec. 19 – Jan. 8	4.13E-02	4.89E-03	6.48E-04	Detected

Table 3-47: Activity concentrations of gamma emitting isotopes (^{137}Cs, ^{60}Co and ^{40}K) in the filter samples collected from East Tower Station

Radionuclides	Sample Date 2017	Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
^{137}Cs	Sep. 15 – Oct. 2	6.97E-07	1.67E-06	5.54E-06	Not detected
	Oct. 2 – Oct. 18	9.54E-07	1.77E-06	5.86E-06	Not detected
	Oct. 18 – Nov. 3	-1.02E-07	1.01E-06	3.36E-06	Not detected
	Nov. 3 – Nov. 29	-9.51E-07	1.65E-06	5.49E-06	Not detected
	Nov. 29 – Dec. 19	-2.71E-07	1.66E-06	5.51E-06	Not detected
	Dec. 19 – Jan. 8	3.02E-06	1.16E-06	3.76E-06	Not detected
^{60}Co	Sep. 15 – Oct. 2	2.71E-07	1.58E-06	5.26E-06	Not detected
	Oct. 2 – Oct. 18	-1.78E-06	1.79E-06	6.01E-06	Not detected
	Oct. 18 – Nov. 3	-8.02E-07	8.85E-07	2.97E-06	Not detected
	Nov. 3 – Nov. 29	-6.00E-07	1.59E-06	5.33E-06	Not detected
	Nov. 29 – Dec. 19	8.86E-07	1.58E-06	5.23E-06	Not detected
	Dec. 19 – Jan. 8	2.52E-06	1.11E-06	3.61E-06	Not detected

Table 3-47: Activity concentrations of gamma emitting isotopes (^{137}Cs, ^{60}Co and ^{40}K) in the filter samples collected from East Tower Station (continued)

Radionuclides	Sample Date 2017	Activity Bq/m^3	Unc. (2σ) Bq/m^3	MDC Bq/m^3	Status
^{40}K	Sep. 15 – Oct. 2	2.44E-05	1.62E-05	5.35E-05	Not detected
	Oct. 2 – Oct. 18	2.15E-05	1.68E-05	5.55E-05	Not detected
	Oct. 18 – Nov. 3	3.91E-05	1.07E-05	3.35E-05	Detected
	Nov. 3 – Nov. 29	4.59E-05	1.55E-05	5.02E-05	Not detected
	Nov. 29 – Dec. 19	3.92E-05	1.59E-05	5.18E-05	Not detected
	Dec. 19 – Jan. 8	5.10E-05	1.18E-05	3.69E-05	Detected
	Dec. 19 – Jan. 8	2.44E-05	1.62E-05	5.35E-05	Not detected

Table 3-48: Specific activity of gamma emitting isotopes (^{137}Cs, ^{60}Co and ^{40}K) in the filter samples collected from East Tower Station

Radionuclides	Sample Date 2017	Activity Bq/g	Unc. (2σ) Bq/g	MDC Bq/g	Status
^{137}Cs	Sep. 15 – Oct. 2	3.11E-02	7.47E-02	2.47E-01	Not detected
	Oct. 2 – Oct. 18	3.71E-02	6.89E-02	2.28E-01	Not detected
	Oct. 18 – Nov. 3	-2.53E-03	2.51E-02	8.32E-02	Not detected
	Nov. 3 – Nov. 29	-2.35E-02	4.08E-02	1.36E-01	Not detected
	Nov. 29 – Dec. 19	-6.69E-03	4.10E-02	1.36E-01	Not detected
	Dec. 19 – Jan. 8	8.09E-02	3.10E-02	1.01E-01	Not detected
^{60}Co	Sep. 15 – Oct. 2	1.21E-02	7.04E-02	2.35E-01	Not detected
	Oct. 2 – Oct. 18	-6.92E-02	6.96E-02	2.34E-01	Not detected
	Oct. 18 – Nov. 3	-1.98E-02	2.19E-02	7.34E-02	Not detected
	Nov. 3 – Nov. 29	-1.48E-02	3.94E-02	1.32E-01	Not detected
	Nov. 29 – Dec. 19	2.19E-02	3.90E-02	1.29E-01	Not detected
	Dec. 19 – Jan. 8	6.75E-02	2.97E-02	9.69E-02	Not detected
^{40}K	Sep. 15 – Oct. 2	1.09E+00	7.25E-01	2.39E+00	Not detected
	Oct. 2 – Oct. 18	8.38E-01	6.55E-01	2.16E+00	Not detected
	Oct. 18 – Nov. 3	9.66E-01	2.65E-01	8.29E-01	Detected
	Nov. 3 – Nov. 29	1.13E+00	3.84E-01	1.24E+00	Not detected
	Nov. 29 – Dec. 19	9.70E-01	3.94E-01	1.28E+00	Not detected
	Dec. 19 – Jan. 8	5.10E-05	1.18E-05	3.69E-05	Detected
	Dec. 19 – Jan. 8	2.44E-05	1.62E-05	5.35E-05	Not detected

CHAPTER 4

Drinking Water Monitoring

Drinking water is typically defined as water that is safe enough to be consumed by humans or to be used with low risk of immediate or long-term impact on human health. For this reason, the quality of drinking water available in the area surrounding the WIPP site is routinely checked to assure the public that health and environmental standards are met and to identify any changes in water quality which might negatively impact public health and/or the environment. Aquifers in the region surrounding the WIPP include the Dewey Lake, the Culebra-Magenta, the Ogallala, the Dockum, the Pecos River alluvium, and the Capitan Reef (Mercer, 1983). The main Carlsbad water supply is the Sheep Draw well field whose primary source is the Capitan Reef aquifer. The Hobbs and WIPP (Double Eagle) public water supply systems are fed by the Ogallala aquifer, while the Loving, Malaga, and Otis public water supply wells are fed by the Pecos River.

In 1974, the United States Congress passed the Safe Drinking Water Act. This law requires the U.S. Environmental Protection Agency (EPA) to determine the safe levels of contaminants in U.S. drinking water. The EPA researches drinking water to determine the level of a contaminant that is safe for a person to consume over a lifetime and that a water system can reasonably be required to remove it, given present technology and resources. This safe level is called the maximum contaminant level (MCL). MCLs in drinking water have been established for a variety of radionuclides. For radium, the MCL has been set at 5 pCi/L (picocuries per liter, a unit of measure for levels of radiation). The MCL for gross alpha radiation is 15 pCi/L (not including radon and uranium), and the maximum level for gross beta radiation is 50 pCi/L. In addition to causing cancer, exposure to uranium in drinking water may have toxic effects on the kidneys. Based on human kidney toxicity data, the MCL for uranium is 30 μg/L. Additionally, the EPA says that a treatment system would be considered vulnerable if it contained 50 pCi/L of uranium. Although the MCL applies only to public drinking water sources, it can give those who use private wells an idea of what an appropriate level of a contaminant should be for private water sources also.

During 2017, the CEMRC drinking water samples were collected from the major drinking water supplies used by communities in the WIPP region. The sources included the community water supplies of Carlsbad (Sheep Draw and Double Eagle), Loving, Otis, Hobbs, and Malaga. These locations are shown in Figure 4-1. While the CEMRC sampling locations are not likely to be affected by any WIPP radioactivity releases, the samples are collected and analyzed by the CEMRC annually because water is a primary vector in the food chain. As with community air sampling, the verification of the absence of WIPP-related radionuclides from CEMRC drinking water samples collected provides further public assurance of the safety of the WIPP and its negligible impact on the local populace or the environment.

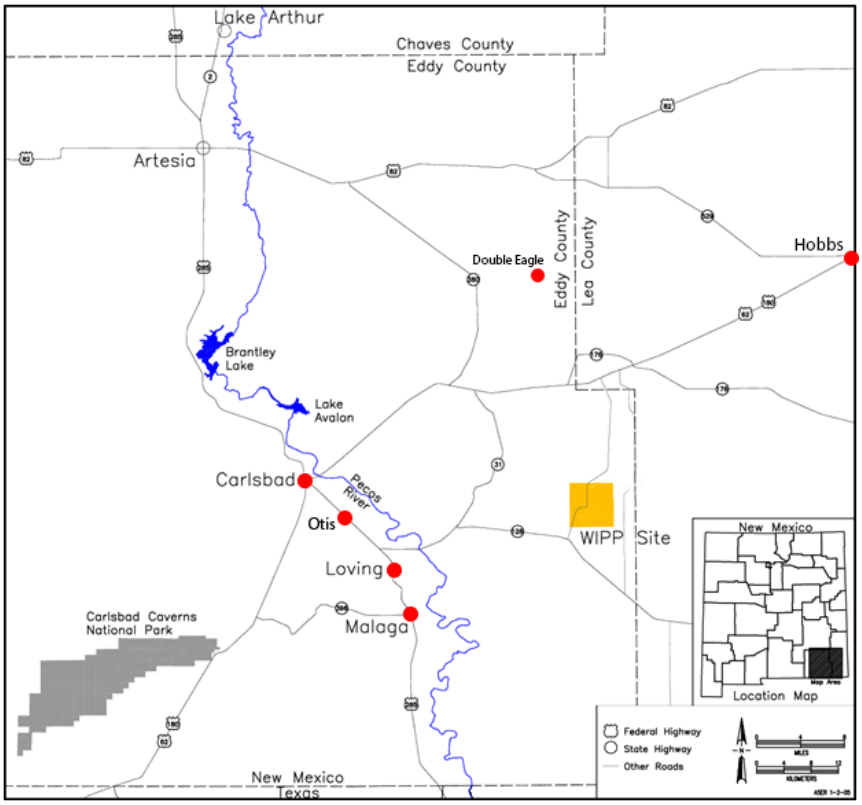


Figure 4-1: Drinking water sampling locations

History of CEMRC's Drinking Water Monitoring

CEMRC began collecting drinking water samples for radiochemical analyses in 1997 and inorganic analyses on drinking water samples commenced in 1998. Summaries of methods, data, and results from previous samplings were reported in earlier CEMRC reports and can be found on the CEMRC website (http://www.cemrc.org) under the annual reports tab. Drinking water samples were not collected during 2004 and 2006 and the Malaga water system was added to the CEMRC sampling sites in 2011. Present results, as well as the results of previous analyses of drinking water, were consistent for each source across sampling periods and were found to be below levels specified under the Safe Drinking Water Act.

It is important to note that after more than 15 years of monitoring, isotopes of ^{238}Pu, $^{239+240}$Pu, and ^{241}Am have never been detected above MDC in any of the samples collected from sampling sites around the WIPP site. Although uranium has been detected above the MDC, the observed activity indicates its presence in regional drinking water samples is most likely from natural sources. For most people in the world, the intake of uranium through food is around 1μg/day. The worldwide average of dietary uranium is estimated at 1.3 μg/day from which the portion from drinking water is 0.2 μg/day or 15.4% (UNSCEAR, 2001). Thus drinking water is not

usually the main source of ingested uranium. The CEMRC Monitoring results for drinking water analyses conducted to date show no increase in the levels of radionuclides that could be attributed to the WIPP related activities.

Drinking water monitoring following the 2014 WIPP Radiation Release Event

Drinking water samples collected from the same locations following the February 14, 2014, underground radiation release event at the WIPP had uranium concentrations in the range from 10.6-72.4 mBq/L for ^{238}U, 0.58-3.46 mBq/L for ^{235}U, and 28-171 mBq/L for ^{234}U. The detailed monitoring results are published in the CEMRC Annual Report 2014 and are available at (www.cemrc.org/Annual Report). The levels detected were consistent with those measured previously from these locations. These sampling locations are not likely to be affected by any WIPP-related radiation releases; however, the verification of no WIPP radionuclides in drinking waters continues to demonstrate the absence of adverse effects to the local and wider public or to the environment from the February 14, 2014, underground radiation release event at the WIPP. Further, the isotopes of plutonium (^{238}Pu and $^{239+240}$Pu) and ^{241}Am, the main radionuclides released from the WIPP repository, were not detected in any of the drinking water samples collected in 2014.

Analyses reported herein are for 2017 drinking water samples only. These samples were analyzed for radionuclides including alpha and gamma-emitting radionuclides of interest to the WIPP. The 2017 monitoring results for drinking water analyses continue to show no increase in the levels of radionuclides that could be attributed to the February 2014 underground radiological event at WIPP.

Sampling, Sample Preparation, and Measurements

All drinking water samples were processed according to CEMRC protocols for the collection, handling, and preservation of drinking water. This year, the drinking water samples were collected in April of 2017. The following samples were taken from each sampling location: (1) 8L for gamma and alpha analyses, (2) 1L for elemental analyses, (3) 1L for anion tests, and (4) 500mL for mercury analysis. None of the samples were filtered before analysis. Current methods used for the various analyses are summarized in Table 4-1.

For radioactive analyses, two aliquots were taken from each 8L sample: (a) Approximately 2L for gamma analyses and (b) 1L for alpha analyses. Both aliquots were acidified to approximately pH = 2 with nitric acid upon collection to avoid losses through microbial activity and adsorption onto the vessel walls. 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 Inc. (Atlanta, GA) in the energy range between 60 to 2000 keV. The counting time for each sample was 48 hours.

The second, 1L aliquot, was used for the alpha analysis of uranium (U) and transuranic radionuclides. Tracers consisting of uranium, americium, and plutonium (^{232}U, ^{243}Am, and ^{242}Pu) were added and the samples were digested using concentrated nitric and hydrochloric acid. The samples were then heated to dryness and wet-ashed using concentrated nitric and hydrogen peroxide. The separation process began by co-precipitation on $Fe(OH)_3$. Plutonium isotopes were separated and purified using a two-column anion exchange resin (Dowex1× 8, Eichrom, 100-200 mesh), while TRU chromatography columns were used for the separation of Am and U. The samples were then micro-co-precipitated using neodymium fluoride (NdF_3) and deposited onto planchets for counting of the uranium/transuranics by alpha spectroscopy for five days.

Table 4-1: Drinking Water Parameters, Methods, and Detection Levels used to analyze Samples from all Locations

Method/Parameters	Analytes of Interest	Typical Detection Limits
Gross alpha/beta EPA 900.0	(Under Development)	0.037-0.11 Bq/L*
Gamma emitters	^{60}Co, ^{137}Cs and ^{40}K	0.03-1.0 Bq/L*
Alpha emitters	$^{239+240}$Pu, ^{238}Pu, ^{241}Am, ^{234}U, ^{238}U, ^{235}U	0.001-0.002 Bq/L*

* Detection limits may vary depending on sample volume, solid concentrations, counting system and time

** Detection limits are determined annually

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 volume of the drinking water in liters (L).

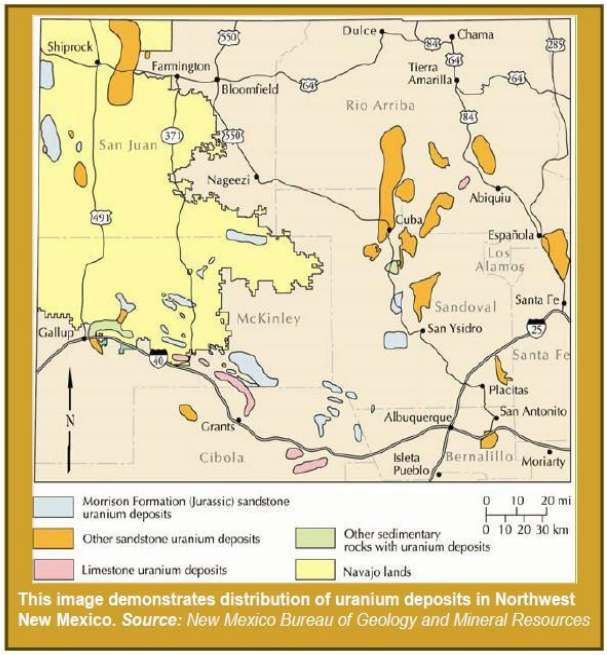
Radiological Monitoring Results

The activity concentrations of ^{238}Pu, $^{239+240}$Pu, ^{241}Am, ^{234}U, ^{235}U, and ^{238}U in regional drinking water samples collected in 2017 are listed in Table 4-2. The alpha-emitting radionuclides, ^{238}Pu, $^{239+240}$Pu, and ^{241}Am have not been detected in any of the drinking water

samples above the MDC since monitoring commenced in 1997. The federal and state action level for gross alpha emitters, which includes isotopes of Pu and U, is 15 pCi/L (0.56 Bq/L). This level measured is over 10,000 times the MDCs used at CEMRC. The historical concentrations of $^{239+240}$Pu, ^{238}Pu, and ^{241}Am measured in the drinking water in the vicinity of the WIPP site are shown in Figures 4-2 through 4-10.

Isotopes of naturally occurring uranium were detected in all of the drinking water samples in 2017 as shown in Table 4-3. Uranium in the environment occurs naturally as three radioactive isotopes: ^{238}U (99.27%), ^{235}U (0.72%), and ^{234}U (0.005%). The isotopes of uranium are also found in the earth's crust with a natural abundance of about 0.0004 % (Hursh et. al, 1973) in rocks and minerals such as granite, metamorphic rocks, lignite, monazite sand; phosphate deposits; as well as in uranium minerals such as uraninite, carnotite and pitchblende. It is also present as a trace element in coal, peat, asphalt and some phosphate fertilizers at a level of about 100 μg/g or 2.5 Bq/g (Hess et. al, 1985). All of these sources can come in contact with water which may be used for drinking purposes. Thus it is expected that some drinking and surface water sources will contain concentrations of uranium. The natural level of uranium in water can also be enhanced due to human activity. For example, the increased concentration of natural radionuclides in water can be caused by the intensive use of phosphate fertilizers in agriculture. The average phosphate fertilizers contain about 100 μg/g (or 24.8 Bq/g), if it is naturally occurring uranium (Cothern, and Lappenbusch, 1983), which can leach from the soil to nearby rivers and lakes (Fleischer, 1980; UNSCEAR, 1982).

Despite its widespread abundance, uranium has not been shown to be an essential element for humans (Hursh et. al, 1973). The major health effect of uranium is its chemical toxicity rather than its radiological hazard. The chemical toxicity of uranium is considered to be similar to lead. The primary target organ from chronic (long-term) ingestion of uranium is kidney damage; however, liver and thyroid damage can also result. Regardless, radiological impacts from the ingestion of uranium continues to be the subject of ongoing research and debate.



Map 1: Major uranium deposits in New Mexico

Uranium levels are naturally high in many areas in the USA. Uranium contaminated drinking water is a common problem, particularly in the Western United States, including New Mexico. Map 1 highlights the major uranium deposits in New Mexico. Natural uranium mineral deposits are concentrated in northern Santa Fe County, the Grants-Gallup area, and other areas within the State. These mineral deposits can leach uranium into groundwater. From the early 1950s until the early 1980s, New Mexico had the second-largest uranium ore reserves of any state in the United States (after Wyoming). Although no uranium ore has been mined in New Mexico since 1998, there are many areas within New Mexico with elevated levels of uranium present in their groundwater. According to the EPA, the MCL for uranium in drinking water is 30 ug/L. Despite this limit, water wells in several New Mexico communities show uranium levels three to six times higher than federally recommended levels for drinking water. Prior to 1980, uranium in drinking water was measured only when contamination from industrial sources was suspected. However, concerns over the radiological quality of drinking water have led to an increased demand for real data assessment. Further, considering the importance of water for human consumption, its quality has to be assured and regularly controlled; however, bathing in water with elevated levels of uranium is not considered to be a health risk. Cothern and Lappenbusch (1983), conducted an extensive investigation of radioactivity in drinking water in the US. Of the 59,812 community drinking water supplies in the US, a projected 25 to 650 exceeded a uranium concentration of 0.74 Bq/L; 100 to 2,000 exceeded 0.37 Bq/L; and 2,500 to 5,000 exceeded 0.185 Bq/L. A survey conducted by the European Food Safety Authority (EFSA) found average uranium concentrations in the 5,474 tap water samples collected from various European countries to be about 0.055 Bq/L.

Measured values for the drinking water samples collected in the vicinity of the WIPP site ranged from 0.11-65.9 mBq/L for ^{238}U, 0.06-3.24 mBq/L for ^{235}U, and 0.36-168.02 mBq/L for ^{234}U. These uranium activity concentrations are well below the EPA recommended level of 746 mBq/L and are within the range expected in waters from this region. According to the United Nations Scientific Committee on the Effects of Atomic Radiation, UNSCEAR, 2008, the ^{238}U concentration in drinking water is about 0.5-149 mBq/L in the US, 0.74-1190 mBq/L in Germany, and 0.25-1389 mBq/L in China. The worldwide reference value for ^{238}U in drinking water is about 2 mBq/L. The levels detected in these drinking water sources were also within the range expected in the US. For comparison purposes, the variation of uranium concentrations in drinking water sources around the world is summarized in Table 4-4.

The activity concentrations of ^{234}U, ^{235}U, and ^{238}U in drinking water collected from the six sources in 2017 are presented in Figure 4-11. The greatest variations appear in the amounts of ^{235}U. The low activity concentration of ^{235}U in the water samples is consistent with the lower activity concentration of ^{235}U in the natural environment as compared to the activity concentrations of ^{234}U and ^{238}U. The highest activity concentrations were found in Malaga and Otis waters. Figure 4-12 shows the total uranium activity concentration at each location.

It has been reported that the activity of uranium in natural water from ^{234}U is higher than that of ^{238}U. The $^{234}U/^{238}U$ activity ratio usually ranges between 1.0 and 3.0 (Cherdynstev et al. 1971; Gilkeson et al. 1982). According to the most recent reports, the fixed mass ratio and fixed activity ratios are still used for reporting the activity of natural uranium. The isotopic composition of natural uranium activities for ^{234}U, ^{235}U, and ^{238}U are 48.9, 2.2, and 48.9 %, respectively (IAEA, 1989). In radiochemical equilibrium, natural activity ratios are typically unity (1.0) for $^{234}U/^{238}U$ and 0.045 for $^{235}U/^{238}U$ (Pimple et al, 1992). However, many studies looking at ^{238}U and ^{234}U in natural bodies of water indicate that these isotopes do not occur in equilibrium and that, with a few exceptions, waters typically contain more ^{234}U than ^{238}U (Cothern et al. 1983; Skwarzec et al. 2002). Higher activity of ^{234}U in water is the result of the ^{234}U atom displacement from the crystal lattice. The recoil atom, ^{234}U, is liable to be oxidized to the hexavalent stage and can be leached into the water phase more easily than its parent nuclide ^{238}U. The oxidation of U(IV) to U(VI) is an important step in leaching because compounds containing U(VI) have a higher solubility due to the formation of strong complexes between uranyl and carbonate ions (UNSCEAR, 1977). All U(IV) compounds of uranium are practically insoluble.

The average activity ratio of $^{235}U/^{238}U$ in the water samples collected around the WIPP site ranged from 0.047-0.065. The natural ratio is reported to be 0.045 in nature. The $^{235}U/^{238}U$ ratio in environmental samples differing from the natural ratio results from anthropogenic nuclear activities. Figure 4-13 shows the $^{234}U/^{238}U$ ratios in the drinking water samples collected in 2017. The results of the activity ratios in this study compared very well with data observed in other countries as shown in Table 4-5. The calculated $^{234}U/^{238}U$ activity ratio varies between 0.95 to 3.62 which means that the two isotopes are not in radioactive equilibrium. The $^{234}U/^{238}U$ activity ratio measured in regional drinking water since 1998 is shown in Figure 4-14. The historical activity concentrations of ^{234}U, ^{235}U and ^{238}U measured at each site in the regional drinking water are summarized in Tables 4-6 through 4-11.

Gamma Radionuclides in the Drinking Water

The analysis data for the gamma isotopes are presented in Table 4-12. As shown in the Table 4-12, the naturally occurring gamma-emitting radionuclide, ^{40}K is not detected in any of the drinking water samples collected in 2017. In 2014, CEMRC had detected ^{40}K in Hobbs drinking water sample at a level of (1.35 Bq/L). Potassium-40 was also detected in drinking water samples

collected from Carlsbad, Malaga and Otis in 2013. This naturally occurring gamma-emitting radionuclide is ubiquitous in nature, therefore an occasional detection of ^{40}K in drinking water is not unusual. 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 these drinking water locations. The other two gamma radionuclides (^{137}Cs and ^{60}Co) were not detected in any of the drinking water samples (Table 4-12). Since these isotopes were not detected, no comparisons between years or among locations were performed.

Radiation Dose Estimation

Given the natural uranium activity found within the drinking waters studied, it is necessary to provide context and values for these low but detectable quantities. Assuming that a person drinks about 2.5 liters of water per day, the annual effective dose (D) resulting from consumption of the water investigated in the present study can be calculated using the following formula (UNSCEAR, 2008):

$$D = K*G*C*T$$

where D is the dose via ingestion (in Sv); K is the ingestion dose conversion factor of the specific radionuclide (Sv/Bq); G is the water consumption per day per person; C is the concentration of the specific radionuclide (Bq/L); and T is the duration of consumption, here it is one year (365 days). Ingestion dose conversion factors (Sv/Bq) for adults (20-70 years) used in the calculations were taken from the International Commission on Radiological Protection (ICRP publication 103) publication and were equal to 4.5×10^{-8} for ^{238}U, 4.7×10^{-8} for ^{235}U and 4.9×10^{-8} for ^{234}U. The calculated effective doses for the analyzed drinking water samples were in the range of 2.1-2.9 μSv/Bq for Carlsbad, 2.3-6.3 μSv/Bq for Double Eagle, 4.2- 11.3 μSv/Bq for Hobbs, 10.1-14.0 μSv/Bq for Otis, and 6.2-8.1 μSv/Bq for Loving as shown in Figure 4-15. The overall annual effective dose contributions due to intake of uranium isotopes were below the WHO and IAEA reference value (100 μSv/y) for drinking water (WHO, 2004). For most people in the world, the intake of uranium through food is around 1 g/day. The worldwide average of dietary uranium is estimated at 1.3 g/day from which the portion from drinking water is 0.2 g/day. Thus, drinking water is not usually the main source of ingested uranium.

Conclusion

The CEMRC monitors the drinking water in the vicinity of the WIPP site to evaluate the potential effects of TRU waste disposal activities in the WIPP. It is important to note that after more than fifteen years of monitoring, isotopes of plutonium (^{238}Pu and $^{239+240}Pu$) and ^{241}Am, none have never been detected above MDC in any of the sampling locations in and around the WIPP. However, the isotopes of uranium (^{234}U, ^{238}U, and ^{235}U) are detected in the drinking water samples. The levels detected were very low and the activity ratio indicates its presence in drinking water is most likely from natural sources. There is no evidence of increases in radiological contaminants in the region that could be attributed to a recent release event at the WIPP or

WIPP-related activities. The study concludes that the internal radiation dose contribution due to intake of uranium via water consumption is not significant and poses no increased health risk.

Table 4-2: ^{241}Am, $^{239+240}Pu$ and ^{238}Pu Concentrations Measured in Drinking Water in 2017

Radionuclide	Location	Activity Bq/L	Unc (2-sig) (Bq/L)	MDC (Bq/L)	Status
^{241}Am	Hobbs	6.25E-12	8.29E-05	2.29E-04	Not detected
	Double Eagle	1.10E-04	1.74E-04	3.88E-04	Not detected
	Carlsbad	3.43E-05	8.25E-05	1.99E-04	Not detected
	Malaga	5.16E-05	1.25E-04	3.00E-04	Not detected
	Otis	-9.04E-05	1.81E-04	5.32E-04	Not detected
	Loving	2.28E-05	7.89E-05	1.98E-04	Not detected
	Loving (Dup)	6.09E-05	1.17E-04	2.73E-04	Not detected
	Blank	-4.25E-05	7.50E-05	2.47E-04	Not detected
$^{239+240}Pu$	Hobbs	-7.18E-05	1.17E-04	3.37E-04	Not detected
	Double Eagle	2.41E-05	5.90E-05	1.45E-04	Not detected
	Carlsbad	-5.08E-05	8.82E-05	2.71E-04	Not detected
	Malaga	4.89E-05	1.38E-04	3.45E-04	Not detected
	Otis	3.15E-05	8.92E-05	2.22E-04	Not detected
	Loving	4.06E-05	8.12E-05	1.90E-04	Not detected
	Loving (Dup)	-1.16E-05	6.97E-05	2.02E-04	Not detected
	Blank	0.00E+00	8.30E-05	2.26E-04	Not detected
^{238}Pu	Hobbs	-9.57E-05	1.40E-04	3.93E-04	Not detected
	Double Eagle	-2.41E-05	4.82E-05	1.70E-04	Not detected
	Carlsbad	2.55E-05	9.51E-05	2.39E-04	Not detected
	Malaga	-2.45E-05	1.30E-04	3.88E-04	Not detected
	Otis	-1.42E-04	1.24E-04	4.01E-04	Not detected
	Loving	-1.35E-05	7.16E-05	2.14E-04	Not detected
	Loving (Dup)	-3.48E-05	4.66E-05	1.63E-04	Not detected
	Blank	-9.58E-05	9.64E-05	3.05E-04	Not detected

Dup = Duplicate

Table 4-3: Uranium Isotope Concentrations Measured in Drinking Water in 2017

Radionuclide	Location	Activity Bq/L	Unc (2-sig) (Bq/L)	MDC (Bq/L)	Status
^{234}U	Hobbs	4.82E-02	5.48E-03	2.86E-04	Detected
	Double Eagle	9.65E-02	1.09E-02	4.24E-04	Detected
	Carlsbad	3.02E-02	3.67E-03	4.29E-04	Detected
	Malaga	1.65E-01	1.95E-02	7.20E-04	Detected
	Otis	1.68E-01	1.89E-02	4.68E-04	Detected
	Loving	7.48E-02	8.43E-03	2.69E-04	Detected
	Loving (Dup)	7.43E-02	8.45E-03	3.04E-04	Detected
	Blank	3.63E-04	1.96E-04	3.09E-04	Detected
^{235}U	Hobbs	2.37E-03	4.87E-04	2.11E-04	Detected
	Double Eagle	2.36E-03	5.04E-04	1.46E-04	Detected
	Carlsbad	5.41E-04	2.46E-04	2.71E-04	Detected
	Malaga	3.24E-03	7.77E-04	6.34E-04	Detected
	Otis	2.86E-03	6.20E-04	4.26E-04	Detected
	Loving	1.01E-03	3.08E-04	2.29E-04	Detected
	Loving (Dup)	1.25E-03	3.54E-04	2.39E-04	Detected
	Blank	6.10E-05	1.23E-04	2.86E-04	Not detected
^{238}U	Hobbs	5.08E-02	5.76E-03	3.33E-04	Detected
	Double Eagle	4.13E-02	4.80E-03	5.01E-04	Detected
	Carlsbad	8.36E-03	1.22E-03	5.12E-04	Detected
	Malaga	6.24E-02	7.61E-03	7.58E-04	Detected
	Otis	6.59E-02	7.63E-03	4.49E-04	Detected
	Loving	2.16E-02	2.63E-03	3.78E-04	Detected
	Loving (Dup)	2.41E-02	2.93E-03	3.95E-04	Detected
	Blank	1.14E-04	1.89E-04	4.33E-04	Not detected

Dup = Duplicate

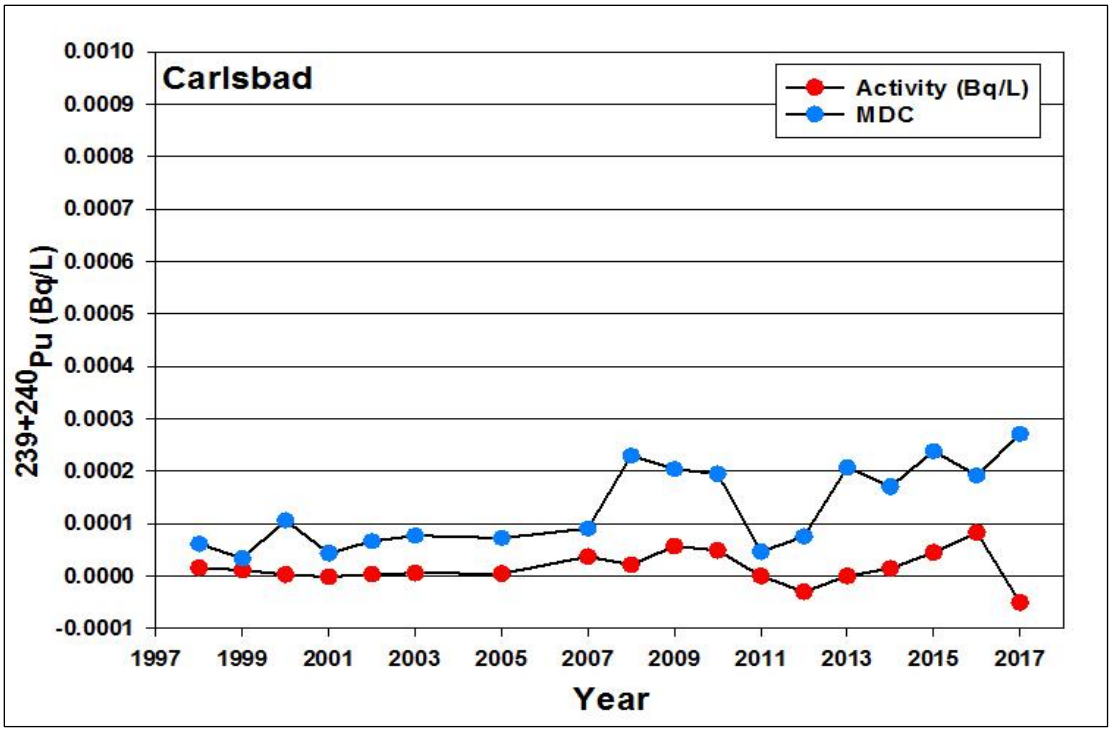


Figure 4-2: $^{239+240}$Pu in Carlsbad Drinking Water from 1998 – 2017

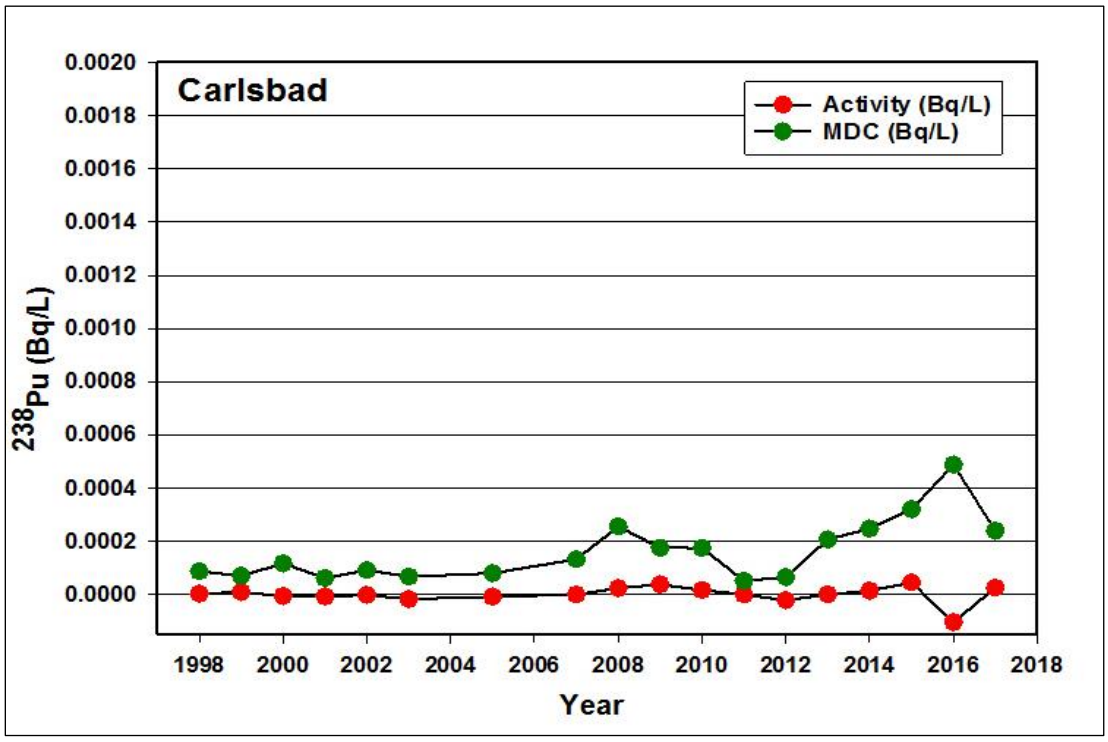


Figure 4-3: ^{238}Pu in Carlsbad Drinking Water from 1998 – 2017

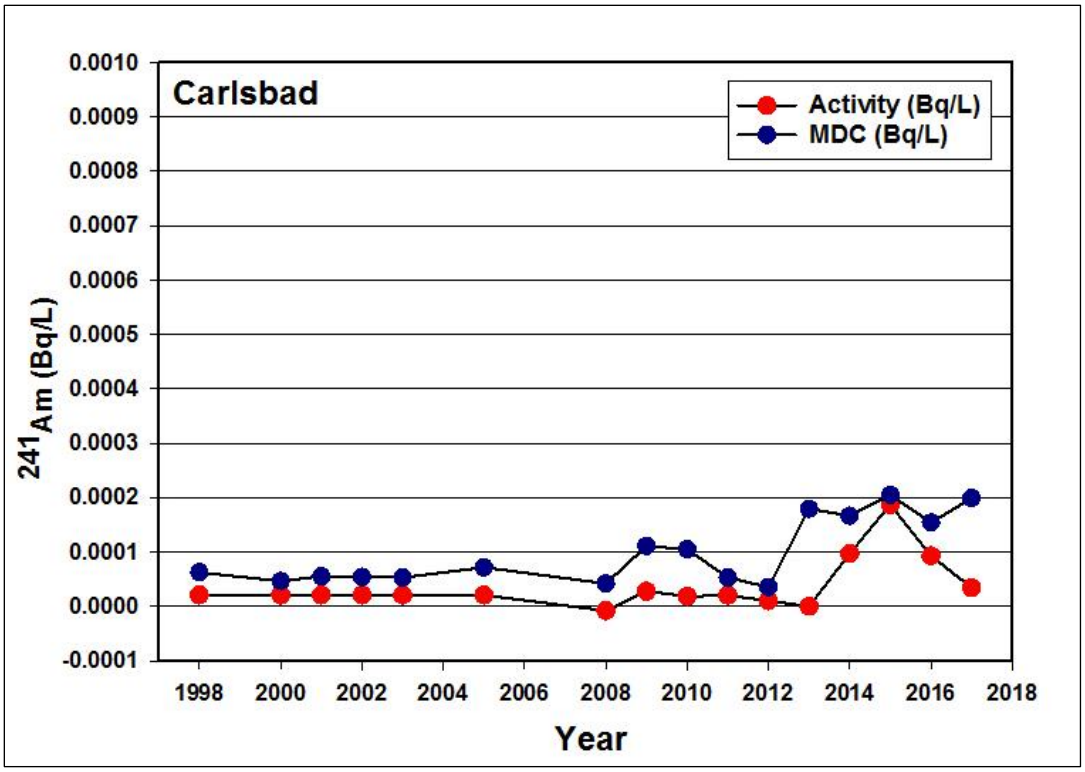


Figure 4-4: ^{241}Am in Carlsbad Drinking Water from 1998 – 2017

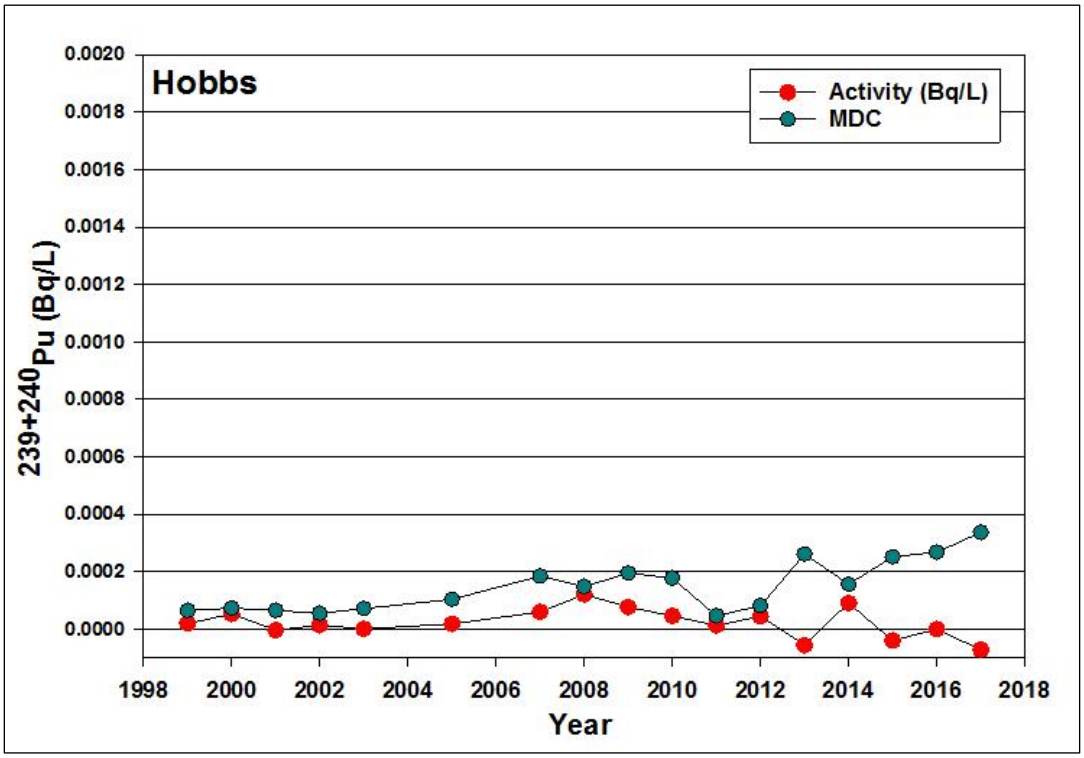


Figure 4-5: $^{239+240}$Pu in Hobbs Drinking Water from 1999 – 2017

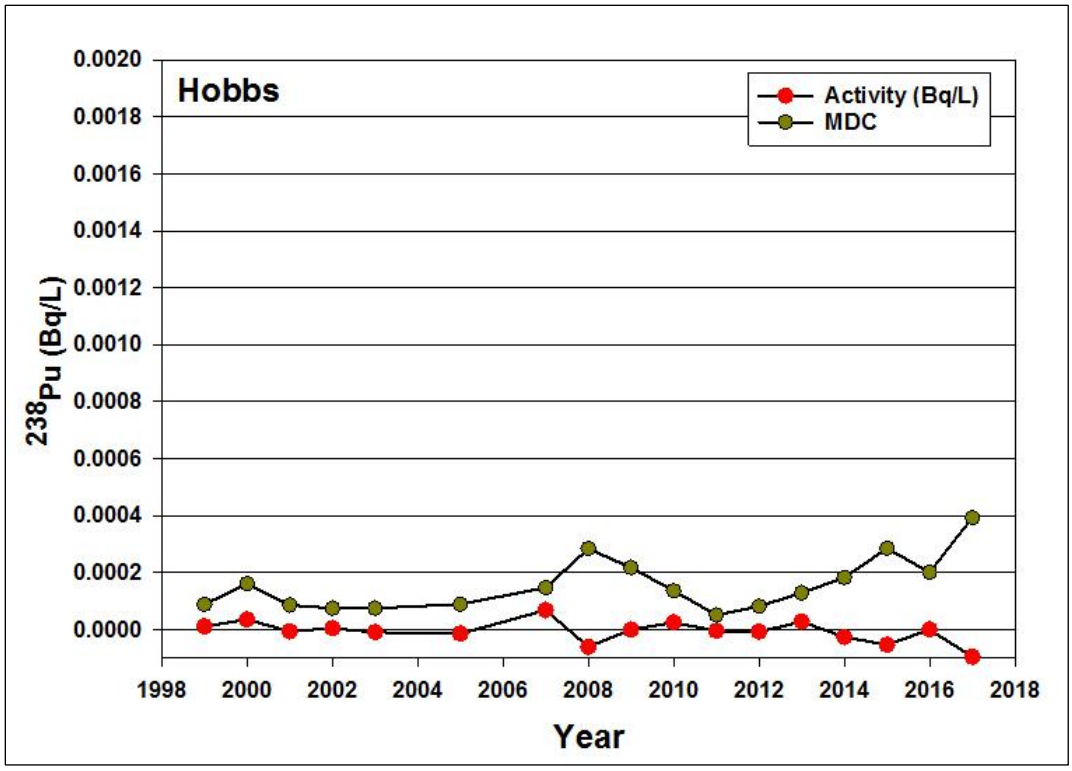


Figure 4-6: ^{238}Pu in Hobbs Drinking Water from 1999 – 2017

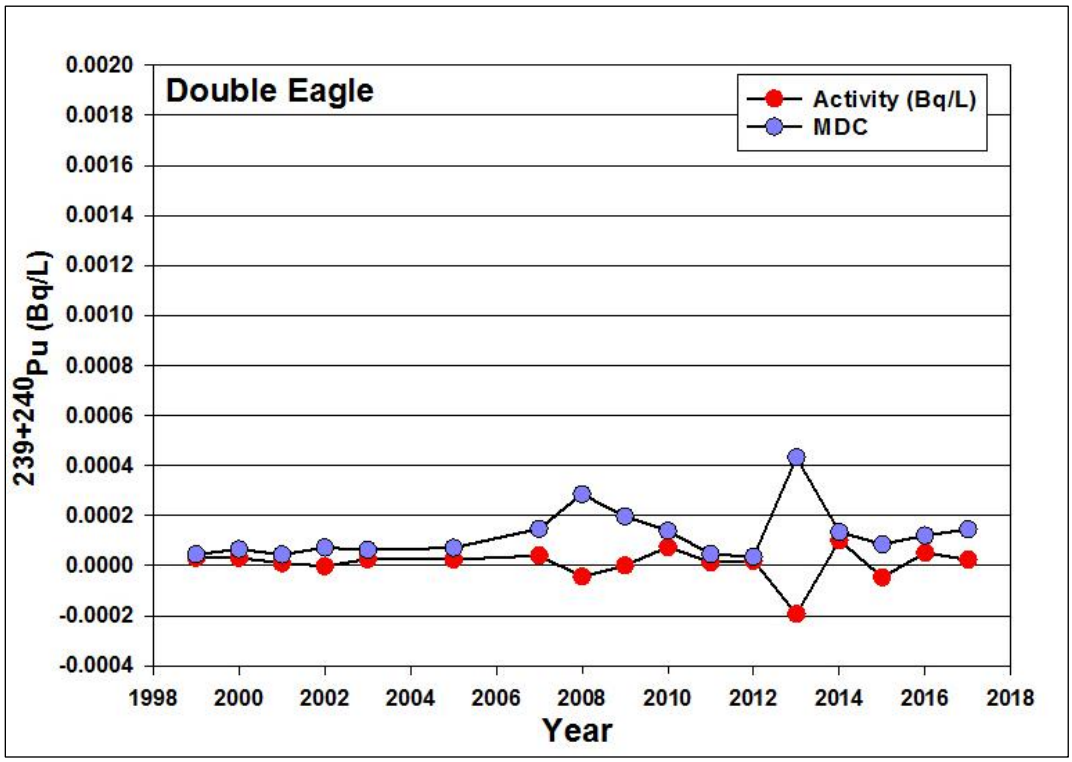


Figure 4-7: $^{239+240}$Pu in Double Eagle Drinking Water from 1999 -2017

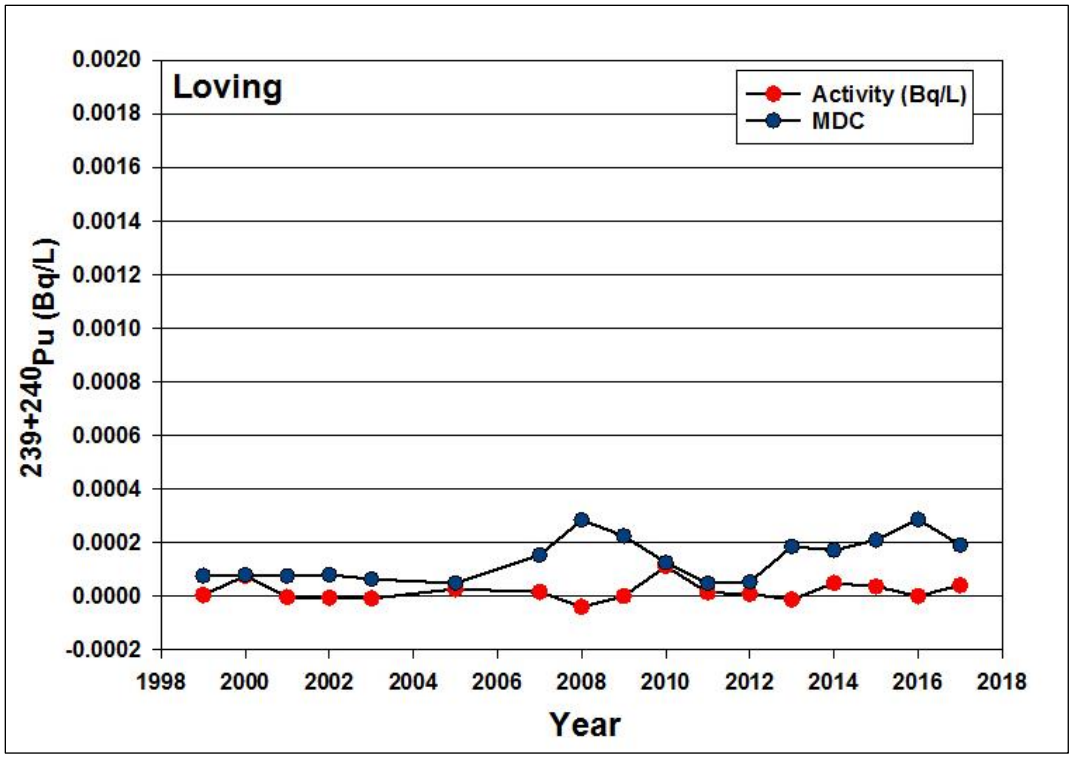


Figure 4-8: $^{239+240}$Pu in Loving Drinking Water from 1999 – 2017

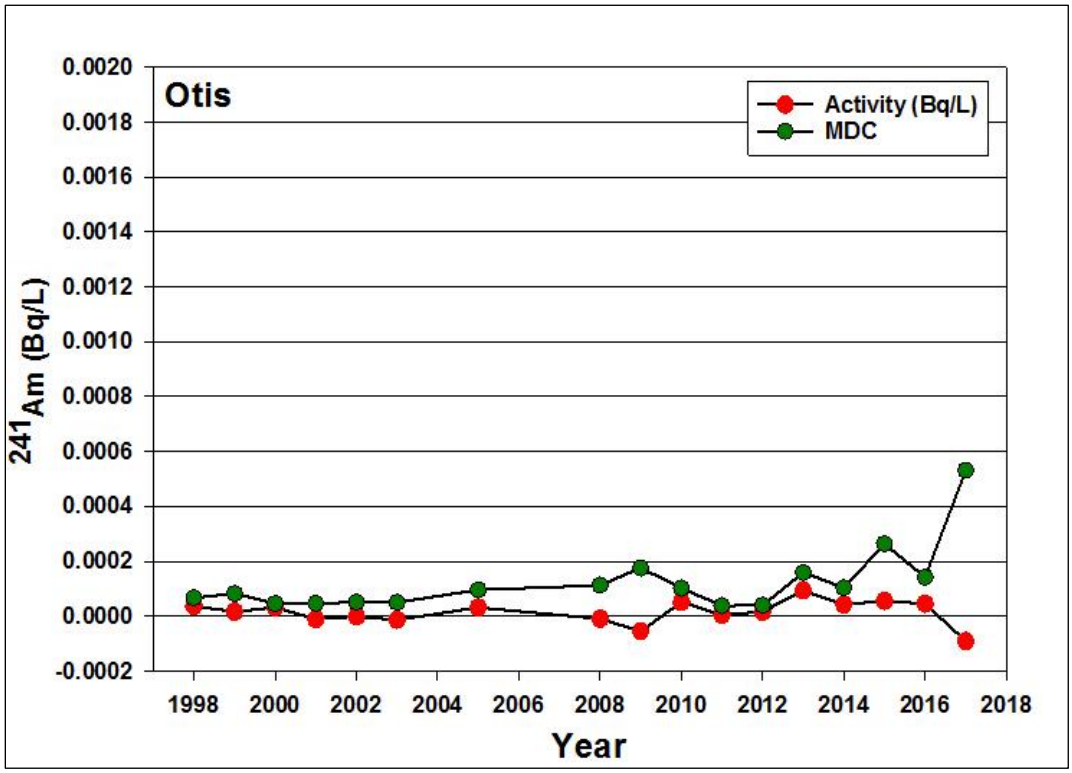


Figure 4-9: ^{241}Am in Otis Drinking Water from 1998 - 2017

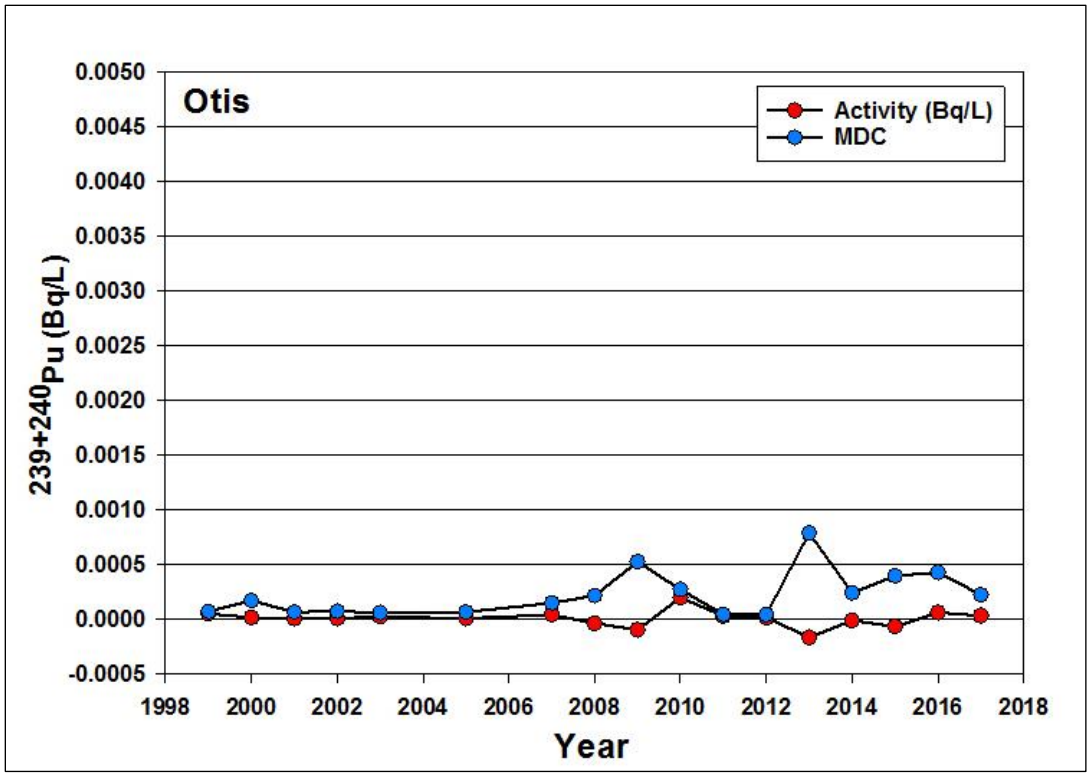


Figure 4-10: $^{239+240}$Pu in Otis Drinking Water from 1998 – 2017

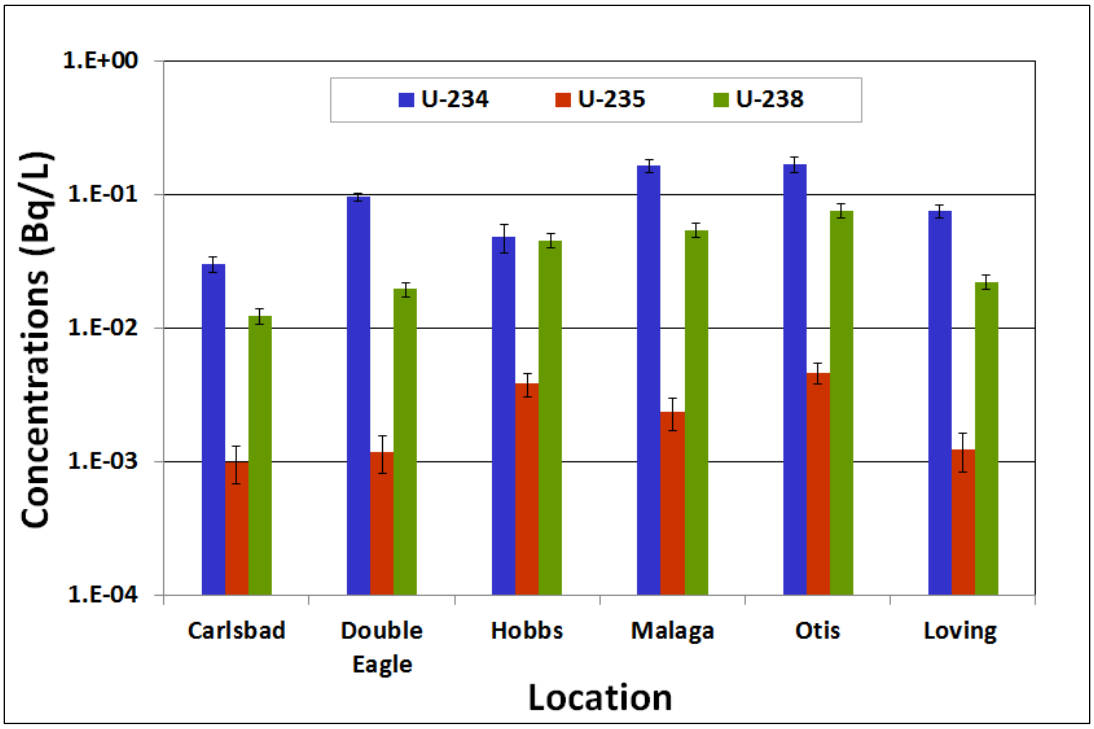


Figure 4-11: The ^{234}U, ^{235}U, and ^{238}U concentrations (Bq/L) in Regional Drinking Water in 2017

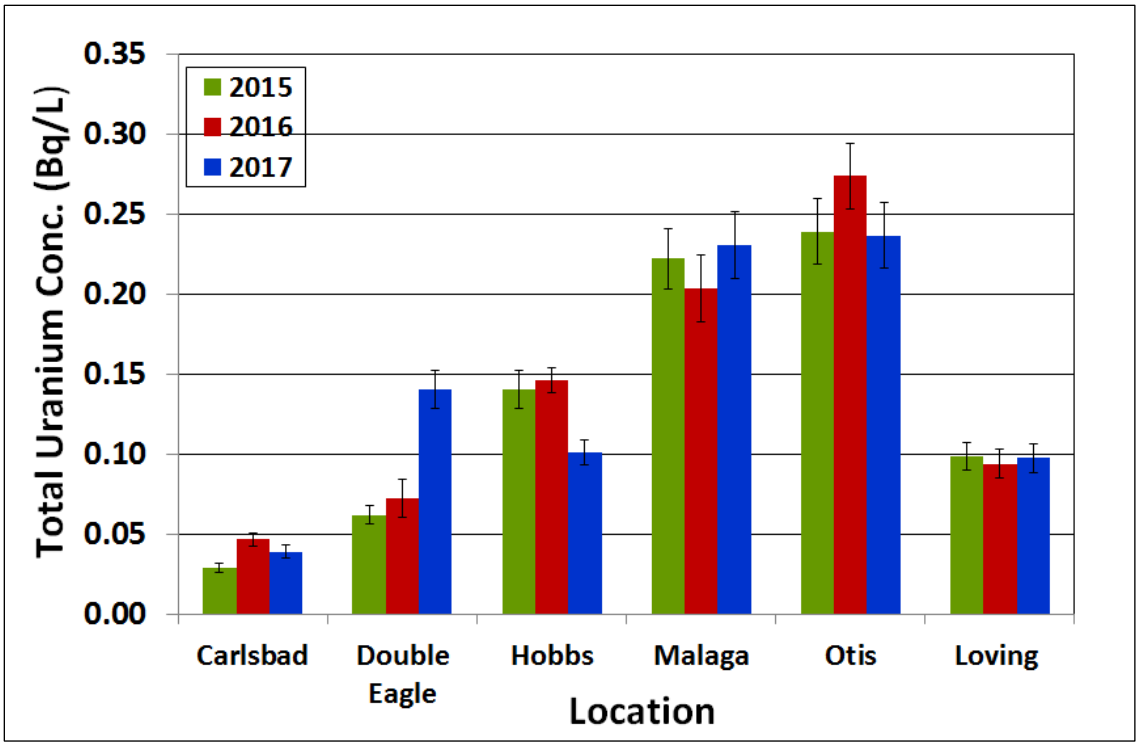


Figure 4-12: Total Uranium Concentrations in Bq/L in Regional Drinking Water collected in 2017

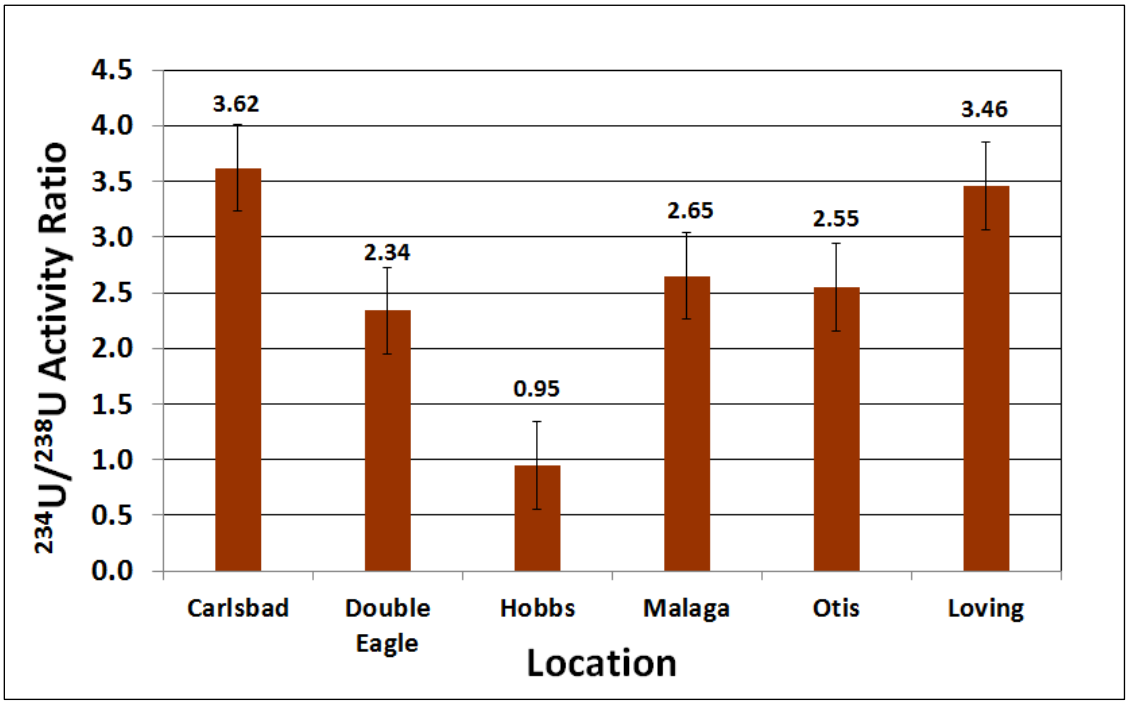


Figure 4-13: $^{234}U/^{238}U$ Activity Ratio in Regional Drinking Water During 2017

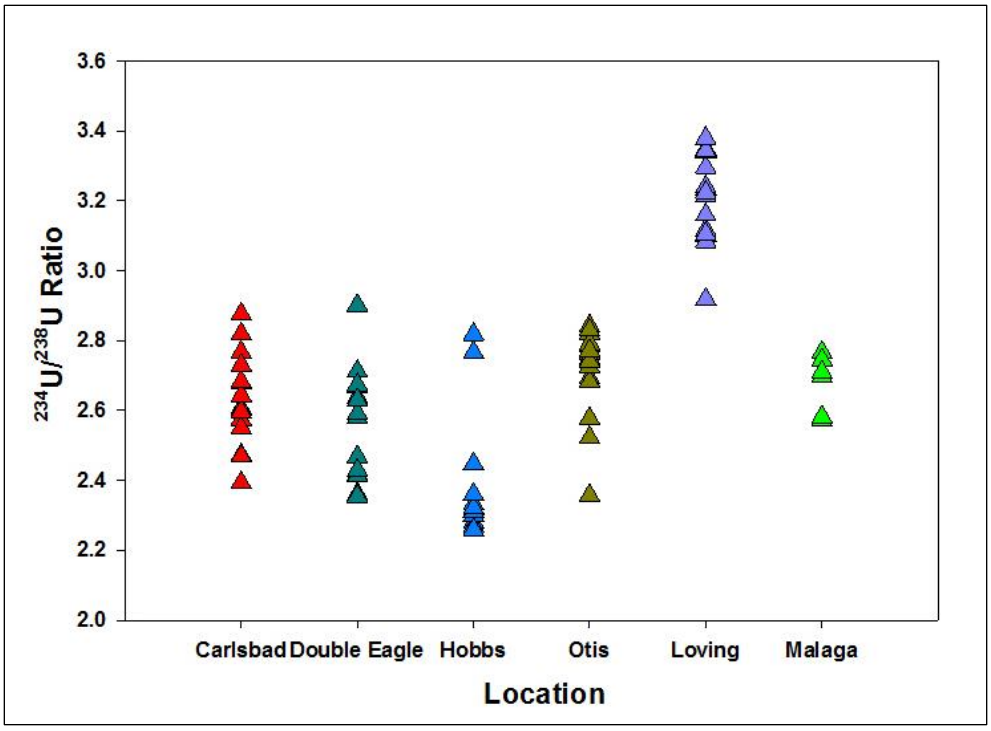


Figure 4-14: Variation in $^{234}U/^{238}U$ Activity Ratio in Regional Drinking Water from 1998 – 2017

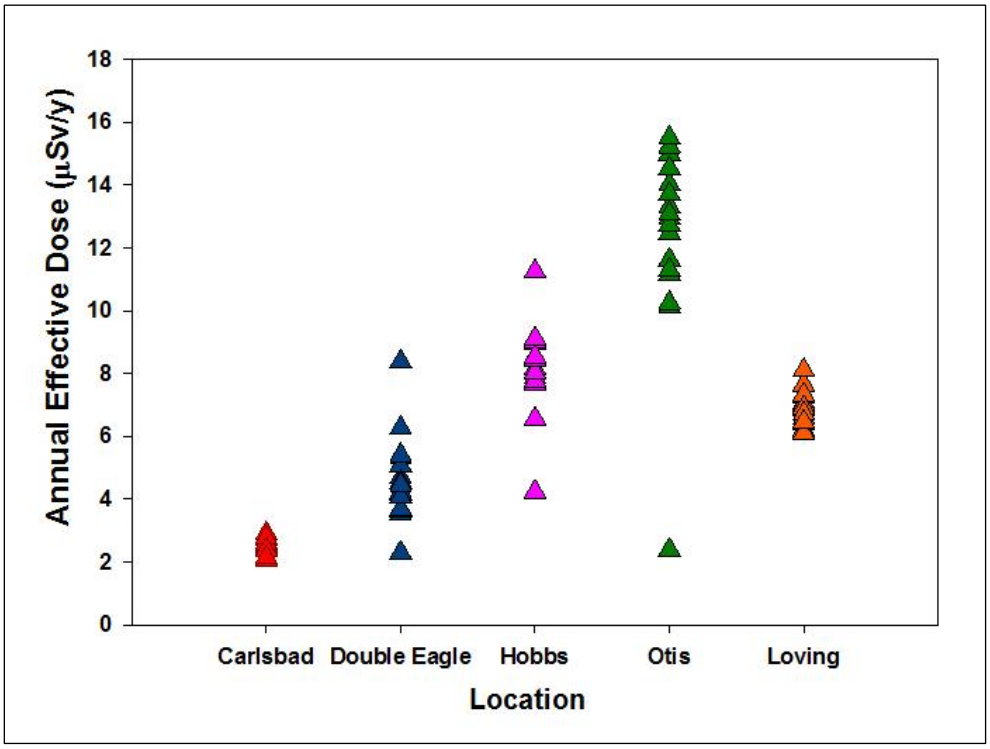


Figure 4-15: Annual Effective Dose (µSv/y) Due to Ingestion of Uranium in Drinking Water in the vicinity of the WIPP Site

Table 4-4: Variability of Natural Uranium Concentrations in the Drinking Water around the World

Country	Uranium Conc. (mBq/L)	Reference
Ontario, Canada	1.24-104.5	OMEE, 1996
Jordan	0.996-348.3	Gedeon, et al., 1994
Kuwait	0.498-62.19	Bou-Rabee, 1995
South Greenland	12.4-24.9	Brown et al., 1983
Turkey	4.98-437.9	Kumru, 1995
China	0.0996-696.6	UNSCEAR, 2008,
Iran	24.9-271.2	Alirezazadeh and Garshasbi, 2003
Norway	<0.498-4229	Banks et al., 1995
Sweden	< 4.98-11,693	Selden et al., 2000
Argentina	0.5-5000	UNSCEAR, 2008
Brazil	0.4-400	Geraldo et al., 1979
China	0.09-950	UNSCEAR, 2008
Czech Republic	3-1100	UNSCEAR, 2008
Finland	0.8-120,000	UNSCEAR, 2008
France	8-1000	UNSCEAR, 2008
Germany	0.5-900	UNSCEAR, 2008
Greece	0.2-30	UNSCEAR, 2008
Hungary	1-1000	UNSCEAR, 2008
India	0.09-2	UNSCEAR, 2008
Italy	0.3-400	UNSCEAR, 2008
Morocco	0.8-700	UNSCEAR, 2008
Romania	0.6-90	UNSCEAR, 2008
Spain	0.05-9	UNSCEAR, 2008
Switzerland	8-800	UNSCEAR, 2008
United States	0.5-90	Cothern and Lappenbusch, 1983
Poland	1.0-56	Kozlowska et al., 2007
Austria	2.5-2226	Gegner and Irweck, 2005

Table 4-5: Comparison of Activity Concentration Ratios of $^{234}U/^{238}U$ and $^{235}U/^{238}U$ in water samples collected near the WIPP Site with Other Countries

Source of water sample	Type of water	$^{234}U/^{238}U$	$^{235}U/^{238}U$	Reference
Carlsbad	Drinking water	3.62	0.065	Present work
Double Eagle	Drinking water	2.34	0.057	Present work
Hobbs	Drinking water	0.95	0.047	Present work
Otis	Drinking water	2.55	0.043	Present work
Loving	Drinking water	3.46	0.047	Present work
Malaga	Drinking water	2.65	0.052	Present work
UK	Water	1.0-3.0	-	Gilkeson et al.
Poland	Mineral water	0.82-1.12	-	Nguyen et al.
India	Sea water	1.11-1.14	0.045-0.047	Joshi et al.
Ghana, Obuasi	Ground water	1.07-1.44	0.042-0.045	Awudu et al.
Ghana, Obuasi	Surface water	1.06-1.76	0.044-0.045	Awudu et al.
Ghana, Obuasi	Tap water	1.06-1.73	0.044-0.045	Awudu et al.
INL, Idaho	Ground water	1.5-3.1	-	Roback et al.
Tunisia	Mineral water	1.16-2.46	-	Gharbi et al.

Table 4-6: Historical Activity Concentrations of ^{234}U, ^{235}U and ^{238}U (Bq/L) Measured in Carlsbad Drinking Water

Year	^{234}U (Bq/L)	^{235}U (Bq/L)	^{238}U (Bq/L)
1998	3.34E-02	7.52E-04	1.35E-02
1999	2.94E-02	6.99E-04	1.14E-02
2000	2.81E-02	8.12E-04	1.08E-02
2001	3.15E-02	9.68E-04	1.21E-02
2002	3.02E-02	7.97E-04	1.26E-02
2003	2.90E-02	5.52E-04	1.05E-02
2005	2.75E-02	1.54E-03	1.11E-02
2007	NR	NR	NR
2008	7.73E-02	3.09E-03	3.18E-02
2009	2.48E-02	3.57E-04	9.24E-03
2010	2.99E-02	5.64E-04	1.17E-02
2011	2.83E-02	7.83E-03	1.09E-02
2012	9.20E-03	1.85E-04	3.26E-03
2013	2.47E-02	3.80E-04	9.35E-03
2014	2.85E-02	5.83E-04	1.06E-02
2015	2.09E-02	3.39E-04	7.80E-03
2016	3.34E-02	9.90E-04	1.23E-02
2017	3.02E-02	5.41E-04	8.36E-02

NR = not reported

Table 4-7: Historical Activity Concentrations of ^{234}U, ^{235}U and ^{238}U (Bq/L) in Double Eagle

Year	^{234}U (Bq/L)	^{235}U (Bq/L)	^{238}U(Bq/L)
1998	NR	NR	NR
1999	6.19E-02	1.35E-04	2.32E-02
2000	5.40E-02	1.38E-04	2.19E-02
2001	4.10E-02	1.22E-04	1.74E-02
2002	4.16E-02	1.01E-04	1.77E-02
2003	4.25E-02	8.89E-05	1.61E-02
2005	5.83E-02	1.43E-04	2.48E-02
2007	NR	NR	NR
2008	1.86E-01	4.31E-04	7.94E-02
2009	6.97E-02	7.55E-04	2.89E-02
2010	4.89E-02	1.36E-04	2.01E-02
2011	4.80E-02	8.45E-05	1.86E-02
2012	8.75E-03	3.55E-04	3.22E-03
2013	4.69E-02	4.90E-03	1.81E-02
2014	4.94E-02	6.12E-04	1.85E-02
2015	4.55E-02	9.19E-04	1.57E-02
2016	5.14E-02	1.19E-03	1.96E-02
2017	9.65E-02	2.36E-03	4.13E-02

NR = not reported

Table 4-8: Historical Activity Concentrations of ^{234}U, ^{235}U and ^{238}U (Bq/L) in Hobbs

Year	^{234}U (Bq/L)	^{235}U (Bq/L)	^{238}U (Bq/L)
1998	NR	NR	NR
1999	8.81E-02	2.46E-03	3.86E-02
2000	9.06E-02	2.34E-03	3.99E-02
2001	7.52E-02	2.59E-03	3.32E-02
2002	9.40E-02	2.37E-03	4.05E-02
2003	1.30E-01	2.51E-03	4.61E-02
2005	9.82E-02	2.68E-03	4.27E-02
2007	NR	NR	NR
2008	2.87E-01	1.18E-02	1.31E-01
2009	8.94E-02	1.99E-03	3.86E-02
2010	1.04E-01	2.23E-03	4.59E-02
2011	1.04E-01	2.60E-03	4.50E-02
2012	1.61E-02	4.31E-04	5.82E-03
2013	9.25E-02	2.18E-03	3.97E-02
2014	9.82E-02	1.89E-03	4.01E-02
2015	9.67E-02	2.17E-03	4.17E-02
2016	1.05E-01	2.48E-03	4.44E-02
2017	4.82E-02	2.37E-03	5.08E-02

NR = not reported

Table 4-9: Historical Activity Concentrations of ^{234}U, ^{235}U and ^{238}U (Bq/L) Measured in Otis Drinking Water

Year	^{234}U (Bq/L)	^{235}U (Bq/L)	^{238}U (Bq/L)
1998	1.29E-01	2.73E-03	4.67E-02
1999	1.50E-01	2.85E-03	5.30E-02
2000	1.44E-01	2.97E-03	5.16E-02
2001	1.62E-01	3.30E-03	6.01E-02
2002	1.47E-01	3.34E-03	5.34E-02
2003	1.34E-01	2.56E-03	4.81E-02
2005	1.17E-01	2.60E-03	4.36E-02
2007	NR	NR	NR
2008	3.89E-01	1.35E-02	1.53E-01
2009	1.47E-01	3.80E-03	5.35E-02
2010	1.54E-01	2.66E-03	5.41E-02
2011	1.54E-01	1.19E-02	2.39E-01
2012	3.94E-02	1.00E-03	1.39E-02
2013	1.51E-01	3.17E-03	5.45E-02
2014	1.71E-01	3.46E-03	7.24E-02
2015	1.70E-01	2.95E-03	6.61E-02
2016	2.70E-02	1.44E-03	1.13E-02
2017	1.68E-01	2.86E-03	6.59E-02

NR = not reported

Table 4-10: Historical Activity Concentrations of ^{234}U, ^{235}U and ^{238}U (Bq/L) Measured in Loving Drinking Water

Year	^{234}U (Bq/L)	^{235}U (Bq/L)	^{238}U (Bq/L)
1998	NR	NR	NR
1999	8.15E-02	1.66E-03	2.63E-02
2000	8.38E-02	1.63E-03	2.59E-02
2001	8.05E-02	1.61E-03	2.48E-02
2002	8.82E-02	1.63E-03	2.83E-02
2003	7.91E-02	1.35E-03	2.40E-02
2005	8.13E-02	1.42E-03	2.64E-02
2007	NR	NR	NR
2008	2.56E-01	5.15E-03	7.71E-02
2009	7.42E-02	1.26E-03	2.22E-02
2010	8.00E-02	1.20E-03	2.49E-02
2011	7.50E-02	3.90E-02	2.57E-02
2012	2.53E-02	4.93E-04	7.58E-03
2013	7.17E-02	1.20E-03	2.31E-02
2014	7.57E-02	1.63E-03	2.24E-02
2015	7.42E-02	1.26E-03	2.30E-02
2016	7.05E-02	1.23E-03	2.23E-02
2017	7.48E-02	1.01E-03	2.16E-02

NR = not reported

Table 4-11: Historical Activity Concentrations of ^{234}U, ^{235}U and ^{238}U (Bq/L) Measured in Malaga Drinking Water

Year	^{234}U (Bq/L)	^{235}U (Bq/L)	^{238}U (Bq/L)
2011	1.38E-01	2.56E-03	5.34E-02
2012	1.33E-01	1.92E-03	4.83E-02
2013	1.40E-01	3.33E-03	5.46E-02
2014	1.67E-01	4.59E-03	6.19E-02
2015	1.57E-01	4.99E-03	6.07E-02
2016	1.47E-01	2.36E-03	5.43E-02
2017	1.65E-01	3.24E-03	6.24E-02

*Collection started in 2011

Table 4-12: Gamma Emitting Radionuclides Measured in Drinking Water in 2017

Radionuclide	Location	Activity Bq/L	Unc(2-sig) (Bq/L)	MDC (Bq/L)	Status
^{137}Cs	Hobbs	-7.74E-03	2.95E-02	9.78E-02	Not detected
	Double Eagle	3.73E-02	3.02E-02	9.94E-02	Not detected
	Sheep Draw	3.03E-02	2.94E-02	9.68E-02	Not detected
	Malaga	4.01E-02	2.98E-02	9.81E-02	Not detected
	Otis	7.98E-03	2.98E-02	9.88E-02	Not detected
	Loving	1.75E-02	2.97E-02	9.81E-02	Not detected
	Loving (Dup)	-4.72E-03	2.97E-02	9.84E-02	Not detected
	Trip Blank	3.24E-02	2.97E-02	9.80E-02	Not detected
^{60}Co	Hobbs	2.50E-02	2.74E-02	9.06E-02	Not detected
	Double Eagle	-5.00E-03	3.16E-02	1.05E-01	Not detected
	Sheep Draw	1.25E-02	3.05E-02	1.01E-01	Not detected
	Malaga	-1.04E-02	3.11E-02	1.04E-01	Not detected
	Otis	7.32E-02	3.08E-02	1.01E-01	Not detected
	Loving	3.01E-02	3.14E-02	1.04E-01	Not detected
	Loving (Dup)	3.77E-02	3.06E-02	1.01E-01	Not detected
	Trip Blank	3.79E-02	3.17E-02	1.05E-01	Not detected
^{40}K	Hobbs	-7.19E-02	3.51E-01	1.17E+00	Not detected
	Double Eagle	3.18E-01	3.44E-01	1.14E+00	Not detected
	Sheep Draw	3.85E-01	3.43E-01	1.13E+00	Not detected
	Malaga	2.10E-01	3.48E-01	1.15E+00	Not detected
	Otis	3.69E-01	3.43E-01	1.13E+00	Not detected
	Loving	4.81E-01	3.33E-01	1.10E+00	Not detected
	Loving (Dup)	4.47E-01	3.30E-01	1.09E+00	Not detected
	Trip Blank	-2.18E-01	3.43E-01	1.14E+00	Not detected

Dup = Duplicate

CHAPTER 5

Surface Water and Sediment

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. Retention of radionuclide fallout by catchment soils and river and lake sediments play 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 into 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 has been collected and analyzed routinely since the beginning of the WIPP environmental monitoring to evaluate the impacts of WIPP operations (if any) or the February 2014 radiation release from the WIPP to the aquatic environment. The surface water samples were collected from three regional reservoirs situated along 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 southwest 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. Radiochemical analyses were performed to assess if there is any evidence of an increase in radionuclide activity concentrations in the region that could be attributed to WIPP operations or to the February 2014 radiation release from the WIPP. The 2017 monitoring results continue to show no evidence of any release from the WIPP contributing to radionuclide concentrations in the environment.

Sample Collection

The surface water samples were collected in the same general area as the sediment samples (see Figure 5-1). At each sampling location, one sample was collected from the surface (~ 0.5 m depth) and a second sample from approximately 1 m above the sediment bed. Approximately 8 L of surface water was collected from each location (See Figure 5-2).

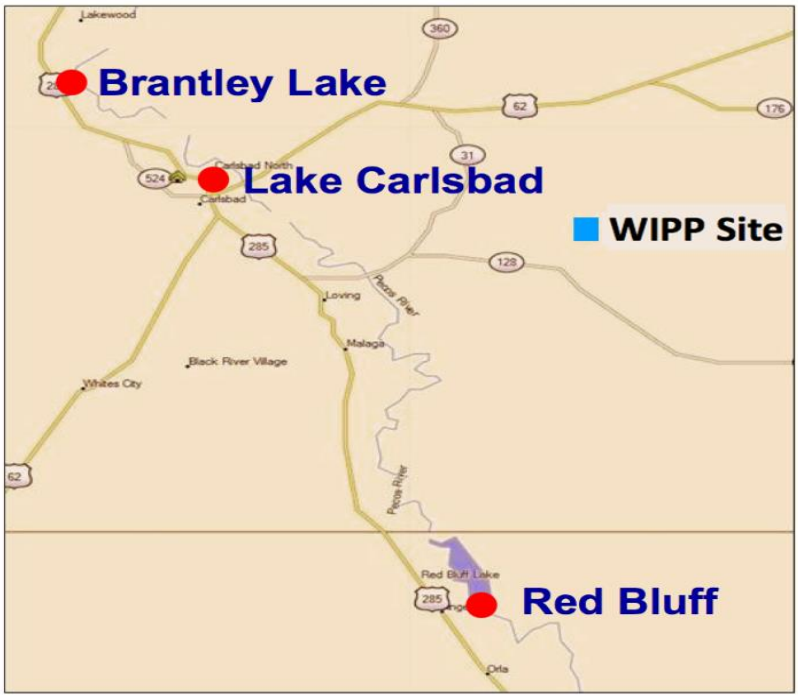


Figure 5-1: Surface Water and Sediment Sampling locations in the vicinity of the WIPP Site

Figure 5-2: Surface water sample 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 2L 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 Inc (Atlanta, 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 plutonium was adjusted by adding 1 mL of 1.0M NH_4I with a 10 min wait step, followed by 2 mL of 2M $NaNO_2$. Plutonium isotopes were then separated and purified using a two-column anion exchange resin (Dowex 1-× 8, 100-200 mesh), while TRU chromatography columns were used for the separation of Am and U. The samples were then micro-co-precipitated using an Nd-carrier and counted on the alpha spectrometer for five days.

Data Reporting

The activities of the actinides and gamma radionuclides were reported as *activity concentration* in Bq/L. *Activity concentration* is calculated as the activity of radionuclides detected in Becquerel (Bq) divided by Volume 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 in 2017. The individual values of ^{241}Am, ^{238}Pu, and $^{239+240}Pu$ measured in the three reservoirs are listed in Table 5-1 and

are shown in Figures 5-3 through 5-5. Since 1998, $^{239+240}$Pu, ^{238}Pu, and ^{241}Am have not been measured above the MDC in any surface water samples. Figures 5-6 through 5-8 show the measured values for $^{239+240}$Pu, ^{238}Pu, and ^{241}Am at all sites between 1998 and 2017. Figures 5-6 through 5-8 illustrate that the activities of these radionuclides measured between 1998 and 2017 were close to zero (all are below the MDC). The absence of a detection of WIPP radionuclides in surface water samples indicates no measured impact of WIPP-related activities to the regional reservoirs.

The analysis results for the uranium isotopes in the surface water samples are shown in Table 5-2. Uranium isotopes (^{234}U, ^{235}U, and ^{238}U) were detected in all the surface water samples collected in 2017. The concentrations range of these radionuclides measured in three reservoirs in 2017 are shown in Figure 5-9. The concentration ranges for these isotopes showed no significant difference between baseline and monitoring phases (CEMRC Report, 1998). The concentrations of the uranium isotopes were also compared between 2015 and 2017 and between sampling locations. There was no significant variation in the concentrations of the uranium isotopes in the surface water between 2015 and 2017. These observations further support our conclusion that there is no evidence of increases in radiological contaminants in the region that could be attributed to releases from WIPP.

The ^{234}U/^{238}U isotopic ratios were very similar among these three lakes. The reservoirs appeared to be slightly enriched in ^{234}U compared to ^{238}U, with the activity ratios ranging from 1.96 to 2.25 (Figure 5-10). In natural bodies of water these isotopes do not occur in equilibrium and that, with a few exceptions, waters typically contain more ^{234}U than ^{238}U (Cothern et al. 1983; Skwarzec et al. 2002). Higher activity of ^{234}U in water is the result of the ^{234}U atom displacement from the crystal lattice. The recoil atom, ^{234}U, is liable to be oxidized to the hexavalent stage and can be leached into the water phase more easily than its parent nuclide ^{238}U. The oxidation of U(IV) to U(VI) is an important step in leaching because compounds containing U(VI) have a higher solubility due to the formation of strong complexes between uranyl and carbonate ions (UNSCEAR, 1977). All U(IV) compounds of uranium are practically insoluble. Maximum activity concentrations for ^{234}U, ^{235}U and ^{238}U (Table 5-2) increased slightly in the monitoring phase relative to the baseline phase for samples collected from all three reservoirs. No significant difference between the baseline and monitoring phase concentrations was observed. The baseline concentration of uranium in surface water samples collected in 1998 is listed in Table 5-3.

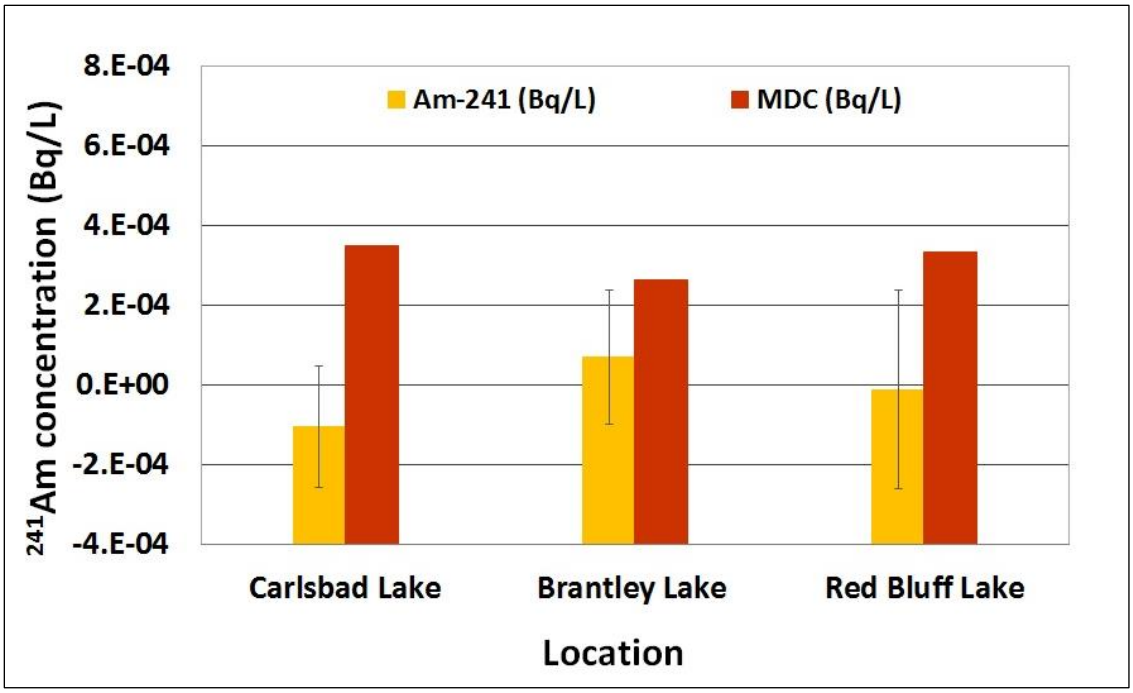


Figure 5-3: ^{241}Am concentration in surface water samples in three regional reservoirs in 2017

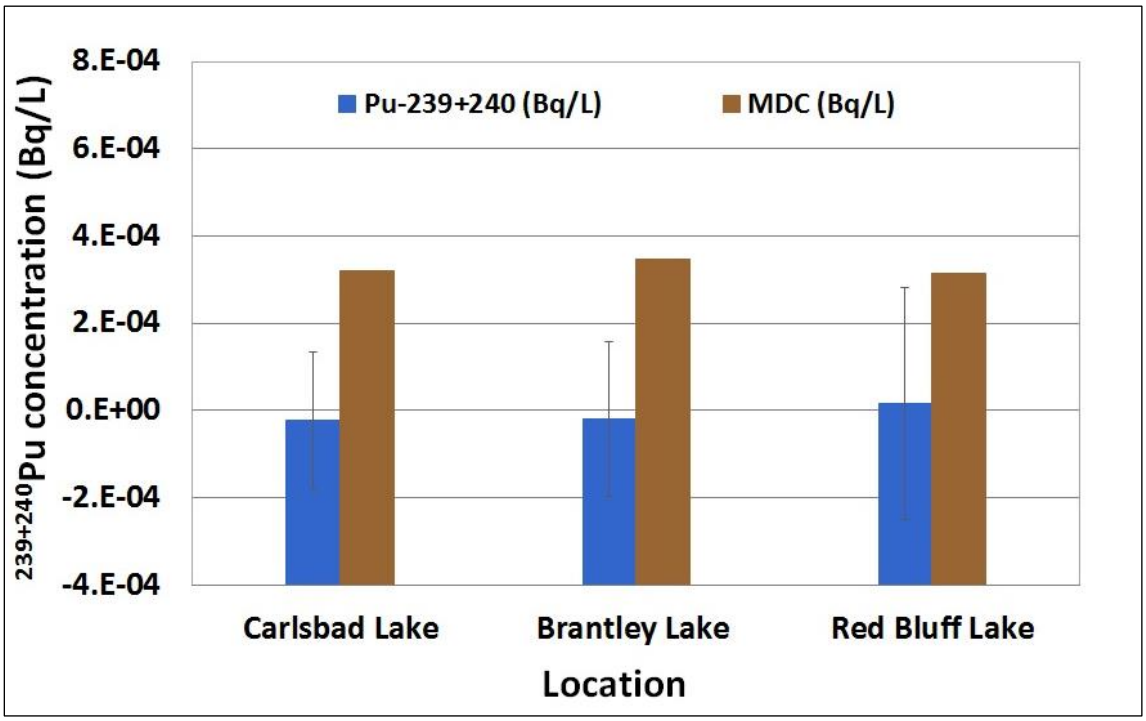


Figure 5-4: $^{239+240}$Pu concentration in surface water samples in three regional reservoirs in 2017

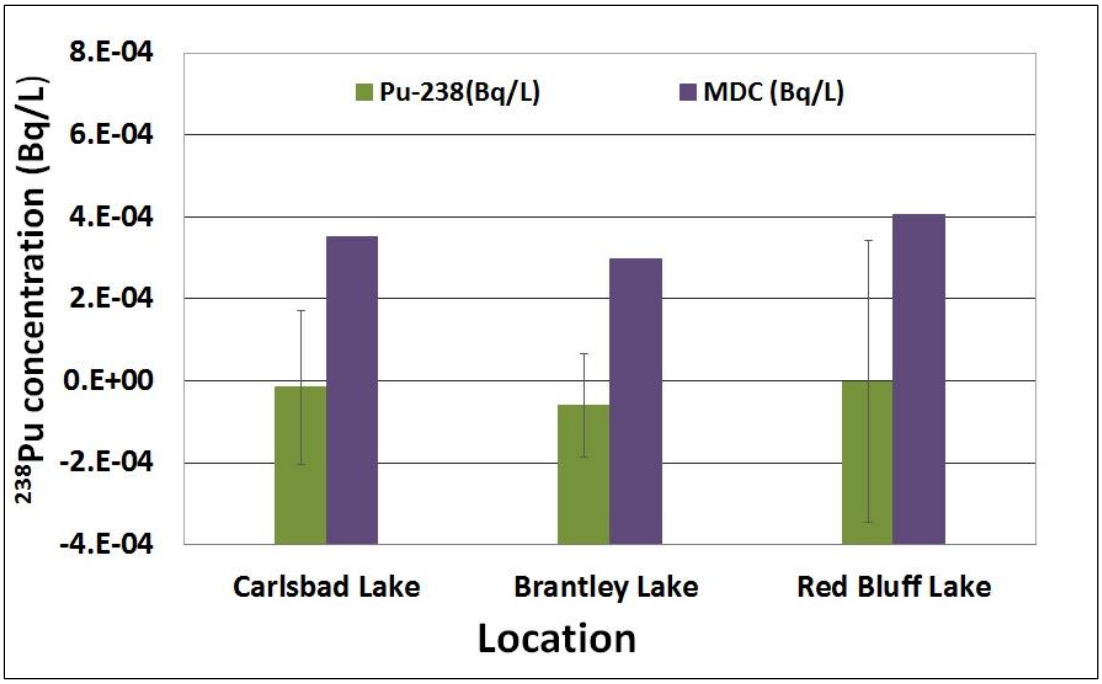


Figure 5-5: ^{238}Pu concentration in surface water samples in three regional reservoirs in 2017

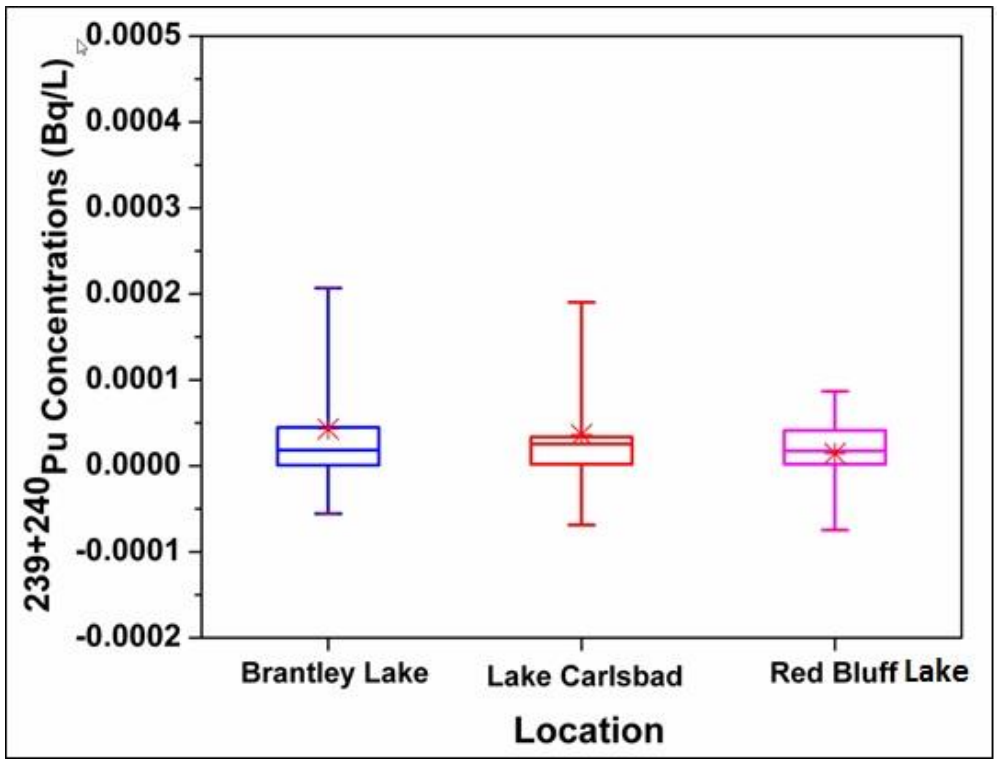


Figure 5-6: $^{239+240}$Pu concentration in surface water samples in three regional reservoirs from 1998 to 2017 (all samples are below MDC)

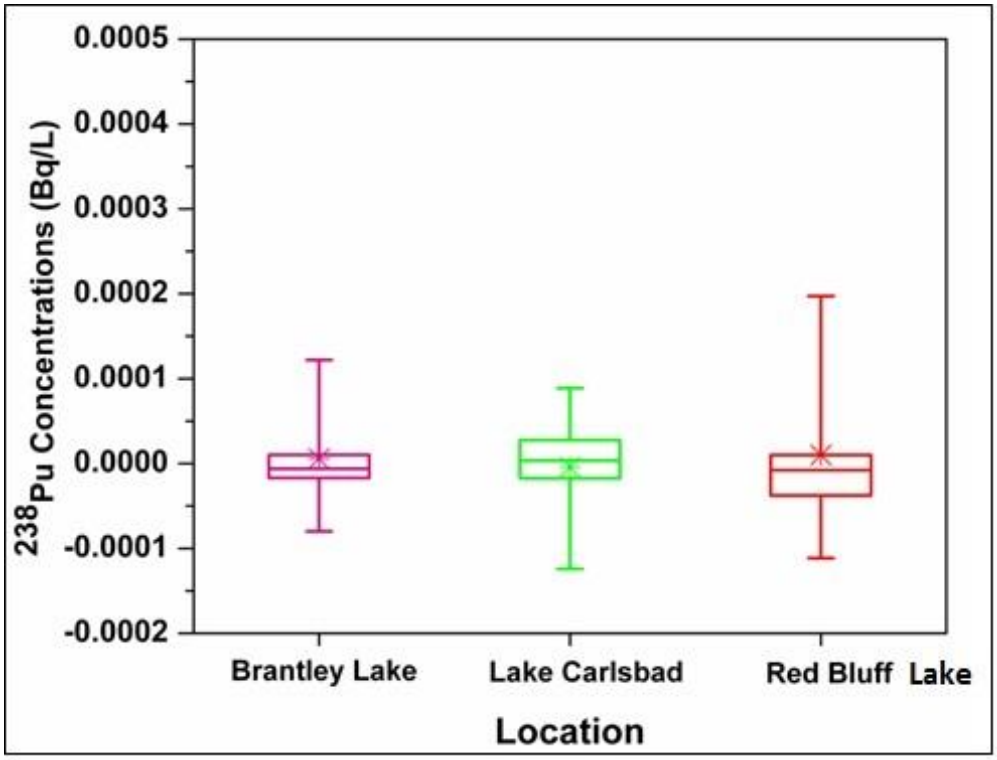


Figure 5-7: ^{238}Pu concentration in surface water samples in three regional reservoirs from 1998 to 2017 (all samples are below MDC)

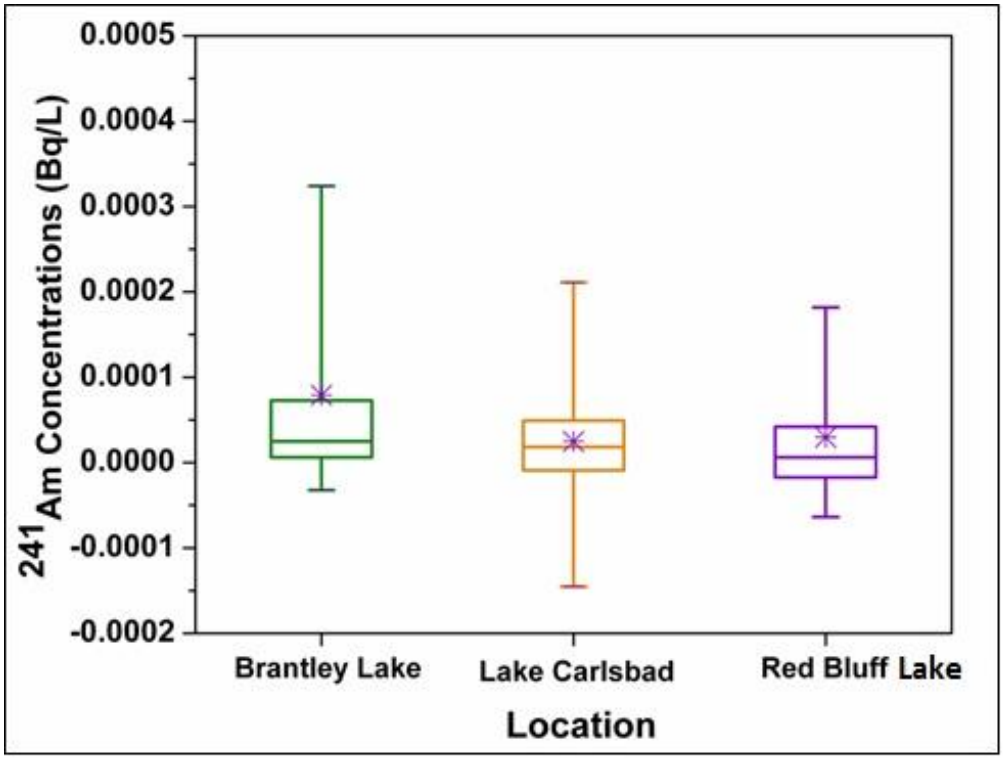


Figure 5-8: ^{241}Am concentration in surface water samples in three regional reservoirs from 1998 to 2017 (all samples are below MDC)

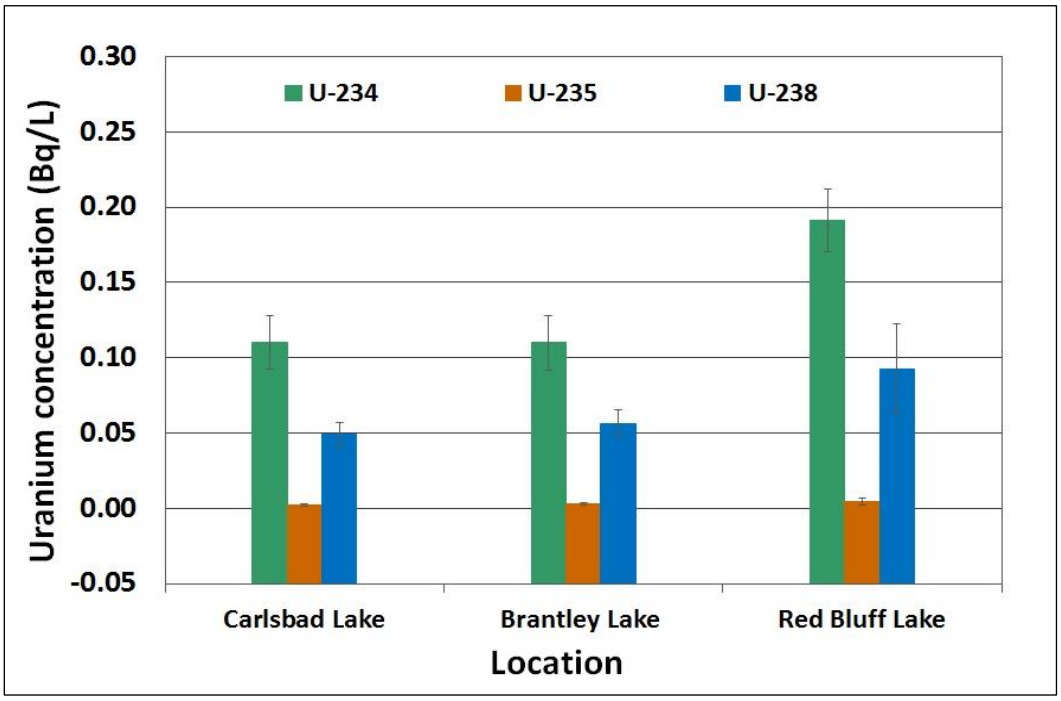


Figure 5-9: Uranium concentrations in surface water samples in three regional reservoirs in 2017

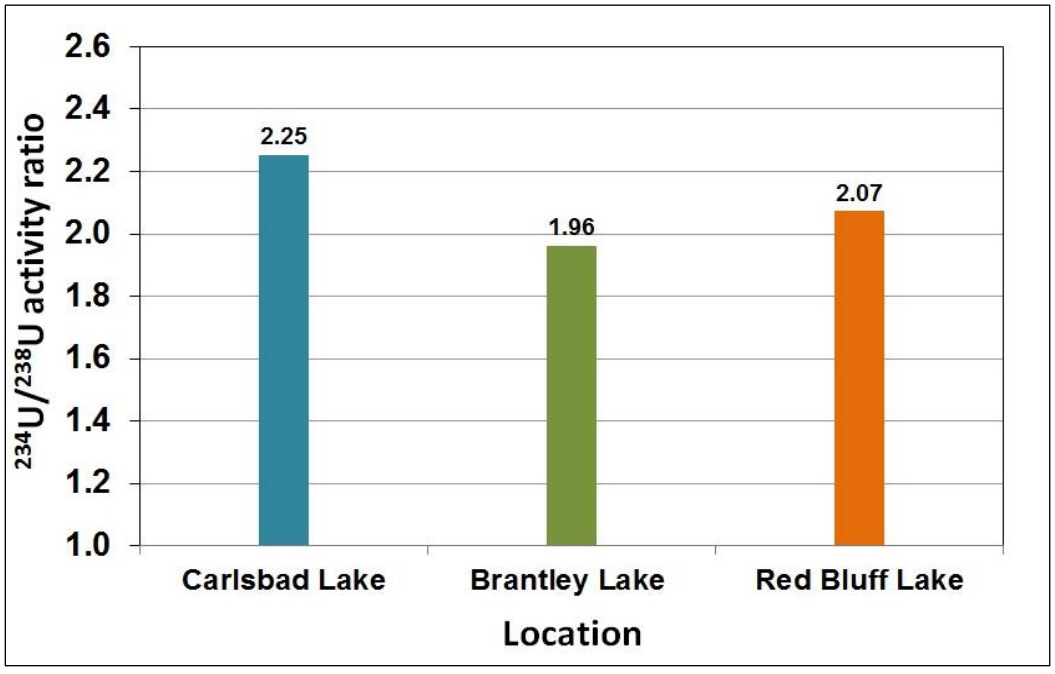


Figure 5-10: The $^{234}U/^{238}U$ Activity Ratio in surface water samples of three reservoirs in the vicinity of the WIPP site.

Concentration of Gamma radionuclides in the Surface water in the WIPP vicinity

The analysis data for the gamma isotopes are presented in Table 5-4. As shown in Table 5-4, gamma radionuclides were not detected in any of the surface water samples collected in 2017. However, ^{40}K was detected in 1998, 2000, and 2012 (CEMRC 1998, 2000, 2012) in surface water samples collected from Red Bluff Lake. 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. Since these isotopes were not regularly detected, no comparisons between years or among locations were performed.

Table 5-1: 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.

Radionuclides	Location	Sample Date	Activity Bq/L	Unc. (2σ) Bq/L	MDC Bq/L	Status
^{241}Am	Carlsbad (shallow)	11/30/17	-1.45E-04	1.16E-04	4.08E-04	Not detected
	Carlsbad (deep)	11/30/17	-6.16E-05	9.58E-05	2.90E-04	Not detected
	Brantley (shallow)	11/30/17	2.48E-05	8.59E-05	2.15E-04	Not detected
	Brantley (deep)	11/30/17	1.17E-04	1.46E-04	3.15E-04	Not detected
	Red Bluff (shallow)	12/11/17	6.36E-05	9.20E-05	2.01E-04	Not detected
	Red Bluff (deep)	12/11/17	-5.67E-05	9.85E-05	3.02E-04	Not detected
	Red Bluff (shallow) Duplicate	12/11/17	-6.38E-05	1.80E-04	5.56E-04	Not detected
	Red Bluff (deep) Duplicate	12/11/17	1.37E-05	1.06E-04	2.76E-04	Not detected
	Blank	11/30/17	3.48E-05	8.37E-05	2.02E-04	Not detected
$^{239+240}$Pu	Carlsbad (shallow)	11/30/17	-5.70E-05	8.52E-05	3.02E-04	Not detected
	Carlsbad (deep)	11/30/17	1.37E-05	1.31E-04	3.37E-04	Not detected
	Brantley (shallow)	11/30/17	-5.57E-05	1.44E-04	4.17E-04	Not detected
	Brantley (deep)	11/30/17	1.58E-05	1.04E-04	2.74E-04	Not detected
	Red Bluff (shallow)	12/11/17	2.55E-05	5.10E-05	1.18E-04	Not detected
	Red Bluff (deep)	12/11/17	-7.46E-05	2.11E-04	6.50E-04	Not detected
	Red Bluff (shallow) Duplicate	12/11/17	5.64E-05	1.13E-04	2.61E-04	Not detected
	Red Bluff (deep) Duplicate	12/11/17	5.72E-05	1.01E-04	2.29E-04	Not detected
	Blank	11/30/17	2.84E-05	1.07E-04	2.67E-04	Not detected
^{238}Pu	Carlsbad (shallow)	11/30/17	-1.90E-05	1.65E-04	4.47E-04	Not detected
	Carlsbad (deep)	11/30/17	-1.37E-05	9.09E-05	2.58E-04	Not detected
	Brantley (shallow)	11/30/17	-7.43E-05	8.35E-05	2.95E-04	Not detected
	Brantley (deep)	11/30/17	-4.72E-05	9.46E-05	2.96E-04	Not detected

Table 5-1: 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. (Continued)

Radionuclides	Location	Sample Date	Activity Bq/L	Unc. (2σ) Bq/L	MDC Bq/L	Status
^{238}Pu	Red Bluff (shallow)	12/11/17	-3.82E-05	1.11E-04	3.12E-04	Not detected
	Red Bluff (deep)	12/11/17	-1.12E-04	2.69E-04	7.95E-04	Not detected
	Red Bluff (shallow) Duplicate	12/11/17	1.97E-04	1.61E-04	2.07E-04	Not detected
	Red Bluff (deep) Duplicate	12/11/17	-5.72E-05	8.54E-05	3.02E-04	Not detected
	Blank	11/30/17	-5.68E-05	9.90E-05	3.03E-04	Not detected

Table 5-2: Activity concentrations of ^{234}U, ^{235}U and ^{238}U (Bq/L) in surface water samples collected from the three reservoirs in the vicinity of the WIPP site.

Radionuclides	Location	Sample Date	Activity Bq/L	Unc. (2σ) Bq/L	MDC Bq/L	Status
^{234}U	Carlsbad (shallow)	11/30/17	1.14E-01	1.30E-02	3.91E-04	Detected
	Carlsbad (deep)	11/30/17	1.08E-01	1.20E-02	3.90E-04	Detected
	Brantley (shallow)	11/30/17	9.70E-02	1.10E-02	4.73E-04	Detected
	Brantley (deep)	11/30/17	1.23E-01	1.43E-02	5.34E-04	Detected
	Red Bluff (shallow)	12/11/17	1.92E-01	2.10E-02	2.97E-04	Detected
	Red Bluff (deep)	12/11/17	1.91E-01	2.07E-02	1.95E-04	Detected
	Red Bluff (shallow) Duplicate	12/11/17	1.87E-01	2.10E-02	2.55E-04	Detected
	Red Bluff (deep) Duplicate	12/11/17	1.88E-01	2.05E-02	2.66E-04	Detected
	Blank	11/30/17	3.88E-04	2.58E-04	4.97E-04	Not detected
^{235}U	Carlsbad (shallow)	11/30/17	2.56E-03	6.04E-04	4.06E-04	Detected
	Carlsbad (deep)	11/30/17	2.47E-03	5.29E-04	3.11E-04	Detected
	Brantley (shallow)	11/30/17	2.54E-03	5.52E-04	1.63E-04	Detected
	Brantley (deep)	11/30/17	3.34E-03	7.27E-04	3.37E-04	Detected
	Red Bluff (shallow)	12/11/17	5.12E-03	8.16E-04	2.72E-04	Detected
	Red Bluff (deep)	12/11/17	5.07E-03	7.79E-04	2.13E-04	Detected
	Red Bluff (shallow) Duplicate	12/11/17	4.31E-04	7.85E-04	2.07E-04	Detected
	Red Bluff (deep) Duplicate	12/11/17	5.14E-03	7.89E-04	1.43E-04	Detected
	Blank	11/30/17	-6.52E-05	1.44E-04	4.37E-04	Not detected

Table 5-2: Activity concentrations of ^{234}U, ^{235}U and ^{238}U (Bq/L) in surface water samples collected from the three reservoirs in the vicinity of the WIPP site. (Continued)

Radionuclides	Location	Sample Date	Activity Bq/L	Unc. (2σ) Bq/L	MDC Bq/L	Status
^{238}U	Carlsbad (shallow)	11/30/17	4.88E-02	5.80E-03	6.00E-04	Detected
	Carlsbad (deep)	11/30/17	4.96E-02	5.71E-03	4.60E-04	Detected
	Brantley (shallow)	11/30/17	5.46E-02	6.36E-03	5.59E-04	Detected
	Brantley (deep)	11/30/17	5.75E-02	6.88E-03	6.37E-04	Detected
	Red Bluff (shallow)	12/11/17	9.36E-02	1.03E-02	3.40E-04	Detected
	Red Bluff (deep)	12/11/17	8.97E-02	9.84E-03	2.60E-04	Detected
	Red Bluff (shallow) Duplicate	12/11/17	9.23E-02	1.05E-02	3.83E-04	Detected
	Red Bluff (deep) Duplicate	12/11/17	9.33E-02	1.03E-02	2.16E-04	Detected
	Blank	11/30/17	-3.51E-05	1.99E-04	5.23E-04	Not Detected

Table 5-3: Range of Activity Concentrations for Uranium Isotopes in surface water samples collected from three regional lakes during 1998.

Radionuclides	Baseline N	Baseline Minimum (Bq/L)	Baseline Maximum (Bq/L)
Brantley Lake			
^{234}U	2	6.99E-02	7.54E-02
^{235}U	4	<MDC	8.43E-02
^{238}U	2	3.80E-02	3.89E-02
Lake Carlsbad			
^{234}U	2	1.13E-01	1.16E-01
^{235}U	4	<MDC	2.74E-03
^{238}U	2	5.66E-02	5.71E-02
Red Bluff reservoir			
^{234}U	2	2.13E-01	2.14E-01
^{235}U	4	<MDC	5.78E-03
^{238}U	2	1.06E-01	1.06E-01

N = number of samples

Table 5-4: 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.

Radionuclides	Location	Sample Date	Activity Bq/L	Unc. (2σ) Bq/L	MDC Bq/L	Status
^{137}Cs	Carlsbad (shallow)	11/30/17	1.70E-02	4.69E-02	1.55E-01	Not detected
	Carlsbad (deep)	11/30/17	1.01E-01	4.66E-02	1.53E-01	Not detected
	Brantley (shallow)	11/30/17	-1.22E-02	4.68E-02	1.55E-01	Not detected
	Brantley (deep)	11/30/17	7.52E-04	5.04E-02	1.67E-01	Not detected
	Red Bluff (shallow)	12/11/17	4.69E-02	4.72E-02	1.56E-01	Not detected
	Red Bluff (deep)	12/11/17	9.05E-02	5.10E-02	1.67E-01	Not detected
	Red Bluff (shallow) Duplicate	12/11/17	3.19E-02	4.76E-02	1.57E-01	Not detected
	Red Bluff (deep) Duplicate	12/11/17	3.49E-02	4.71E-02	1.56E-01	Not detected
	Blank	11/30/17	8.94E-03	4.70E-02	1.56E-01	Not detected
^{40}K	Carlsbad (shallow)	11/30/17	7.69E-01	5.37E-01	1.77E+00	Not detected
	Carlsbad (deep)	11/30/17	7.67E-01	5.49E-01	1.81E+00	Not detected
	Brantley (shallow)	11/30/17	1.13E+00	5.43E-01	1.78E+00	Not detected
	Brantley (deep)	11/30/17	1.20E-02	5.75E-01	1.91E+00	Not detected
^{40}K	Red Bluff (shallow)	12/11/17	8.81E-01	5.62E-01	1.85E+00	Not detected
	Red Bluff (deep)	12/11/17	1.27E+00	6.04E-01	1.98E+00	Not detected
	Red Bluff (shallow) Duplicate	12/11/17	1.68E+00	5.67E-01	1.82E+00	Not detected
	Red Bluff (deep) Duplicate	12/11/17	2.11E+00	5.54E-01	1.78E+00	Detected
	Blank	11/30/17	7.98E-02	5.45E-01	1.81E+00	Not detected
^{60}Co	Carlsbad (shallow)	11/30/17	-1.79E-03	4.51E-02	1.50E-01	Not detected
	Carlsbad (deep)	11/30/17	-1.78E-02	4.60E-02	1.54E-01	Not detected
	Brantley (shallow)	11/30/17	7.09E-02	4.41E-02	1.45E-01	Not detected
	Brantley (deep)	11/30/17	8.16E-02	4.72E-02	1.55E-01	Not detected
	Red Bluff (shallow)	12/11/17	4.56E-02	4.51E-02	1.49E-01	Not detected
	Red Bluff (deep)	12/11/17	6.43E-02	5.03E-02	1.66E-01	Not detected
	Red Bluff (shallow) Duplicate	12/11/17	-3.38E-03	4.62E-02	1.54E-01	Not detected
	Red Bluff (deep) Duplicate	12/11/17	2.32E-02	4.65E-02	1.54E-01	Not detected
	Blank	11/30/17	4.43E-02	4.50E-02	1.49E-01	Not detected

SEDIMENT MONITORING

Sediments are defined as finely divided solid materials that have settled out of a liquid stream or from 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 three 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 the 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 nuclear accidents such as Chernobyl and Fukushima. Naturally occurring radionuclides uranium, thorium and ^{40}K were also detected. Many of the measured values were low, near the limits of detection. At high enough activities, 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, the CEMRC sampled sediment in the vicinity of the WIPP site in November and December 2017. The sediment samples were collected from three regional reservoirs situated along 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 Lake on the Pecos River, the upstream end of which is the nearest standing water body ~ 48 km (30 miles) southwest 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. 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 WIPP related activities or to the February 2014 radiation release from the WIPP.

Sample collection

Sediment samples were collected from three locations around the WIPP site as shown in Figure 5-1, with one duplicate sample collected from one site chosen at random.

Figure 5-11: Sediment Samples collection by the CEMRC Personnel

Four locations at each lake were identified using sonar and a combination of triangulation to known shoreline locations and GPS coordinates established during the 1998 and 1999 sampling seasons. These locations fall within the deep basins of each 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 upon collection (Figure 5-11). 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 were dried at 105° for at least 12 hours

and pulverized in a jar mill prior to analysis. Approximately 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 & Ziegler Analytics Inc. (Atlanta, GA) was used to establish matrix-specific calibration and counting efficiencies. Reported concentrations are blank-corrected.

For actinide analyses, approximately 5g of the sample was heated in a muffle furnace at 500°C for at least six hours to combust organic material. Each sample was then spiked with a radioactive tracer 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 two hours; however, longer heating does no harm. After digestion was complete, the samples were evaporated to dryness and 40 mL of $HClO_4$ were added and evaporated to complete dryness. This step was repeated once more with 30 mL of $HClO_4$. Then 20 mL of HF was 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 were 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 were then separated and purified using a two-column anion exchange resin (Dowex1-x 8, 100-200 mesh), while TRU chromatography columns were used for the separation of Am and U. The Am fraction was subsequently purified from lanthanides using a TEVA column. The samples were then micro-co-precipitated using an Nd-carrier and counted on the alpha spectrometer for five days.

Data Reporting

The activities of the actinides and gamma radionuclides are reported in Bq/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 5-5. Concentrations of ^{241}Am and $^{239+240}Pu$ slightly greater than MDC were detected in some sediment samples, but ^{238}Pu was not detected in any sediment samples. The activity concentrations of ^{241}Am in the sediment samples ranged from <MDC -0.076 mBq/g, while that of $^{239+240}Pu$ varied from 0.078-0.185 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, 1998). The concentrations of $^{239+240}$Pu and ^{241}Am measured in sediments samples in 2017 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 in 2017 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 Brantley Lake (0.19 mBq/g) and lowest in Red Bluff Lake (0.078 mBq/g). The $^{239+240}$Pu activities in samples from Lake Carlsbad are intermediate between Brantley Lake and Red Bluff Lake. Comparison of activity concentrations of ^{241}Am, $^{239+240}$Pu, and ^{238}Pu determined in 2017 to that of the baseline and monitoring phase activities reflects no increase in radionuclide concentrations (Figures 5-12 through 5-14).

Concentrations of Uranium Isotopes in the sediment

Uranium isotopes (^{234}U, ^{235}U, and ^{238}U) were detected in all the sediment samples collected in 2017. The concentrations of uranium isotopes measured in the sediment samples are summarized in Table 5-6. The concentrations range of uranium isotopes measured in the sediment samples collected from all three reservoirs for 2017 are shown in Figure 5-15 and historically from 2013-2017 in Figures 5-16 and 5-17. Maximum activity concentrations for ^{234}U, ^{235}U, and ^{238}U increased slightly in the monitoring phase relative to the baseline phase for samples collected from all three reservoirs. The concentrations of ^{238}U were lowest in Lake Carlsbad, and highest in Red Bluff reservoir, while that of ^{234}U were lowest in Brantley Lake and highest in Red Bluff. The activity concentration ranges for these isotopes, showed no significant difference between baseline and monitoring phases, considering the 95% confidence intervals of the radio-analytical uncertainty. Although the sediment concentrations of uranium isotopes were variable between reservoirs, the isotopic ratios were very similar across all three reservoirs. The reservoirs appeared to be slightly enriched in ^{234}U compared to ^{238}U, with the activity ratios ranging from 1.49 to 1.65 (Figure 5-18).

Concentrations of Gamma Radionuclides in the Sediment

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 Table 5-7. The ^{137}Cs was detected in all sediment samples collected (Table 5-7). Variability among the ^{137}Cs concentrations was not very significant. Maximum activity concentrations for ^{137}Cs (3.16 mBq/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 5-7). 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 5-7, ^{60}Co was not detected at any sampling location. Comparison of activity concentrations of ^{137}Cs and ^{40}K determined in 2017 to that of the baseline and monitoring phase activities reflects no increase in radionuclide concentrations (Figures 5-19 and 5-20).

Conclusions

Surface water and sediment samples were collected and analyzed to evaluate the increase in concentrations of radiological contaminants that could be attributed to the WIPP operations or to the February 2014 radiation release from the WIPP. Comparisons of baseline to monitoring phase levels of radionuclides in surface water and sediment samples revealed no detectable increases above those typical of natural variation, indicating no impact of WIPP-related activities to the local environment.

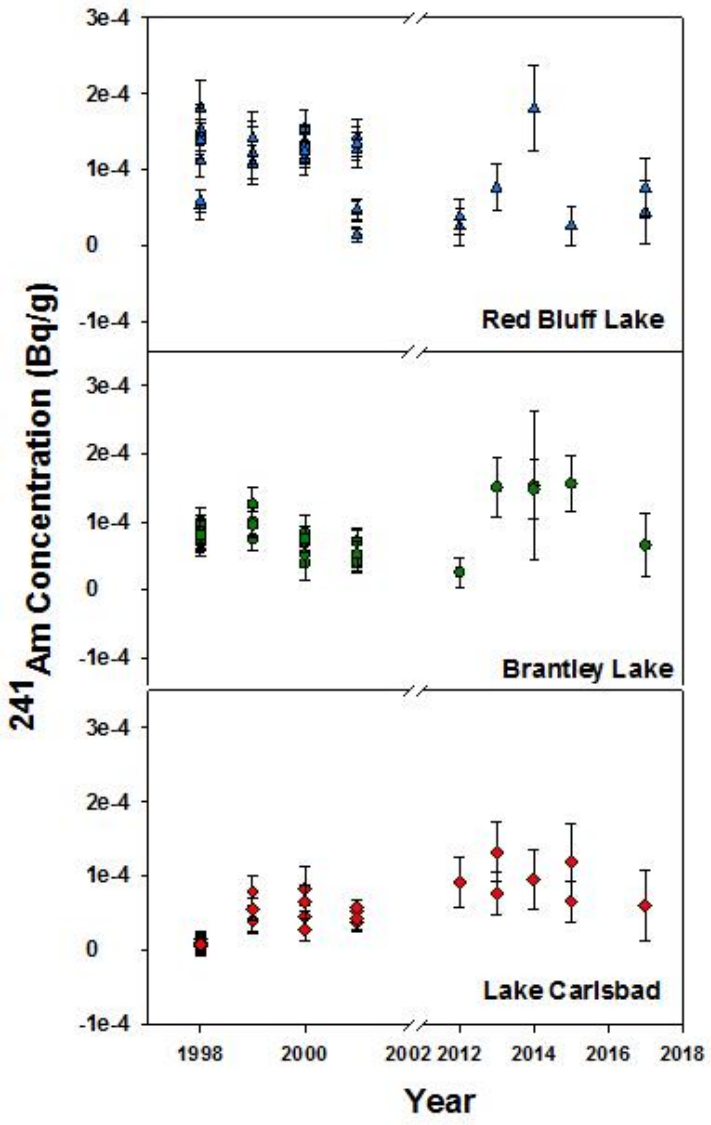


Figure 5-12: The Pre- and Post-radiological event sediment concentrations of ^{241}Am from the three reservoirs in the vicinity of the WIPP site

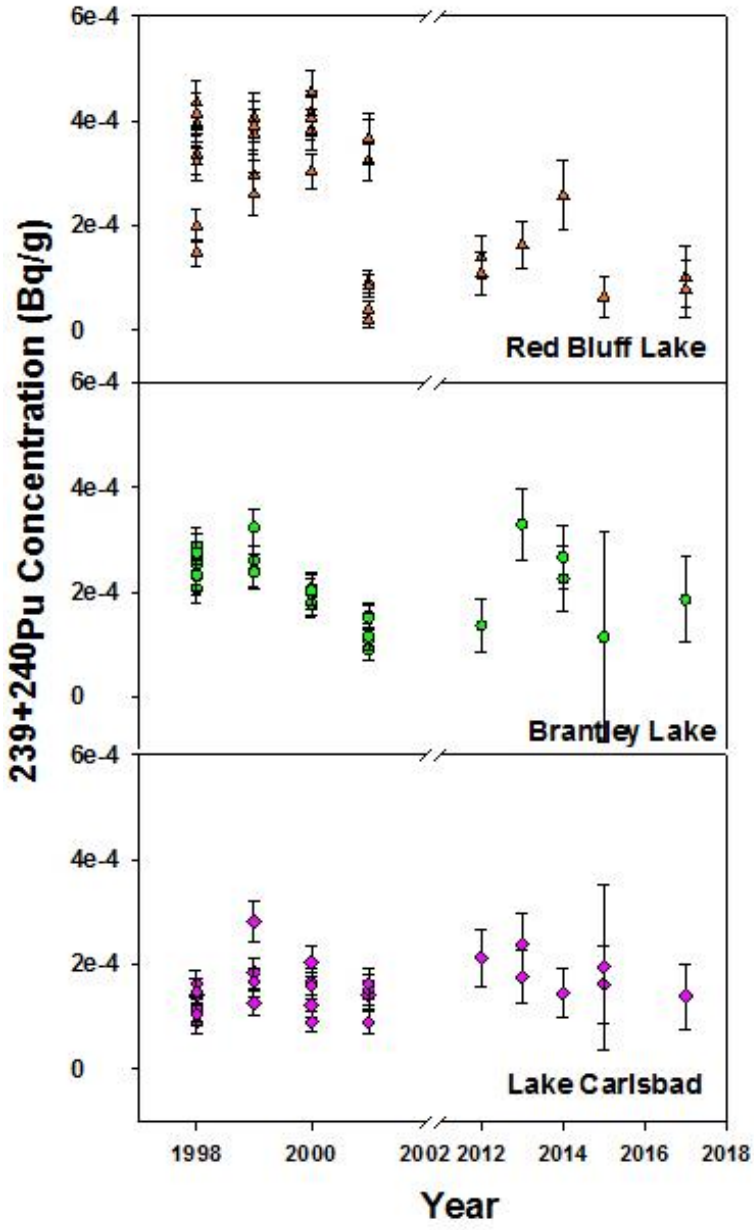


Figure 5-13: The Pre- and Post-radiological event sediment concentrations of $^{239+240}Pu$ from the three reservoirs in the vicinity of the WIPP site

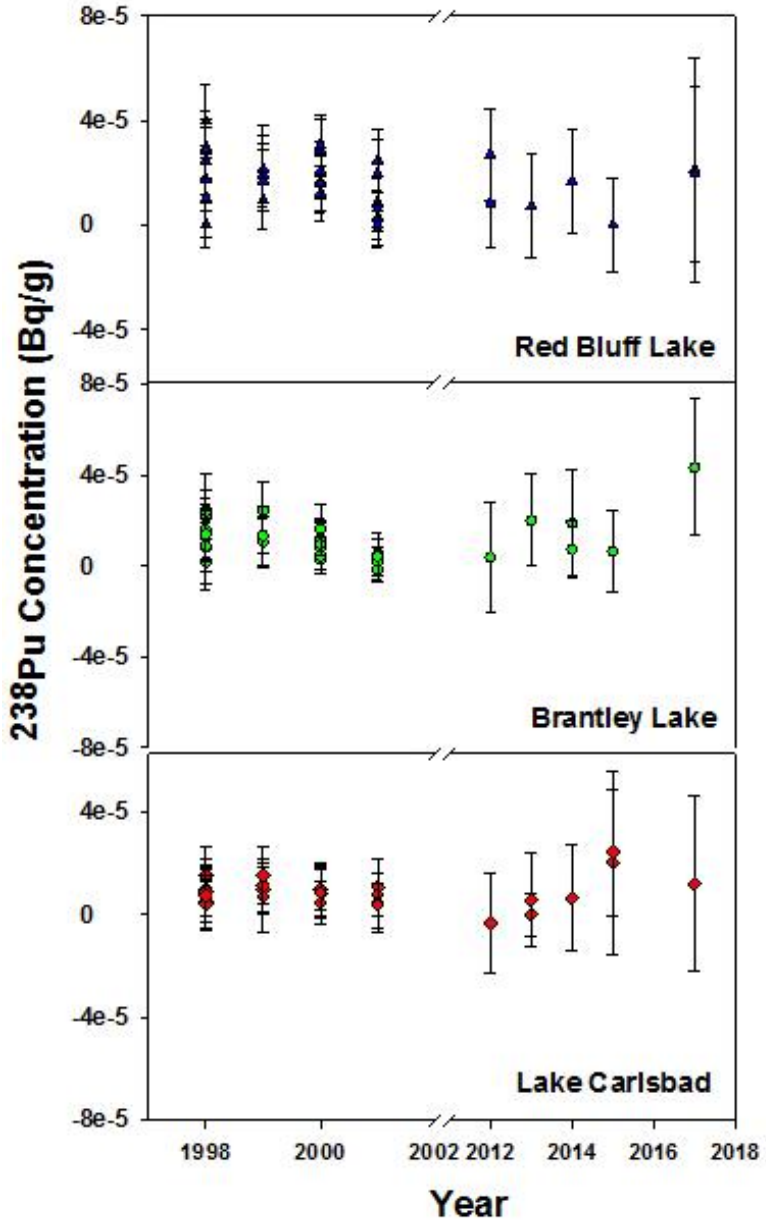


Figure 5-14: The Pre- and Post-radiological event sediment concentrations of ^{238}Pu from the three reservoirs in the vicinity of the WIPP site

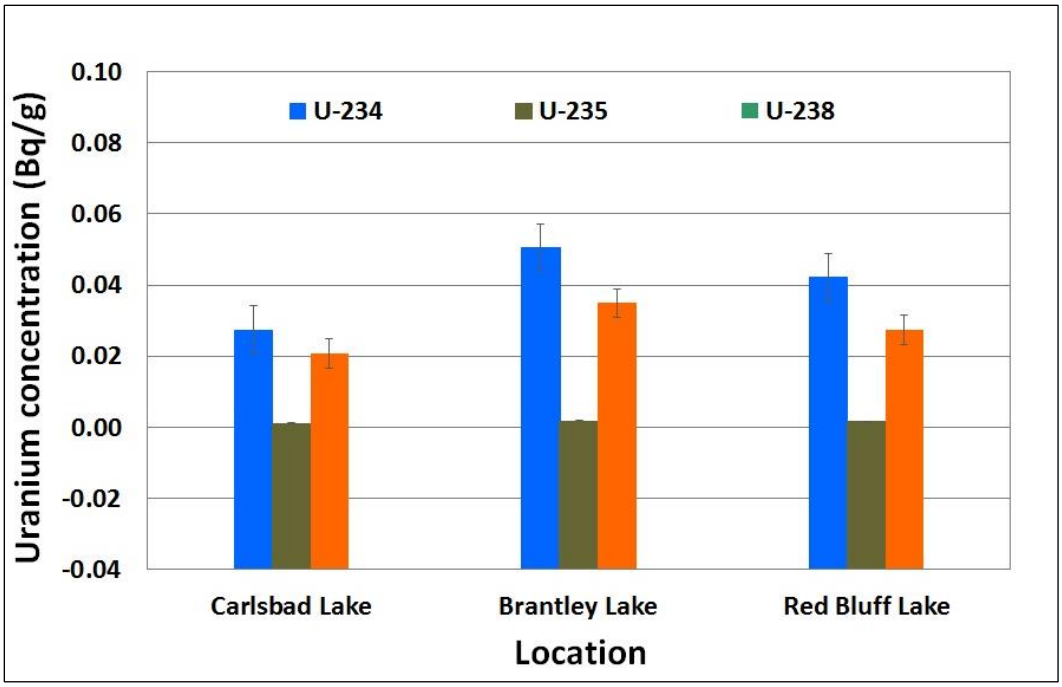


Figure 5-15: Uranium concentrations in sediment samples in three regional reservoirs in 2017

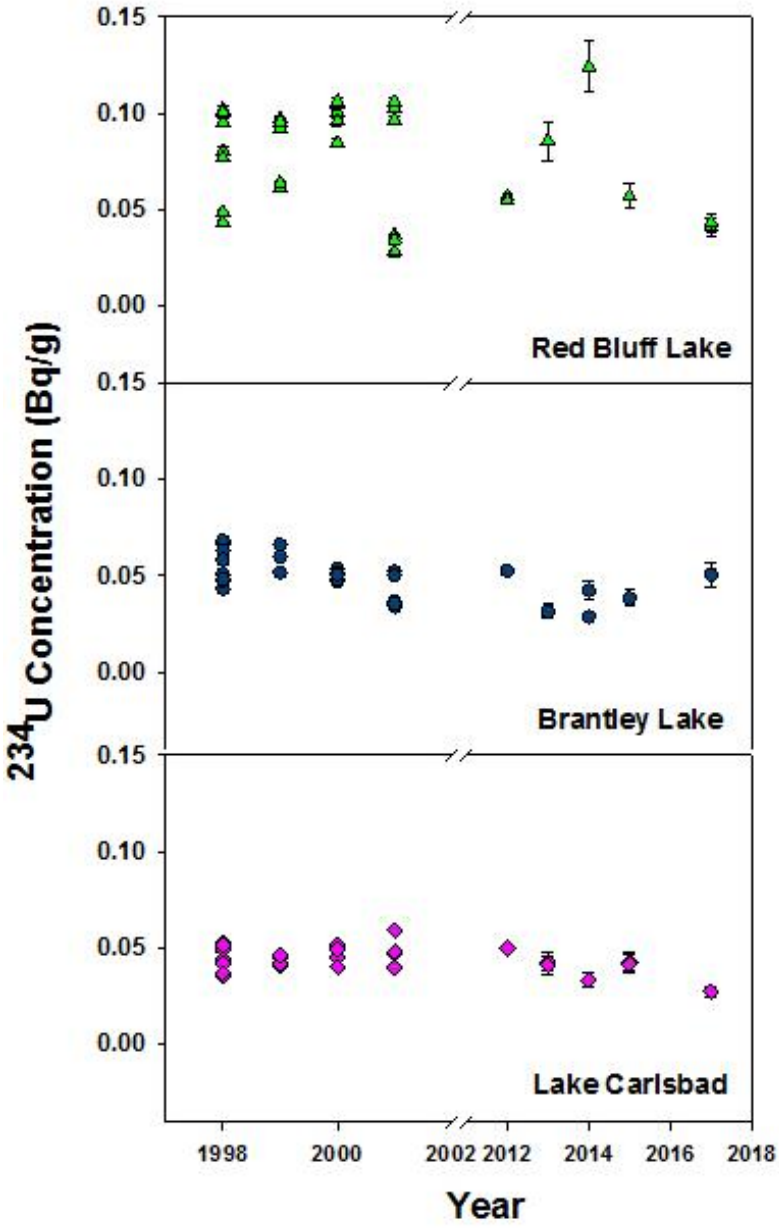


Figure 5-16: The Pre- and Post-radiological event sediment concentrations of ^{234}U from the three reservoirs in the vicinity of the WIPP site

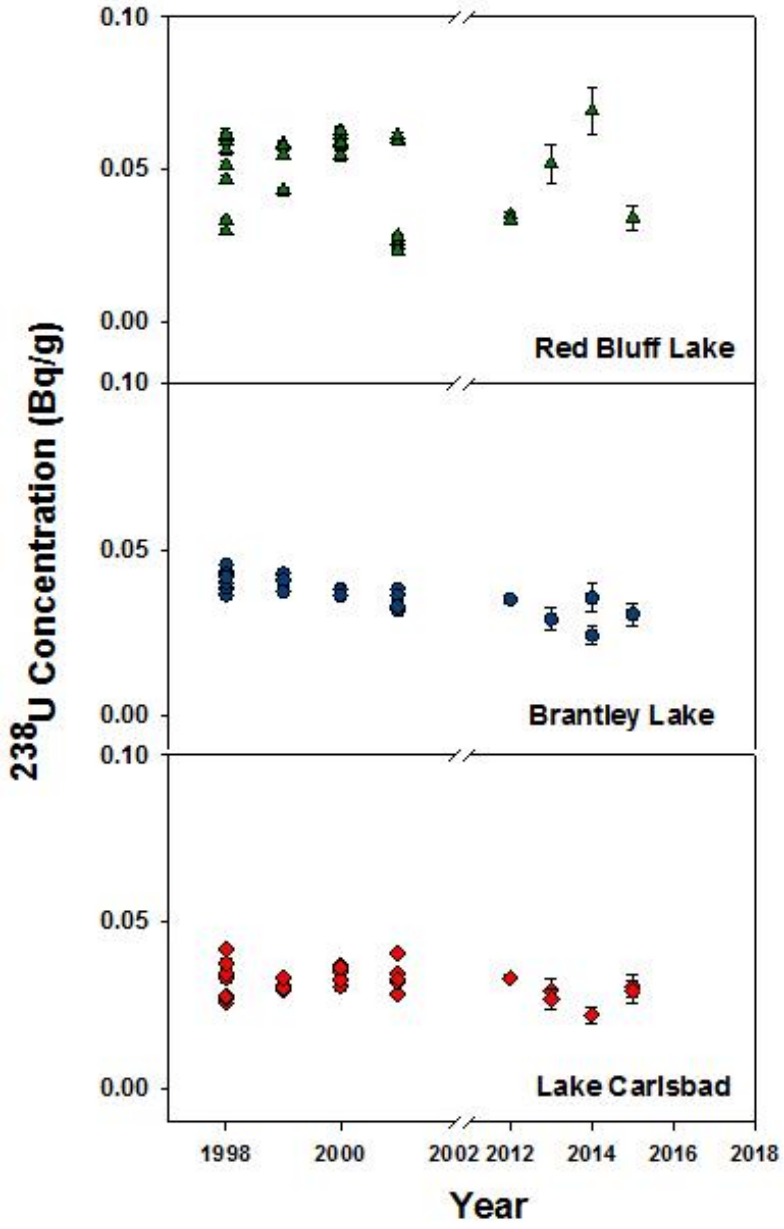


Figure 5-17: The Pre- and Post-radiological event sediment concentrations of ^{238}U from the three reservoirs in the vicinity of the WIPP site

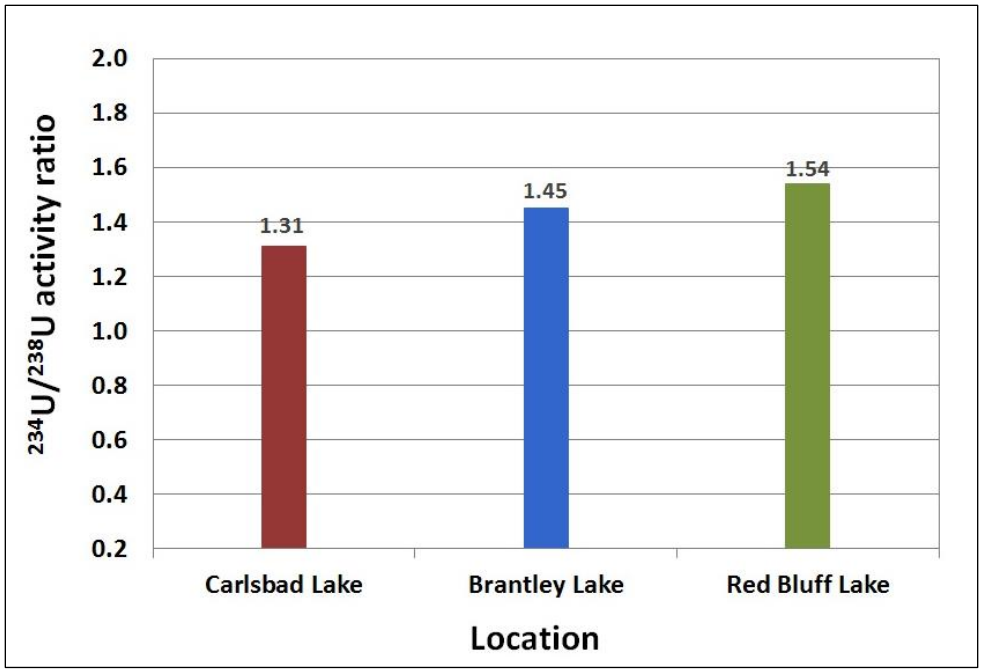


Figure 5-18: The $^{234}U/^{238}U$ Activity Ratio in sediment samples of three reservoirs in the vicinity of the WIPP site

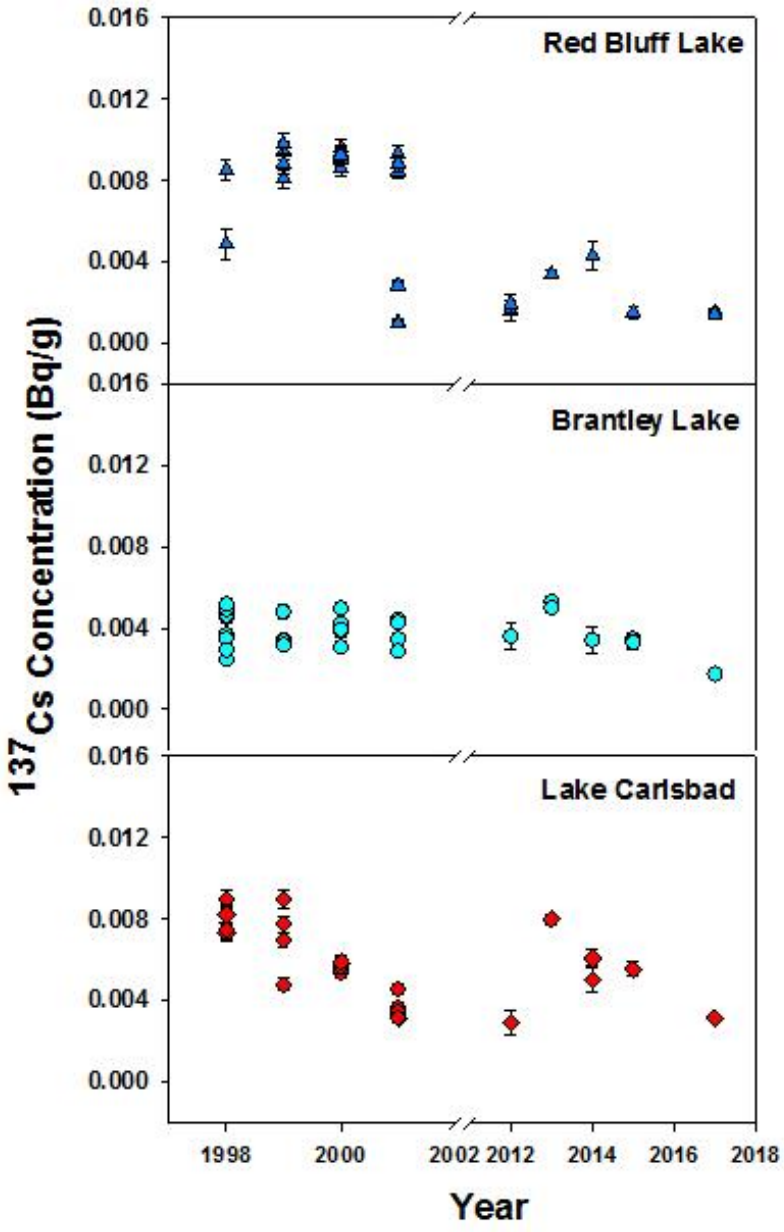


Figure 5-19: The Pre- and Post-radiological event sediment concentrations of ^{137}Cs from the three reservoirs in the vicinity of the WIPP site

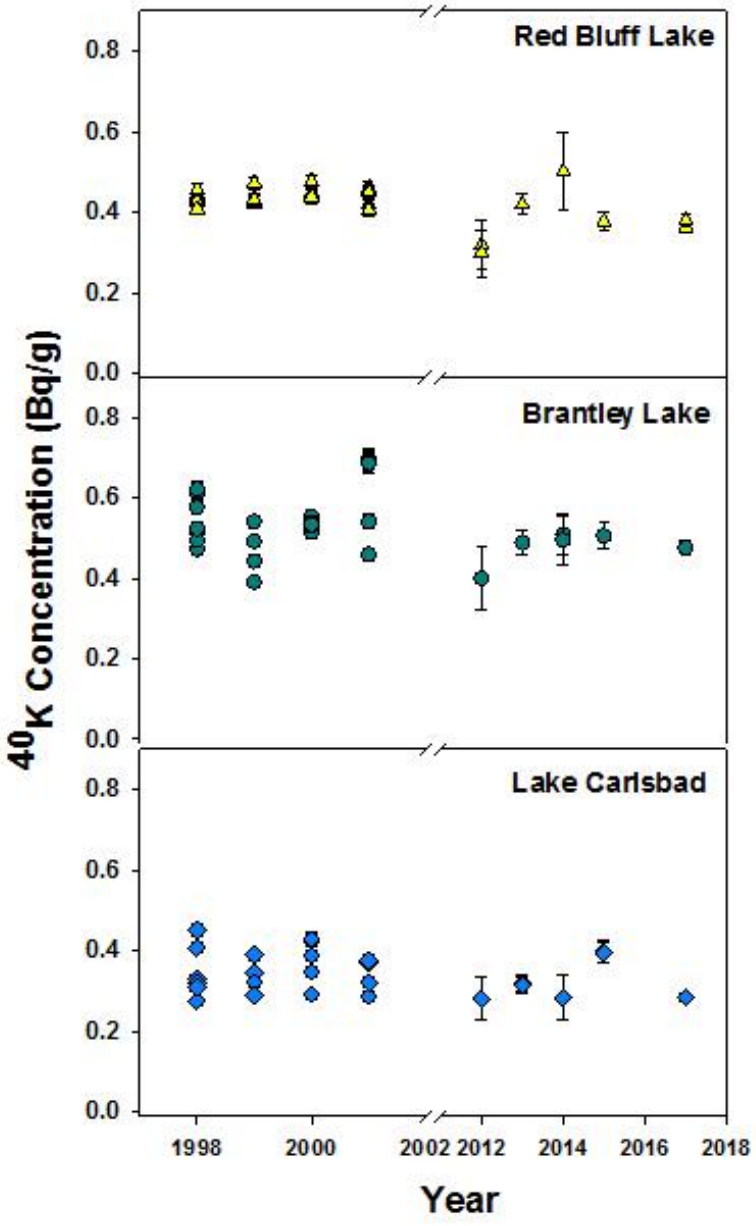


Figure 5-20: The Pre- and Post-radiological event sediment concentrations of ^{40}K from the three reservoirs in the vicinity of the WIPP site

Table 5-5: 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

Radionuclides	Location	Sample Date	Activity Bq/g	Unc. (2σ) Bq/g	MDC Bq/g	Status
^{241}Am	Lake Carlsbad	11/30/17	6.58E-05	4.70E-05	8.03E-05	Not detected
	Brantley	11/30/17	6.06E-05	4.69E-05	9.06E-05	Not detected
	Red Bluff	12/11/17	4.38E-05	4.17E-05	8.49E-05	Not detected
	Red Bluff (Dup)	12/11/17	7.56E-05	3.86E-05	5.72E-05	Detected
$^{239+240}Pu$	Lake Carlsbad	11/30/17	1.39E-04	6.27E-05	5.62E-05	Detected
	Brantley	11/30/17	1.85E-04	8.12E-05	1.08E-04	Detected
	Red Bluff	12/11/17	1.01E-04	5.87E-05	9.30E-05	Detected
	Red Bluff (Dup)	12/11/17	7.81E-05	5.43E-05	9.81E-05	Not detected
^{238}Pu	Lake Carlsbad	11/30/17	-1.21E-05	5.41E-05	1.48E-04	Not detected
	Brantley	11/30/17	4.33E-05	6.44E-05	1.45E-04	Not detected
	Red Bluff	12/11/17	2.13E-05	4.28E-05	1.00E-04	Not detected
	Red Bluff (Dup)	12/11/17	-1.95E-05	3.38E-05	1.04E-04	Not detected

Table 5-6: Activity concentrations of ^{234}U, ^{235}U and ^{238}U (Bq/g) in sediment samples collected from the three reservoirs in the vicinity of the WIPP site

Radionuclides	Location	Sample Date	Activity Bq/g	Unc. (2σ) Bq/g	MDC Bq/g	Status
^{234}U	Lake Carlsbad	11/30/17	2.73E-02	3.00E-03	7.99E-05	Detected
	Brantley	11/30/17	5.05E-02	6.18E-03	1.92E-04	Detected
	Red Bluff	12/11/17	4.11E-02	4.53E-03	9.77E-05	Detected
	Red Bluff (Dup)	12/11/17	4.34E-02	4.78E-03	7.33E-05	Detected
^{235}U	Lake Carlsbad	11/30/17	1.05E-03	1.68E-04	7.02E-05	Detected
	Brantley	11/30/17	1.79E-03	2.13E-04	1.16E-04	Detected
	Red Bluff	12/11/17	1.65E-03	2.47E-04	8.36E-05	Detected
	Red Bluff (Dup)	12/11/17	1.45E-03	2.21E-04	5.68E-05	Detected
^{238}U	Lake Carlsbad	11/30/17	2.08E-02	2.29E-03	8.43E-05	Detected
	Brantley	11/30/17	3.48E-02	4.31E-03	2.39E-04	Detected
	Red Bluff	12/11/17	2.70E-02	3.00E-03	1.45E-04	Detected
	Red Bluff (Dup)	12/11/17	2.78E-02	3.07E-03	7.66E-05	Detected

Table 5-7: 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

Radionuclides	Location	Sample Date	Activity Bq/g	Unc. (2σ) Bq/g	MDC Bq/g	Status
^{137}Cs	Lake Carlsbad	11/30/17	1.73E-03	1.58E-04	4.87E-04	Detected
	Brantley	11/30/17	3.16E-03	1.70E-04	4.85E-04	Detected
	Red Bluff	12/11/17	1.55E-03	1.54E-04	4.79E-04	Detected
	Red Bluff (Dup)	12/11/17	1.44E-03	1.53E-04	4.81E-04	Detected
^{40}K	Lake Carlsbad	11/30/17	2.84E-01	1.13E-02	3.98E-03	Detected
	Brantley	11/30/17	4.76E-01	1.89E-02	3.23E-03	Detected
	Red Bluff	12/11/17	3.62E-01	1.43E-02	3.50E-03	Detected
	Red Bluff (Dup)	12/11/17	3.78E-01	1.51E-02	3.30E-03	Detected
^{60}Co	Lake Carlsbad	11/30/17	2.94E-05	1.49E-04	4.94E-04	Not detected
	Brantley	11/30/17	1.03E-04	1.56E-04	5.14E-04	Not detected
	Red Bluff	12/11/17	6.56E-05	1.54E-04	5.10E-04	Not detected
	Red Bluff (Dup)	12/11/17	1.97E-05	1.50E-04	4.98E-04	Not detected

CHAPTER 6

Non-Radiochemical Analyses

The Environmental Chemistry (EC) group is a vital part of the WIPP-EM program since the WIPP waste contains both radioactive materials and hazardous (non-radioactive) materials. Hazardous, or toxic, materials are defined as those pollutants which might cause serious health effects, such as cancer or birth defects, and can adversely affect the environment and ecology from a non-radiological standpoint. The primary focus of the EC group is to monitor the hazardous (non-radioactive) aspect of the environment surrounding the WIPP-site. The types of hazardous materials monitored by the EC group include an assortment of heavy metals and salt-components in addition to a select number of inorganic anion and cation constituents.

The EC group utilizes two types of instrumentation for sample analyses: a Metrohm USA Compact 930 FLEX Ion Chromatograph (IC) and two Perkin Elmer Inductively Coupled Plasma-Mass Spectrometers (ICP-MS). The IC is used to measure inorganic anion constituents in drinking water (DW) and surface water (SW) samples. The list of anions includes chlorides, fluorides, nitrates, phosphates, and sulfates. Recently the EC group expanded the anions list to include bromide and nitrite as well. In addition to anions, the IC instrument is capable of analyzing water samples for some inorganic cation constituents such as ammonium, calcium, potassium, and sodium. While some of these inorganic cation constituents can also be detected by ICP-MS analysis, they are sometimes difficult to quantify using the current ICP-MS methods due to the high salt content of most samples.

The two ICP-MS instruments are the "work-horses" of the EC group. These instruments are capable of determining over 30 different metals (including lead, arsenic, chromium, iron, cadmium, mercury, magnesium, aluminum, thorium, and natural uranium) in a variety of environmental sample types. Currently, the EC group analyzes both drinking water and surface water as well as the WIPP underground aerosol samples by ICP-MS. The EC group is currently working on expanding the ICP-MS analysis capabilities to look for a variety of metals in aerosol samples as well.

All WIPP-EM samples are collected from the field in the same manner regardless of the type of analyses to be performed (i.e. radiochemical or non-radiochemical). Details regarding the field collection of all sample types gathered by the CEMRC are described in the corresponding radiological chapters of this annual report. It should be noted that all of the environmental samples collected by the CEMRC undergo radiochemical analyses. The following sample types also receive one or more forms of non-radiochemical examination: WIPP underground aerosol samples (i.e. FAS filters), drinking water samples, and surface water samples. Most samples to be

analyzed for inorganic constituents and metals require additional processing once they arrive at the CEMRC facility. Details are described herein.

Sample Collection and Preparation

Drinking Water

Drinking water samples are collected annually and have undergone non-radiochemical analyses since 1998. It should be noted that drinking water samples were not collected during 2004 and 2006 due to a change in the sample collection schedule. Sampling at the Malaga site began in 2011. In 2016, the Double Eagle sampling location changed due to improvements being made to the water lines in that region. The new Double Eagle sampling location is referred to as Double Eagle PRV4.

In 2017, drinking water samples were collected in April. The sources for this years' drinking water sampling include the community water supplies of Carlsbad (Sheep Draw and Double Eagle PRV4), Loving, Otis, Hobbs, and Malaga. Details regarding the procedure for drinking water sample collection are included in Chapter 4.

Once the water samples reach the CEMRC facility, several aliquots are removed for analysis of a variety of inorganic constituents and metals. The following sub-samples are taken from each water sample: (1) 1 L for inorganic analysis, (2) 500 mL for mercury analysis and (3) 1 L for metals analyses. Each 1 L aliquot removed for inorganic constituent analysis is split into two parts. The first 1 L sub-sample is immediately refrigerated and analyzed for anions within 48 hours of collection. No preservatives are added to the sample used for anion analysis. Part of the 1 L inorganic aliquot is preserved with a dilute nitric acid solution for cations analysis. Due to the high salt content observed in drinking water samples, both types of inorganic analyses (anions and cations) require dilution prior to analysis. Dilutions are performed using ultrapure water.

For mercury analysis, each sample aliquot is collected in a 500 mL glass container and preserved with a bromine monochloride solution immediately upon arrival at CEMRC. No sample dilution is necessary for mercury analysis of water samples since mercury is rarely detected above background levels. It should be noted that mercury analysis is performed separately from other metals in drinking water samples because of the requirements for sample preservation.

For metals analysis, each aliquot is preserved with dilute nitric acid during collection. Again, because of the high salt content, drinking water samples are diluted using a similar nitric acid solution prior to analysis.

Drinking water samples are currently analyzed for metals and both types of inorganic constituents (anions and cations). The current ICP-MS method for metals analysis of DW samples

(See Table 6-1) used at CEMRC can provide data for up to 37 elements, but due to the high concentrations of sodium, potassium, magnesium, and calcium some of the lanthanides and actinides are often below detectable levels.

Drinking water aliquots have been analyzed for anions (specifically chloride, fluoride, nitrate, phosphate, and sulfate) since the CEMRC commenced drinking water analyses in 1998. Bromide and nitrite were added to the list of anions in 2007. Therefore baselines for these ions are not available. However, they have rarely been measured above the MDC since these analyses began. It should be noted that cation analysis on drinking water samples for ammonium, calcium, lithium, magnesium, potassium, and sodium began in 2016.

Results reported herein are for 2017 drinking water samples. Previous results published by the CEMRC can be found on the CEMRC website (www.cemrc.org). The 2017 metal results and how they compare to previous results are summarized in tables 6-2 through 6-7 for the six regional drinking water sources. Present results, as well as the results of previous analyses of drinking water, were consistent for each source across sampling periods and were found to be below levels specified under the Safe Drinking Water Act (U.S. EPA 2012). The CEMRC results for drinking water from the Carlsbad (Sheep Draw) and WIPP (Double Eagle) locations generally agree with the measurements for the same elements published by the City of Carlsbad every year (http://cityofcarlsbadnm.com/CCR%202016.pdf). General information about inorganic contaminants in drinking water is listed in Table 6-8.

Figures 6-1 through 6-6 compare the history of the following selected metals measured in drinking water collected from the surrounding areas of WIPP: Arsenic (As), Barium (Ba), Chromium (Cr), Copper (Cu), Lead (Pb), Antimony (Sb), and Uranium (U). As mentioned earlier, drinking water sampling did not take place during the 2004 and 2006 years due to a change in sampling frequency. Since the CEMRC began monitoring the regional drinking water, the results have exhibited a high level of consistency with past results.

Minerals are a natural part of all water sources. The amount of inorganic materials in drinking water is determined primarily by local geology and topography, but it can be influenced by urban stormwater runoff, industrial or domestic wastewater discharges, oil and gas production, mining, and/or farming, etc. The elemental constituents, As, Ba, Cr, Cu, Pb, Sb, and U are commonly found in the drinking water of the southwest. For example, the city of Midland, TX, has naturally occurring levels of Arsenic, Fluoride, and Selenium in their drinking water (http://www.midlandtexas.gov/ArchiveCenter/ViewFile/Item/152). The drinking water from this part of Texas is supplied from the Ogallala and Dockum formations which are also accessed by the WIPP (Double Eagle) and Hobbs communities. Indeed the typical concentrations of Arsenic measured at the Double Eagle and Hobbs sites are higher than the drinking water for other sampling locations around the WIPP site (most of which have concentrations below the MDC.

However, the levels determined for Double Eagle and Hobbs are still below the EPA limit of 10 µg/L (0.01 mg/L) for Arsenic as listed in Table 6-8.

The WIPP site is located in the Delaware Basin of New Mexico, the second-largest region of the greater Permian Basin. This 600-meter deep salt basin was formed during the Permian Era approximately 250 million years ago when an ancient Sea, once covering the area, evaporated and left behind a nearly impermeable layer of salt. Over time this salt layer was covered by 300 meters of soil and rock (Kerr 1999 and Weeks 2011). The Permian Basin is now a major source of potassium salts (potash), which are mined from bedded deposits of sylvite and langbeinite (Alto and Fulton 1965). Sylvite is potassium chloride (KCl) in its natural mineral form while langbeinite is a potassium magnesium sulfate mineral ($K_2Mg_2(SO_4)_3$). Langbeinite ore occurs in evaporated marine deposits in association with carnallite, halite, and sylvite (Mereiter 1979) and (Palache et al., 1951). Therefore, it is to be expected that through leaching and other natural processes the water in this region would contain significant quantities of potassium (K), magnesium (Mg) and, of course, sodium (Na). Figure 6-7 summarizes the concentrations of metals in common salts measured in the areas surrounding the WIPP site. Currently, there are no EPA regulations for salt-containing components like K, Mg, and Na in drinking water.

By far, the highest concentration of the measured metals found in the drinking water of this area is Calcium (Ca) for each of the sites sampled around the WIPP (Figure 6-7). This is likely due to the natural calcium deposits found along the edge of the Delaware Basin which once existed as the Capitan Reef during the Permian Era. Limestone is a sedimentary rock composed largely of the minerals calcite and aragonite, which are different crystal forms of calcium carbonate ($CaCO_3$). Limestone leaching creates the stalactites and stalagmites found in the world-famous Carlsbad Caverns, located approximately 18 miles southwest of Carlsbad, NM.

Current inorganic anion analysis results are compared to previous years in Table 6-9 through Table 6-14 for the following anions: bromide, chloride, fluoride, nitrate, nitrite, phosphate and sulfate. The bromide, nitrite, and phosphate anions often hover right around the MDC or below. Only once (at the Loving location in 2009) since analysis began, has phosphate ever been detected in the drinking water above the MDC. Since 2007 (when analysis of this anion began), nitrite has never been detected at any of the sites above the MDC in drinking water samples. Bromide has occasionally been detected above the MDC in drinking water collected at the seven different locations although the observations are few. It should be noted that the EPA (see Table 6-8) does not list regulatory information about bromide.

The other anions are routinely detected above MDC. Figures 6-8 through 6-11 are shown for chloride, fluoride, nitrate, and sulfate. Just like with metals, annual measurements for these anions in drinking water show some variation within several orders of magnitude. Chloride has never been detected above the EPA secondary limit of 250 mg/L (250,000 µg/L) for Carlsbad, Double Eagle, Hobbs, and Loving since 1998. However, this anion has frequently been detected

above the EPA secondary limit for the Otis and Malaga drinking water (See Figure 6-8). All measurements made from the Malaga site thus far have been detected above the EPA secondary limit; however, no baseline is available for the Malaga site for comparison. It should be noted that secondary EPA regulations are not enforceable.

In 2017 all reported fluoride concentrations were below the EPA limit of 4 mg/L (4,000 µg/L) as shown in Figure 6-9. Fluoride concentrations since sampling began are highly variable and occasionally, concentrations fall below the MDC at some locations. For example, between 2004 and 2008 for Carlsbad drinking water and after 2008 for Otis drinking water.

Nitrate is regularly measured in the drinking water at all of the locations around the WIPP site. Loving, Otis, Malaga, and Hobbs water typically have higher nitrate concentrations than Double Eagle and Carlsbad. See Figure 6-10 for a comparison of nitrate concentrations at the different locations. All reported nitrate concentrations are below the EPA limit for nitrate (measured as nitrogen = 10 mg/L or approximately 44,200 µg/L nitrate ion). According to the EPA (2012), common sources of nitrogen (i.e. in the form of nitrites and nitrates) are fertilizer runoff, leaching from septic tanks and sewage, and erosion of natural deposits.

Like nitrate and chloride, sulfate is another common constituent of drinking water sampled around the WIPP site. Sulfate (See Figure 6-11) has never been detected above the EPA secondary limit for the Carlsbad, Double Eagle, Hobbs, and Loving locations. On the other hand, sulfate concentrations in Malaga and Otis water are routinely above the EPA secondary limit of 250 mg/L. There are no baseline measurements available for the Malaga site. High sulfate concentrations in Otis water have been observed since CEMRC commenced sulfate analyses in 1998 (before the WIPP began accepting mixed waste). Therefore, sulfate concentrations in Otis water cannot be a result of the WIPP activities. It should be noted that secondary EPA (2012) regulations are not enforceable. Furthermore, the EPA does not list any potential health effects from long-term exposure to sulfate anions (Table 6-8).

Inorganic cation analyses on drinking water began in 2016. Therefore, no baseline for these six constituents exist. The 2017 results are compared to the 2016 results in Tables 6-15 through 6-20. Ammonium has never been detected above the MDC at any of the DW locations surrounding the WIPP site. Currently, none of these inorganic cations are monitored by the EPA (2012).

Surface Water

Surface water samples are typically collected every other year. The first sampling of regional surface water occurred in 1999. Since then, surface water samples were collected and non-radiochemical results were reported during the following years: 2000, 2001, 2005 (only metals analysis was performed this year), 2012, 2013, 2015, and 2017. It should be noted that

surface water samples were also collected in 2014 after the WIPP radiological event; however, only radiochemical analyses were performed on those samples. In 2017 surface water samples were collected in November from Carlsbad Lake and Brantley Lake. Samples from Red Bluff were collected in December. Details regarding the specific locations and sample collection techniques for the surface water samples are included in Chapter 5.

Once the surface water samples are received by the CEMRC facility, they are divided into the same aliquots as drinking water: (1) 1 L for inorganic constituent analysis, (2) 500 mL for mercury analysis and (3) 1 L for elemental analyses. They are preserved and analyzed in the same manner as drinking water samples. The only difference between drinking water and surface water preparation is surface water samples must be filtered prior to analysis because of the high particulate content.

Just like with drinking water, surface water samples are also analyzed for metals and both types of inorganic constituents (anions and cations). See Table 6-8 for the current methods used to analyzed SW samples. Surface water aliquots have been analyzed for anions (specifically chloride, fluoride, nitrate, phosphate, and sulfate) since the CEMRC commenced SW analyses in 1999. The two additional inorganic constituents were approved for reporting beginning in 2012: bromide and nitrite. Therefore baselines for these ions are not available. However, since 2012 they are rarely measured above the MDC. Cation analysis on surface water samples began this year (2017) for ammonium, calcium, lithium, magnesium, potassium, and sodium.

The 2017 non-radiochemical metal results are compared to previous data in Tables 6-21 through 6-23 for the three regional water sources. Present results, as well as the results of previous analyses for surface water, are consistent for each source across sampling periods.

Minerals are a natural part of all water sources. The amount of metal and inorganic materials in surface water is determined primarily by local geology and topography, but it can be easily influenced by urban stormwater runoff, industrial or domestic wastewater discharges, oil and gas production, mining, and/or farming, etc. The metal constituents, As, Ba, Cr, Cu, Pb, Sb, and U are naturally found in water sources of the southwest (http://www.midlandtexas.gov/ArchiveCenter/ViewFile/Item/152). All of these metals are detected above the MDC in the regional surface water collected around the WIPP site.

Of the surface water metals monitored by the EPA (listed in Table 6-24) only: aluminum (Al), arsenic (As), iron (Fe), nickel (Ni), and lead (Pb) are measured regularly above the MDC. Figures for these metals are shown in Figures 6-12 through 6-16. While most show fairly constant measurements since 1999, arsenic (Figure 6-14) appeared to be increasing up until the last measurement taken in December of 2013. However, arsenic has not been detected above the MDC since then.

Mercury (Hg) has only been detected above the MDC during three sampling years. In 2001, mercury was detected at Lake Carlsbad and Brantley Lake with the highest measurement of 0.177 µg/L from Brantley. In 2012, mercury was detected at Lake Carlsbad and Red Bluff with the highest measurement at 0.424 µg/L (Lake Carlsbad). In 2017, mercury was only measured above the MDC at Lake Carlsbad with a value of 0.0297 µg/L. All of these concentrations are well below the recommended limit. The EPA limit of 0.77 µg/L is defined as the highest concentration in surface water to which an aquatic community can be exposed indefinitely without resulting in an unacceptable effect (see Table 6-24).

Current inorganic anion analysis results are compared to previous years in Table 6-25 through 6-27 for the following anions: bromide, chloride, fluoride, nitrate, nitrite, phosphate and sulfate. Of the seven anions, only chloride, fluoride, and sulfate are detected regularly above the MDC at both the shallow and deep levels. Figures 6-17 through 6-19 are shown for chloride, fluoride, and sulfate for the three surface water locations. While fluoride concentration measurements are fairly constant for all three surface water locations (~600 µg/L), chloride and sulfate show the typical variation of several orders of magnitude over years of sampling. There is no current explanation for the regularity exhibited by fluoride in regional surface water. The chloride measurements for Lake Carlsbad, Brantley Lake, and Red Bluff are all above the EPA recommendations (See Table 6-24). Only Chloride is monitored by the EPA. These limits are recommendations only and are not used in assessing regulatory compliance.

Inorganic cation analyses on surface water began this year. Therefore, no baseline for these six constituents exist for comparison. The 2017 results are reported in Tables 6-28 through 6-30. Currently, none of these inorganic cations are monitored by the EPA.

Sample Analysis

All non-radiochemical analyses are performed according to CEMRC's rigorous quality assurance program. For both ICP-MS and IC analyses, a variety of quality control samples (including blanks, spiked blanks, duplicates, and spiked samples) are prepared and run alongside every set of WIPP-EM samples during analysis. Certified references materials are also analyzed with every sample batch. And once a year, CEMRC participates in several blind proficiency test (PT) studies coordinated by the Environmental Resource Associates (ERA). The results of the 2017 PT studies are shown in Figures 9-7a through 9-7c (Quality Assurance).

The EC group also utilizes a variety of databases, maintained by the Information Management (IM) group. Each database used by the EC group has undergone an extensive verification and validation process to ensure that all data adheres to CEMRC analysis procedures and reporting requirements. These databases are critical to storing, processing, verifying, and reporting non-radiochemical results. Each database also provides permanent storage of verified

results and allows easy access to the data for reporting and a variety of environmental research projects.

Two types of analytical instrumentation are utilized for the routine analysis of WIPP-EM water and air samples: two Inductively Coupled Plasma Mass Spectrometry (ICP-MS) instruments and an Ion Chromatography (IC) instrument. The ICP-MS is used for metals analysis while the IC instrument is used for the analysis of a variety of inorganic constituents. Current methods used for the various analyses performed on each sample type are summarized in Table 6-1.

The ICP-MS instruments have a peak resolution of <0.71amu for the mass range reported. The mass calibration value is within 0.1amu of the vendor's true values. These systems are configured with cyclonic spray chambers. Triplicate readings are performed on each sample, with the average result reported. The instrument(s) is/are calibrated before every sample analysis and Daily Performance checks are run as shown in Table 9-1 (Quality Assurance). The current ICP-MS methods for metals analysis used at CEMRC can provide data for up to 35 elements, but in practice, the concentrations of some elements are often at or below detectable levels depending on the types of samples undergoing analysis.

Inorganic analyses are performed on both types of water samples (drinking water and surface water) for a select variety of cations and anions using an Ion Chromatograph instrument. Table 6-1 lists the particular cation and anion constituents for each sample type, along with the current reference methods and detection limits. In order to handle both inorganic anion and cation analyses, the IC instrument is equipped to change between two different configurations. The configuration for inorganic anions analysis includes a suppressor and a Metrosep A Supp 5 guard and analytical column set. The instrument is calibrated for inorganic anion concentrations ranging from 0.02 to 100 ppm. For cations analysis, the instrument is reconfigured to bypass the suppressor system and utilizes a Metrosep C6 cation guard and analytical column set. The instrument is calibrated for inorganic cation concentrations ranging between 0.25 to 10 ppm. Current CEMRC procedures for IC analysis only requires calibrating the IC instrument once a month, but calibration checks are performed during every sample analysis as routine quality assurance.

Data Reporting

Summaries of data and results from previous samplings were reported in earlier CEMRC reports which are available online (http://www.cemrc.org) under the annual reports tab. All non-radioactive analyses of samples are reported according to the methods detailed in the CEMRC document-controlled, standard operating procedures. For each type of analysis (metals, mercury, and inorganics, etc.), results are blank-corrected after the application of dilution factors. As per the CEMRC procedure, only concentrations above laboratory MDC values are reported. Table 6-1 summarizes the sample type, methods, analytes of interest, and the current detection limits

(MDCs) used for reporting 2017 sample results. Results for all water analyses are reported in units of µg/L.

The primary purpose of the CEMRC WIPP-EM program is to compare pre- vs. post-disposal conditions to ensure that changes in the environment are not directly related to the presence/storage of nuclear waste at the WIPP site. The WIPP received its first radioactive waste shipment in March of 1999 and the first shipment of mixed waste (i.e. radioactive waste that also contains non-radioactive hazardous materials) in September of 2000. In this chapter, samples collected prior to the September 2000 date compose a pre-mixed waste baseline for metals and inorganic analyses. Data presented from non-radiochemical analyses is, therefore, distinguished by color for "pre-operational" and "operational" monitoring using the September 2000 cut-off marker.

Conclusions

The results exhibited in this chapter are not used in assessing regulatory compliance. No noticeable increases in the elemental or inorganic levels were observed in any water samples after the WIPP site started accepting mixed waste in September of 2000 that could be attributed to activities at the WIPP site. More importantly, no noticeable increases in the details or inorganic constituent levels were observed in the water samples after the February 2014 WIPP events.

Table 6-1: Summary of Sample Type, Analysis Parameters, Methods, and Detection Levels used to Analyze Samples for non-radioactive materials in 2017

Sample Type	Instrument	Method/ Parameters	Analytes of Interest	Detection Limits*
Drinking Water	ICP-MS	Metals analysis (EPA 200.8)	Over 30 different metals	Varies by element**
Drinking Water	IC	Anions (EPA 300.0)	F^-, Cl^-, Br^-, NO_2^-, NO_3^-, PO_4^{3-}, SO_4^{2-}	2.7 – 48.3 µg/L
Drinking Water	ICP-MS	Mercury (EPA 200.8)	Hg	0.049 µg/L
Drinking Water	IC	Cations (ASTM Standard D6919-09)	Li^+, Na^+, K^+, Ca^{2+}, Mg^{2+}, NH_4^+, Mg^{2+}	15 – 69 µg/L
Surface Water	ICP-MS	Metals analysis (EPA 200.8)	Over 30 different metals	Varies by element**
Surface Water	IC	Anions (EPA 300.0)	F^-, Cl^-, Br^-, NO_2^-, NO_3^-, PO_4^{3-}, SO_4^{2-}	2.3 – 17.0 µg/L
Surface Water	ICP-MS	Mercury (EPA 200.8)	Hg	0.023 µg/L
Surface Water	IC	Cations (ASTM Standard D6919-09)	Li^+, Na^+, K^+, Ca^{2+}, Mg^{2+}, NH_4^+, Mg^{2+}	32.3 – 127.7 µg/L
FAS filters	ICP-MS	Metals analysis (EPA 200.8)	Al Cd Mg Pb Th U	2.1 µg/L 0.16 µg/L 7.3 µg/L 0.014 µg/L 0.0063 µg/L 0.0050 µg/L

* Detection limits are determined/updated annually.
** Current MDC values for individual metals are included in the results section of this chapter.

Table 6-2: Summary of Metal Concentrations in Carlsbad Drinking Water

Carlsbad						
1998 - 2016					2017	
Metals	N	N_{DET}	Min	Max	MDC (µg/L)	Sample Conc. (µg/L)
Ag	14	2	1.75E-02	2.88E-02	9.20E-03	<MDC
Al	15	8	1.83E+00	4.11E+01	1.64E+00	4.45E+00
As	17	11	2.97E-01	1.42E+00	2.60E+00	<MDC
B	3	3	2.89E+01	4.44E+01	N/A	N/A
Ba	13	13	6.64E+01	8.19E+01	1.48E-01	7.08E+01
Be	14	0	N/A	N/A	6.60E-01	<MDC
Ca	10	10	5.90E+04	7.30E+04	4.70E+02	6.83E+04
Cd	13	0	N/A	N/A	2.40E-01	<MDC
Ce	13	5	5.81E-03	3.42E-02	1.36E-02	<MDC
Co	15	13	8.80E-02	3.41E-01	5.40E-02	1.16E-01
Cr	16	14	5.14E-01	1.02E+01	3.20E-01	4.71E+00
Cu	15	14	1.30E+00	1.67E+01	2.20E-01	1.15E+01
Dy	15	1	3.56E-03	3.56E-03	3.40E-02	<MDC
Er	15	2	3.32E-03	3.38E-03	2.80E-02	<MDC
Eu	14	11	1.04E-02	2.42E-02	2.80E-01	<MDC
Fe	12	9	7.10E-01	6.52E+02	9.80E+00	1.97E+02
Ga	1	1	3.25E+00	3.25E+00	N/A	N/A
Gd	12	3	1.96E-03	3.91E-03	2.20E-02	<MDC
Hg	9	2	2.26E-02	3.14E-02	4.90E-02	<MDC
K	14	14	1.02E+03	3.56E+03	3.94E+01	1.12E+03
La	14	6	5.81E-03	4.42E-02	4.60E-02	<MDC
Li	12	12	5.14E+00	8.86E+00	4.20E-01	6.14E+00
Mg	13	13	2.73E+04	3.47E+04	1.20E+01	3.10E+04
Mn	16	11	5.50E-02	2.93E+01	6.80E-02	2.31E+01
Mo	12	11	8.93E-01	1.37E+00	2.80E-01	1.20E+00
Na	15	15	8.16E+03	4.55E+04	1.30E+01	1.29E+04
Nd	15	2	8.50E-03	9.35E-03	3.00E-02	<MDC
Ni	15	14	1.46E+00	3.14E+00	1.44E-01	2.39E+00
P	9	8	1.61E+01	4.95E+01	7.36E+01	<MDC
Pb	14	12	1.01E-01	2.07E+00	4.60E-01	7.17E-01

Table 6-2: Summary of Metal Concentrations in Carlsbad Drinking Water (continued)

Carlsbad						
1998 - 2016					2017	
Metals	N	N_{DET}	Min	Max	MDC (µg/L)	Sample Conc. (µg/L)
Pr	14	2	1.93E-03	3.72E-03	1.68E-02	<MDC
Sb	14	9	2.50E-02	1.99E-01	6.80E-02	<MDC
Sc	12	11	1.18E+00	3.03E+00	2.60E-01	1.39E+00
Se	14	7	-8.83E-02	1.93E+00	4.80E+00	<MDC
Si	11	11	5.35E+03	6.87E+03	2.51E+02	5.88E+03
Sr	14	14	2.61E+02	3.62E+02	6.30E-01	2.95E+02
Th	12	3	6.32E-03	1.76E-02	3.80E-01	<MDC
Tl	14	14	8.97E-02	1.30E+00	4.40E-01	<MDC
U	15	15	7.36E-01	1.05E+00	2.80E-01	7.13E-01
V	16	16	3.07E+00	6.57E+00	1.38E-01	5.26E+00
Zn	15	14	2.13E+00	1.57E+01	2.80E-01	3.49E+01

N = Total number of samples analyzed; N_{det} = number of samples with detectable (above MDC) values;
Min = the lowest value measured above MDC; Max = the highest value measured;
MDC = Minimum detectable concentration;
Concentrations below the MDC are reported as <MDC;
N/A = Not Available

Table 6-3: Summary of Metal Concentrations in Double Eagle and Double Eagle PRV4 Drinking Water

Double Eagle & Double Eagle PRV4						
1998 - 2016					2017	
Metals	N	N_{DET}	Min	Max	MDC (µg/L)	Sample Conc. (µg/L)
Ag	16	3	3.62E-03	1.78E-01	9.20E-03	<MDC
Al	17	11	1.93E+00	7.22E+01	1.64E+00	6.63E+00
As	16	14	4.48E+00	9.11E+00	2.60E+00	5.31E+00
B	3	3	2.98E+01	8.55E+01	N/A	N/A
Ba	14	14	3.82E+01	1.26E+02	1.48E-01	9.27E+01
Be	15	2	3.63E-02	6.76E-02	6.60E-01	<MDC
Ca	10	10	4.15E+04	5.94E+04	4.70E+02	5.36E+04
Cd	14	1	1.87E-02	1.87E-02	2.40E-01	<MDC
Ce	14	3	3.63E-03	3.22E-02	1.36E-02	<MDC
Co	16	13	5.73E-02	1.12E+00	5.40E-02	1.06E-01
Cr	17	16	8.38E-01	3.25E+01	3.20E-01	3.13E+00
Cu	16	15	8.09E-01	5.69E+00	2.20E-01	2.64E+00
Dy	16	1	6.15E-02	6.15E-02	3.40E-02	<MDC
Er	16	1	5.79E-02	5.79E-02	2.80E-02	<MDC
Eu	15	12	1.68E-02	9.32E-02	2.80E-01	<MDC
Fe	13	11	3.01E-02	9.32E+02	9.80E+00	2.27E+02
Ga	1	1	4.46E+00	4.46E+00	N/A	N/A
Gd	14	0	N/A	N/A	2.20E-02	<MDC
Hg	8	0	N/A	N/A	4.90E-02	<MDC
K	15	15	2.22E+03	2.94E+04	3.94E+01	3.09E+03
La	15	6	1.19E-02	7.50E-02	4.60E-02	<MDC
Li	13	13	9.97E+00	1.97E+01	4.20E-01	1.90E+01
Mg	13	13	8.51E+03	1.25E+04	2.40E+00	9.40E+03
Mn	17	14	2.22E-01	6.04E+00	6.80E-02	6.65E-01
Mo	13	13	1.42E+00	6.70E+00	2.80E-01	1.52E+00
Na	16	16	3.84E+03	4.04E+04	1.30E+01	3.29E+04
Nd	16	2	2.35E-03	4.88E-02	3.00E-02	<MDC
Ni	16	15	7.68E-01	4.03E+00	1.44E-01	1.39E+00
P	9	5	6.38E+00	2.35E+01	7.36E+01	<MDC
Pb	15	14	2.56E-01	5.32E+00	4.60E-01	8.46E-01
Pr	15	1	9.05E-04	9.05E-04	1.68E-02	<MDC

Table 6-3: Summary of Measured Metal Concentrations in Double Eagle and Double Eagle PRV4 Drinking Water (continued)

Double Eagle & Double Eagle PRV4						
1998 - 2016					2017	
Metals	N	N_{DET}	Min	Max	MDC (µg/L)	Sample Conc. (µg/L)
Sb	15	11	2.41E-02	1.39E-01	6.80E-02	<MDC
Sc	13	12	1.40E+00	6.59E+00	2.60E-01	3.13E+00
Se	14	10	-4.16E-02	5.30E+00	4.80E+00	<MDC
Si	11	11	7.37E+03	1.81E+04	2.51E+02	1.31E+04
Sr	15	15	5.06E+01	5.82E+02	6.30E-01	5.55E+02
Th	14	5	2.07E-03	8.38E-02	3.80E-01	<MDC
Tl	15	1	-1.23E-02	-1.23E-02	4.40E-01	<MDC
U	16	16	1.17E+00	2.38E+00	2.80E-01	1.65E+00
V	17	17	7.71E+00	4.06E+01	1.38E-01	2.38E+01
Zn	16	15	1.46E+00	1.25E+01	2.80E-01	5.20E+00

N = Total number of samples analyzed; N_{det} = number of samples with detectable (above MDC) values;
Min = the lowest value measured above MDC; Max = the highest value measured;
MDC = Minimum detectable concentration;
Concentrations below the MDC are reported as <MDC;
N/A = Not Available

Table 6-4: Summary of Metal Concentrations in Hobbs Drinking Water

Hobbs						
1998 - 2016					2017	
Metals	N	N_{DET}	Min	Max	MDC (µg/L)	Sample Conc. (µg/L)
Ag	16	2	3.86E-03	1.04E-01	2.30E-02	<MDC
Al	17	14	3.03E+00	1.14E+02	4.10E+00	6.20E+01
As	16	15	4.55E+00	8.56E+00	6.50E+00	<MDC
B	3	3	1.41E+02	1.97E+02	N/A	N/A
Ba	14	14	5.63E+01	6.79E+01	3.70E-01	5.65E+01
Be	15	1	5.39E-02	5.39E-02	1.65E+00	<MDC
Ca	10	10	7.63E+04	1.10E+05	4.70E+02	8.81E+04
Cd	14	0	N/A	N/A	6.00E-01	<MDC
Ce	14	10	5.10E-03	3.56E-02	3.40E-02	<MDC
Co	16	14	9.78E-02	3.61E-01	1.35E-01	1.60E-01
Cr	17	16	6.44E-01	1.13E+01	8.00E-01	3.36E+00

Table 6-4: Summary of Metal Concentrations in Hobbs Drinking Water
(continued)

Hobbs						
1998 - 2016					2017	
Metals	N	N_{DET}	Min	Max	MDC (µg/L)	Sample Conc. (µg/L)
Cu	16	15	1.06E+00	6.93E+00	5.50E-01	1.71E+00
Dy	16	1	4.18E-03	4.18E-03	8.50E-02	<MDC
Er	16	0	N/A	N/A	7.00E-02	<MDC
Eu	15	10	1.12E-02	1.97E-02	7.00E-01	<MDC
Fe	13	11	3.64E+01	4.44E+02	2.45E+01	1.96E+02
Ga	1	1	2.56E+00	2.56E+00	N/A	N/A
Gd	14	0	N/A	N/A	5.50E-02	<MDC
Hg	8	0	N/A	N/A	4.90E-02	<MDC
K	15	15	2.11E+03	2.52E+04	9.85E+01	2.41E+03
La	15	5	1.25E-02	5.01E-02	1.15E-01	<MDC
Li	13	13	2.65E+01	3.89E+01	1.05E+00	3.22E+01
Mg	13	13	1.90E+04	2.67E+04	6.00E+00	2.16E+04
Mn	17	16	3.79E-01	3.62E+00	1.70E-01	3.76E+00
Mo	13	13	2.36E+00	3.31E+00	7.00E-01	2.51E+00
Na	16	16	4.97E+03	5.80E+04	2.60E+01	4.06E+04
Nd	16	5	3.01E-03	1.44E-02	7.50E-02	<MDC
Ni	16	16	1.67E+00	4.78E+00	3.60E-01	2.83E+00
P	9	7	1.74E+01	8.31E+01	1.84E+02	<MDC
Pb	15	13	9.44E-02	1.19E+00	1.15E+00	<MDC
Pr	15	2	1.57E-03	1.88E-03	4.20E-02	<MDC
Sb	15	11	3.88E-02	8.53E-02	1.70E-01	<MDC
Sc	12	12	3.06E+00	1.05E+01	6.50E-01	4.77E+00
Se	14	11	-1.70E-01	1.23E+01	1.20E+01	<MDC
Si	11	11	2.30E+04	2.86E+04	6.27E+02	2.20E+04
Sr	15	15	7.89E+01	1.22E+03	1.26E+00	1.13E+03
Th	14	4	2.29E-03	1.36E-01	9.50E-01	<MDC
Tl	14	2	9.45E-03	2.24E-02	1.10E+00	<MDC
U	16	16	2.90E+00	4.30E+00	7.00E-01	3.14E+00
V	17	17	3.11E+01	3.99E+01	3.45E-01	3.46E+01
Zn	16	12	8.44E-01	4.37E+00	7.00E-01	1.30E+00

N = Total number of samples analyzed; N_{det} = number of samples with detectable (above MDC) values;
Min = the lowest value measured above MDC; Max = the highest value measured;
MDC = Minimum detectable concentration;
Concentrations below the MDC are reported as <MDC;
N/A = Not Available

Table 6-5: Summary of Measured Metal Concentrations in Loving Drinking Water

Loving						
1998 - 2016					2017	
Metals	N	N_{DET}	Min	Max	MDC (µg/L)	Sample Conc. (µg/L)
Ag	16	4	2.55E-03	2.17E-01	9.20E-03	1.22E-02
Al	17	12	1.43E+00	3.76E+02	1.64E+00	3.93E+00
As	16	13	7.89E-01	2.35E+00	2.60E+00	<MDC
B	3	3	7.55E+01	1.12E+02	N/A	N/A
Ba	14	14	2.96E+01	3.47E+01	1.48E-01	3.26E+01
Be	15	1	9.35E-02	9.35E-02	6.60E-01	<MDC
Ca	10	10	6.71E+04	1.00E+05	4.70E+02	7.89E+04
Cd	15	0	N/A	N/A	2.40E-01	<MDC
Ce	15	6	9.74E-04	2.53E-01	1.36E-02	<MDC
Co	16	14	8.42E-02	4.04E-01	5.40E-02	1.12E-01
Cr	17	15	1.12E+00	1.12E+01	3.20E-01	6.70E+00
Cu	16	14	8.06E-01	5.59E+00	2.20E-01	2.16E+01
Dy	16	0	N/A	N/A	3.40E-02	<MDC
Er	17	0	N/A	N/A	2.80E-02	<MDC
Eu	16	11	7.00E-03	1.64E-02	2.80E-01	<MDC
Fe	13	10	3.60E+00	2.57E+02	9.80E+00	1.78E+02
Ga	1	1	1.26E+00	1.26E+00	N/A	N/A
Gd	15	2	2.15E-03	1.04E-02	2.20E-02	<MDC
Hg	8	0	N/A	N/A	4.90E-02	<MDC
K	15	15	1.69E+03	1.98E+04	3.94E+01	1.89E+03
La	16	5	6.66E-03	2.22E-02	4.60E-02	<MDC
Li	13	13	1.50E+01	2.24E+01	4.20E-01	1.98E+01
Mg	13	13	3.02E+04	4.21E+04	1.20E+01	3.62E+04
Mn	17	11	1.43E-02	1.77E+00	6.80E-02	1.48E-01
Mo	13	12	1.28E+00	1.72E+00	2.80E-01	1.49E+00
Na	16	16	2.33E+03	2.82E+04	1.30E+01	2.38E+04
Nd	17	2	3.37E-03	7.68E-03	3.00E-02	<MDC

N = Total number of samples analyzed; N_{det} = number of samples with detectable (above MDC) values;
Min = the lowest value measured above MDC; Max = the highest value measured;
MDC = Minimum detectable concentration;
Concentrations below the MDC are reported as <MDC;
N/A = Not Available

Table 6-5: Summary of Metal Concentrations in Loving Drinking Water
(continued)

Loving						
1998 - 2016					2017	
Metals	N	N_{DET}	Min	Max	MDC (µg/L)	Sample Conc. (µg/L)
Ni	16	15	1.41E+00	3.38E+00	1.44E-01	2.68E+00
P	9	8	2.46E+01	7.32E+01	7.36E+01	<MDC
Pb	15	11	8.03E-02	1.67E+00	4.60E-01	<MDC
Pr	16	0	N/A	N/A	1.68E-02	<MDC
Sb	15	10	3.40E-02	1.84E-01	6.80E-02	<MDC
Sc	12	11	1.50E+00	4.72E+00	2.60E-01	2.12E+00
Se	14	6	-2.89E+00	1.53E+00	4.80E+00	<MDC
Si	11	11	8.91E+03	1.09E+04	2.51E+02	9.40E+03
Sr	15	15	7.60E+01	9.37E+02	6.30E-01	7.46E+02
Th	15	2	5.69E-03	7.38E-03	3.80E-01	<MDC
Tl	16	2	2.24E-03	4.32E-02	4.40E-01	<MDC
U	16	16	1.87E+00	2.30E+00	2.80E-01	1.68E+00
V	17	17	1.11E+01	1.61E+01	1.38E-01	1.47E+01
Zn	16	15	4.79E+00	2.01E+01	2.80E-01	5.33E+01

N = Total number of samples analyzed; N_{det} = number of samples with detectable (above MDC) values;
Min = the lowest value measured above MDC; Max = the highest value measured;
MDC = Minimum detectable concentration;
Concentrations below the MDC are reported as <MDC;
N/A = Not Available

Table 6-6: Summary of Metal Concentrations in Otis Drinking Water

Otis						
1998 - 2016					2017	
Metals	N	N_{DET}	Min	Max	MDC (µg/L)	Sample Conc. (µg/L)
Ag	14	1	2.63E-02	2.63E-02	4.60E-02	<MDC
Al	15	6	2.69E+00	1.06E+03	8.20E+00	<MDC
As	16	7	6.53E-01	2.34E+00	1.30E+01	<MDC
B	3	3	1.46E+02	2.39E+02	N/A	N/A
Ba	13	12	1.26E+01	1.97E+01	7.40E-01	1.53E+01
Be	14	0	N/A	N/A	3.30E+00	<MDC
Ca	10	10	1.89E+05	3.60E+05	2.35E+03	3.47E+05
Cd	13	0	N/A	N/A	1.20E+00	<MDC
Ce	13	1	2.75E-02	2.75E-02	6.80E-02	<MDC
Co	15	13	2.44E-01	9.51E-01	2.70E-01	4.88E-01
Cr	16	14	8.12E-01	8.72E+00	1.60E+00	3.68E+00
Cu	15	14	2.43E+00	6.02E+00	1.10E+00	3.14E+00
Dy	15	2	3.39E-03	1.17E-01	1.70E-01	<MDC
Er	15	1	9.99E-02	9.99E-02	1.40E-01	<MDC
Eu	14	4	3.42E-03	1.11E-01	1.40E+00	<MDC
Fe	13	12	2.87E+00	1.07E+03	4.90E+01	8.73E+02
Ga	1	1	6.54E-01	6.54E-01	N/A	N/A
Gd	13	0	N/A	N/A	1.10E-01	<MDC
Hg	8	1	3.23E-02	3.23E-02	4.90E-02	<MDC
K	14	14	2.41E+03	4.01E+03	1.97E+02	3.10E+03
La	14	3	3.36E-03	1.06E-01	2.30E-01	<MDC
Li	12	12	3.37E+01	6.79E+01	2.10E+00	5.26E+01
Mg	13	13	5.16E+04	1.08E+05	1.20E+02	9.17E+04
Mn	15	6	1.98E-01	4.91E+00	3.40E-01	<MDC
Mo	12	12	2.25E+00	5.03E+00	1.40E+00	4.51E+00
Na	14	14	5.35E+04	1.97E+05	1.30E+02	1.14E+05
Nd	15	4	4.80E-03	9.05E-02	1.50E-01	<MDC
Ni	15	14	2.62E+00	1.11E+01	7.20E-01	1.05E+01
P	9	9	4.54E+01	3.68E+02	3.68E+02	<MDC
Pb	14	9	1.08E-01	5.98E-01	2.30E+00	<MDC
Pr	14	0	N/A	N/A	8.40E-02	<MDC

Table 6-6: Summary of Metal Concentrations in Otis Drinking Water
(continued)

Otis						
1998 - 2016					2017	
Metals	N	N_{DET}	Min	Max	MDC (µg/L)	Sample Conc. (µg/L)
Sb	14	8	3.66E-02	4.10E-01	3.40E-01	<MDC
Sc	12	10	6.55E-01	5.35E+00	1.30E+00	1.52E+00
Se	14	6	-2.43E-02	1.19E+00	2.40E+01	<MDC
Si	11	11	9.30E+03	1.39E+04	1.25E+03	9.29E+03
Sr	13	13	2.20E+03	4.97E+03	6.30E+00	4.43E+03
Th	12	4	1.19E-03	1.16E-01	1.90E+00	<MDC
Tl	14	1	-6.30E-03	-6.30E-03	2.20E+00	<MDC
U	15	15	3.73E+00	6.10E+00	1.40E+00	4.91E+00
V	16	15	7.87E+00	1.29E+01	6.90E-01	1.01E+01
Zn	14	11	1.54E+00	1.16E+01	1.40E+00	2.58E+00

N = Total number of samples analyzed; N_{det} = number of samples with detectable (above MDC) values;
Min = the lowest value measured above MDC; Max = the highest value measured;
MDC = Minimum detectable concentration;
Concentrations below the MDC are reported as <MDC;
N/A = Not Available

Table 6-7: Summary of Metal Concentrations in Malaga Drinking Water

Malaga						
2011 - 2016					2017	
Metals	N	N_{DET}	Min	Max	MDC (µg/L)	Sample Conc. (µg/L)
Ag	6		N/A	N/A	4.60E-02	<MDC
Al	6	3	2.39E+00	3.99E+00	8.20E+00	<MDC
As	6	1	5.44E+00	5.44E+00	1.30E+01	<MDC
B	0	0	N/A	N/A	N/A	N/A
Ba	6	6	1.44E+01	1.66E+01	7.40E-01	1.45E+01
Be	6	1	3.04E-01	3.04E-01	3.30E+00	<MDC
Ca	6	6	2.41E+05	3.51E+05	2.35E+03	3.84E+05
Cd	6	0	N/A	N/A	1.20E+00	<MDC
Ce	5	0	N/A	N/A	6.80E-02	<MDC
Co	6	6	3.39E-01	8.57E-01	2.70E-01	4.98E-01
Cr	6	6	5.80E-01	1.00E+01	1.60E+00	4.10E+00
Cu	6	5	1.57E+00	3.66E+00	1.10E+00	2.57E+00
Dy	6	0	N/A	N/A	1.70E-01	<MDC
Er	6	0	N/A	N/A	1.40E-01	<MDC
Eu	6	0	N/A	N/A	1.40E+00	<MDC
Fe	6	6	5.90E+02	1.33E+03	4.90E+01	2.14E+03
Ga	0	0	N/A	N/A	N/A	N/A
Gd	5	0	N/A	N/A	1.10E-01	<MDC
Hg	6	0	N/A	N/A	4.90E-02	<MDC
K	6	6	2.57E+03	3.38E+03	1.97E+02	3.39E+03
La	6	0	N/A	N/A	2.30E-01	<MDC
Li	5	5	3.72E+01	5.48E+01	2.10E+00	4.94E+01
Mg	6	6	6.98E+04	1.07E+05	1.20E+02	1.20E+05
Mn	6	3	2.84E-01	8.34E-01	3.40E-01	1.30E+00
Mo	5	5	3.23E+00	3.99E+00	1.40E+00	3.63E+00
Na	6	6	7.53E+04	1.11E+05	1.30E+02	1.38E+05
Nd	6	0	N/A	N/A	1.50E-01	<MDC

N = Total number of samples analyzed; N_{det} = number of samples with detectable (above MDC) values;
Min = the lowest value measured above MDC; Max = the highest value measured;
MDC = Minimum detectable concentration;
Concentrations below the MDC are reported as <MDC;
N/A = Not Available

Table 6-7: Summary of Metal Concentrations in Malaga Drinking Water
(continued)

Malaga						
2011 - 2016					2017	
Metals	N	N_{DET}	Min	Max	MDC (µg/L)	Sample Conc. (µg/L)
Ni	6	6	5.66E+00	1.06E+01	7.20E-01	1.03E+01
P	6	6	5.64E+01	4.45E+02	3.68E+02	<MDC
Pb	6	5	1.46E-01	2.01E+00	2.30E+00	7.98E+00
Pr	5	0	N/A	N/A	8.40E-02	<MDC
Sb	6	2	3.95E-02	6.38E-02	3.40E-01	<MDC
Sc	4	4	1.54E+00	2.41E+00	1.30E+00	1.45E+00
Se	6	1	1.65E+01	1.65E+01	2.40E+01	<MDC
Si	6	6	9.12E+03	1.04E+04	1.25E+03	9.28E+03
Sr	6	6	3.71E+03	4.57E+03	6.30E+00	4.44E+03
Th	5	0	N/A	N/A	1.90E+00	<MDC
Tl	6	0	N/A	N/A	2.20E+00	<MDC
U	6	6	4.38E+00	5.61E+00	1.40E+00	4.68E+00
V	6	6	8.30E+00	1.20E+01	6.90E-01	1.29E+01
Zn	6	6	1.52E+01	4.64E+01	1.40E+00	1.67E+02

N = Total number of samples analyzed; N_{det} = number of samples with detectable (above MDC) values;
Min = the lowest value measured above MDC; Max = the highest value measured;
MDC = Minimum detectable concentration;
Concentrations below the MDC are reported as <MDC;
N/A = Not Available

Table 6-8: General Information about Metal Contaminants in Drinking Water from the EPA[1]

Contaminant	Minimum Contaminants Level	Potential Health Effects from Long-term Exposure	Sources of Drinking Water Contaminants
Antimony, Sb	0.006 mg/L	Increase in blood cholesterol; decrease in blood sugar	Discharge from petroleum refineries; fire retardants; ceramics; electronics; solder
Arsenic, As	0.010 mg/L	Skin damage or problems with circulatory systems, and may have increased risk of cancer	Erosion of natural deposits; runoff from orchards; runoff from glass & electronics production wastes
Barium, Ba	2 mg/L	Increase in blood pressure	Discharge of drilling wastes; discharge from metal refineries; erosion of natural deposits
Beryllium, Be	0.004mg/L	Intestinal lesions	Discharge from metal refineries and coal-burning factories; discharge from electrical, aerospace, and defense industries
Cadmium, Cd	0.005 mg/L	Kidney damage	Corrosion of galvanized pipes; erosion of natural deposits; discharge from metal refineries; runoff from waste batteries and paints
Chloride, Cl^-	250 mg/L*[2]	N/A	N/A
Chromium, Cr (total)	0.1 mg/L	Allergic dermatitis	Discharge from steel and pulp mills; erosion of natural deposits
Copper, Cu	1.3 mg/L	**Short term exposure**: gastrointestinal distress. **Long term exposure**: liver or kidney damage	Corrosion of household plumbing systems; erosion of natural deposits
Fluoride, F^-	4.0 mg/L	Bone disease; children may get mottled teeth	Water additive which promotes strong teeth; erosion of natural deposits; discharge from fertilizer and aluminum factories
Lead, Pb	0.015 mg/L	**Infants and children**: delays in physical or mental development; **Adults**: kidney problems; high blood pressure	Corrosion of household plumbing systems; erosion of natural deposits
Mercury, Hg (Inorganic)	0.002 mg/L	Kidney damage	Erosion of natural deposits; discharge from refineries; runoff from landfills and croplands
Nitrate (measured as N)	10 mg/L	Shortness of breath and blue-baby syndrome	Runoff from fertilizer use; leaching from septic tanks, sewage; erosion of natural deposits
Nitrite (measured as N)	1 mg/L		

Table 6-8: General Information about Metal Contaminants in Drinking Water from the EPA[1] (continued)

Contaminant	Minimum Contaminants Level	Potential Health Effects from Long-term Exposure	Sources of Drinking Water Contaminants
Selenium, Se	0.05 mg/L	Hair or fingernail loss; numbness in fingers or toes; circulatory problems	Discharge from petroleum and metal refineries; erosion of natural deposits; discharge from mines
Sulfate, SO_4^{2-}	250 mg/L[2]	N/A	N/A
Thallium, Tl	0.002 mg/L	Hair loss; changes in blood; kidney, intestine, or liver problems	Leaching from ore-processing sites; discharge from electronics, glass, and drug factories
Uranium, U	30 µg/L	Increased risk of cancer; kidney toxicity	Erosion of natural deposits

(1) U.S. EPA: United States Environmental Protection Agency (2012), Drinking Water Contaminants, http://water.epa.gov/drink/contaminants/index.cfm#Inorganic
(2) Secondary regulations are not enforceable.
N/A = Not available

Table 6-9: Measured Concentrations of Anions in Carlsbad Drinking Water

Carlsbad						
1998-2016					2017	
Anions	N	N_{DET}	Min	Max	MDC (µg/L)	Sample Conc. (µg/L)
Bromide, Br^-	10	1	8.40E+01	8.40E+01	1.36E+01	7.30E+01
Chloride, Cl^-	16	15	7.83E+03	7.88E+04	4.83E+01	1.64E+04
Fluoride, F^-	13	12	1.23E+02	8.62E+02	2.70E+00	3.45E+02
Nitrate, NO_3^-	17	17	1.57E+03	5.91E+03	2.65E+01	3.63E+03
Nitrite, NO_2^-	9	0	N/A	N/A	8.50E+00	<MDC
Phosphate, PO_4^{3-}	17	0	N/A	N/A	1.47E+01	<MDC
Sulfate, SO_4^{2-}	16	16	7.61E+04	1.17E+05	3.47E+01	7.45E+04

N = Total number of samples analyzed; N_{det} = number of samples with detectable (above MDC) values;
Min = the lowest value measured above MDC; Max = the highest value measured;
MDC = Minimum detectable concentration;
Concentrations below the MDC are reported as <MDC;
N/A = Not Available

Table 6-10: Measured Concentrations of Anions in Double Eagle and Double Eagle PRV4 Drinking Water

Double Eagle & Double Eagle PRV4						
1998-2016					2017	
Anions	N	N_{DET}	Min	Max	MDC (µg/L)	Sample Conc. (µg/L)
Bromide, Br^-	10	5	9.49E+01	2.78E+02	1.36E+01	2.56E+02
Chloride, Cl^-	17	16	2.23E+04	4.59E+04	4.83E+01	4.02E+04
Fluoride, F^-	13	12	4.40E+02	1.36E+03	2.70E+00	7.97E+02
Nitrate, NO_3^-	16	15	6.98E+03	1.46E+04	2.65E+01	1.09E+04
Nitrite, NO_2^-	10	0	N/A	N/A	8.50E+00	<MDC
Phosphate, PO_4^{3-}	17	0	N/A	N/A	1.47E+01	<MDC
Sulfate, SO_4^{2-}	17	16	3.04E+04	5.69E+04	3.47E+01	3.97E+04

N = Total number of samples analyzed; N_{det} = number of samples with detectable (above MDC) values;
Min = the lowest value measured above MDC; Max = the highest value measured;
MDC = Minimum detectable concentration;
Concentrations below the MDC are reported as <MDC;
N/A = Not Available

Table 6-11: Measured Concentrations of Anions in Hobbs Drinking Water

Hobbs						
1998-2016					2017	
Anions	N	N_{DET}	Min	Max	MDC (µg/L)	Sample Conc. (µg/L)
Bromide, Br^-	10	4	8.27E+01	3.94E+02	1.36E+01	3.08E+02
Chloride, Cl^-	17	17	6.32E+04	1.07E+05	2.42E+02	9.91E+04
Fluoride, F^-	14	14	4.91E+02	2.88E+03	2.70E+00	1.15E+03
Nitrate, NO_3^-	17	17	1.56E+04	2.21E+04	2.65E+01	1.87E+04
Nitrite, NO_2^-	10	0	N/A	N/A	8.50E+00	<MDC
Phosphate, PO_4^{3-}	16	0	N/A	N/A	1.47E+01	<MDC
Sulfate, SO_4^{2-}	17	17	9.60E+04	1.51E+05	1.74E+02	1.25E+05

N = Total number of samples analyzed; N_{det} = number of samples with detectable (above MDC) values;
Min = the lowest value measured above MDC; Max = the highest value measured;
MDC = Minimum detectable concentration;
Concentrations below the MDC are reported as <MDC;
N/A = Not Available

Table 6-12: Measured Concentrations of Anions in Loving Drinking Water

Loving						
1998-2016					2017	
Anions	N	N_{DET}	Min	Max	MDC (µg/L)	Sample Conc. (µg/L)
Bromide, Br^-	9	2	3.58E+01	4.40E+01	1.36E+01	1.15E+02
Chloride, Cl^-	16	16	1.59E+04	3.62E+04	4.83E+01	3.65E+04
Fluoride, F^-	13	10	1.31E+02	2.34E+03	2.70E+00	4.76E+02
Nitrate, NO_3^-	16	16	1.59E+04	2.91E+04	2.65E+01	1.89E+04
Nitrite, NO_2^-	8	0	N/A	N/A	8.50E+00	<MDC
Phosphate, PO_4^{3-}	16	1	5.28E+01	5.28E+01	1.47E+01	<MDC
Sulfate, SO_4^{2-}	15	15	1.10E+05	2.05E+05	1.74E+02	1.10E+05

N = Total number of samples analyzed; N_{det} = number of samples with detectable (above MDC) values;
Min = the lowest value measured above MDC; Max = the highest value measured;
MDC = Minimum detectable concentration;
Concentrations below the MDC are reported as <MDC;
N/A = Not Available

Table 6-13: Measured Concentrations of Anions in Otis Drinking Water

Otis						
1998-2016					2017	
Anions	N	N_{DET}	Min	Max	MDC (µg/L)	Sample Conc. (µg/L)
Bromide, Br^-	9	3	5.67E+01	3.30E+02	6.80E+01	3.25E+02
Chloride, Cl^-	16	16	1.26E+05	4.21E+05	2.42E+02	3.81E+05
Fluoride, F^-	14	9	4.70E+02	1.53E+03	1.35E+01	9.05E+02
Nitrate, NO_3^-	17	17	9.59E+03	2.53E+04	1.33E+02	1.63E+04
Nitrite, NO_2^-	9	0	N/A	N/A	4.25E+01	<MDC
Phosphate, PO_4^{3-}	17	0	N/A	N/A	7.35E+01	<MDC
Sulfate, SO_4^{2-}	15	15	3.27E+05	8.94E+05	3.47E+02	7.72E+05

N = Total number of samples analyzed; N_{det} = number of samples with detectable (above MDC) values;
Min = the lowest value measured above MDC; Max = the highest value measured;
MDC = Minimum detectable concentration;
Concentrations below the MDC are reported as <MDC;
N/A = Not Available

Table 6-14: Measured Concentrations of Anions in Malaga Drinking Water

Malaga						
1998-2016					2017	
Anions	N	N_{DET}	Min	Max	MDC (µg/L)	Sample Conc. (µg/L)
Bromide, Br^-	6	2	2.40E+02	3.45E+02	6.80E+01	3.40E+02
Chloride, Cl^-	6	6	3.63E+05	4.30E+05	2.42E+02	4.48E+05
Fluoride, F^-	6	2	8.15E+02	8.55E+02	1.35E+01	7.80E+02
Nitrate, NO_3^-	6	6	1.07E+04	2.41E+04	1.33E+02	1.60E+04
Nitrite, NO_2^-	6	0	N/A	N/A	4.25E+01	<MDC
Phosphate, PO_4^{3-}	6	0	N/A	N/A	7.35E+01	<MDC
Sulfate, SO_4^{2-}	6	6	6.73E+05	7.98E+05	3.47E+02	8.01E+05

N = Total number of samples analyzed; N_{det} = number of samples with detectable (above MDC) values;
Min = the lowest value measured above MDC; Max = the highest value measured;
MDC = Minimum detectable concentration;
Concentrations below the MDC are reported as <MDC;
N/A = Not Available

Table 6-15: Measured Concentrations of Inorganic Cations in Carlsbad Drinking Water

Carlsbad			
2016		2017	
Cations	Sample Conc. (µg/L)[2]	MDC (µg/L)	Sample Conc. (µg/L)
Ammonium, NH_4^+	<MDC	1.05E-01	<MDC
Calcium, Ca^{2+}	7.29E+04	4.90E-01	6.71E+04
Lithium, Li^+	<MDC	7.50E-02	<MDC
Magnesium, Mg^{2+}	3.09E+04	1.35E-01	2.96E+04
Potassium, K^+	<MDC	3.45E-01	3.90E+02
Sodium, Na^+	2.03E+04	1.45E-01	1.25E+04

MDC = Minimum detectable concentration;
Concentrations below the MDC are reported as <MDC;
N/A = Not Available

Table 6-16: Measured Concentrations of Inorganic Cations in Double Eagle PRV4 Drinking Water

Double Eagle PRV4			
2016		2017	
Cations	Sample Conc. (µg/L)	MDC (µg/L)	Sample Conc. (µg/L)
Ammonium, NH_4^+	<MDC	4.20E-02	<MDC
Calcium, Ca^{2+}	4.77E+04	4.90E-01	5.34E+04
Lithium, Li^+	9.50E+01	3.00E-02	<MDC
Magnesium, Mg^{2+}	9.99E+03	5.40E-02	1.04E+04
Potassium, K^+	2.51E+03	1.38E-01	3.26E+03
Sodium, Na^+	2.74E+04	2.90E-01	3.54E+04

MDC = Minimum detectable concentration;
Concentrations below the MDC are reported as <MDC;
N/A = Not Available

Table 6-17: Measured Concentrations of Inorganic Cations in Hobbs Drinking Water

Hobbs			
2016		2017	
Cations	Sample Conc. (µg/L)	MDC (µg/L)	Sample Conc. (µg/L)
Ammonium, NH_4^+	<MDC	2.10E-01	<MDC
Calcium, Ca^{2+}	1.04E+05	4.90E-01	9.69E+04
Lithium, Li^+	<MDC	1.50E-01	<MDC
Magnesium, Mg^{2+}	2.24E+04	2.70E-01	2.25E+04
Potassium, K^+	<MDC	6.90E-01	1.28E+03
Sodium, Na^+	4.94E+04	2.90E-01	4.76E+04

MDC = Minimum detectable concentration;
Concentrations below the MDC are reported as <MDC;
N/A = Not Available

Table 6-18: Measured Concentrations of Inorganic Cations in Loving Drinking Water

Loving			
2016		2017	
Cations	Sample Conc. (µg/L)	MDC (µg/L)	Sample Conc. (µg/L)
Ammonium, NH_4^+	<MDC	1.05E-01	<MDC
Calcium, Ca^{2+}	8.47E+04	4.90E-01	8.36E+04
Lithium, Li^+	<MDC	7.50E-02	<MDC
Magnesium, Mg^{2+}	3.44E+04	1.35E-01	3.49E+04
Potassium, K^+	<MDC	3.45E-01	9.20E+02
Sodium, Na^+	1.90E+04	1.45E-01	2.39E+04

MDC = Minimum detectable concentration;
Concentrations below the MDC are reported as <MDC;
N/A = Not Available

Table 6-19: Measured Concentrations of Inorganic Cations in Malaga Drinking Water

Malaga			
2016		2017	
Cations	Sample Conc. (µg/L)	MDC (µg/L)	Sample Conc. (µg/L)
Ammonium, NH_4^+	<MDC	4.20E-01	<MDC
Calcium, Ca^{2+}	3.34E+05	2.45E+00	3.65E+05
Lithium, Li^+	<MDC	3.00E-01	<MDC
Magnesium, Mg^{2+}	1.01E+05	5.40E-01	1.06E+05
Potassium, K^+	<MDC	1.38E+00	2.72E+03
Sodium, Na^+	1.15E+05	5.80E-01	1.31E+05

MDC = Minimum detectable concentration;
Concentrations below the MDC are reported as <MDC;
N/A = Not Available

Table 6-20: Measured Concentrations of Inorganic Cations in Otis Drinking Water

Otis			
2016		2017	
Cations	Sample Conc. (µg/L)	MDC (µg/L)	Sample Conc. (µg/L)
Ammonium, NH_4^+	<MDC	4.20E-01	<MDC
Calcium, Ca^{2+}	3.66E+05	2.45E+00	3.52E+05
Lithium, Li^+	<MDC	3.00E-01	<MDC
Magnesium, Mg^{2+}	8.88E+04	5.40E-01	8.84E+04
Potassium, K^+	<MDC	1.38E+00	<MDC
Sodium, Na^+	1.16E+05	5.80E-01	1.16E+05

MDC = Minimum detectable concentration;
Concentrations below the MDC are reported as <MDC;
N/A = Not Available

Table 6-21: Metal Concentrations in Lake Carlsbad Surface Water

1999 - 2015					2017		
Metals	N	N_{DET}	Min	Max	MDC (µg/L)	Shallow Sample Conc. (µg/L)	Deep Sample Conc. (µg/L)
Ag	14	0	N/A	N/A	N/A	N/A	N/A
Al	14	14	5.69e+001	5.03e+002	9.00e+001	<MDC	<MDC
As	14	7	1.23e+000	1.22e+001	2.30e+001	<MDC	<MDC
B	2	2	1.97e+002	2.25e+002	N/A	N/A	N/A
Ba	14	14	1.73e+001	3.30e+001	3.20e+000	1.69e+001	1.63e+001
Be	14	4	1.51e-002	1.47e-001	1.00e+001	<MDC	<MDC
Ca	12	12	3.03e+005	4.19e+005	2.81e+004	3.40e+005	3.49e+005
Cd	12	1	9.00e-002	9.00e-002	5.00e+000	<MDC	<MDC
Ce	12	8	8.08e-002	4.87e-001	2.85e-001	<MDC	<MDC
Co	14	12	6.58e-001	5.22e+000	5.50e+000	<MDC	<MDC
Cr	12	6	3.02e-001	4.42e+000	9.00e+000	<MDC	<MDC
Cu	12	8	2.63e+000	1.13e+001	5.00e+000	<MDC	<MDC
Dy	12	5	6.67e-003	1.00e-001	4.35e-001	<MDC	<MDC
Er	14	6	1.17e-003	4.25e-001	3.35e-001	<MDC	<MDC
Eu	14	5	6.54e-003	4.30e-001	1.85e+000	8.30e+000	<MDC
Fe	14	14	7.60e+001	3.96e+003	1.50e+002	1.36e+003	1.17e+003
Gd	14	7	9.10e-003	3.64e-001	3.85e-001	<MDC	<MDC
Hg	10	3	2.82e-002	4.24e-001	2.30e-002	2.97e-002	<MDC
K	14	14	4.41e+003	1.24e+004	1.16e+003	5.21e+003	5.42e+003
La	14	8	4.29e-002	5.17e-001	2.65e+000	8.27e+000	<MDC
Li	10	10	3.95e+001	7.75e+001	N/A	N/A	N/A
Mg	14	14	9.05e+004	1.51e+005	6.50e+001	1.01e+005	1.00e+005
Mn	10	9	8.47e+000	6.65e+001	8.00e+000	<MDC	<MDC
Mo	14	14	2.32e+000	5.17e+000	5.50e+000	1.22e+001	<MDC
Na	12	12	3.17e+005	5.06e+005	5.00e+002	3.48e+005	3.52e+005
Nd	14	9	3.79e-002	6.65e-001	1.40e+000	6.97e+000	<MDC

N = Total number of samples analyzed; N_{det} = number of samples with detectable (above MDC) values;
Min = the lowest value measured above MDC; Max = the highest value measured;
MDC = Minimum detectable concentration;
For Lake Carlsbad, "Shallow" measurements were taken at ~0.5m from the surface while "Deep" measurements were taken at ~2m from the sediment bed;
Concentrations below the MDC are reported as <MDC;
N/A = Not Applicable

Table 6-21: Metal Concentrations in Lake Carlsbad Surface Water
(continued)

Lake Carlsbad							
1999 - 2015					2017		
Metals	N	N_{DET}	Min	Max	MDC (µg/L)	Shallow Sample Conc. (µg/L)	Deep Sample Conc. (µg/L)
Ni	14	14	2.33e+000	2.29e+001	5.50e+000	1.39e+001	1.14e+001
P	8	8	8.35e+001	1.39e+003	1.04e+003	<MDC	<MDC
Pb	14	12	1.73e-001	4.01e+000	1.85e+001	<MDC	<MDC
Pr	12	6	1.11e-002	4.71e-001	2.95e-001	<MDC	<MDC
Sb	14	1	1.17e-001	1.17e-001	1.90e+000	<MDC	<MDC
Sc	8	5	2.81e+000	4.72e+000	3.45e+000	9.47e+000	<MDC
Se	12	3	5.54e-001	3.56e+001	8.00e+001	<MDC	<MDC
Si	6	6	7.15e+003	9.53e+003	3.73e+003	9.29e+003	8.24e+003
Sm	8	3	1.51e-002	5.94e-002	N/A	N/A	N/A
Sn	4	0	N/A	N/A	N/A	N/A	N/A
Sr	14	14	4.16e+003	6.15e+003	3.70e+000	4.45e+003	4.44e+003
Th	14	10	9.10e-003	5.01e-001	5.50e+000	1.05e+001	<MDC
Ti	2	2	8.56e+000	1.40e+001	N/A	N/A	N/A
Tl	14	8	1.20e-001	2.47e-001	3.30e+000	<MDC	<MDC
U	14	14	3.56e+000	9.17e+000	5.00e+000	5.56e+000	<MDC
V	12	12	5.05e+000	9.31e+000	9.00e+000	<MDC	<MDC
Zn	12	6	5.93e+000	2.78e+002	8.70e+002	<MDC	<MDC

N = Total number of samples analyzed; N_{det} = number of samples with detectable (above MDC) values;
Min = the lowest value measured above MDC; Max = the highest value measured;
MDC = Minimum detectable concentration;
For Lake Carlsbad, "Shallow" measurements were taken at ~0.5m from the surface while "Deep" measurements were taken at ~2m from the sediment bed;
Concentrations below the MDC are reported as <MDC;
N/A = Not Applicable

Table 6-22: Metal Concentrations in Brantley Lake Surface Water

Brantley Lake							
1999 - 2015					2017		
Metals	N	N_{DET}	Min	Max	MDC (µg/L)	Shallow Sample Conc. (µg/L)	Deep Sample Conc. (µg/L)
Ag	14	1	1.03e-002	1.03e-002	N/A	N/A	N/A
Al	14	13	2.62e+001	7.11e+002	9.00e+001	1.43e+002	2.01e+002
As	15	10	1.21e+000	5.86e+001	2.30e+001	<MDC	<MDC
B	2	2	2.09e+002	2.18e+002	N/A	N/A	N/A
Ba	14	14	3.03e+001	9.23e+001	3.20e+000	7.70e+001	8.09e+001
Be	14	3	1.92e-002	1.43e-001	1.00e+001	<MDC	<MDC
Ca	12	12	3.46e+005	6.67e+005	2.81e+004	3.77e+005	3.79e+005
Cd	12	0	N/A	N/A	5.00e+000	<MDC	<MDC
Ce	12	9	5.71e-002	4.90e-001	2.85e-001	6.57e-001	3.09e-001
Co	14	12	7.31e-001	6.76e+000	5.50e+000	<MDC	<MDC
Cr	12	6	3.17e-001	1.80e+001	9.00e+000	<MDC	<MDC
Cu	12	7	3.10e+000	8.07e+000	5.00e+000	5.17e+000	<MDC
Dy	12	6	5.79e-003	1.55e-001	4.35e-001	5.20e-001	<MDC
Er	14	4	3.52e-003	2.21e-001	3.35e-001	4.04e-001	<MDC
Eu	14	6	1.55e-002	2.29e-001	1.85e+000	<MDC	<MDC
Fe	14	14	5.30e+001	2.26e+003	1.50e+002	1.17e+003	1.41e+003
Gd	14	6	7.34e-003	3.25e-001	3.85e-001	5.38e-001	<MDC
Hg	10	1	1.77e-001	1.77e-001	2.30e-002	<MDC	<MDC
K	14	14	4.67e+003	1.51e+004	1.16e+003	6.41e+003	5.99e+003
La	14	9	3.38e-002	6.36e-001	2.65e+000	<MDC	<MDC
Li	10	10	3.50e+001	7.77e+001	N/A	N/A	N/A
Mg	14	14	9.31e+004	2.01e+005	6.50e+001	7.42e+004	8.27e+004
Mn	10	9	8.98e+000	7.53e+002	8.00e+000	2.97e+001	7.06e+001
Mo	14	14	2.41e+000	5.01e+000	5.50e+000	<MDC	<MDC
Na	12	12	3.50e+005	1.25e+006	5.00e+002	3.54e+005	4.01e+005
Nd	14	9	3.34e-002	5.34e-001	1.40e+000	<MDC	<MDC

N = Total number of samples analyzed; N_{det} = number of samples with detectable (above MDC) values;
Min = the lowest value measured above MDC; Max = the highest value measured;
MDC = Minimum detectable concentration;
For Lake Carlsbad, "Shallow" measurements were taken at ~0.5m from the surface while "Deep" measurements were taken at ~2m from the sediment bed;
Concentrations below the MDC are reported as <MDC;
N/A = Not Applicable

Table 6-22: Metal Concentrations in Brantley Lake Surface Water
(continued)

Brantley Lake							
1999 - 2015					2017		
Metals	N	N_{DET}	Min	Max	MDC (µg/L)	Shallow Sample Conc. (µg/L)	Deep Sample Conc. (µg/L)
Ni	14	14	3.65e+000	2.91e+001	5.50e+000	1.34e+001	1.64e+001
P	8	8	1.27e+002	5.13e+003	1.04e+003	<MDC	<MDC
Pb	14	10	2.64e-001	1.37e+000	1.85e+001	<MDC	<MDC
Pr	12	6	1.08e-002	3.40e-001	2.95e-001	6.41e-001	<MDC
Sb	14	4	2.54e-001	3.01e-001	N/A	N/A	N/A
Sc	8	2	9.33e-001	1.56e+000	3.45e+000	<MDC	<MDC
Se	12	3	2.82e+001	1.86e+002	8.00e+001	<MDC	<MDC
Si	6	5	3.01e+003	8.13e+003	3.73e+003	6.10e+003	6.11e+003
Sm	8	4	2.00e-002	5.67e-002	N/A	N/A	N/A
Sn	4	0	N/A	N/A	N/A	N/A	N/A
Sr	14	14	5.00e+003	1.02e+004	1.48e+001	5.27e+003	5.47e+003
Th	14	8	1.67e-002	4.07e-001	5.50e+000	<MDC	<MDC
Ti	2	0	N/A	N/A	N/A	N/A	N/A
Tl	14	1	4.81e-002	4.81e-002	3.30e+000	<MDC	<MDC
U	14	14	3.32e+000	7.94e+000	5.00e+000	6.00e+000	<MDC
V	12	12	3.47e+000	7.14e+000	9.00e+000	<MDC	<MDC
Zn	12	6	1.07e+001	3.75e+002	8.70e+002	<MDC	<MDC

N = Total number of samples analyzed; N_{det} = number of samples with detectable (above MDC) values;
Min = the lowest value measured above MDC; Max = the highest value measured;
MDC = Minimum detectable concentration;
For Lake Carlsbad, "Shallow" measurements were taken at ~0.5m from the surface while "Deep" measurements were taken at ~2m from the sediment bed;
Concentrations below the MDC are reported as <MDC;
N/A = Not Applicable

Table 6-23: Metal Concentrations in Red Bluff Surface Water

Red Bluff							
1999 - 2015					2017		
Metals	N	N_{DET}	Min	Max	MDC (µg/L)	Shallow Sample Conc. (µg/L)	Deep Sample Conc. (µg/L)
Ag	13	0	N/A	N/A	N/A	N/A	N/A
Al	13	8	1.65e+001	3.96e+002	9.00e+001	<MDC	4.59e+002
As	14	10	1.96e+000	1.69e+002	4.60e+001	<MDC	<MDC
B	2	2	3.72e+002	3.76e+002	N/A	N/A	N/A
Ba	13	13	6.83e+001	1.37e+002	6.40e+000	7.12e+001	7.05e+001
Be	13	4	3.28e-002	2.68e-001	2.00e+001	<MDC	<MDC
Ca	12	12	4.19e+005	8.99e+005	1.40e+005	6.90e+005	7.29e+005
Cd	11	4	4.11e-001	7.73e+001	1.00e+001	<MDC	<MDC
Ce	11	7	3.93e-002	5.71e-001	2.85e-001	<MDC	4.65e+000
Co	13	13	7.66e-001	6.01e+000	1.10e+001	<MDC	<MDC
Cr	11	4	1.86e+000	3.86e+001	1.80e+001	<MDC	<MDC
Cu	11	5	6.73e+000	8.87e+000	1.00e+001	<MDC	<MDC
Dy	11	3	2.99e-003	4.24e-002	4.35e-001	<MDC	2.53e+000
Er	13	2	2.08e-003	8.34e-003	3.35e-001	<MDC	2.35e+000
Eu	13	6	2.36e-002	6.86e-002	3.70e+000	<MDC	8.58e+000
Fe	13	13	3.38e+001	3.29e+003	3.00e+002	2.34e+003	2.80e+003
Gd	13	4	1.44e-002	8.33e-002	3.85e-001	<MDC	3.59e+000
Hg	9	2	6.12e-002	2.14e-001	2.30e-002	<MDC	<MDC
K	14	14	1.60e+004	8.39e+004	2.32e+003	2.45e+004	2.56e+004
La	13	6	3.51e-002	4.47e-001	5.30e+000	<MDC	8.45e+000
Li	8	8	4.30e+001	1.34e+002	N/A	N/A	N/A
Mg	14	14	1.20e+005	4.10e+005	1.30e+002	2.04e+005	2.05e+005
Mn	10	10	3.85e+001	2.97e+002	1.60e+001	3.70e+001	4.12e+001
Mo	13	9	3.16e+000	5.82e+000	1.10e+001	<MDC	1.51e+001
Na	12	12	5.79e+005	2.65e+006	2.50e+003	1.24e+006	1.27e+006
Nd	13	3	2.06e-002	6.47e-002	2.80e+000	<MDC	7.47e+000

N = Total number of samples analyzed; N_{det} = number of samples with detectable (above MDC) values;
Min = the lowest value measured above MDC; Max = the highest value measured;
MDC = Minimum detectable concentration;
For Lake Carlsbad, "Shallow" measurements were taken at ~0.5m from the surface while "Deep" measurements were taken at ~2m from the sediment bed;
Concentrations below the MDC are reported as <MDC;
N/A = Not Applicable

Table 6-23: Metal Concentrations in Red Bluff Surface Water
(continued)

Red Bluff							
1999 - 2015					2017		
Metals	N	N_{DET}	Min	Max	MDC (µg/L)	Shallow Sample Conc. (µg/L)	Deep Sample Conc. (µg/L)
Ni	13	13	1.24e+001	3.25e+001	1.10e+001	2.30e+001	2.35e+001
P	8	7	1.33e+002	1.16e+004	2.08e+003	<MDC	<MDC
Pb	13	10	2.62e-001	3.24e+000	3.70e+001	<MDC	<MDC
Pr	11	3	7.11e-003	7.55e-002	2.95e-001	<MDC	4.01e+000
Sb	13	7	2.47e-001	4.83e-001	N/A	N/A	N/A
Sc	8	1	5.93e-001	5.93e-001	6.90e+000	<MDC	<MDC
Se	12	4	8.37e+001	5.29e+002	1.60e+002	<MDC	<MDC
Si	6	2	5.63e+003	5.90e+003	7.47e+003	<MDC	<MDC
Sm	7	3	3.80e-002	4.71e-002	N/A	N/A	N/A
Sn	3	0	N/A	N/A	N/A	N/A	N/A
Sr	14	14	5.76e+003	1.50e+004	7.40e+000	9.05e+003	9.16e+003
Th	13	6	4.68e-003	4.77e-001	1.10e+001	<MDC	1.26e+001
Ti	2	2	9.92e+000	1.30e+001	N/A	N/A	N/A
Tl	13	0	N/A	N/A	6.60e+000	<MDC	<MDC
U	13	13	3.28e+000	1.23e+001	1.00e+001	<MDC	<MDC
V	11	11	2.42e+000	2.07e+001	1.80e+001	<MDC	<MDC
Zn	11	5	6.21e+000	1.30e+003	1.74e+003	<MDC	<MDC

N = Total number of samples analyzed; N_{det} = number of samples with detectable (above MDC) values;
Min = the lowest value measured above MDC; Max = the highest value measured;
MDC = Minimum detectable concentration;
For Lake Carlsbad, "Shallow" measurements were taken at ~0.5m from the surface while "Deep" measurements were taken at ~2m from the sediment bed;
Concentrations below the MDC are reported as <MDC;
N/A = Not Applicable

Table 6-24: EPA standards for National Recommended Water Quality Criteria (for Freshwater Aquatic Life)

Contaminant	Freshwater CMC[1] (Acute)	Freshwater CCC[2] (Chronic)	EPA Comments[3]
Aluminum, Al	750 µg/L	87µg/L	Limit for aluminum is expressed in terms of total recoverable metal in the water column.
Arsenic, As	340 µg/L	150µg/L	This recommended water quality criterion was derived from data for arsenic (III), but is applied here to total arsenic.
Cadmium, Cd	1.8 µg/L	0.72µg/L	Freshwater acute and chronic criteria are hardness-dependent and were normalized to a hardness of 100mg/L as CaCO3 to allow the presentation of representative criteria values.
Chloride, Cl^-	860000µg/L	230000µg/L	N/A
Chromium, Cr (III & IV)	16 - 570 µg/L	11 - 74 µg/L	Freshwater criteria for metals are expressed in terms of the dissolved metal in the water column.
Iron, Fe	N/A	1000µg/L	N/A
Lead, Pb	65µg/L	2.5µg/L	Freshwater criteria for metals are expressed in terms of the dissolved metal in the water column.
Mercury, Hg (methylmercury)	1.4µg/L	0.77µg/L	Freshwater criteria for metals are expressed in terms of the dissolved metal in the water column.
Nickel, Ni	470µg/L	52µg/L	The freshwater criterion for this metal is expressed as a function of hardness (mg/L). The value given here corresponds to a hardness of 100 mg/L
Silver, Ag	3.2µg/L	N/A	N/A
Zinc, Zn	120µg/L	120µg/L	N/A

[1]Criteria Maximum Concentration (CMC) - is an estimate of the highest concentration of a material in surface water to which an aquatic community can be exposed briefly without resulting in an unacceptable effect.

[2]Criterion Continuous Concentration (CCC) - is an estimate of the highest concentration of a material in surface water to which an aquatic community can be exposed indefinitely without resulting in an unacceptable effect.

[3]Calculations for dissolved metals are available on the EPA website: http://water.epa.gov/scitech/swguidance/standards/criteria/current/index.cfm

Table 6-25: Concentration of Anions in Lake Carlsbad Surface Water

Lake Carlsbad							
1999 - 2015					2017		
Anions	N	N_{DET}	Min	Max	MDC (µg/L)	Shallow[4] Sample Conc. (µg/L)	Deep Sample Conc. (µg/L)
Bromide, Br^-	3	1	4.10e+002	4.10e+002	1.80e+001	3.85e+002	3.90e+002
Chloride, Cl^-	10	10	4.14e+005	1.06e+006	7.20e+001	6.60e+005	6.62e+005
Fluoride, F^-	7	6	5.48e+002	1.05e+003	1.15e+001	7.40e+002	7.35e+002
Nitrate, NO_3^-	6	4	3.16e+003	6.28e+003	3.85e+001	6.55e+003	6.63e+003
Nitrite, NO_2^-	3	2	4.38e+004	6.41e+004	6.15e+001	<MDC	<MDC
Phosphate, PO_4^{3-}	2	0	N/A	N/A	8.50e+001	<MDC	<MDC
Sulfate, SO_4^{2-}	10	10	7.54e+005	2.01e+006	2.34e+002	1.03e+006	1.03e+006

N = Total number of samples analyzed; N_{det} = number of samples with detectable (above MDC) values;
Min = the lowest value measured above MDC; Max = the highest value measured;
MDC = Minimum detectable concentration;
For Lake Carlsbad, "Shallow" measurements were taken at ~0.5m from the surface while "Deep" measurements were taken at ~2m from the sediment bed;
Concentrations below the MDC are reported as <MDC;
N/A = Not Applicable

Table 6-26: Concentration of Anions in Brantley Lake Surface Water

Brantley Lake							
1999 - 2015					2017		
Anions	N	N_{DET}	Min	Max	MDC (µg/L)	Shallow Sample Conc. (µg/L)	Deep Sample Conc. (µg/L)
Bromide, Br^-	3	0	N/A	N/A	3.60e+001	2.60e+002	3.00e+002
Chloride, Cl^-	13	13	5.10e+005	2.20e+006	3.60e+001	6.52e+005	7.62e+005
Fluoride, F^-	8	7	5.20e+002	1.98e+003	2.30e+001	5.80e+002	5.90e+002
Nitrate, NO_3^-	4	2	1.02e+004	9.54e+004	7.70e+001	4.90e+002	6.80e+002
Nitrite, NO_2^-	3	2	6.96e+004	1.20e+005	1.23e+002	<MDC	<MDC
Phosphate, PO_4^{3-}	2	0	N/A	N/A	1.70e+002	<MDC	<MDC
Sulfate, SO_4^{2-}	13	13	1.02e+006	2.61e+006	5.85e+002	1.11e+006	1.18e+006

N = Total number of samples analyzed; N_{det} = number of samples with detectable (above MDC) values;
Min = the lowest value measured above MDC; Max = the highest value measured;
MDC = Minimum detectable concentration;
For Lake Carlsbad, "Shallow" measurements were taken at ~0.5m from the surface while "Deep" measurements were taken at ~2m from the sediment bed;
Concentrations below the MDC are reported as <MDC;
N/A = Not Applicable

Table 6-27: Concentration of Anions in Red Bluff Surface Water

Red Bluff							
1999 - 2015					2017		
Anions	N[1]	N_{DET}	Min	Max	MDC (µg/L)	Shallow Sample Conc. (µg/L)[6]	Deep Sample Conc. (µg/L)
Bromide, Br^-	2	0	N/A	N/A	7.20e+001	8.80e+002	9.40e+002
Chloride, Cl^-	12	12	1.13e+006	4.71e+006	7.20e+001	1.88e+006	2.00e+006
Fluoride, F^-	8	5	6.40e+002	3.77e+003	4.60e+001	7.20e+002	7.80e+002
Nitrate, NO_3^-	7	3	2.38e+003	1.20e+005	1.54e+002	2.80e+002	<MDC
Nitrite, NO_2^-	3	2	1.57e+005	2.48e+005	2.46e+002	<MDC	<MDC
Phosphate, PO_4^{3-}	3	1	5.68e+003	5.68e+003	3.40e+002	<MDC	<MDC
Sulfate, SO_4^{2-}	12	12	1.35e+006	3.23e+006	5.85e+002	2.13e+006	2.13e+006

N = Total number of samples analyzed; N_{det} = number of samples with detectable (above MDC) values;
Min = the lowest value measured above MDC; Max = the highest value measured;
MDC = Minimum detectable concentration;
For Lake Carlsbad, "Shallow" measurements were taken at ~0.5m from the surface while "Deep" measurements were taken at ~2m from the sediment bed;
Concentrations below the MDC are reported as <MDC;
N/A = Not Applicable

Table 6-28: Concentrations of Inorganic Cations in Brantley Lake Surface Water in 2017

Brantley Lake			
Cations	MDC (µg/L)	Shallow Sample Conc. (µg/L)	Deep Sample Conc. (µg/L)
Ammonium, NH_4^+	7.50e+002	<MDC	<MDC
Calcium, Ca^{2+}	2.38e+003	3.77e+005	3.94e+005
Lithium, Li^+	6.46e+002	<MDC	<MDC
Magnesium, Mg^{2+}	1.34e+003	8.32e+004	9.16e+004
Potassium, K^+	2.55e+003	<MDC	<MDC
Sodium, Na^+	2.06e+003	3.85e+005	4.45e+005

MDC = Minimum detectable concentration;
Concentrations below the MDC are reported as <MDC;
N/A = Not Available

Table 6-29: Concentrations of Inorganic Cations in Lake Carlsbad Surface Water in 2017

Lake Carlsbad			
Cations	**MDC (µg/L)**	**Shallow Sample Conc. (µg/L)**	**Deep Sample Conc. (µg/L)**
Ammonium, NH_4^+	7.50e+002	<MDC	<MDC
Calcium, Ca^{2+}	2.38e+003	3.40e+005	3.25e+005
Lithium, Li^+	6.46e+002	<MDC	<MDC
Magnesium, Mg^{2+}	1.34e+003	1.12e+005	1.14e+005
Potassium, K^+	2.55e+003	<MDC	<MDC
Sodium, Na^+	2.06e+003	3.76e+005	3.59e+005

MDC = Minimum detectable concentration;
Concentrations below the MDC are reported as <MDC;
N/A = Not Available

Table 6-30: Concentrations of Cations in Red Bluff Surface Water in 2017

Red Bluff			
Cations	**MDC (µg/L)**	**Shallow Sample Conc. (µg/L)**	**Deep Sample Conc. (µg/L)**
Ammonium, NH_4^+	1.88e+003	<MDC	<MDC
Calcium, Ca^{2+}	4.75e+003	6.33e+005	6.25e+005
Lithium, Li^+	1.61e+003	<MDC	<MDC
Magnesium, Mg^{2+}	3.34e+003	2.17e+005	2.20e+005
Potassium, K^+	6.38e+003	2.24e+004	2.06e+004
Sodium, Na^+	8.26e+003	1.23e+006	1.20e+006

MDC = Minimum detectable concentration;
Concentrations below the MDC are reported as <MDC;
N/A = Not Available

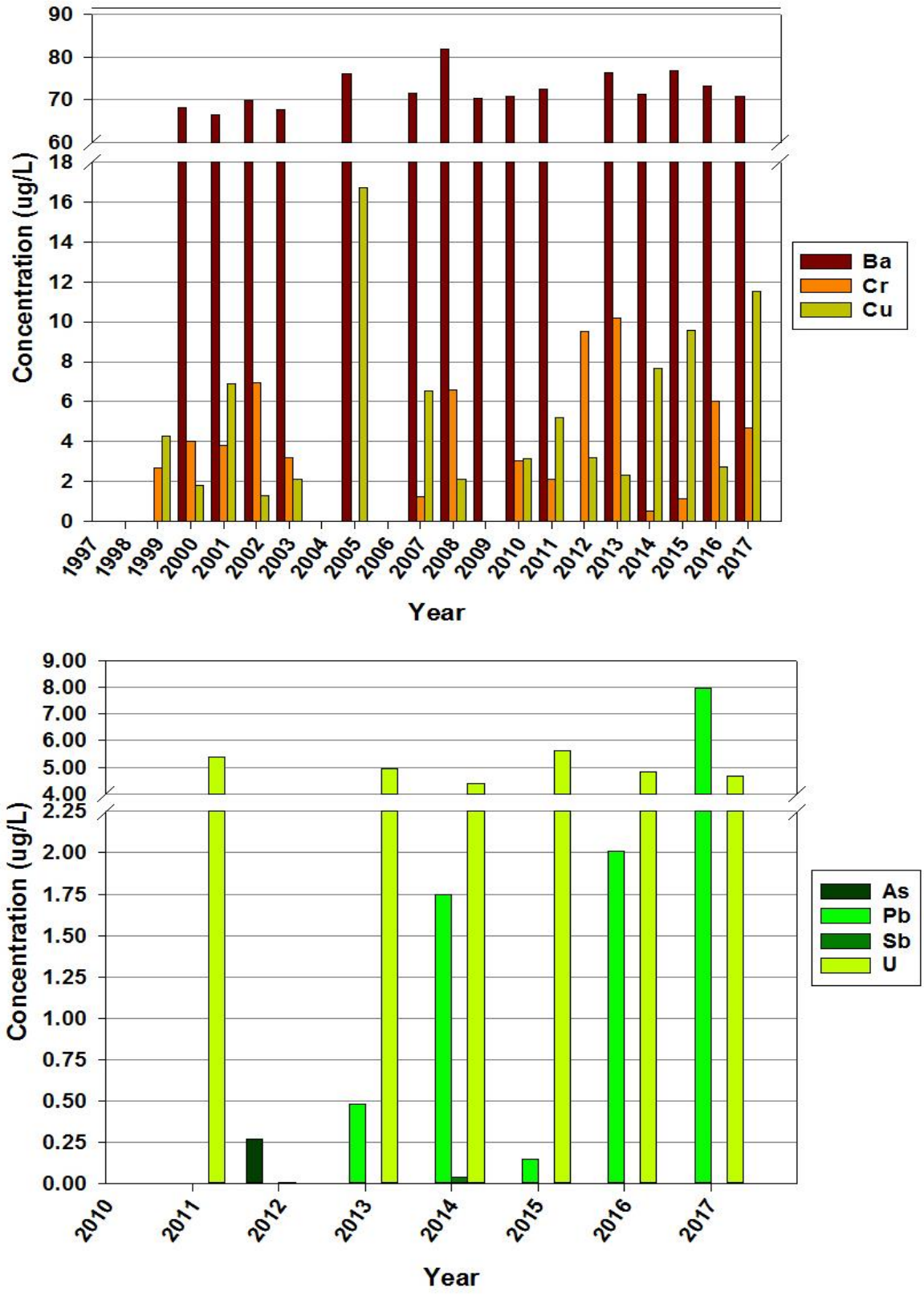


Figure 6-1: Concentrations (µg/L) of Select Metals Measured in Carlsbad Drinking Water (1998-2017)

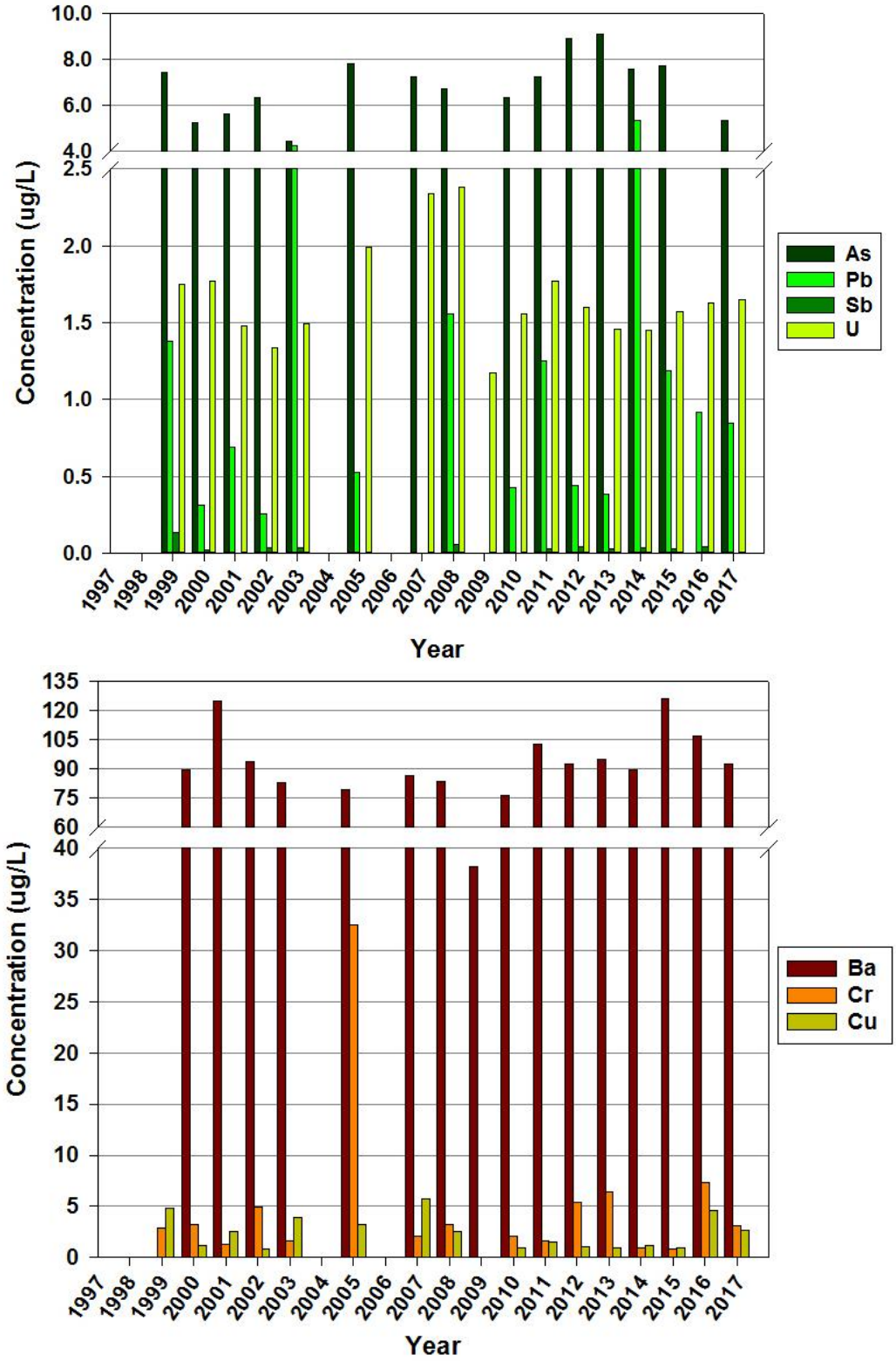


Figure 6-2: Concentrations (µg/L) of Select Metals Measured in Double Eagle Drinking Water (1998 – 2017)

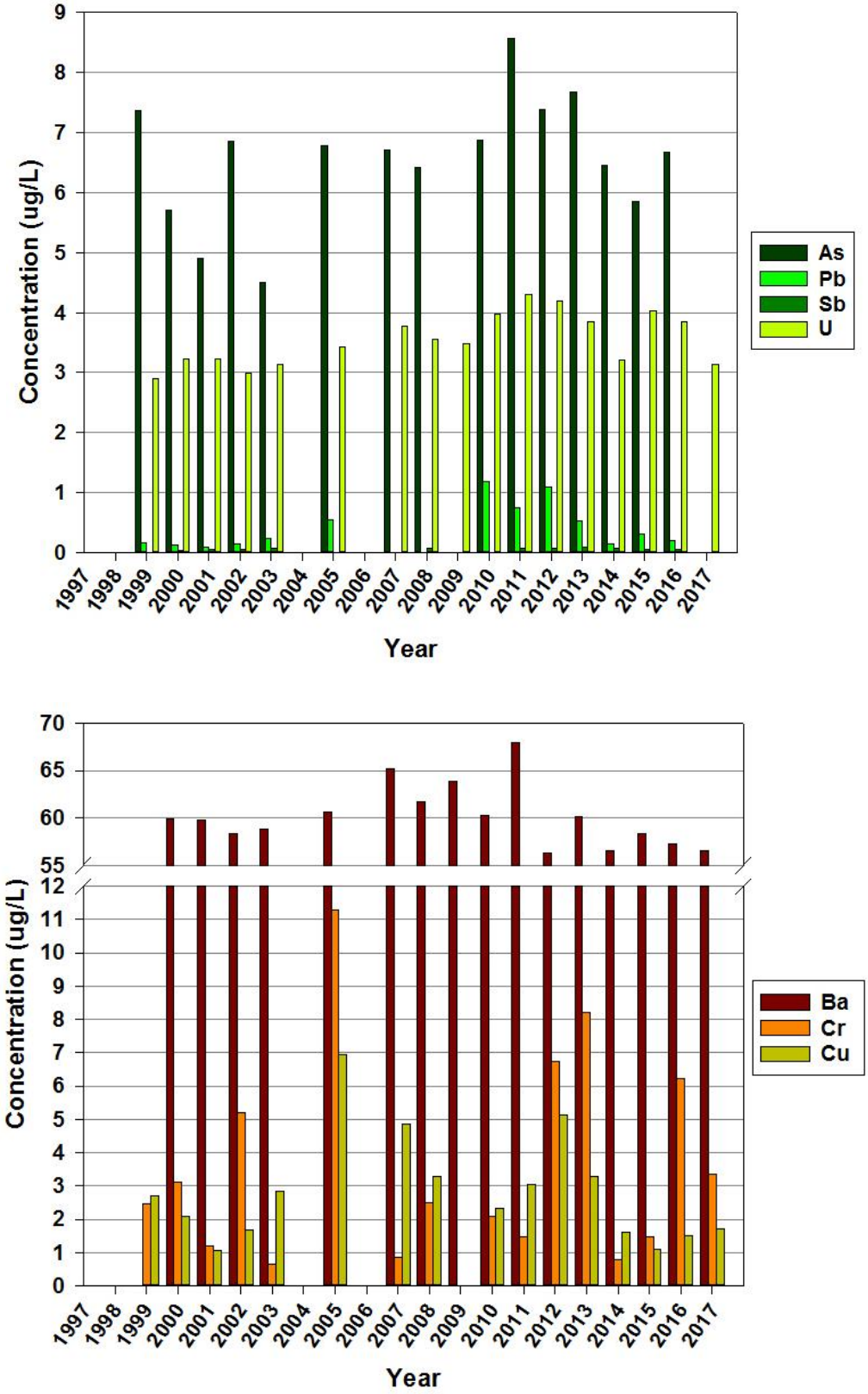


Figure 6-3: Concentrations (µg/L) of Select Metals Measured in Hobbs Drinking Water (1998 – 2017)

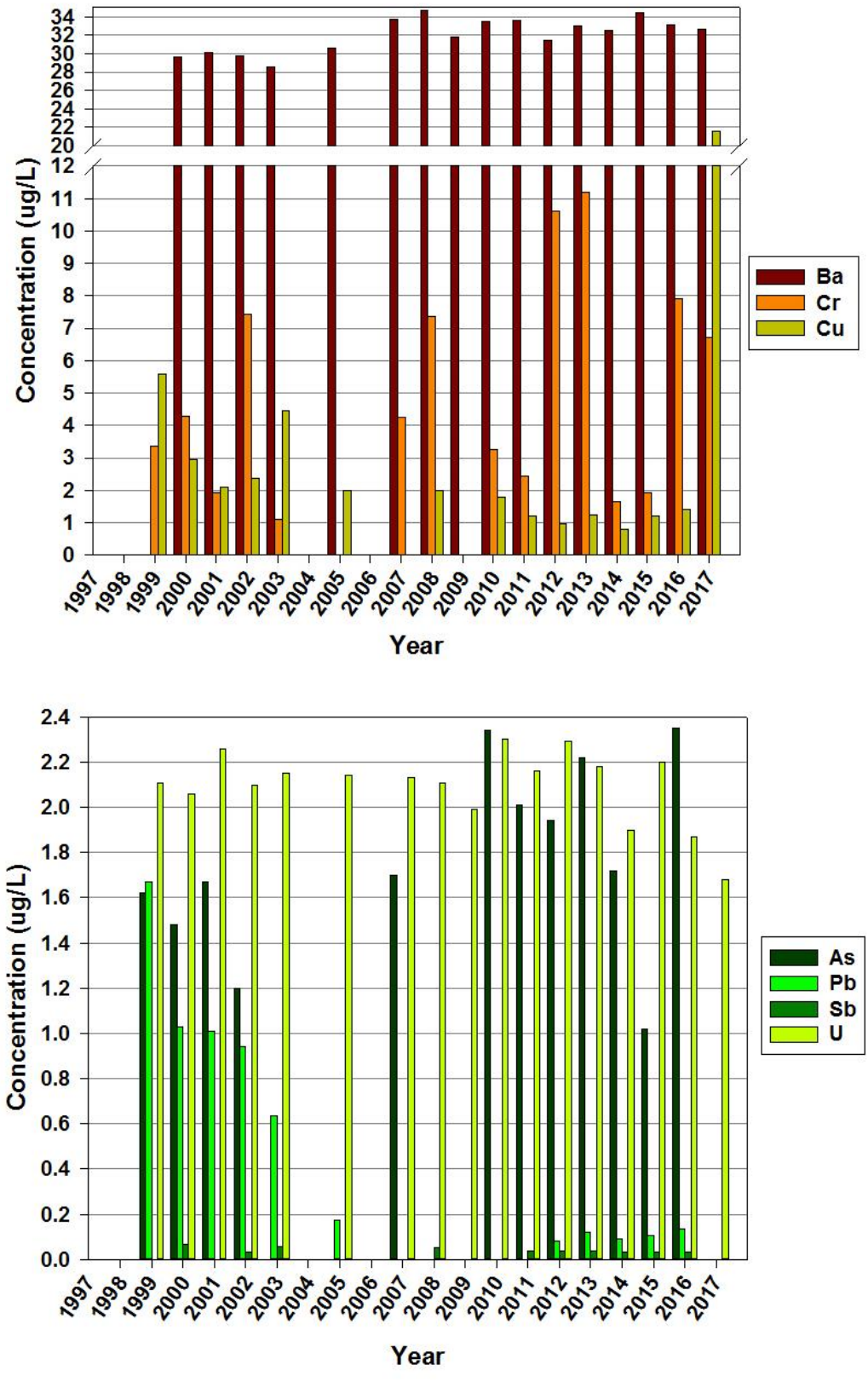


Figure 6-4: Concentrations (µg/L) of Select Metals Measured in Loving Drinking Water (1998 – 2017)

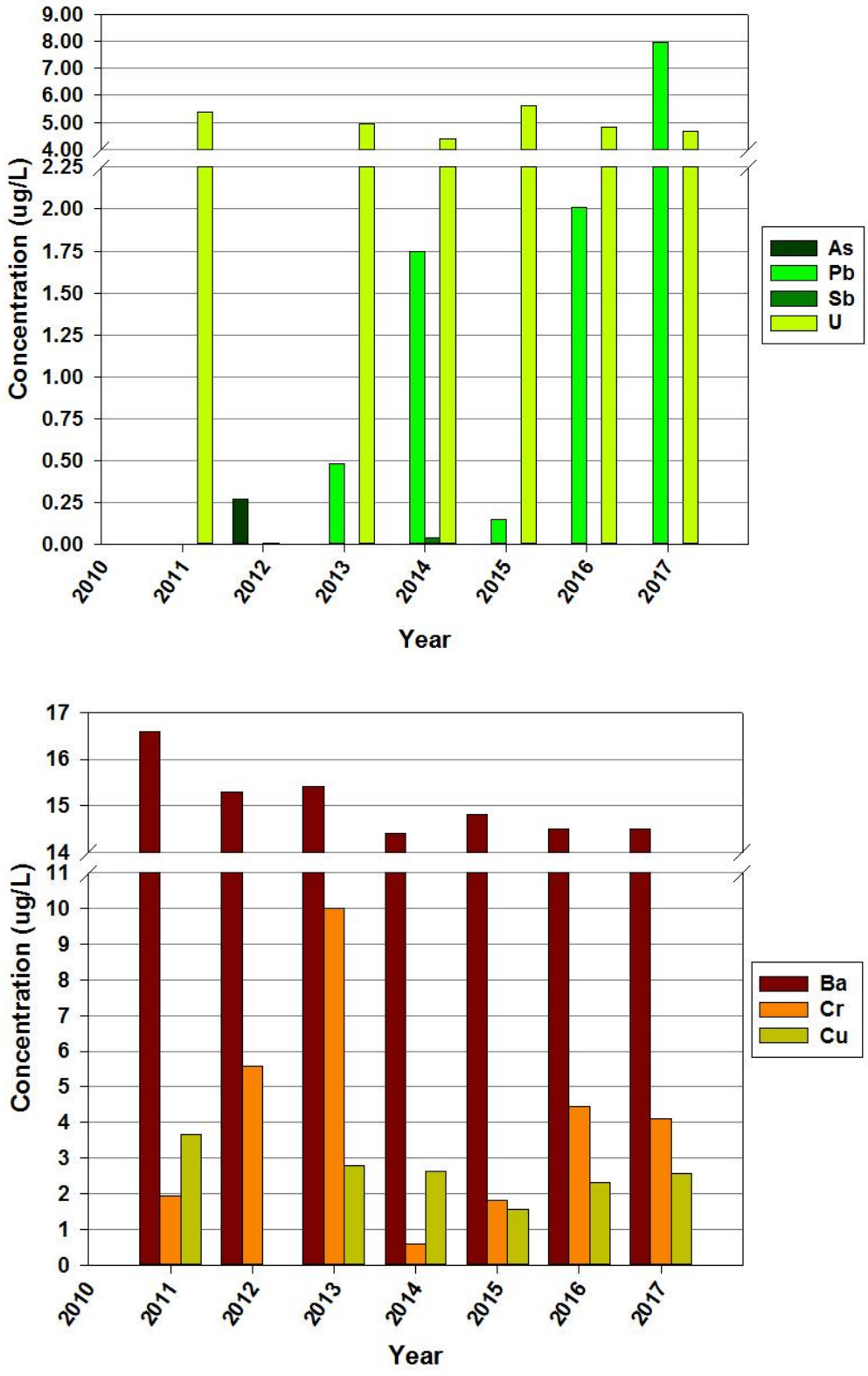


Figure 6-5: Concentrations (µg/L) of Select Metals Measured in Malaga Drinking Water (1998 – 2017)

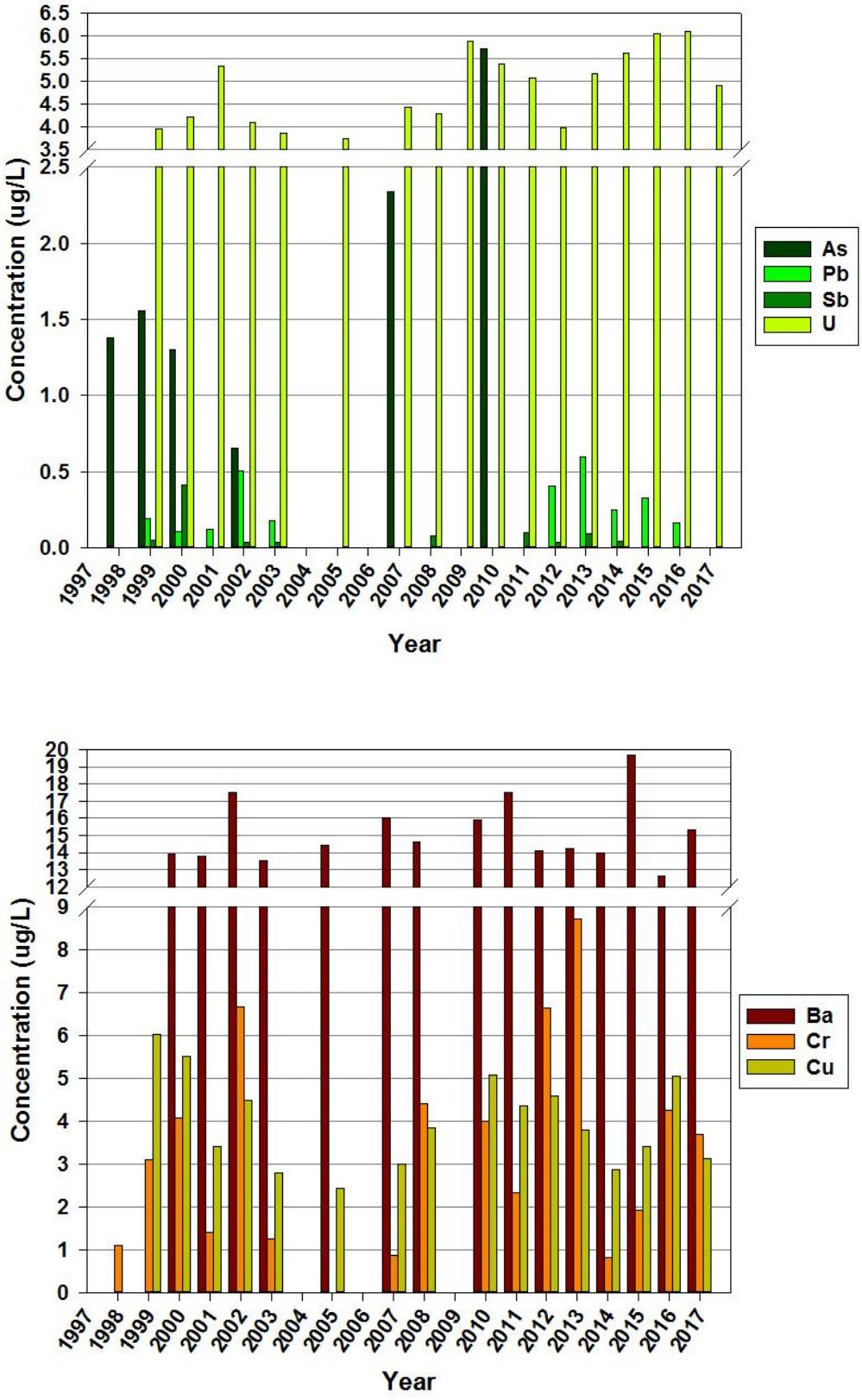


Figure 6-6: Concentrations (µg/L) of Select Metals Measured in Otis Drinking Water (1998 – 2017)

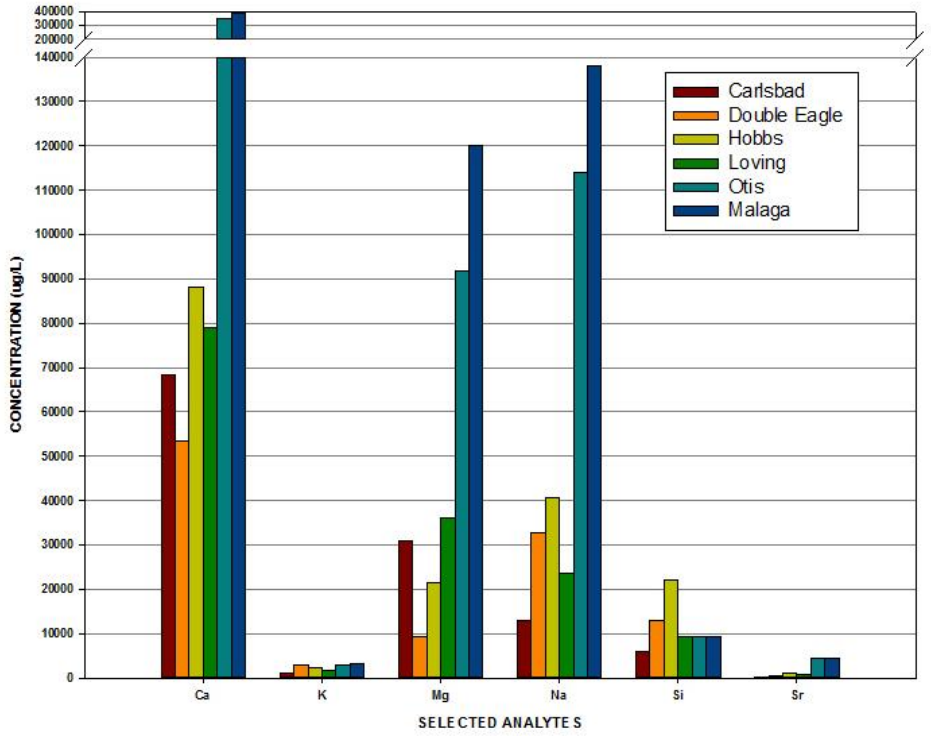


Figure 6-7: Location Comparison of Select High-concentration Metals in 2017 Drinking Water

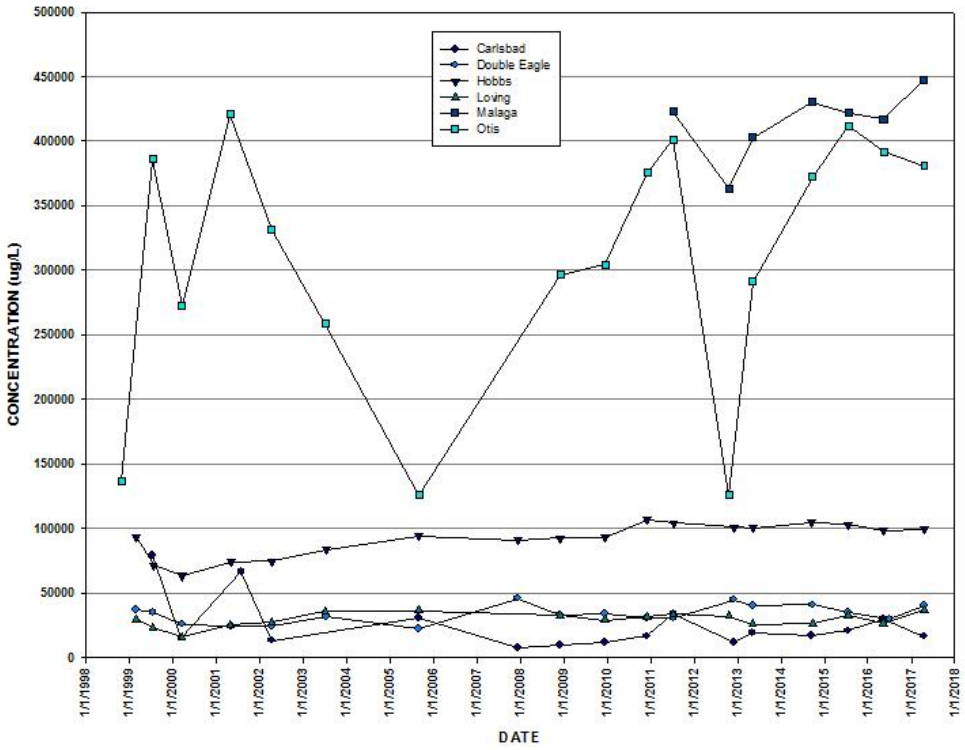


Figure 6-8: Concentrations of Chloride in Drinking Water (1998 – 2017)

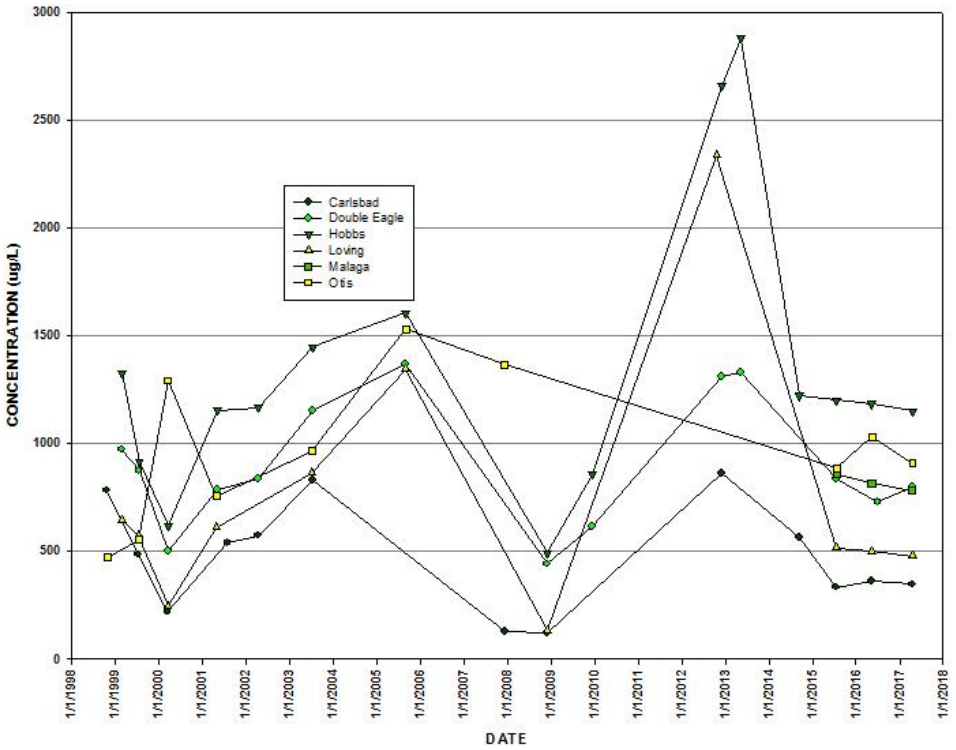


Figure 6-9: Concentrations of Fluoride in Drinking Water (1998 – 2017)

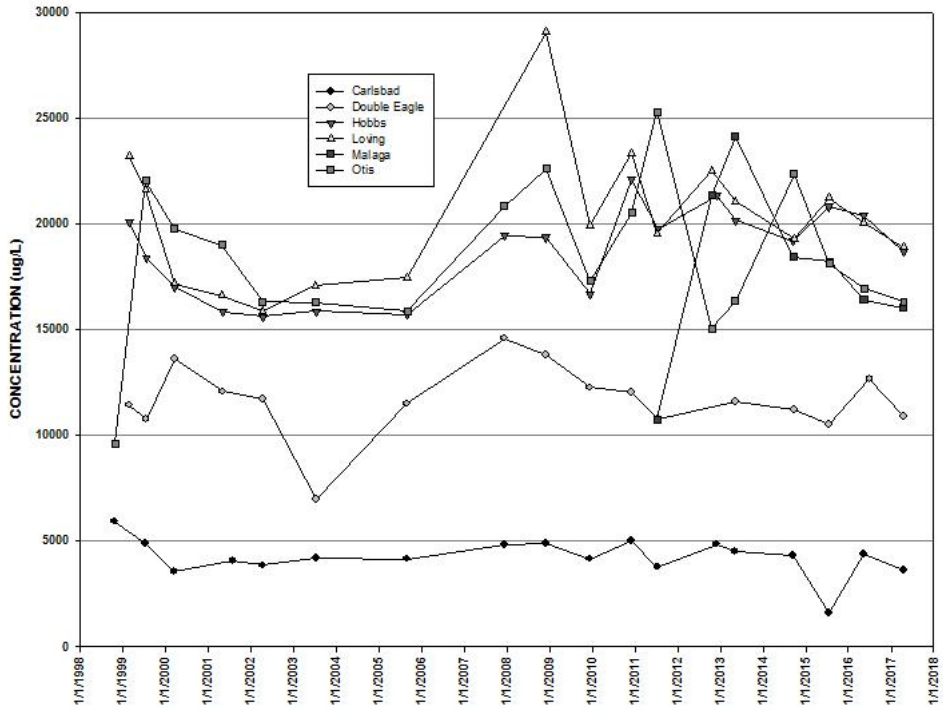


Figure 6-10: Concentrations of Nitrate in Drinking Water (1998 – 2017)

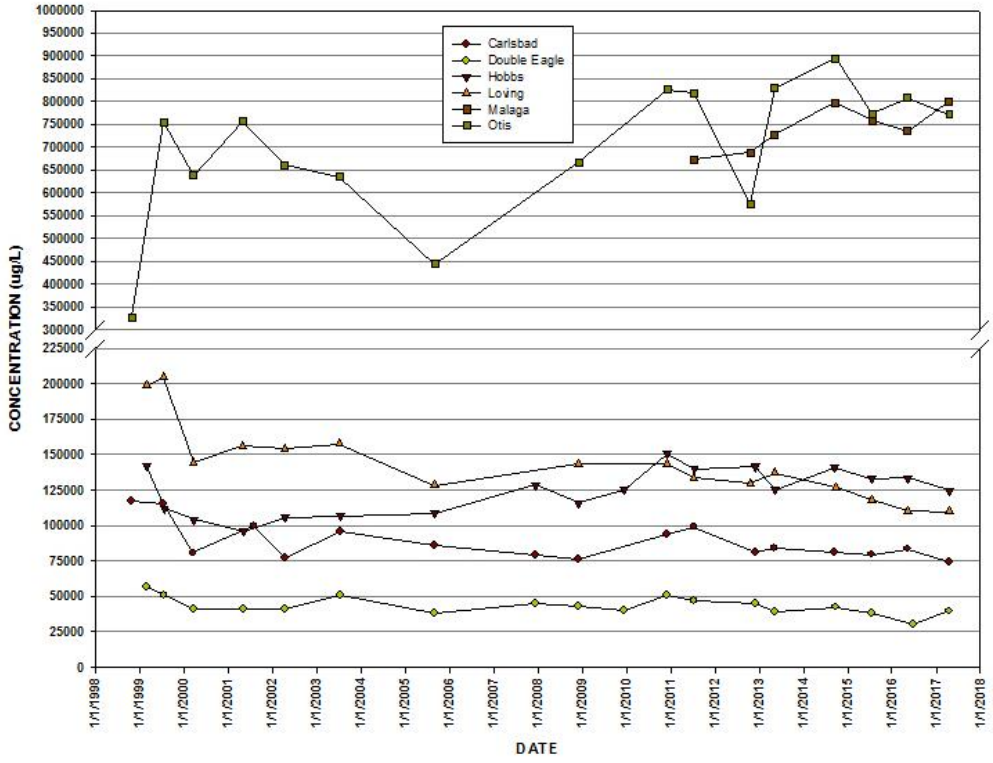


Figure 6-11: Concentrations of Sulfate in Drinking Water (1998 – 2017)

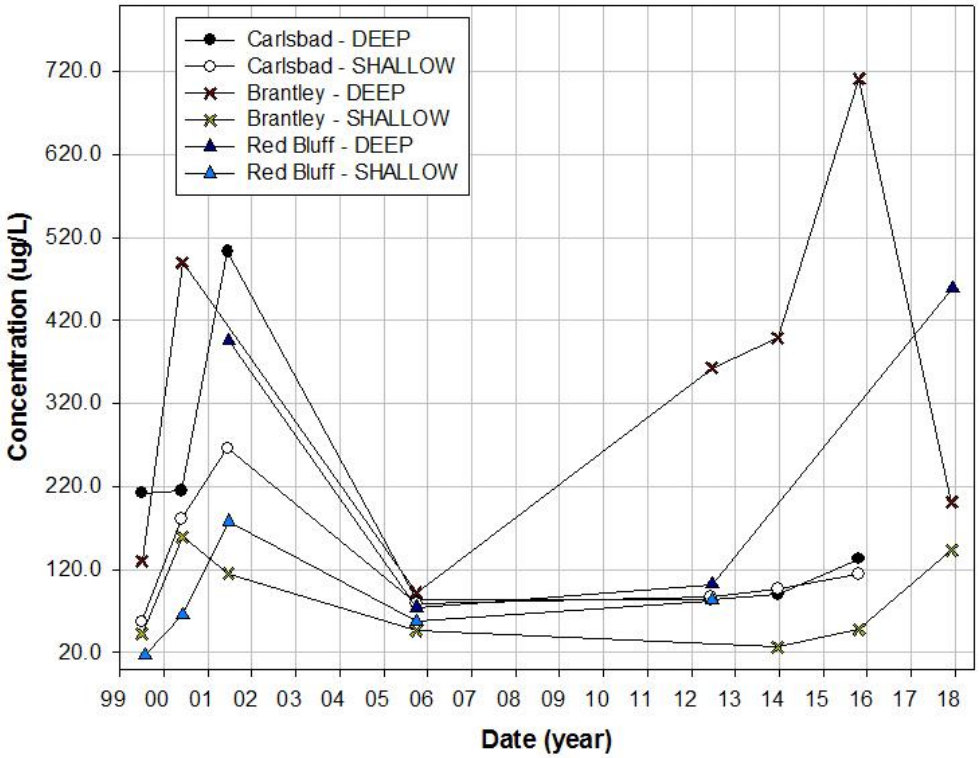


Figure 6-12: Aluminum Concentrations (µg/L) Measured at the Three Regional Surface Water Sources (1999 – 2017)

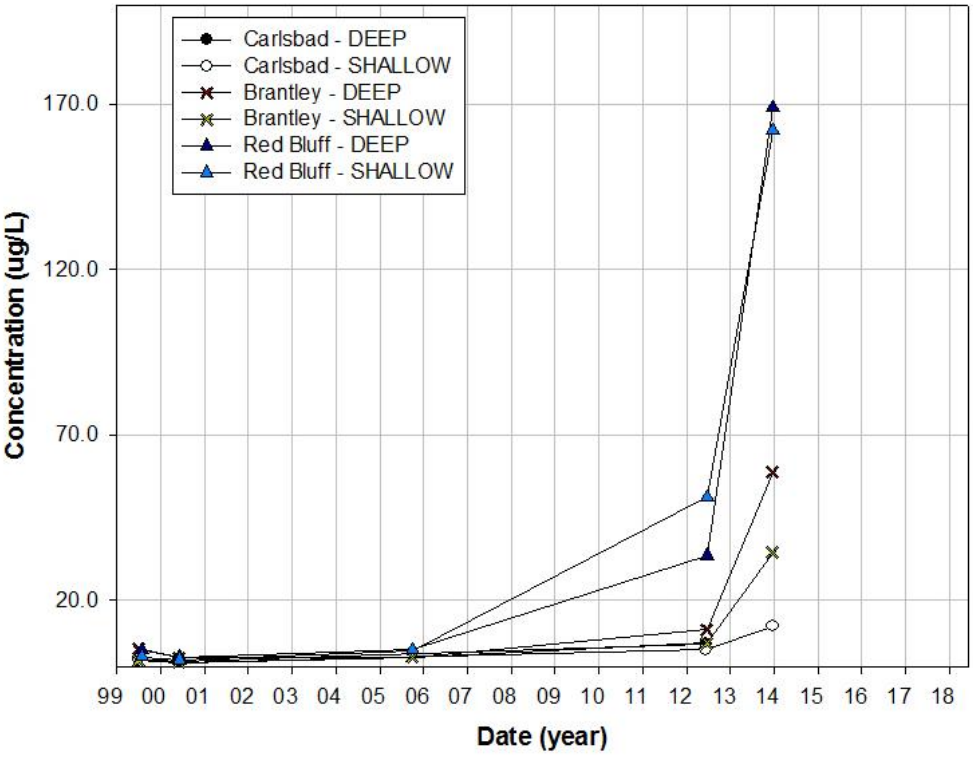


Figure 613: Arsenic Concentrations (µg/L) Measured at the Three Regional Surface Water Sources (1999 – 2017)

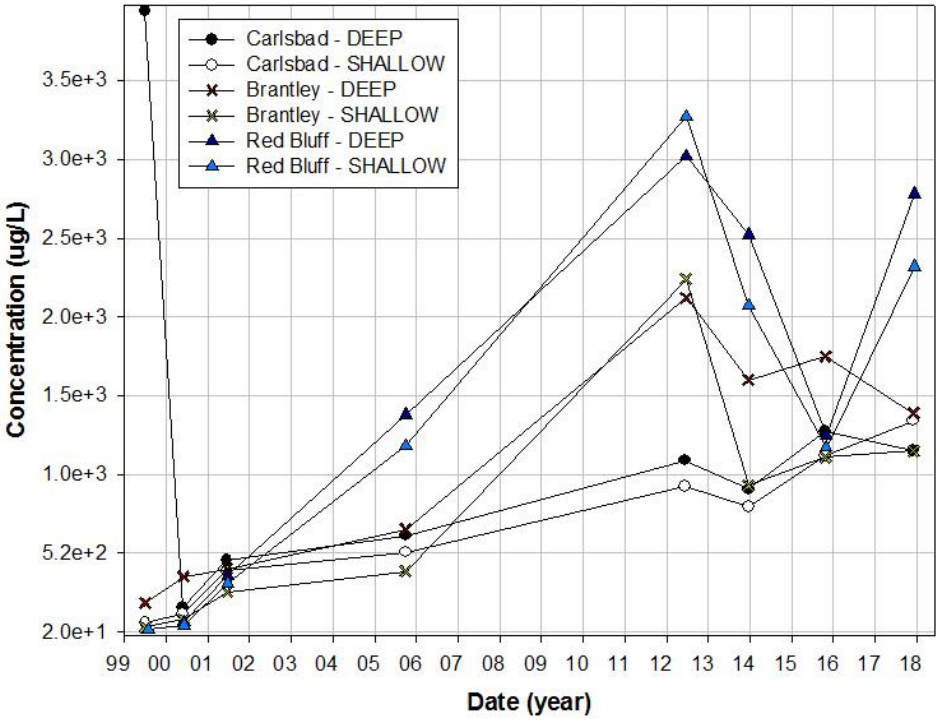


Figure 6-14: Iron Concentrations (µg/L) Measured at the Three Regional Surface Water Sources (1999 – 2017)

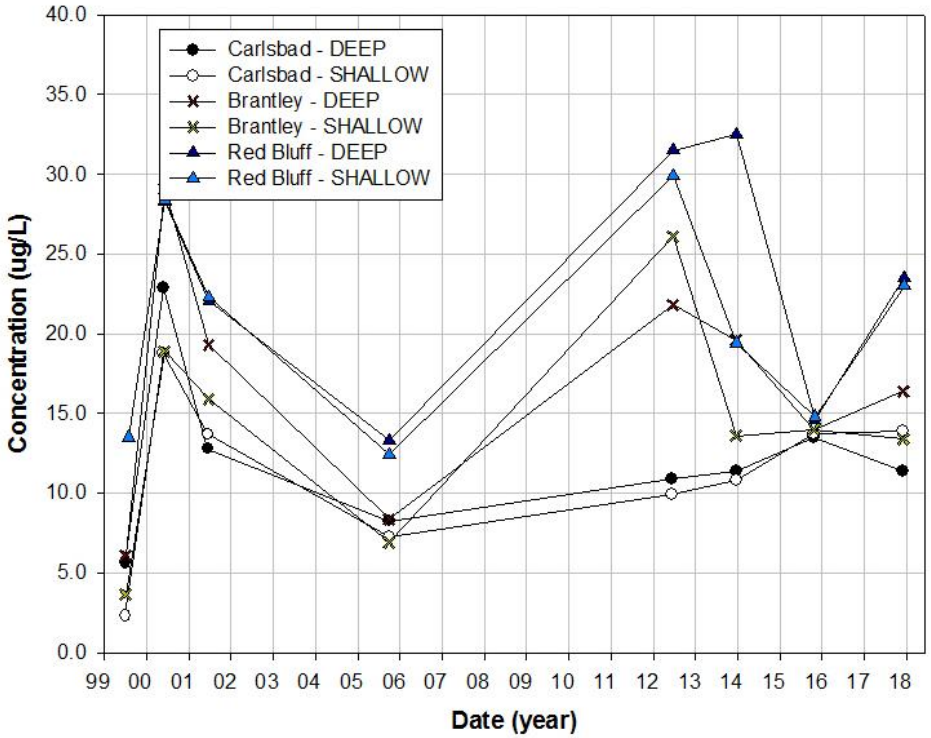


Figure 6-15: Nickel Concentrations (µg/L) Measured at the Three Regional Surface Water Sources (1999 – 2017)

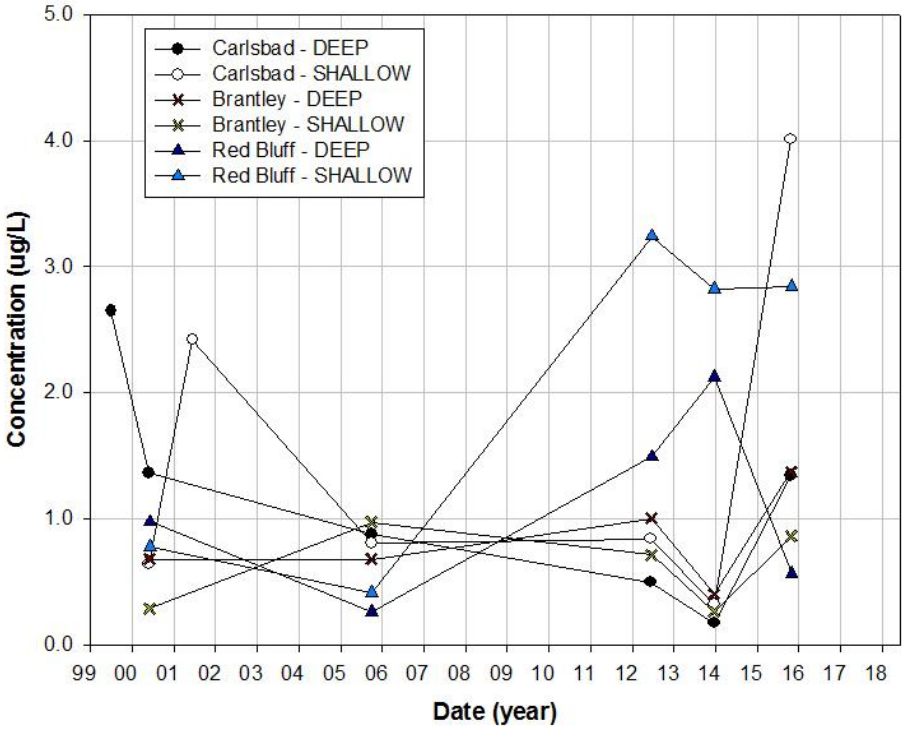


Figure 6-16: Lead Concentrations (µg/L) Measured at the Three Regional Surface Water Sources (1999 – 2017)

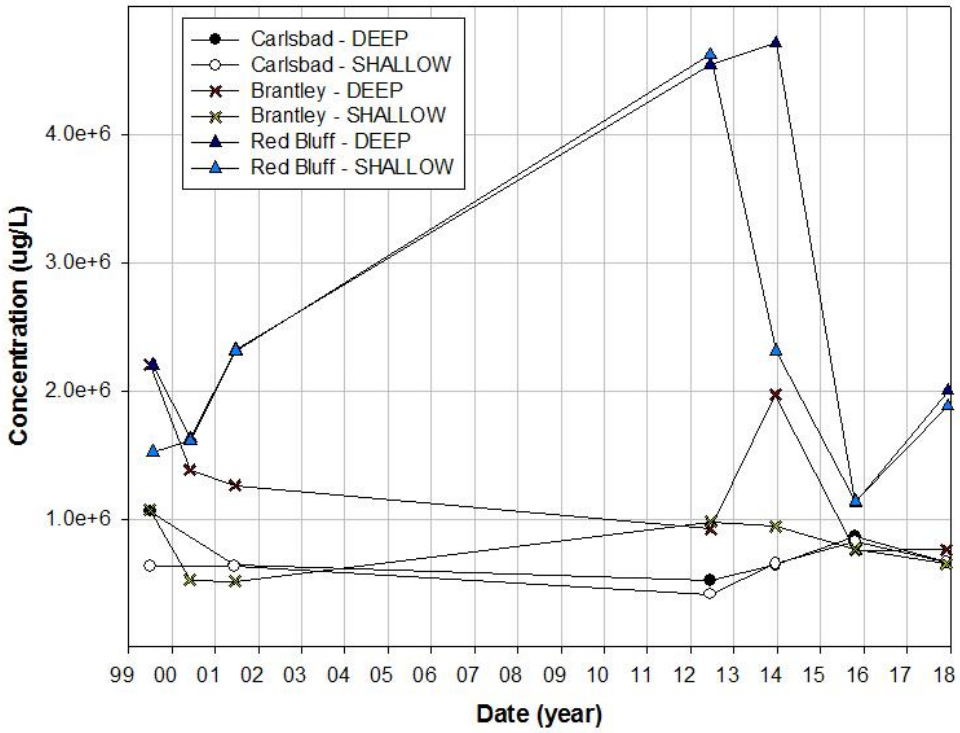


Figure 6-17: Chloride Concentrations (µg/L) Measured at the Three Regional Surface Water Sources (1999 – 2017)

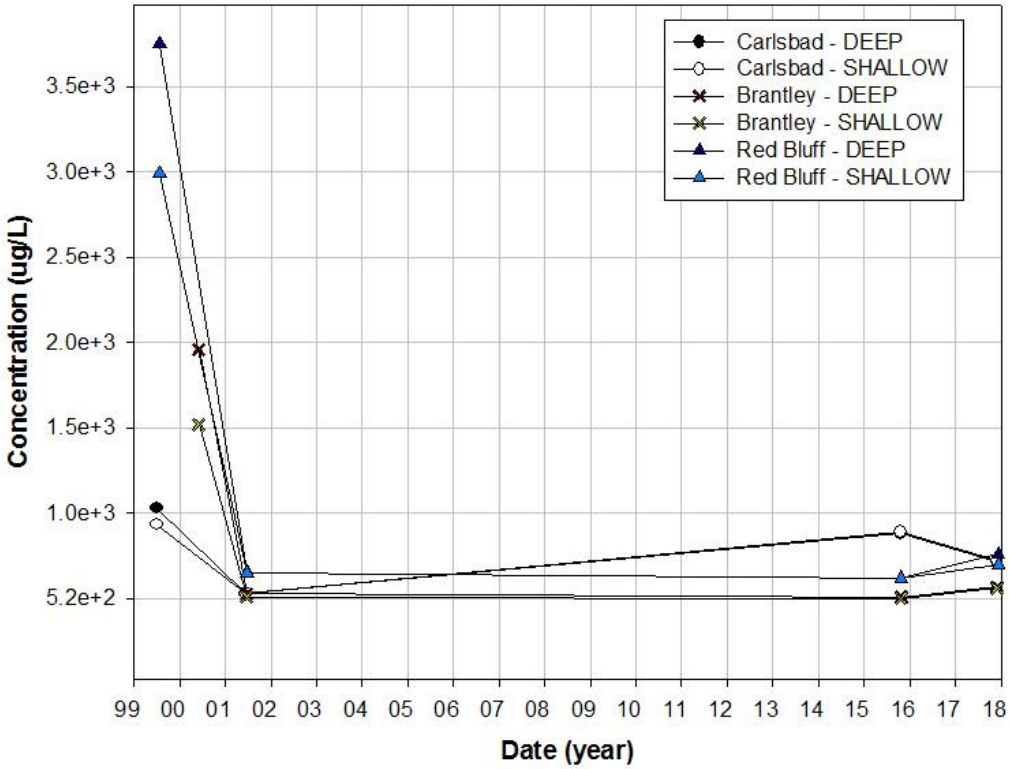


Figure 6-18: Fluoride Concentrations (µg/L) Measured at the Three Regional Surface Water Sources (1999 – 2017)

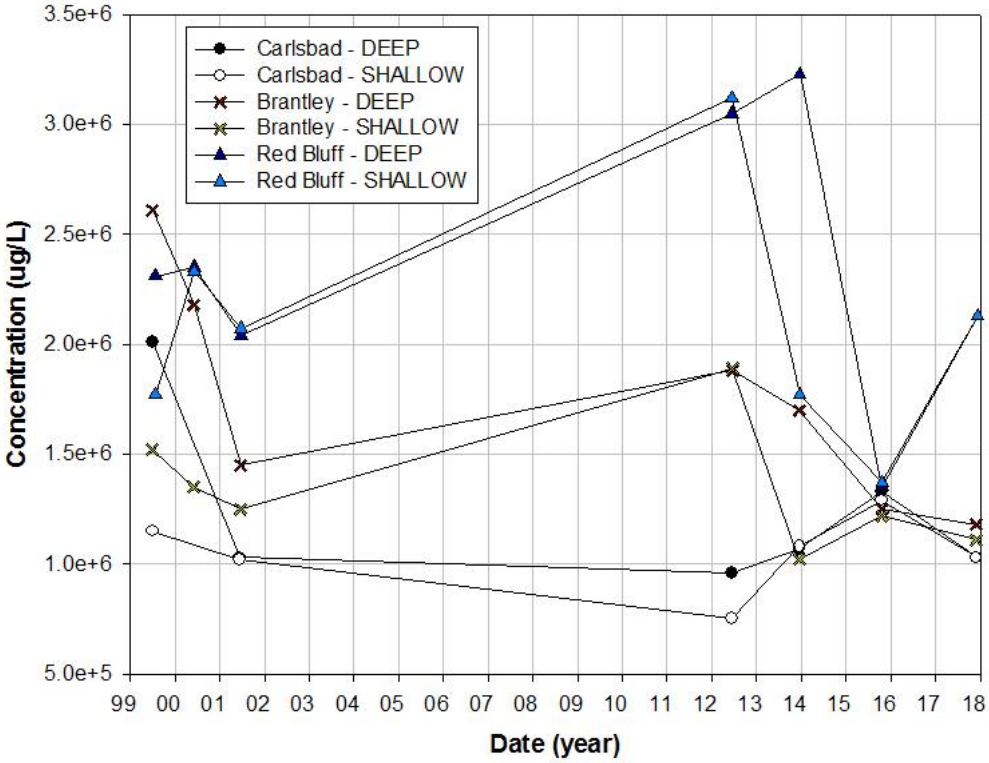


Figure 6-19: Sulfate Concentrations (µg/L) Measured at the Three Regional Surface Water Sources (1999 – 2017)

CHAPTER 7

Lung and Whole-Body In Vivo Radiobioassay Measurements

Introduction

The Internal Dosimetry department of CEMRC manages the Lung and Whole-Body *in vivo* radiobioassay Counting Facility (LWCF) which operates the 'Lie Down and be Counted (LDBC)' project. The *in vivo* LWCF, which is located in Room 161 of the CEMRC radio-bioassay Wing (indicated with red rectangular box in Figure 7.1), was commissioned in July 1997.

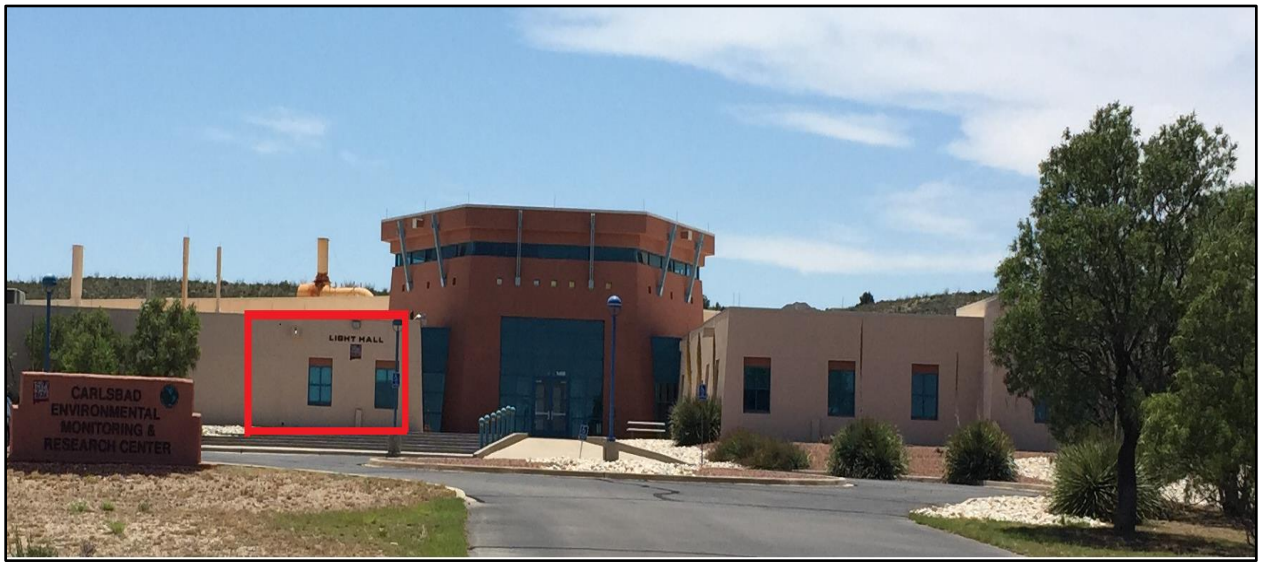


Figure 7.1 Carlsbad Environmental Monitoring and Research Center

The LDBC project was started in Aug1997 after the completion of the LWCF. The LDBC project monitors internally deposited radionuclides through a non-invasive *in vivo* radiobioassay measurement of lungs and whole-body. This project is provided free of charge to residents living within a 100-mile radius (Figure 7.2) of the WIPP site. LDBC is an outreach service to the public to (1) support education about naturally occurring and manmade radioactivity present in the environment, (2) observe the radionuclides present internally in the bodies of persons residing within 100-mile radius of the WIPP location, and (3) evaluate and improve upon the uncertainties associated with bioassay methodologies using the information obtained from these measurements. The project began approximately two years before the WIPP site began the operation of accepting radioactive nuclear waste. Thus, the LDBC project provides a pre-operational baseline with which to compare operational and post-operational activities. The project also provides a scientific understanding of how low-level nuclear waste disposed of in the region may impact the residents living near the WIPP repository.

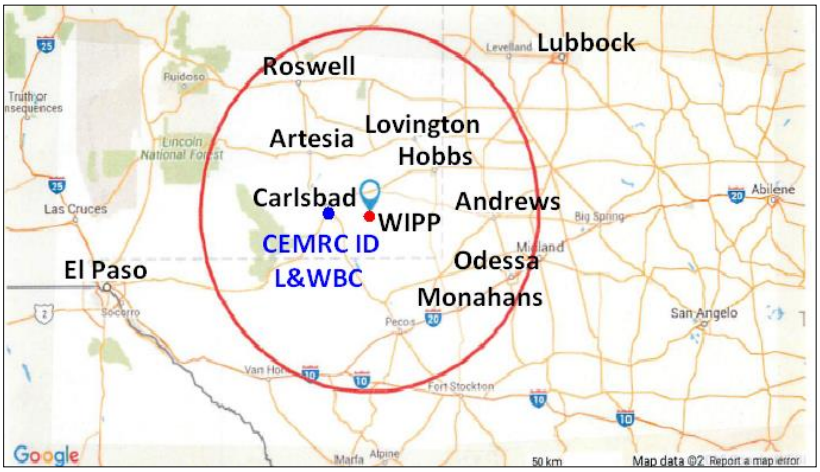


Figure 7.2. Map showing the area within a 100 mile radius of the WIPP site.

LWCF

Description of the facility

The LWCF occupies approximately 90 m^2 (966 ft^2) and provides the primary analytical infrastructure for the internal dosimetry program. The facility includes a large shielded counting chamber (Figure 7.3), dedicated instrument control workstation, two change rooms with showers and toilets, and a reception area. The counting chamber measuring 2.7 m x 3.0 m x 2.7 m is constructed of 25.40 cm thick cast iron, with a full graded-Z liner consisting of lead, tin and stainless steel. The cast iron composing the chamber was produced for industrial use prior to 1945, and re-cast for the chamber using a specially selected foundry, resulting in very low background radiation from anthropogenic and naturally occurring constituents. The instrument control workstation (Figure 7.4) includes a video display terminal and intercom used to monitor subjects during the examination. Signal processing electronics are located outside the counting shield next to the instrument control workstation. Inside the shielded chamber, there are oxygen monitor, speakers to listen to music during counting of the subjects, a video camera, emergency backup lights, voice-activated intercom for the subjects to communicate with the operator at any time during the counting, and the knob to open the chamber from inside (Figure 7.5). Lung detectors are located on top of the bed and are positioned close to the counting subject's chest and whole-body detectors are located under the bed (Figure 7.5). The whole-body detectors face the torso and upper leg parts of the body. LWCF is completely ANSI/HPS N13.30 (1996, 2011) compliant.

Figure 7.3. Lung and whole body counting chamber (iron wall on the side is shown in white and iron entrance door is shown in blue).

Figure 7.4. Operator's control room: (1) instrument control workstation, (2) computer monitor display, (3) intercom (4) video display terminal.

Figure 7.5. Inside the Whole Body counting chamber, (1) oxygen monitor, (2) speakers, (3) video camera, (4) intercom, (5) backup lights (6) knobs to open and close from inside, (7) emergency stop. Volunteer on the bed with lung detectors positioned on top.

Inside the shield, a specially designed counting bed and positioning mechanism are secured (Figure 7.5). This bed was designed to allow for simultaneous lung and whole-body measurements. The bed is constructed from low background steel and provides minimal attenuation of photons between the counting subject and whole-body counting detectors (8% attenuation at 662 keV gamma energy). The positioning mechanism for the lung counting detectors was designed to support four, 3800 mm^2 detectors mounted in two cryostats. The mechanism provides for longitudinal and vertical positioning as well as independent lateral angle and longitudinal tilt adjustment between the two cryostats. Sufficient positioning flexibility is provided in the positioning mechanism such that other body loci, such as skull, liver, wounds, and thyroid, can be examined.

Conditioned air is provided to the shield from the Center's centralized heating and cooling units. The air is high-efficiency particulate air (HEPA) filtered just prior to entering the room to remove any particulates. Additionally, an oxygen monitor is installed inside the shield to monitor oxygen levels in the room.

Lung and Whole-Body Counting System Calibration

Calibration of the lung and whole-body counter determines the relationship between radioactivity present in the body and the response of the detectors to radioactivity emitted from the body. The lung and whole-body counting system is calibrated at least annually. Any time new components are added or major changes are made, the system performance is, at a minimum, verified by comparison to control charts and verification counts are conducted using calibration phantoms. If the system operates within the control limits, calibration is performed at the next scheduled annual interval. If discrepancies are noted, calibration is performed at that time.

The energy calibration procedure establishes predictive equations for analyzer channel energy and photopeak resolution as a function of photon energy for the individual detectors and the groups of lung and whole-body detectors. The efficiency calibration of lung and whole-body counting system is performed using a variety of calibration phantoms consisting of National Institute of Standards and Technology certified activities. The humanoid phantom is a simulation of a human torso and is used to calibrate the lung counting arrangements. A bottle manikin absorption phantom (BOMAB) is used for the whole-body counter efficiency calibration. Detailed information on energy and efficiency calibration specifications of the lung and whole body counting system can be obtained by contacting the Internal Dosimetry department of CEMRC.

DOELAP Accreditation

Accreditation of personnel dosimetry systems is required for laboratories that conduct personnel dosimetry for the U.S. Department of Energy (DOE). Accreditation is a two-step process which requires the participant to pass a proficiency test and an onsite assessment. The DOE Laboratory Accreditation Program (DOELAP) is a measurement quality assurance program for DOE laboratories. DOELAP grants *in vivo* radiobioassay accreditation by assessing direct (*in vivo*) radiobioassay categories including ^{238}Pu, ^{241}Am, ^{238}U, ^{235}U, fission or activation products (^{57}CO, ^{60}CO, ^{134}Cs, ^{137}Cs and ^{54}Mn) in the lung counting system, and fission or activation products (^{57}CO, ^{60}CO, ^{134}Cs, ^{137}Cs and ^{54}Mn) in whole-body counting system, through participation in DOELAP performance testing for radiobioassay and on-site assessment. DOELAP accreditation dates starting from 1999 to the present for LWCF as a radiobioassay facility are listed in Table 7.1

Table 7-1: DOELAP accreditation dates for the CEMRC ID Lung and Whole Body counting facility

	DOELAP accreditation effective date	DOELAP accreditation expiry date
1	1/9/1999	11/19/2003
2	8/19/2003	8/1/2006
3	8/1/2006	8/1/2009
4	9/30/2009	November, 2013 (actual date not available)
5	1/6/2014	8/1/2016
6	12/12/2016	8/1/2019

The accreditation is valid even after the end of effective date, as long as the laboratory is in the process of renewal and is participating in the current performance testing program.

Lung and Whole Body detector system minimum detectable amount of internally deposited radionuclides in humans

Two important parameters when interpreting bioassay data are Minimum Detectable Amount (MDA) and Decision Level (L_C). The value of MDA indicates the ability of a facility to detect a radionuclide in a person. The MDA represents the amount of a radionuclide that, if present, would be detected 95% of the time under the routine operation of a facility. The MDA is used to measure the efficacy of a facility and should not be used to decide if a specific radiobioassay has or has not detected activity within a person (ANSI/HPS N13.30, 1996). To determine whether or not activity has been detected in a particular person, the parameter L_C is used. The L_C represents the 95th percentile of a null distribution resulting from the differences of repeated, pair-wise background measurements. An individual result is assumed to be statistically greater than background if it is greater than L_C. It is important to note that use of this criterion will result in a statistically inherent 5% false positive error rate (5% of all measurements will be determined to be positive when there is no true activity in the person). Details of MDA and L_C calculations are available (CEMRC, 1998; ANSI/HPS N13.30, 1996; Webb et al, 2000).

Detection efficiency, as it applies to lung measurements, varies greatly with the person's chest wall thickness (CWT). Readily accessible computerized MDA values are available from 2002 for the whole-body detector system and from 2006 for the lung detector system. Average MDA (nCi), 1 Standard deviation (nCi) and % variation for lung and whole body detector systems are provided respectively in Tables 7.2 and 7.3.

Table 7.2 Lung detector system's Average MDA (nCi), 1 Standard deviation (nCi) and % deviation for chest wall thickness 1.6 cm to 6.0 cm (from 2006 to 2017).

		Chest Wall Thickness														
		1.6 cm			3.01 cm			4.18 cm			5.10 cm			6.0 cm		
Radionuclide	Energy (keV)	Average MDA (nCi)	1 Standard Deviation (nCi)	Deviation %	Average MDA (nCi)	1 Standard Deviation (nCi)	Deviation %	Average MDA (nCi)	1 Standard Deviation (nCi)	Deviation %	Average MDA (nCi)	1 Standard Deviation (nCi)	Deviation %	Average MDA (nCi)	1 Standard Deviation (nCi)	Deviation %
Am-241	59.50	0.18	0.01	4	0.30	0.01	3	0.46	0.02	4	0.65	0.03	5	0.90	0.06	6
Ce-144	133.50	0.48	0.01	2	0.71	0.01	1	1.01	0.03	2	1.32	0.05	4	1.73	0.08	5
Cf-252	19.20	18	1	6	83	3	4	301	20	7	833	75	9	2251	255	11
Cm-244	18.10	17	1	5	91	4	4	383	25	7	1179	99	8	3546	372	10
Eu-155	105.30	0.27	0.01	2	0.43	0.01	1	0.64	0.02	3	0.86	0.04	5	1.16	0.08	7
Np-237	86.50	0.47	0.02	5	0.79	0.02	2	1.19	0.05	4	1.64	0.10	6	2.24	0.18	8
Pu-238	17.10	18	1	5	120	6	5	585	37	6	2040	159	8	6923	643	9
Pu-239	17.10	44	2	5	297	15	5	1456	93	6	5075	396	8	17224	1601	9
Pu-240	17.10	17	1	5	117	6	5	572	37	6	1994	156	8	6767	629	9
Pu-242	17.10	21	1	5	141	7	5	690	44	6	2405	188	8	8163	759	9
Ra-226	186.10	1.72	0.08	5	2.37	0.03	1	3.21	0.06	2	4.08	0.11	3	5.15	0.18	4
Th-232 Via Pb-212	238.60	0.15	0.00	2	0.22	0.00	1	0.30	0.01	2	0.38	0.01	3	0.49	0.02	4
Th-232	59.00	33	1	3	57	2	3	87	4	5	123	8	6	170	13	8
U-233	440.30	0.65	0.02	3	0.92	0.02	2	1.23	0.02	2	1.54	0.04	2	1.93	0.07	3
U-235	185.70	0.11	0.00	4	0.15	0.00	2	0.20	0.01	3	0.25	0.01	3	0.32	0.01	4
Natural U via Th-234	63.30	1.56	0.07	4	2.66	0.07	2	4.07	0.17	4	5.7	0.3	6	7.9	0.6	7

Table 7.3. Whole body detector system's Average MDA (nCi), 1 Standard deviation (nCi) and % deviation (from 2002 to 2017).

Radionuclide	Energy (keV)	Average MDA (nCi)	1 Standard Deviation (nCi)	Deviation (%)
Ba-133	0.356	0.77	0.05	6
Ba-140	0.537	1.50	0.09	6
Ce-141	0.145	1.64	0.16	10
Co-58	0.811	0.36	0.02	6
Co-60	1.333	0.36	0.01	3
Cr-51	0.320	4.42	0.42	9
Cs-134	0.604	0.34	0.03	8
Cs-137	0.662	0.42	0.02	5
Eu-152	0.344	1.58	0.12	8
Eu-154	1.275	0.94	0.04	4
Eu-155	0.105	3.81	0.39	10
Fe-59	1.099	0.66	0.03	5
I-131	0.365	0.47	0.04	8
I-133	0.530	0.41	0.03	7
Ir-192	0.317	0.55	0.05	9
Mn-54	0.835	0.45	0.01	2
Ru-103	0.497	0.39	0.03	8
Ru-106	0.622	3.28	0.15	5
Sb-125	0.428	1.32	0.12	9
Th-232 via Ac-228	0.911	1.23	0.08	6
Y-88	0.898	0.37	0.02	6
Zn-65	1.116	1.10	0.04	4

A routine radiobioassay program should be able to detect intakes within a year that will deliver a Committed Effective Dose of 100 mrem. If this *performance objective* cannot be met, then a *performance shortfall* is said to exist. Current version of CEMRC's Lung and Whole-Body Counting technical manual (RB-TBM-016, 2017) provides a detailed comparison of lung and whole-body detector system's MDAs with annual limit of intakes.

LDBC Project

Lung and whole-body in vivo radiobioassay measurements

Participating in the LDBC project consists of having a lung and whole body count. Volunteers are recruited through presentations to local community groups and businesses, community job fairs, informal out-reach, publications in the local newspaper, and students attending NMSU Carlsbad Campus and Early College. The entire measurement protocol process takes approximately one hour. A detailed description of the measurement protocol, analysis, and instrument detection limits were initially provided in the CEMRC report (1998). In addition, the results of the measurements from 1998 -2017 are available in CEMRC annual reports, on the web site https://www.cemrc.org/annual-reports/.

Internally deposited radionuclides of interest (Table 7.4) were identified from the review of the WIPP Safety Analysis Report (DOE/WIPP-95-2065, 1995; DOE/WID-96-2196, 1996). In addition, the naturally occurring radionuclide ^{40}K was also monitored. Theses radionuclides are detected and identified by the lung and whole body detectors.

Table 7.4. Radionuclides of Interest for "Lie Down and Be Counted" Project

In-Vivo measurement type	Radionuclides of interest
Lung	^{241}Am, ^{144}Ce, ^{252}Cf, ^{244}Cm, ^{155}Eu, ^{237}Np, $^{238, 239, 240, 242}$Pu, $^{228, 232}$Th, $^{233, 234, 235, 238}$U
Whole Body	$^{133, 140}$Ba, ^{141}Ce, $^{58, 60}$Co, ^{51}Cr, ^{134,137}Cs, $^{152, 154, 155}$Eu, ^{59}Fe, $^{131, 133}$I, ^{192}Ir, ^{40}K, ^{54}Mn, $^{103, 106}$Ru, ^{125}Sb, ^{232}Th, ^{88}Y, ^{65}Zn, ^{95}Zr.

Data Reporting

Volunteer participation per year from 1997 to 2007

366 public volunteers were counted during 7/21/1997 – 3/26/1999 in order to establish a baseline of radiological activities in the inhabitants within the local population. This group of 366 measurements constituted the pre-operational baseline to which subsequent results are compared. Counts performed after the opening of the WIPP are considered to be a part of the operational monitoring phase of the WIPP environmental monitoring program. The WIPP became operational accepting its first radioactive waste shipment from Los Alamos National Labs on

March 27, 1999. From 3/27/1997 to 12/31/2017, a total of 1129 measurements were performed for the LDBC project. These measurements include baseline (first time counting), routine (measurement performed after the baseline count, when a participant returns for a required annual count or a walk-in public count), and recounts (measurement repeated to investigate elevated activity). Figure 7.6 shows the number of male, female and total public volunteers participated, per year, thus far during the program period (7/21/1997 to 12/31/2017). Figure 7.7 shows the number of public volunteers who participated more than once.

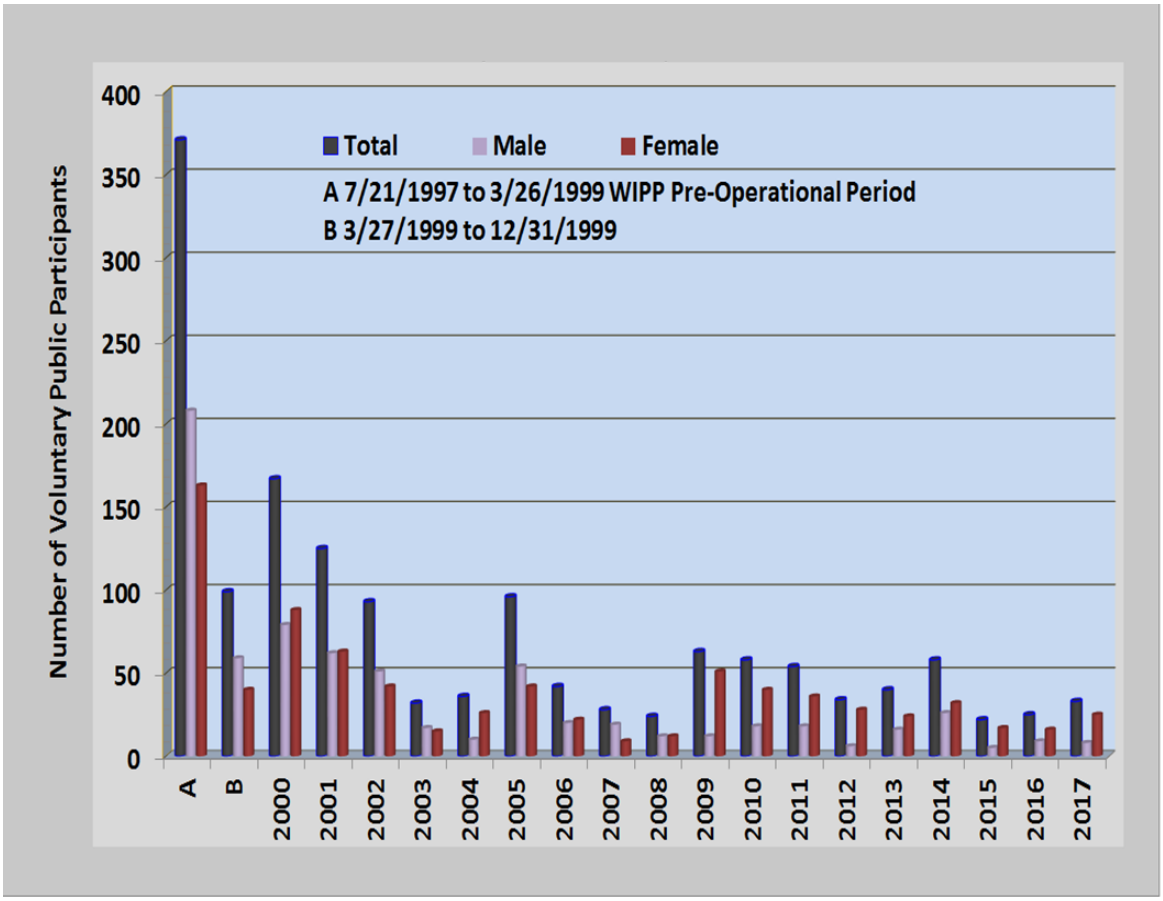


Figure 7.6. Number of LDBC voluntary public participants (total and by gender) participated during the period 1997-2017.

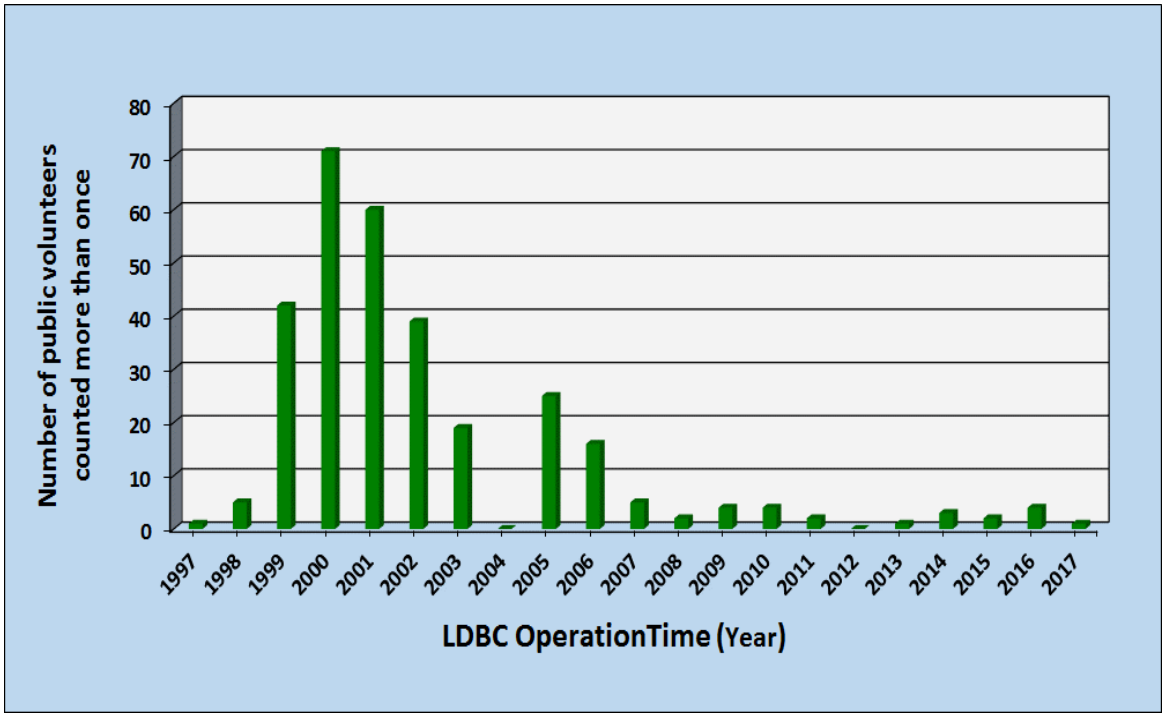


Figure 7.7. Number of individuals participated more than once in the LDBC project during the period1997-2017.

In addition to the LDBC project for public, CEMRC LWCF conducts *in vivo radiobioassay* services for radiation control workers in the area and has performed about 5277 counts, which include baseline (in this context baseline means the first time counted at CEMRC), routine, recounts, exit, potential intake, and any other special counts on radiological trained workers in the region. Current contracts for internal dosimetry services include WIPP, Waste Control Specialists, Andrews, TX; and Los Alamos National Laboratory, Carlsbad, NM; as well as CEMRC radiological workers.

Demographics

Volunteers participating in the LDBC project are requested to complete a questionnaire providing demographic information regarding age, gender, ethnicity, occupation, foreign travel, wild game consumption, smoking habits, and any nuclear medicine procedure. Table 7.4.2 compares the LDBC demographic characteristics for the WIPP operational period 3/27/1999 to 12/31/2017 with the baseline cohort study of 7/21/1997 to 3/26/1999. It shows an increase of voluntary participation by Hispanics from 13.4% to 21.7% in the period 1999 - 2017. According to the U.S. census, the percentage of the Hispanic population nationwide for this same time period increased from 12.5% to 18.1% and increased from 42.1% to 48.8% for the State of New Mexico. In addition, it is important to note that if the presence of a radionuclide is dependent on a subclass of interest (i.e. gender, ethnicity, etc.), valid population estimates can still be made by correcting for the proportion of under- or over-sampling for the particular subclass. Table 7.5 lists the variations observed for the remainder of the demographic characteristics.

Table 7.5. Demographic Characteristics of the LDBC Population Sample groups

Voluntary Participants				Census			
Characteristic		(7/21/1997 to 3/26/1999)	(3/27/1999 to 12/31/2017)	2000[a]		2017[b] Estimates	
		(margin of error[d])	(margin of error[c])	NM	US	NM	US
Gender	Male	56.2%	44.5% (41.6 % to 47.4 %)	49.20%	49.10%	49.50%	49.20%
	Female	43.8%	55.5% (52.6 to 58.4 %)	50.80%	50.90%	50.50%	50.80%
Ethnicity	Hispanic	13.4 % margin of error[d]	21.7% (19.3 to 24.1 %)	42.10%	12.50%	48.80%	18.10%
	All others	86.6%	78.3% (75.9 to 80.7 %)	57.90%	87.50%	51.20%	81.90%
Age 65 years or over		16.7% margin of error [d]	34.2% (31.4 to 37.0 %)	11.70%	12.40%	16.90%	15.60%
Currently or previously classified as a radiation worker		4% margin of error [d]	9.9% (8.2 to 11.7 %)	NA	NA	NA	NA
Consumption of wild game within 3 months prior to count		16.4 % margin of error [d]	23.3% (20.8 to 25.8 %)	NA	NA	NA	NA
Medical treatment other than X-rays using radionuclides		9% margin of error [d]	5.9% (4.5 to 7.3 %)	NA	NA	NA	NA
European/Japan travel within 2 years prior to the count		4% margin of error [d]	4.8% (3.5 to 6.0 %)	NA	NA	NA	NA
Current smoker		13.9% margin of error [d]	13.6% (11.6 to 15.5 %)	N/A	N/A	16[+]% - 19 %[e]	15.1%[f]

a 2000 Census: https://www.census.gov/census2000/states/us.html
USA: https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?src=bkmk
NM: https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?src=CF
Web accessed on 11/1/2017

b 2017 Census: https://www.census.gov/quickfacts/fact/table/US/PST045217#PST045217
Estimates: https://www.census.gov/quickfacts/fact/table/nm/PST045217#PST045217
Web accessed on 10/28/2018

c **Margin of error:** The margin of error represents the 95% confidence interval of the observed proportion; under complete replication of this experiment, one would expect the confidence interval to include the true population proportion 95% of the time if the sample was representative of the true population.

d Margin of error cannot be quoted, sample too small.

e CDC (USA): https://www.cdc.gov/vitalsigns/tobaccouse/smoking/infographic.html

f CDC (USA): https://www.cdc.gov/tobacco/data_statistics/fact_sheets/index.htm
Web accessed on 10/28/2018

Summary of LDBC results greater than the decision limits (L_C)

Table 7.6 lists the results greater than the decision limits (L_C) for the baseline and operational measurements during the period 1997-2017. For the baseline measurement counts (N = 366), the percentage of results greater than L_C were consistent with a 5% random false-positive error rate, at the 95% confidence level (1% to 9%), for all radionuclides except ^{232}Th via the decay of ^{212}Pb, ^{235}U/^{226}Ra, ^{60}Co, ^{137}Cs, ^{40}K, ^{54}Mn, and ^{232}Th via the decay of ^{228}Ac. As discussed in detail in the 1998 report, five of these radionuclides [^{232}Th via ^{212}Pb, ^{60}Co, ^{40}K, ^{54}Mn (^{228}Ac interference) and ^{232}Th (via ^{228}Ac)] are part of the shield-room background and positive detection is expected at low frequency. ^{40}K is a naturally occurring isotope of an essential biological element, so detection in all individuals is expected. ^{137}Cs and ^{235}U / ^{226}Ra are not components of the shielded room background and were observed at frequencies greater than the 95% confidence interval for the false-positive error rate (discussed in more detail below).

For the operational measurement counts (Table 7.6, N = 1129), the percentage of results greater than L_C were consistent with baseline at a 95% confidence level (margin of error), except for ^{60}Co and ^{232}Th (via ^{228}Ac). For these radionuclides, the percentage of results greater than L_C decreased relative to the baseline. This would be expected for ^{60}Co since the radionuclide has a relatively short half-life (5.2 years) and the content of ^{60}Co within the shield has decreased via decay by approximately 80% since the baseline phase of monitoring. Additionally, the differences in ^{232}Th (via ^{228}Ac) results between the baseline and operational monitoring phase were also observed in 2001 and 2002. This was likely due to the replacement of some detector cryostat components, which now contain aluminum, originally those components were manufactured from low radiation background steel.

The percentage of results greater than L_C for ^{235}U/^{226}Ra (11 % for the baseline) is significantly higher than the distribution-free confidence interval for a 5 % random false-positive error rate. These data are not nearly as compelling as those for ^{137}Cs, but the large sample size of the current cohort tends to support the observed pattern. Although ^{235}U and ^{226}Ra cannot be differentiated via gamma spectroscopy, it is likely that the signal observed is the result of ^{226}Ra because the natural abundance of ^{226}Ra is much greater than that of ^{235}U. Currently, this is considered to be performance shortfall. Procedural development needed to further enhance the detection capability is expected to be investigated during the upgrade of the facility by the end of the year 2020.

Also included in Table 7.6 are the results of the public monitored during the year, after the radiological incidence at Fukushima, Japan on 3/11/2011 and the WIPP radiological incidence at the WIPP site, New Mexico, USA on 2/14/2014. The results of the public monitored during the year 2011, after the radiological incidents at Fukushima, showed that the margin of error (for the results > decision limit) for the nuclides $^{152, 155}$Eu, ^{59}Fe, ^{131}I, ^{192}Ir, ^{54}Mn, ^{106}Ru was higher compared to the corresponding baseline values. For these nuclides, all the results were evaluated individually by visually inspecting the spectra on the display monitor. Except for ^{131}I and ^{137}Cs of

one specific public participant's results, all the other results showed no significant gamma photo-peaks. Also, the margin of error, for these nuclides for the period 3/27/1999 to 12/31/2017 was comparable to the baseline values, indicating normalcy of the results. The WIPP radiological incident report providing the evaluation of the 2014 LDBC results is available at the CEMRC website (www.cemrc.org) under the annual reports tab, 2014 Release Event, Section 7: Whole body Counting pp 109 -118. http://www.cemrc.org/annual-reports/. Figures 7.8 and 7.9 contain respectively ^{40}K and ^{137}Cs average activities for the total number of participants, separated by gender, listed for the baseline and operational periods. ^{40}K results are positive for all participants through December 2017. Such results are expected since K is an essential biological element contained primarily in muscle. Therefore, ^{40}K, the radioactive isotope, is the theoretical constant fraction of all naturally occurring K. ^{40}K average value per person for males was significantly greater than that of females. Since in general, males tend to have larger body sizes and greater muscle content than females. The CEMRC report (1999) and Webb et al (2000), provided initial correlation studies of detectable ^{137}Cs with parameters like age, ethnicity, European travel, gender, consumption of wild game, nuclear medical treatments, radiation work history, and smoking. ^{241}Am and the Pu-isotopes account for 99.98% of radionuclide inventory activity in WIPP radioactive waste. Currently, for each result greater than the decision limit, reconfirmation is on-going to verify the detectable activity level with reference to the background and MDA level, by visual inspection of the gamma photo-peaks of ^{241}Am 59.5 keV and Pu-isotopes' 17 keV. The baseline data of 1997-1999 was archived and efforts are continuing for the retrieval on to the new computer system. The information about the detectable activity levels of ^{241}Am and the Pu-isotopes during baseline and operational periods will be updated in the future reports.

Table 7.6. LDBC Project 1997 – 2017 results greater than the decision limits (L_C). Warning: These results are the first time measurements only and should not be used, reproduced or evaluated without permission from CEMRC.

Radionuclide	*In Vivo* Count Type	Baseline Counts [b](margin of error) (7/21/1997 - 3/26/1999) [a]N = 366	Operational Monitoring Counts (margin of error) (3/27/1999 – 12/31/2017) N = 1129	Operational Monitoring Counts (margin of error) (3/11/2011 – 12/31/2011)[c] N = 45	Operational Monitoring Counts (margin of error) (2/14/2014 – 12/31/2014)[d] N = 58
		% of Results > L_C	% of Results > L_C	% of Results > L_C	% of Results > L_C
^{241}Am	Lung	5.2 (4.0 to 6.4)	4.4 (3.2 to 5.6)	6.7 (3.0 to 10.3)	3.4 (1.1 to 5.8)
^{144}Ce	Lung	4.6 (3.5 to 5.7)	4.5 (3.3 to 5.7)	0 (0 to 0)	6.9 (3.6 to 10.2)
^{252}Cf	Lung	4.1 (3.1 to 5.1)	5.9 (4.6 to 7.3)	8.9 (4.7 to 13)	6.9 (3.6 to 10.2)
^{244}Cm	Lung	5.7 (4.5 to 7.0)	4.9 (3.6 to 6.1)	8.9 (4.7 to 13)	5.2 (2.3 to 8)
^{155}Eu	Lung	7.1 (5.8 to 8.4)	5.0 (3.8 to 6.3)	11.1 (6.5 to 15.7)	8.6 (5 to 12.2)
^{237}Np	Lung	3.6 (2.6 to 4.5)	3.7 (2.6 to 4.8)	2.2 (0.1 to 4.4)	1.7 (0 to 3.4)
^{210}Pb	Lung	4.4 (3.3 to 5.4)	6.3 (4.9 to 7.7)	2.2 (0.1 to 4.4)	8.6 (5.0 to 12.2)
[e]Pu-Isotopes	Lung	5.7 (4.5 to 7.0)	5.1 (3.8 to 6.4)	4.4 (1.4 to 7.5)	3.4 (1.1 to 5.8)
[f] ^{232}Th via ^{212}Pb	Lung	34.2 (31.7 to 36.6)	31.4 (28.6 to 34.1)	24.4 (18.2 to 30.7)	37.9 (31.7 to 44.2)
^{232}Th	Lung	4.9 (3.8 to 6.0)	5.3 (4 to 6.6)	6.7 (3.0 to 10.3)	6.9 (3.6 to 10.2)
^{232}Th via ^{228}Th	Lung	4.1 (3.1 to 5.1)	4.6 (3.4 to 5.8)	2.2 (0.1 to 4.4)	0 (0 to 0)
^{233}U	Lung	5.7 (4.5 to 7.0)	9.0 (7.4 to 10.7)	2.2 (0.1 to 4.4)	8.6 (5.0 to 12.2)
^{235}U/^{226}Ra	Lung	10.7 (9.0 to 12.3)	11.1 (9.2 to 12.9)	13.3 (8.4 to 18.3)	3.4 (1.1 to 5.8)
^{238}U	Lung	5.2 (4.0 to 6.4)	5.5 (4.2 to 6.8)	8.9 (4.7 to 13)	0 (0 to 0)
^{133}Ba	Whole Body	3.6 (2.6 to 4.5)	3.0 (2 to 4)	0 (0 to 0)	6.9 (3.6 to 10.2)
^{140}Ba	Whole Body	5.2 (4.0 to 6.4)	4.1 (2.9 to 5.2)	2.2 (0.1 to 4.4)	3.4 (1.1 to 5.8)
^{141}Ce	Whole Body	3.6 (2.6 to 4.5)	4.8 (3.5 to 6)	0 (0 to 0)	3.4 (1.1 to 5.8)
^{58}Co	Whole Body	4.4 (3.3 to 5.4)	3.5 (2.5 to 4.6)	2.2 (0.1 to 4.4)	12.1 (7.9 to 16.3)
[f] ^{60}Co	Whole Body	54.6 (52.0 to 57.2)	22.5 (20.1 to 24.9)	17.8 (12.2 to 23.4)	6.9 (3.6 to 10.2)
^{51}Cr	Whole Body	5.7 (4.5 to 7.0)	4.3 (3.1 to 5.4)	6.7 (3.0 to 10.3)	1.7 (0 to 3.4)
^{134}Cs	Whole Body	1.6 (1.0 to 2.3)	2.6 (1.6 to 3.5)	2.2 (0.1 to 4.4)	0 (0 to 0)
^{137}Cs	Whole Body	28.4 (26.1 to 30.8)	17.0 (14.8 to 19.2)	24.4 (18.2 to 30.7)	17.2 (12.4 to 22.1)
^{152}Eu	Whole Body	7.4 (6.0 to 8.7)	5.8 (4.4 to 7.1)	6.7 (3.0 to 10.3)	0 (0 to 0)
^{154}Eu	Whole Body	3.8 (2.8 to 4.8)	3.4 (2.3 to 4.4)	2.2 (0.1 to 4.4)	3.4 (1.1 to 5.8)
^{155}Eu	Whole Body	3.8 (2.8 to 4.8)	3.5 (2.4 to 4.5)	11.1 (6.5 to 15.7)	8.6 (5.0 to 12.2)
^{59}Fe	Whole Body	3.8 (2.8 to 4.8)	5.7 (4.3 to 7)	15.6 (10.3 to 20.9)	3.4 (1.1 to 5.8)
^{131}I	Whole Body	5.2 (4.0 to 6.4)	4.3 (3.2 to 5.5)	11.1 (6.5 to 15.7)	3.4 (1.1 to 5.8)
^{133}I	Whole Body	3.3 (2.3 to 4.2)	4.0 (2.8 to 5.1)	2.2 (0.1 to 4.4)	8.6 (5.0 to 12.2)
^{192}Ir	Whole Body	4.1 (3.1 to 5.1)	4.0 (2.8 to 5.1)	13.3 (8.4 to 18.3)	6.9 (3.6 to 10.2)
^{40}K	Whole Body	100.0 (100.0 to 100.0)	100.0 (100.0 to 100.0)	100.0 (100.0 to 100.0)	100.0 (100.0 to 100.0)
[f] ^{54}Mn	Whole Body	12.3 (10.6 to 14.0)	12.6 (10.6 to 14.5)	13.3 (8.4 to 18.3)	8.6 (5.0 to 12.2)
^{103}Ru	Whole Body	2.2 (1.4 to 3.0)	1.9 (1.1 to 2.6)	2.2 (0.1 to 4.4)	3.4 (1.1 to 5.8)
^{106}Ru	Whole Body	4.4 (3.3 to 5.4)	4.5 (3.3 to 5.7)	8.9 (4.7 to 13)	3.4 (1.1 to 5.8)
^{125}Sb	Whole Body	5.2 (4.0 to 6.4)	4.4 (3.2 to 5.6)	8.9 (4.7 to 13)	5.2 (2.3 to 8)
^{232}Th via ^{228}Ac	Whole Body	34.7 (32.2 to 37.2)	25.6 (23.1 to 28.1)	35.6 (28.6 to 42.5)	20.7 (15.5 to 25.9)
^{88}Y	Whole Body	7.7 (6.3 to 9.0)	6.6 (5.1 to 8)	4.4 (1.4 to 7.5)	8.6 (5.0 to 12.2)
^{95}Zr	Whole Body	6.6 (5.3 to 7.9)	3.7 (2.6 to 4.8)	4.4 (1.4 to 7.5)	1.7 (0 to 3.4)

[a] N = number of individuals. Baseline counts include only the initial counts during this baseline period.
[b] 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.
[c] Public counts performed during 3/11/2011 to 12/31/2011, after the Fukushima radiological incidence happened on 3/11/2011. The visual gamma photo-peak evaluation of the results for $^{152, 155}$Eu· ^{59}Fe, ^{131} I, ^{192}Ir, ^{54}Mn, ^{106}Ru showed no significant peaks, except for one public participant for only ^{131}I.
[d] Public counts performed during 2/14/2014 to 12/31/2014, after the WIPP radiological incidence happened on 2/14/2014.
[e] $^{238-240, 242}$ Pu isotopes are identified as a group, denoted as Pu-Isotopes by the software.
[f] These radionuclides are present in the shield background, so they are expected to be detected periodically.

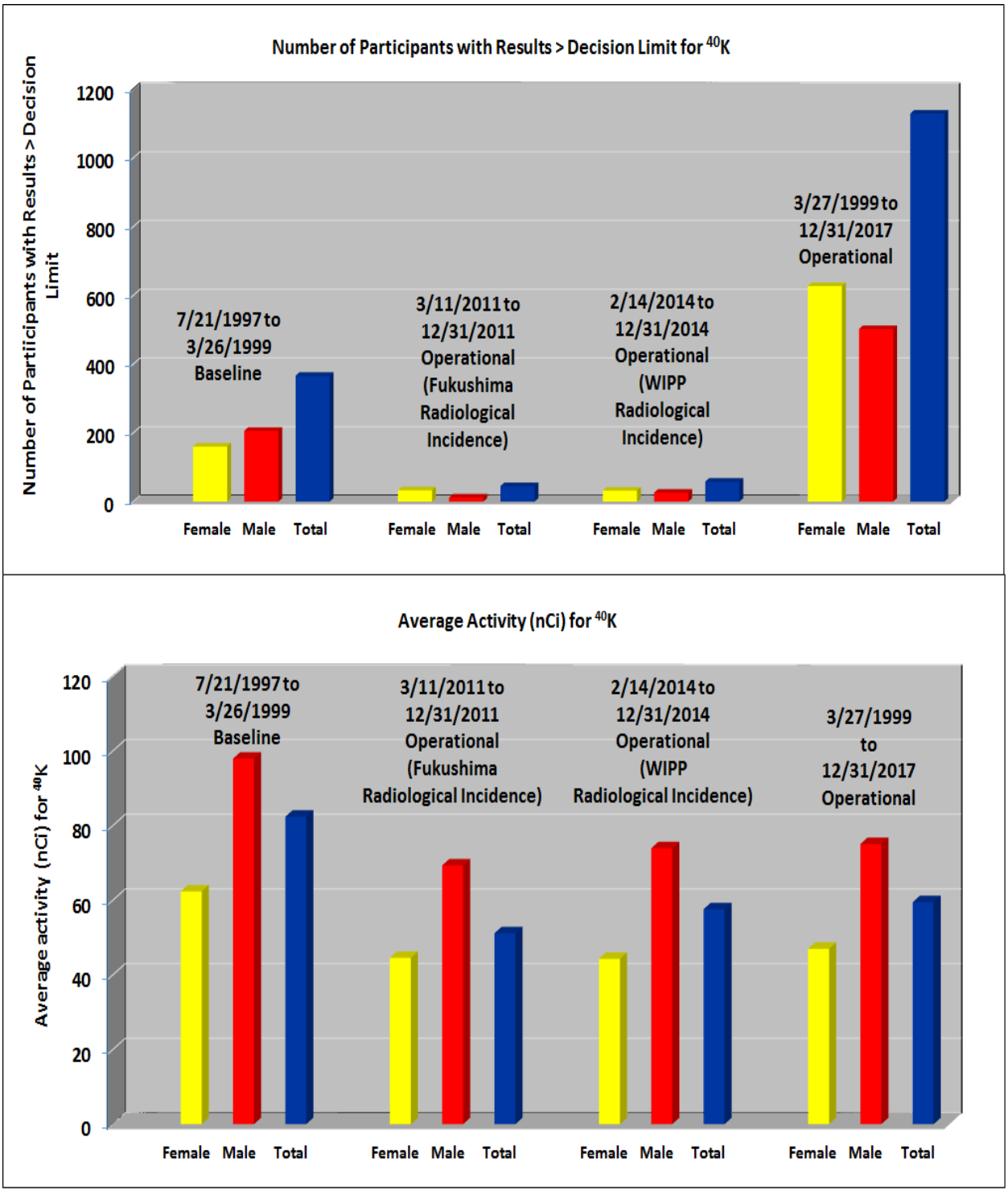


Figure 7.8. Variation of ^{40}K nuclides detectable activities during baseline and operational periods. ^{40}K results are positive for all participants.

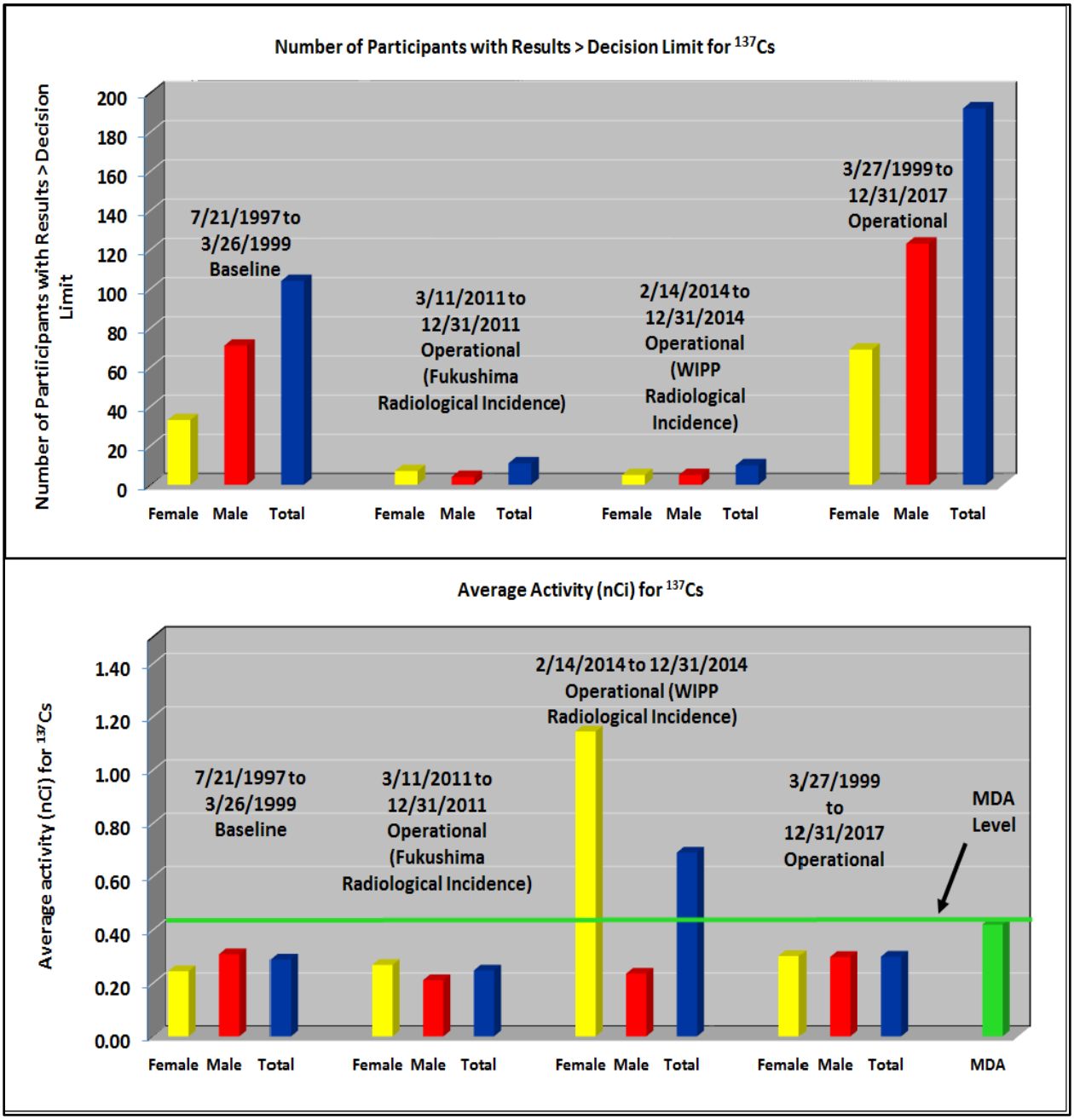


Figure 7.9 Comparison of ^{137}Cs nuclide detectable activities during baseline and operational periods with reference to the average MDA level of the whole body counting system. Visual inspection of the ^{137}Cs 662 keV gamma photo-peak of each result showed that the activities (nCi) greater than (about) 0.35 nCi have significant gamma photo-peaks. A follow-up measurement option is available to the participant. Note: It was verified that the increase in the ^{137}Cs average activity was not due to the WIPP radiological incidence, but could be attributable to the eating habits.

Research summaries of LWCF and LDBC project studies from 2000 – 2017

An evaluation of recent Lung Counting Technology (Webb et al, 2000):
In vivo Lung and whole-body detectors employ two types of hyper pure germanium (HPGe) detectors, the broad energy (BEGe) and coaxial (COAX) manufactured by Canberra (now Mirion) Industries. The primary function of the BEGe detectors is lung counting; however, the high-energy performance was matched to that of the COAX detectors to allow for both low and high energy counting. The development and testing of the lung counting detectors was described.

An evaluation of in vivo sensitivity via public monitoring (Webb et al, 2000):
Webb et al studied i) demographic characteristics of LDBC cohort, ii) demographic characteristics associated with occurrence of ^{137}Cs in local residents, iii) variation of minimum detectable amount (MDA) of nuclides with background count rates and chest wall thickness (for radionuclides deposited in lungs between individuals, iv) comparison of human background was to that observed from phantoms, and v) observed false positive and negative error rates compared with those expected from statistical theory.

Development of a reliable non-invasive non-destructive in vivo method for the detection of the activities of the transuranic isotopes at sub-nano curie level:

I. The initial investigation by Pillalamarri et al (2013) consisted of measurement of the minimum detection activity using minimum available resources such as HPGe detector, a volunteer and an existing shielded chamber at 2150' below ground at the WIPP. The minimum detectable activity (MDA) was established with this system to be 0.2 Bq (5 pCi) in 25 hour counting time with a 15 mm diameter and 7 mm thick Ge detector, having a beryllium window of thickness 0.08 mm, in contact with the cranium just above the ear adjacent to the temple region. In order to establish an MDA of 0.004 Bq (0.1 pCi) with this system, the limitation arising from the ambient radon level at 10 Bq/m^3 was investigated.

II. The second investigation by Pillalamarri et al (2015) was to identify the transmitted component arising from the ^{40}K 1461 keV incident photon flux on-site at the WIPP underground location. One of the further considerations in the present work, while setting up a low background whole body counter underground at the WIPP is to reduce the background in the energy region of interest below 100 keV. The transmitted photon flux was simulated with the GEANT4 code for an incident photon flux consisting only of 1461 keV photons. The results were discussed with respect to a detector of choice for detecting < 50 mBq emitting photons in the energy region below 100 keV.

III. The third investigation by Pillalamarri et al (2017) was to estimate the interfering background recorded in the energy regions of interest (ROI), that represent the

detection of trans-uranium isotopes deposited in the lungs, in the presence of ^{40}K internal to the human body. GEANT4 simulations were carried out for a point source without and with the shielding, and for a BOMAB phantom in the shielded whole-body counting chamber underground at the WIPP.

Conclusion

The CEMRC internal dosimetry LWCF has been accomplishing the mission of the LDBC project from its inception in 1997 to the present as follows:

1) Support education about naturally occurring and manmade radioactivity present in the environment; each time a public volunteer participates in the LDBC, at the end of the lung and whole-body measurement, a technical staff member provides a 5 to 10 minutes scientific explanation. Also, LWCF facilitates Early College and Community College-New Mexico State University students to routinely participating in the LDBC. More workforce will be helpful to spread the message across.

2) Observe the radionuclides present internally in the bodies of persons residing within 100-mile radius of the WIPP location: The LWCF is a dedicated and accredited facility which has been in continuous operation, since 1997, without performance gaps and downtime. The LDBC results, particularly with no significant variation in the percentage of public participants with detectable levels of plutonium and americium, suggest that there have been no observable effects from the WIPP on the residents living in proximity. More resources are needed to diversify the LDBC participation.

3) Evaluate and improve upon the uncertainties associated with radiobioassay methodologies using the information obtained from these measurements: The LWCF was instrumental during 1996-97 in the historical research and development of the lung BEGe detectors. Currently, research efforts are continuing, with minimum resources and funding, to investigate and improve the lung detector sensitivities for the transuranic nuclides. These efforts are on par with international studies. More funding and resources are required.

CHAPTER 8

Analysis of Volatile Organic Compounds, Hydrogen and Methane

The WIPP Hazardous Waste Facility Permit (HWFP), Attachment N, (issued by the New Mexico Environment Department (NMED) under the Resource Conservation and Recovery Act (RCRA)) mandates the monitoring of volatile organic compound (VOC) emissions from mixed waste, that may be entrained in the exhaust air from the WIPP underground hazardous waste disposal units (HWDUs). The monitoring is conducted to assure that VOC concentrations do not exceed regulatory limits, during or after disposal. Ten target VOCs are actively monitored as they represent 99% risk to safety due to air emissions, and any other compounds consistently detected in air samples may be added to the list of compounds of interest. The HWFP, Attachment N1 describes the monitoring plan for hydrogen and methane (HM) generated from underground panels. This HM monitoring focuses on "filled" underground HWDUs that have not had an explosion-isolation wall installed.

VOC monitoring is conducted in accordance with the *"Volatile Organic Compound Monitoring Plan (WP 12-VC.01)",* prepared by the Nuclear Waste Partnership LLC (NWP), formerly Washington TRU Solutions (WTS). Hydrogen and Methane monitoring is performed in accordance with the *"Hydrogen and Methane Monitoring Plan (WP 12-VC.03)".* NWP personnel collect air samples in six-liter passivated canisters and are delivered for analysis to CEMRC in weekly batches.

CEMRC first began analysis of samples for the Confirmatory VOCs Monitoring Plan in April 2004. The program was established and successfully audited by the WTS QA group prior to acceptance of actual samples and has since been audited at yearly intervals. Initially, CEMRC had one 6890/5973 Hewlett Packard (now Agilent) gas chromatograph/mass spectrometer (GC/MS) which had previously been used by Los Alamos National Laboratory (LANL). Now, CEMRC uses an Entech 7100 Preconcentrator as the sample concentration and introduction system and an Entech 3100 Canister Cleaning System for cleaning and evacuation of canisters after analysis. Currently, underground samples are analyzed using a 6890/5975 GC/MS system and an Entech 7100 preconcentrator. In 2015, CEMRC purchased a new Agilent 7820/5977 GC/MS along with an Entech 7200/7016D preconcentrator/autosampler system for analysis of low-levels of VOCs. HM analysis is performed using a gas chromatograph/thermal conductivity detector.

In 2014, there were two incidents in the WIPP underground which affected the sampling of VOCs. The first incident was an underground fire on February 5, 2014, and the second was an underground radiological release on February 14, 2014. The last regular samples were taken on February 3, 2014. Following those incidents, the WIPP began collecting surface samples from February 26, 2014, to ensure that VOCs on the surface were well within regulatory limits and to

confirm that there was no seepage from the underground. VOC monitoring in disposal rooms resumed on December 19, 2016, prior to the January 4, 2017, re-start of waste emplacement.

As underground sampling was restarted in December 2016; CEMRC received these samples in January 2017. Since the CEMRC VOC lab is a clean lab, the underground samples, which are collected in radiologically contaminated areas, need to be free released prior to the canisters being delivered to the CEMRC. NWP uses filters in the flow path of the sample collection apparatus to reduce the potential amount of radioactive particles that could enter the sample canisters. The filters are sent for isotopic analysis to ensure the results are below MDL, and the exterior surface of the canisters are analyzed for any external or other dose contributors. Assessment filter samples must be below the MDL for the canisters to be released to CEMRC for VOC analysis. Due to the extra precautions and radiological analysis, canisters are delivered to CEMRC two to three weeks after the sample collection date. The CEMRC has thirty days from the sample collection date to complete the analysis.

Methods for Volatile Organic Compound Monitoring

Confirmatory VOCs Monitoring requires method detection limits in the low parts per billion volume (ppbv) range. This type of analysis requires preconcentration of a given volume of air into a much smaller volume prior to introduction into the GC column. In order to maintain the performance of the mass analyzer, most of the water vapor and carbon dioxide present in the air sample must be removed prior to analysis. The Entech 7100 Preconcentrator performs these tasks automatically by transferring the sample through three consecutive cryogenic traps at different controlled temperatures. This results in very low detection limits unattainable without cryogenic preconcentration.

Stock cylinders of Calibration Standard and Laboratory Control Sample gases are purchased certified from a reputable supplier and are then diluted to working concentrations with Ultra-High Purity (UHP) Nitrogen using the Entech 4600 Dynamic Diluter. Canisters are cleaned after sample analysis using the Entech 3100 Canister Cleaning system, which consists of a computerized control module with vacuum pumps and an oven containing a passivated manifold with fittings for connection of canisters. The control software initiates the cleaning of canisters by heating coupled with multiple pressurization/evacuation cycles. A blank sample is analyzed from each cleaning batch as a control to assure proper cleaning has been achieved.

Analyses for Volatile Organic Compound Monitoring were conducted under procedures using concepts of EPA Method TO-15 *"Determination of Volatile Organic Compounds (VOCs) in Air Collected in Specially-Prepared Canisters and Analyzed by Gas Chromatography/Mass Spectrometry (GC/MS)"* (1999).

Quality assurance requirements for these activities were detailed in the *"Quality Assurance Project Plan for Volatile Organic Compound Monitoring (WP 12-VC.02)"* prepared by NWP. CEMRC personnel wrote procedures for this project under the CEMRC Quality Assurance Plan, which were verified, validated, and placed in the CEMRC Document Control Program.

Procedures were composed to include QA requirements from EPA Method TO-15 and all WIPP documents relevant to the Confirmatory Monitoring Program. See Table 8-2 for a list of CEMRC Procedures for Confirmatory Monitoring.

In November 2006, a WIPP permit modification incorporated an expansion of sampling in the Volatile Organic Compounds Monitoring Program. Originally, the samples were collected from only two stations in the WIPP underground (VOC-A and VOC-B). The permit change requires sampling from closed rooms within the current panel until the entire panel is full. Therefore, Attachment N now refers to both Repository VOCs Monitoring and Disposal Room Monitoring.

Table 8-3 lists the ten permit specified target compounds and their required reporting limits for different types of samples. Trichloroethylene was an additionally requested compound at the start of 2014 but was made a target analyte based on an order from NMED in May 2014.

Method Modification for Analysis of Low-Levels of VOCs

The February 2014 incidents resulted in the stoppage of sample collection in the WIPP underground as a precaution. It was decided to continue the collection of surface samples to determine if there was any VOC seepage from the underground and to ensure worker safety.

CEMRC modified the regular VOC analysis method so as to analyze low-levels of VOCs. The regular method was based on a calibration range of 1 to 100 ppbv; the calibration range of the modified method is 0.2 to 10 ppbv. This ensured that sub-ppbv level VOCs can be accurately reported as the method reporting limit for undiluted samples was changed to 0.2 ppbv. The regular and modified methods are based on the GC/MS full scan mode, wherein, the system will monitor a range of masses to detect compound fragments within that range. This full scan mode is quite useful to monitor unknown compounds in a sample, but the major drawback is that it prevents the GC/MS system from being calibrated to a much lower range.

The CEMRC was tasked with developing a methodology for the analysis of target analytes in the pptv range using the Selected Ion Monitoring (SIM) GC/MS mode. SIM is a GC/MS scanning mode in which only a limited mass-to-charge ratio range is transmitted/detected by the instrument, as opposed to the full spectrum range. SIM increases sensitivity for target analytes through the selective detection of ions most indicative of the compounds of interest. The CEMRC has developed a low-level VOC analysis method using the SIM mode where the low calibration level is 50 pptv (0.05 ppbv) with MDLs less than 10 pptv. SIM mode is 10 to 100 times more sensitive than the full scan mode. The CEMRC has been analyzing surface samples using both SIM and full scan mode synchronously from December 2014.

Methods for Hydrogen and Methane Analysis

The HM analysis in closed room samples began in August 2007. Under the analysis scheme used at the CEMRC, sample canisters would be pressurized to twice the canister pressure (if not already received at above atmospheric pressure) by the addition of ultra-high purity nitrogen,

and then simultaneously analyzed for hydrogen and methane by a GC/Thermal Conductivity Detector (TCD) and screened for VOCs by GC/MS. The sampling system incorporates three auto-samplers in series to allow for the analysis of two complete batches of six 6 L samples per run. Samples from the auto-samplers pass through heated transfer lines into two injection loops attached to an automated valve for simultaneous injection into the GC. The VOC screening results are used to determine pre-analysis dilutions required for analysis by Method TO-15. The HM analysis results are reported in separate data packages from the VOCs results. Quality assurance requirements for these activities were detailed in the *"Quality Assurance Project Plan for Hydrogen and Methane Monitoring (WP 12-VC.04)"* prepared by NWP.

Laboratory Precision

Laboratory Control Sample (LCS) and LCS-duplicate are analyzed at a rate of once per batch, or once every ten samples, whichever is applicable, to verify instrument calibration and quantitative analytical accuracy. LCS is a standard that contains compounds of interest which have been prepared from a different source than that used to prepare the calibration standard. An LCS is the same as a spiked blank or blank spike. The LCS % recovery must be within $\pm$ 40% for all target and additional requested compounds. The relative percentage deviation (RPD) must be 25% or less for all target and additional requested compounds. The laboratory achieved the precision limit for all the target compounds. Figures 8-1 through 8-4 show examples of laboratory precision through LCS % recovery and RPD for the target analytes Carbon tetrachloride and Trichloroethylene using the low-level in SIM and regular Scan modes respectively. Percent recovery for LCS analysis is used to assess laboratory accuracy by NWP. As per the statement of work, NWP tracks RPD through these charts to ascertain any sample matrix effects on analytical precision.

Sample Analysis and Reporting

The OC lab analyzed a total of 234 surface and 46 underground samples in 2017 using GC/MS regular and low-level methods. All of the samples were analyzed and reported in a timely manner under an extensive quality assurance (QA) / quality control (QC) program. All of these samples achieved 100% completeness.

Table 8-1 shows the number of VOC and HM samples processed from 2005 to 2017. It is important to note that the CEMRC has not received any HM samples since the 2014 fire and radiation release incidents.

Table 8-1: Number of VOC and HM samples processed 2005 – 2017

Year	VOC Samples	HM Samples
2005	353	0
2006	430	0
2007	749	182
2008	608	254
2009	571	339
2010	711	441
2011	615	398
2012	559	376
2013	709	360
2014	342	46
2015	253	0
2016	233	0
2017	280	0

The OC lab also received a number of canisters for cleaning and certification at various times throughout the year. All of the canisters were cleaned and certified with appropriate QA/QC in place. The requirements for analysis of low-levels of VOCs made it necessary to clean and certify every canister and Passive Air Sampling Kit (PASK) to ensure that the VOC levels were well below the MRL. In 2017, CEMRC cleaned 279 canisters and 249 PASKs, and all these were individually certified using low-level GC/MS SIM/scan method.

Batch reports for VOCs results are submitted in hardcopy in the EPA Contract Laboratory Program format. An electronic report in the client's specified format is also provided for each batch. Hardcopy and electronic reports for hydrogen and methane analyses are submitted in the formats specified by the client. Copies of batch reports and all QA records associated with these analyses are maintained according to the CEMRC records management policies, detailed in the QAP.

No Hydrogen/Methane samples were analyzed in 2017.

Laboratory Proficiency Testing Plan

In January 2016, the New Mexico Environment Department (NMED) approved a Permit modification that incorporated the use of ambient air sampling for VOCs at the WIPP. The April 2016, Class 1 Permit modification revised Permit, Part 4.6.2.1 and Attachment N, Section N-5e adding an option for proficiency testing (PT). The Permit now requires that NWP develop and implement a Laboratory Performance Evaluation Plan or participate in PT for the Repository Volatile Organic Compound Monitoring Program. On May 2, 2016, the Permittees notified NMED of the intention to require the CEMRC to participate in PT. This plan addresses the requirements in Permit Attachment N, Section N-5e for PT.

NWP/CEMRC identified low-level PT provided by Battelle Inc. which is contracted directly to the EPA. This PT program is part of the National Air Toxics Trends Station (NATTS) Program which monitors low-level VOCs in ambient air across the United States CEMRC is responsible for initiating and maintaining participation in the PT program.

In accordance with this requirement, the CEMRC participated in two proficiency tests in 2017. Only six of the ten WIPP target compounds were in the PT canisters. In the first PT performed, three of the compounds failed PT, whereas in the following PT all compounds were within acceptable criteria.

Conclusions

Due to the proprietary nature of the VOC data, none are reported herein, and any requests for data are to be directed to NWP. The CEMRC cannot provide VOC data without written permission from NWP. The success of the VOCs Monitoring Program and the successful external audits demonstrate CEMRC's ability to initiate new programs to successfully perform regulatory monitoring tasks in accordance with specific QA/QC requirements.

The CEMRC participated in proficiency testing as set forth by NMED and NWP. CEMRC also underwent an extensive external audit in October 2017. As there were no findings during the audit, it showed that the CEMRC has performed in accordance with contractual, regulatory, programmatic, and procedural requirements.

Presently, the CEMRC has the capability to analyze over 2,000 VOC and hydrogen/methane samples per year. CEMRC has the instrumentation and facilities to analyze air samples for VOCs from and around Carlsbad which might be affected due to the increasing mining, oil and gas industries.

Table 8-2: CEMRC Procedures for Volatile Organic Compounds and Hydrogen/Methane Monitoring Program

Procedure Number	Procedure Title
OC-PLAN-001	Quality Assurance Project Plan for Analysis of Volatile Organic Compounds and/or Hydrogen and Methane in Canister Samples
OC-PROC-002	Preparation of Canisters and Sample Trains for Ambient Air Sampling
OC-PROC-003	Gas Chromatography-Mass Spectrometry Analysis of Volatile Organic Compounds (VOCs) in Ambient Air from Canisters at ppbv/pptv Concentration Levels
OC-PROC-004	Preparation of Calibration Standards in Specially Prepared Canisters for Analysis by Gas Chromatography/Mass Spectrometry
OC-PROC-005	Data Validation and Reporting of Volatile Organic Compounds from Gas Chromatography/Mass Spectrometry Analysis of Ambient Air in Canisters for the WIPP Volatile Organic Compound Monitoring Plan
OC-PROC-006	Receipt, Control, and Storage of Gas Samples in Passivated Canisters
OC-PROC-009	Analysis of Hydrogen and Methane in Passivated Canisters Using Gas Chromatography with Thermal Conductivity Detection

Table 8-3: Compounds of Interest for WIPP Confirmatory Volatile Organic Compounds Monitoring Program

Compound	Required Repository Surface Monitoring MRL for SIM mode (ppbv)	Required Repository Surface Monitoring MRL for SCAN mode (ppbv)	Required Disposal Room MRL (ppbv)
1,1-Dichloroethylene	0.1	0.2	500
Carbon tetrachloride	0.1	0.2	500
Methylene chloride	0.1	0.2	500
Chloroform	0.1	0.2	500
1,1,2,2-Tetrachloroethane	0.1	0.2	500
1,1,1-Trichloroethane	0.1	0.2	500
Chlorobenzene	0.1	0.2	500
1,2-Dichloroethane	0.1	0.2	500
Toluene	0.1	0.2	500
Trichloroethylene	0.1	0.2	500

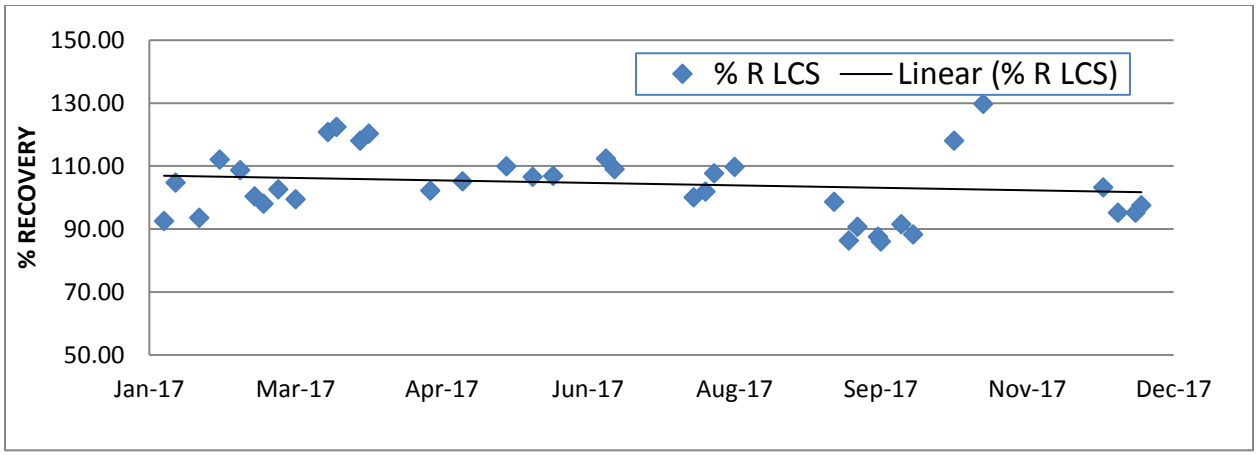


Figure 8-1: Percent Recovery of Carbon Tetrachloride in LCS (Recovery range: 60-140%) using low-level GC/MS SIM mode

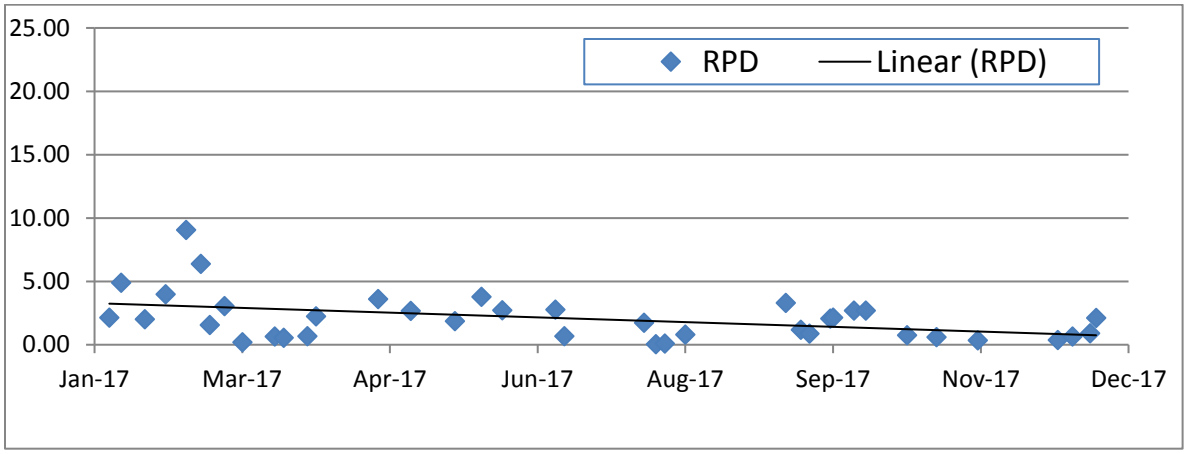


Figure 8-2: Relative Percent Deviation (RPD) between LCS and LCS-Duplicate for Carbon Tetrachloride (RPD range: 25%) using low-level GC/MS SIM mode.

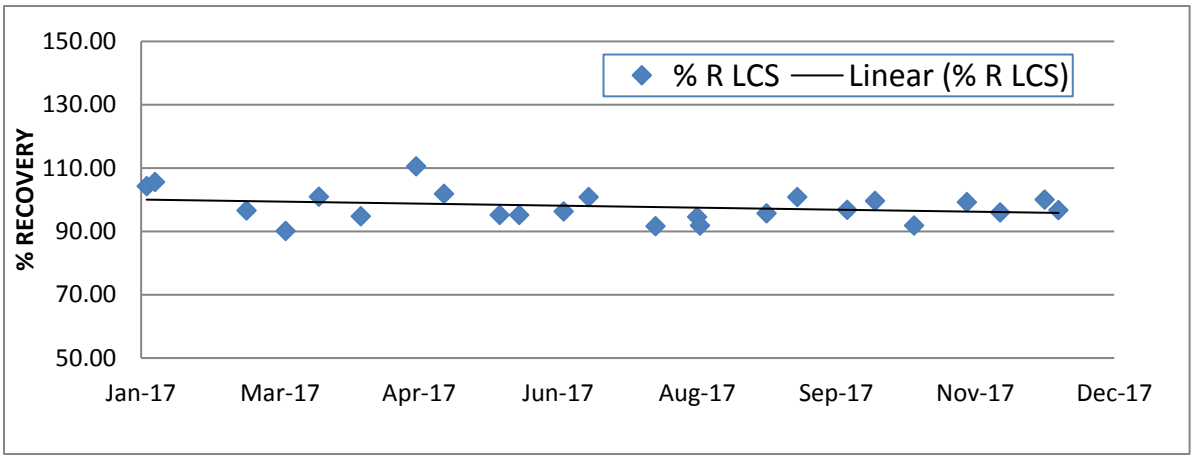


Figure 8-3: Percent Recovery of Trichloroethylene in LCS (Recovery range: 60-140%) using regular GC/MS scan mode.

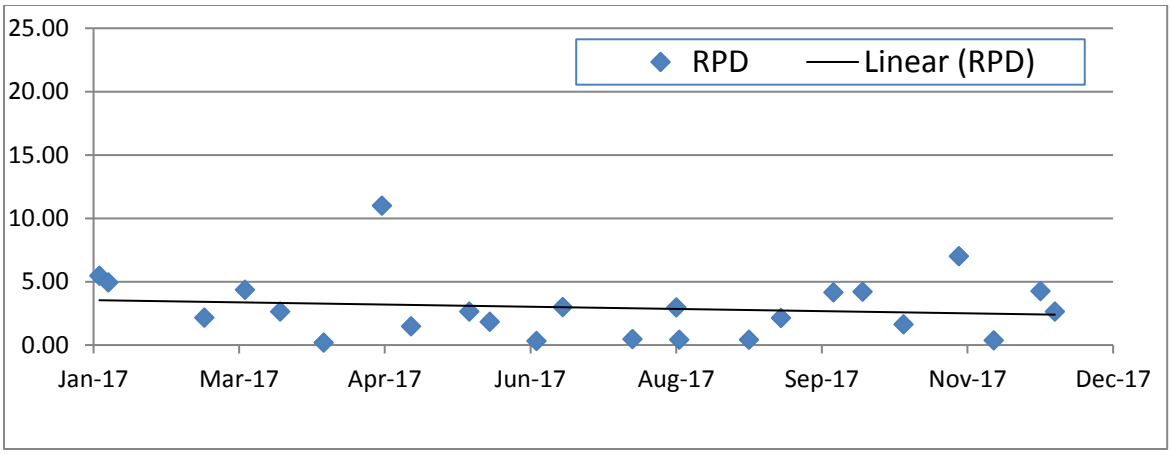


Figure 8-4: Relative Percent Deviation (RPD) between LCS and LCS-Duplicate for Trichloroethylene (RPD range: 25%) using regular GC/MS scan mode.

CHAPTER 9

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, meaning that it operates without any compliance, regulatory, or oversight responsibilities. As such, there are no specific requirements for reporting data other than following 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, through the use of American Chemical Society certified reagents, through the use of National Institute of Standards and Technology (NIST) traceable radionuclide solutions and through 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, Figures 9-1 thru 9-4. 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 five days were used as a background history for calculating results. Analytical data were verified and validated as required by project-specific quality objectives before being used to support decision making.

The CEMRC also participates in the two national performance evaluation programs, NIST Radiochemistry Inter-comparison Program (NIST-RIP) (Figure 9-5) and the DOE-Mixed-Analyte Performance Evaluation Program (MAPEP) (Figure 9-6) 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 2016, CEMRC radio-analytical program analyzed MAPEP- air filter, water, soil, gross alpha/beta on air filters & water and unknown sample matrix 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, ^{244}Cm 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 are presented in this annual report. All analysis results except for ^{134}Cs for MAPEP soil and ^{234}U for NIST soil and air filter were deemed unacceptable. 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.

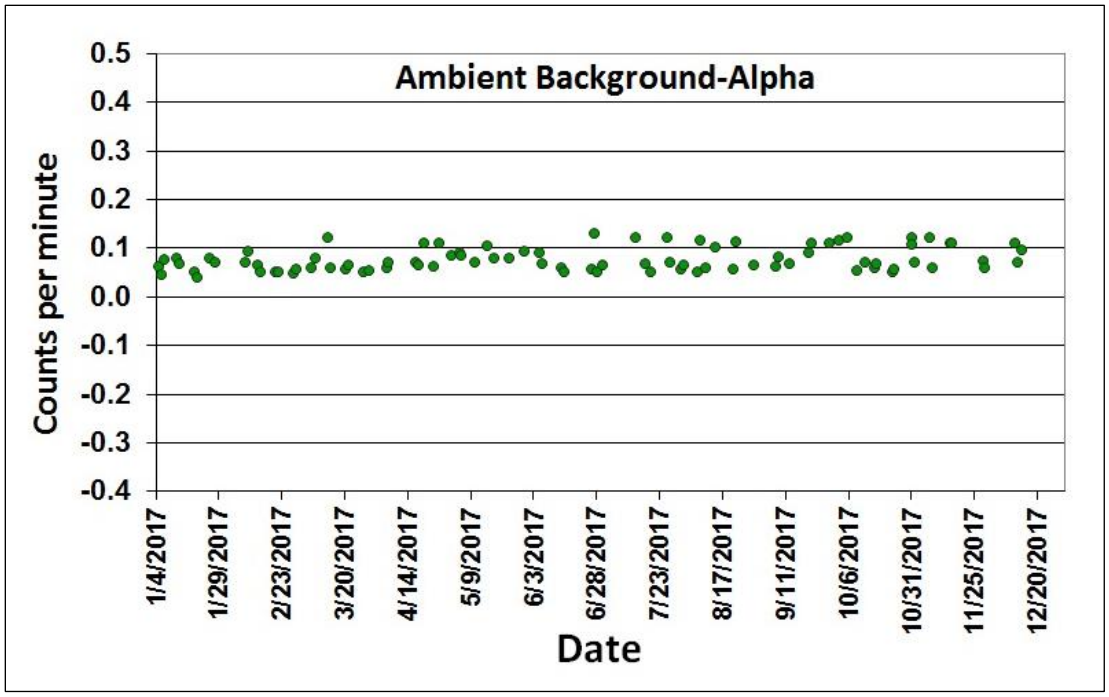


Figure 9-1: Sixty Minutes Alpha Ambient Background Count for the PIC-MPC 9604 Gross Alpha and Beta

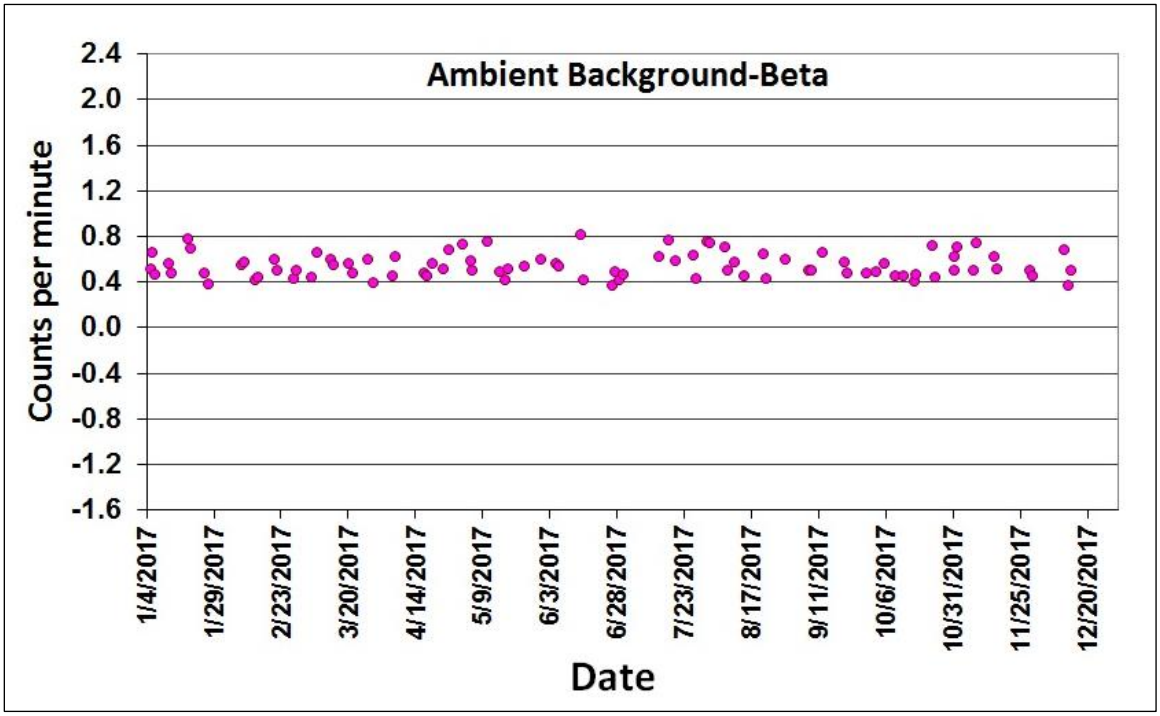


Figure 9-2: Sixty Minutes Beta Ambient Background Count for PICMPC 9604 Gross Alpha and Beta Counter

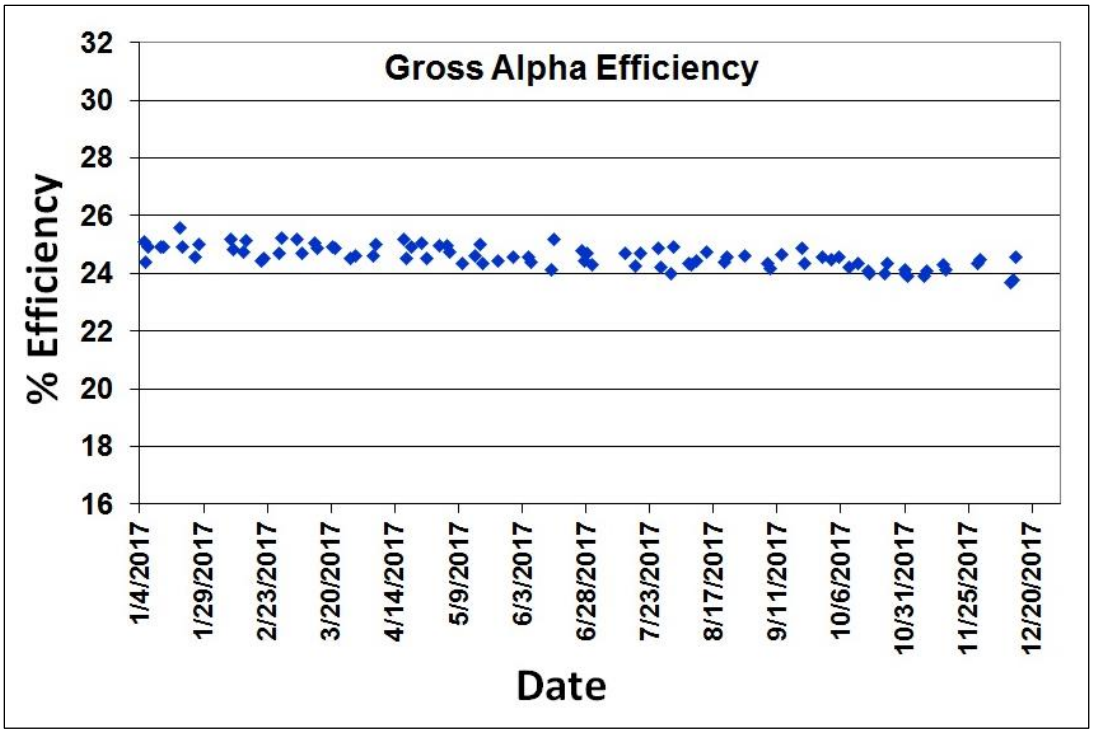


Figure 9-3: Control Chart of Daily Alpha Efficiency of the PICMPC 9604 Gross Alpha and Beta Counter

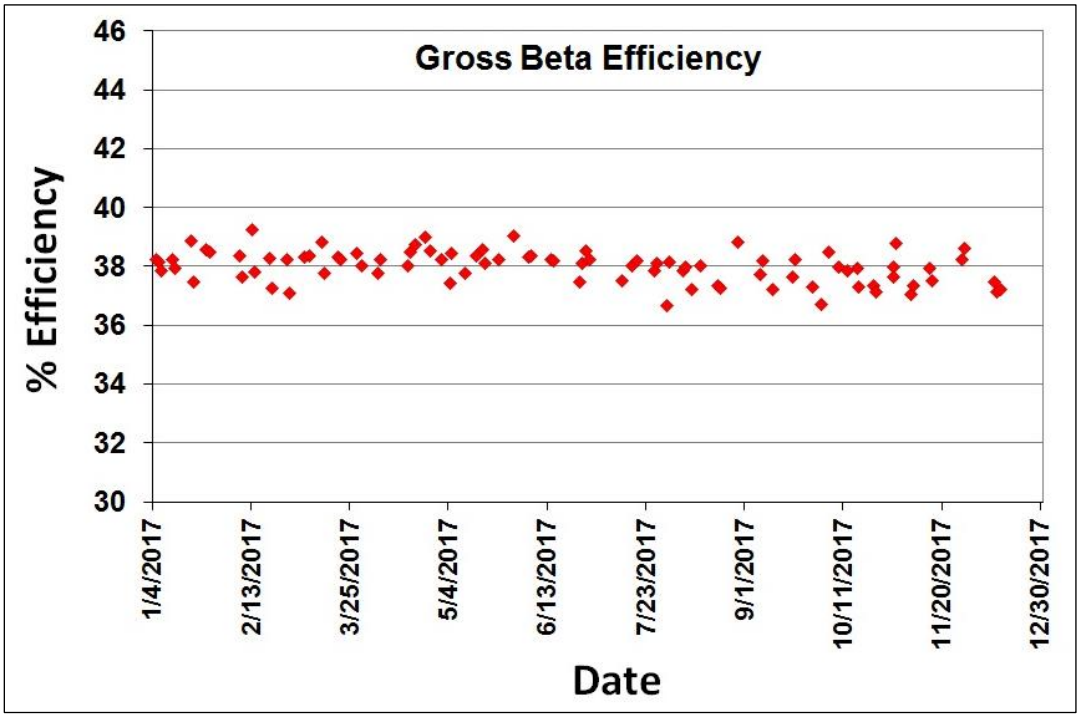


Figure 9-4: Control Chart of Daily Beta Efficiency of the PIC-MPC 9604 Gross Alpha and Beta Counter

U.S. DEPARTMENT OF COMMERCE

National Institute of Standards and Technology
Gaithersburg, MD

REPORT OF TRACEABILITY

Carlsbad Environmental Monitoring and Research Center
Carlsbad, NM

Test Identification: NRIP'17-AF
Matrix Description: ^{60}Co, ^{90}Sr, ^{137}Cs, ^{230}Th, ^{234}U, ^{235}U, ^{238}U, ^{237}Np, ^{238}Pu, ^{239}Pu, and ^{241}Am on Glass-Fiber Filters[1]
Test Activity Range: 0.02 Bq•sample^{-1} to 250 Bq•sample^{-1}
Reference Time: 12:00 EST, April 1, 2017

Measurement Results

Nuclide	NIST Value [2,3]		Reported Value[4]		Difference[5]
	Massic Activity Bq•g^{-1}	Relative Expanded Uncertainty (%, k=2)	Massic Activity Bq•g^{-1}	Relative Expanded Uncertainty (%, k=2)	(±% Bias)
^{60}Co	298.4	0.62	301.6	14.6	1.1
^{137}Cs	785.1	0.79	808.7	15.7	3.0
^{234}U	3.56	1.00	4.05	13.6	13.6
^{235}U	0.170	0.65	0.181	26.8	6.4
^{238}U	3.70	0.63	3.61	13.7	-2.4
^{238}Pu	2.73	0.71	2.60	13.1	-4.5
^{239}Pu	2.34	0.71	2.30	13.2	-1.7
^{241}Am	2.62	0.33	2.57	14.6	-1.8

Methods

	NIST[6]	Reporting Laboratory[7]
Activity Measurements	Alpha- and Beta-Spectrometry Mass Spectrometry	Alpha and Gamma Spectrometry

Evaluation (per ANSI N42.22)

Nuclide	ANSI N42.22 Traceable[8]	Traceability Limit (%)
^{60}Co	Yes	22
^{137}Cs	Yes	24
^{234}U	Yes	23
^{235}U	Yes	43

Nuclide	ANSI N42.22 Traceable[8]	Traceability Limit (%)
^{238}U	Yes	20
^{238}Pu	Yes	19
^{239}Pu	Yes	20
^{241}Am	Yes	22

Samples Distributed 04 December 2017
Reporting Data Received 30 January 2018

For the Director

Brian E. Zimmerman, Acting Group Leader
Radioactivity Group
Physical Measurement Laboratory
(continued)

Figure 9-5: Participation in 2017-NIST Radiochemistry Intercomparison Program

U.S. DEPARTMENT OF COMMERCE

National Institute of Standards and Technology
Gaithersburg, MD

REPORT OF TRACEABILITY

Carlsbad Environmental Monitoring and Research Center, Carlsbad, NM

Test Identification	NRIP'17-AW
Matrix Description	^{60}Co, ^{90}Sr, ^{137}Cs, ^{230}Th, ^{234}U, ^{235}U, ^{238}U, ^{237}Np, ^{238}Pu, ^{239}Pu, and ^{241}Am in acidified water[1]
Test Activity Range	0.01 Bq•sample^{-1} to 50 Bq•sample^{-1}
Reference Time	12:00 EST, April 1, 2017

Measurement Results

Nuclide	NIST Value [2,3]		Reported Value[4]		Difference[5]
	Massic Activity Bq•g^{-1}	Relative Expanded Uncertainty (%, k=2)	Massic Activity Bq•g^{-1}	Relative Expanded Uncertainty (%, k=2)	(%)
^{60}Co	298.4	0.62	300.5	15.0	0.7
^{137}Cs	785.1	0.79	826.1	16.2	5.2
^{234}U	3.56	1.00	4.35	15.4	22.3
^{235}U	0.170	0.65	0.193	47.0	13.3
^{238}U	3.70	0.63	3.46	16.0	-6.3
^{238}Pu	2.73	0.71	2.67	15.2	-2.2
^{239}Pu	2.34	0.71	2.32	15.6	-0.7
^{241}Am	2.62	0.33	2.40	16.8	-8.5

Methods

	NIST[6]	Reporting Laboratory[7]
Activity Measurements	Alpha-, Beta-, Gamma-Spectrometry Mass Spectrometry	Alpha-, Gamma-Spectrometry

Evaluation (per ANSI N42.22)

Nuclide	ANSI N42.22 Traceable[8]	Traceability Limit (%)
^{60}Co	Yes	23
^{137}Cs	Yes	26
^{234}U	Yes	28
^{235}U	Yes	80

Nuclide	ANSI N42.22 Traceable[8]	Traceability Limit (%)
^{238}U	Yes	22
^{238}Pu	Yes	22
^{239}Pu	Yes	23
^{241}Am	Yes	23

Samples Distributed 4 December 2017
Reporting Data Received 30 January 2018

For the Director

Brian E. Zimmerman, Acting Group Leader
Radioactivity Group
Physical Measurement Laboratory
(continued)

Figure 9-5: Participation in 2017-NIST Radiochemistry Intercomparison Program (continued)

U.S. DEPARTMENT OF COMMERCE

National Institute of Standards and Technology
Gaithersburg, MD

REPORT OF TRACEABILITY

Carlsbad Environmental Monitoring and Research Center,
Carlsbad, NM

Test Identification NRIP'17-SS
Test Radionuclides ^{60}Co, ^{90}Sr, ^{137}Cs, ^{230}Th, ^{234}U, ^{235}U, ^{238}U, ^{237}Np, ^{238}Pu, ^{239}Pu, and ^{241}Am in soil[1]
Test Activity Range 0.01 Bq•sample^{-1} to 250 Bq•sample^{-1}
Reference Time 12:00 EST, April 1, 2017

Measurement Results

Nuclide	NIST Value [2,3]		Reported Value[4]		Difference[5]
	Massic Activity Bq•g^{-1}	Relative Expanded Uncertainty (%, k=2)	Massic Activity Bq•g^{-1}	Relative Expanded Uncertainty (%, k=2)	(%)
^{60}Co	298.4	0.62	303.5	15.9	1.7
^{137}Cs	785.1	0.79	806.7	15.9	2.8
^{234}U	3.56	1.00	5.30	13.5	49.0
^{235}U	0.170	0.65	0.235	24.1	38.0
^{238}U	3.70	0.63	4.28	13.6	15.7
^{238}Pu	2.73	0.71	2.50	14.3	-8.3
^{239}Pu	2.34	0.71	2.38	14.4	1.8
^{241}Am	2.62	0.33	2.37	15.1	-9.4

Methods

Activity Measurements	NIST[6]	Reporting Laboratory[7]
	Alpha-, Beta-, Gamma-Spectrometry, Mass Spectrometry	Alpha- and Gamma-Spectrometry

Evaluation (per ANSI N42.22)

Nuclide	ANSI N42.22 Traceable[8]	Traceability Limit (%)
^{60}Co	Yes	24
^{137}Cs	Yes	24
^{234}U	No	30
^{235}U	Yes	50

Nuclide	ANSI N42.22 Traceable[8]	Traceability Limit (%)
^{238}U	Yes	24
^{238}Pu	Yes	20
^{239}Pu	Yes	22
^{241}Am	Yes	20

Samples Distributed 4 December 2017
Reporting Data Received 30 January 2018

For the Director

Brian E. Zimmerman, Acting Group Leader
Radioactivity Group
Physical Measurement Laboratory
(continued)

Figure 9-5: Participation in 2017-NIST Radiochemistry Intercomparison Program (continued)

MAPEP Mixed Analyte Performance Evaluation Program

Department of Energy RESL - 1955 Fremont Ave, MS4149 - Idaho Falls, ID 83415

Laboratory Results For MAPEP-17-XrM37

(CMRC01) Carlsbad Environmental Monitoring and Research Center
1400 University Dr.
Carlsbad, NM 88220

Radiological

Sample ID	Nuclide	Known Activity	Experimental Activity	Bias (%)
MAPEP-17-XrM37	Am-241	0.155 +/- 0.004 Bq/sample	0.142 +/- 0.0303 Bq/sample	-8.4
MAPEP-17-XrM37	Cs-134	1.52 +/- 0.03 Bq/sample		
MAPEP-17-XrM37	Cs-137	2.05 +/- 0.03 Bq/sample		
MAPEP-17-XrM37	Co-57	3.16 +/- 0.06 Bq/sample		
MAPEP-17-XrM37	Co-60	1.26 +/- 0.03 Bq/sample		
MAPEP-17-XrM37	Cm-244	0.130 +/- 0.002 Bq/sample		
MAPEP-17-XrM37	Mn-54	0.76 +/- 0.02 Bq/sample		
MAPEP-17-XrM37	Pu-238	0.180 +/- 0.004 Bq/sample	0.189 +/- 0.0437 Bq/sample	5.0
MAPEP-17-XrM37	Pu-239	0.234 +/- 0.005 Bq/sample	0.233 +/- 0.0532 Bq/sample	-0.4
MAPEP-17-XrM37	Sr-90	0.88 +/- 0.02 Bq/sample		
MAPEP-17-XrM37	Tc-99	1.11 +/- 0.03 Bq/sample		
MAPEP-17-XrM37	U-234	0.0207 +/- 0.0008 Bq/sample	0.0223 +/- 0.0054 Bq/sample	7.7
MAPEP-17-XrM37	U-235	0.00183 +/- 0.00005 Bq/sample	0.0017 +/- 0.00133 Bq/sample	-7.1
MAPEP-17-XrM37	U-238	0.146 +/- 0.005 Bq/sample	0.154 +/- 0.0264 Bq/sample	5.5
MAPEP-17-XrM37	Zn-65	0.64 +/- 0.02 Bq/sample		

Radiological Reference Date: August 1, 2017

Issued 11/28/2017 Printed 11/29/2017

Figure 9-6: Radiochemistry MAPEP 2017 Inter-comparison Results

MAPEP Mixed Analyte Performance Evaluation Program

Department of Energy RESL - 1955 Fremont Ave, MS4149 - Idaho Falls, ID 83415

Laboratory Results For MAPEP-17-MaS37

(CMRC01) Carlsbad Environmental Monitoring and Research Center
1400 University Dr.
Carlsbad, NM 88220

Inorganic								Units: (mg/kg)
Analyte	Result	Ref Value	Flag	Notes	Bias (%)	Acceptance Range	Unc Value	Unc Flag
Antimony	NR	24.1				16.9 - 31.3		
Arsenic	NR	77.1				54.0 - 100.2		
Barium	NR	248				174 - 322		
Beryllium	NR	32.0				22.4 - 41.6		
Cadmium	NR	16.8				11.8 - 21.8		
Chromium	NR	52.3				36.6 - 68.0		
Cobalt	NR	17.2				12.0 - 22.4		
Copper	NR	264				185 - 343		
Lead	NR	52.0				36.4 - 67.6		
Mercury	NR	0.158				0.111 - 0.205		
Nickel	NR	117				82 - 152		
Selenium	NR	10.3				7.2 - 13.4		
Silver	NR	92.3				64.6 - 120.0		
Technetium-99	NR	1.91E-3				0.00134 - 0.00248		
Thallium	NR	128				90 - 166		
Uranium-235	NR	0.0534				0.0374 - 0.0694		
Uranium-238	NR	17.6				12.3 - 22.9		
Uranium-Total	NR	17.7				12.4 - 23.0		
Vanadium	NR	240				168 - 312		
Zinc	NR	283				198 - 368		

Radiological								Units: (Bq/kg)
Analyte	Result	Ref Value	Flag	Notes	Bias (%)	Acceptance Range	Unc Value	Unc Flag
Americium-241	5.35E+01	58.8	A		-9.0	41.2 - 76.4	6.43	A
Cesium-134	4.37E+02	448	A		-2.5	314 - 582	1.05	A
Cesium-137	7.86E+02	722	A		8.9	505 - 939	2.97	A
Cobalt-57	1.50E+03	1458	A		2.9	1021 - 1895	4.91	A
Cobalt-60	1.65E-01		A			False Positive Test	5.74E-01	
Iron-55	NR	1010				707 - 1313		
Manganese-54	8.79E+02	825	A		6.5	578 - 1073	2.50	A
Nickel-63	NR	1220				854 - 1586		
Plutonium-238	1.07E+02	92	A		16.3	64 - 120	1.03	A
Plutonium-239/240	7.61E+01	68.8	A		10.6	48.2 - 89.4	7.45	A
Potassium-40	5.78E+02	592	A		-2.4	414 - 770	6.01	A
Strontium-90	NR	289				202 - 376		
Technetium-99	NR	1195				837 - 1554		

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Figure 9-6: Radiochemistry MAPEP 2017 Inter-comparison Results (continued)

Radiological								Units: (Bq/kg)
Analyte	Result	Ref Value	Flag	Notes	Bias (%)	Acceptance Range	Unc Value	Unc Flag
Uranium-234/233	7.23E+01	69	A		4.8	48 - 90	4.72	A
Uranium-238	1.81E+02	219	A		-17.4	153 - 285	1.18	A
Zinc-65	6.31E+02	559	A		12.9	391 - 727	1.95	A

Radiological Reference Date: August 1, 2017

Results Flags:

A = Result acceptable Bias <=20%

W = Result acceptable with warning 20% < Bias < 30%

N = Result not acceptable Bias > 30%

RW = Report Warning

NR = Not Reported

Uncertainty Flags:

NOT ACCEPTABLE.....RP<2%

ACCEPTABLE.....2%<=RP<=15%

ACCEPTABLE WITH WARNING.....15%<RP<=30%

NOT ACCEPTABLE.....RP>30%

RP = Relative Precision

Issued 11/28/2017 Printed 11/29/2017

Figure 9-6: Radiochemistry MAPEP 2017 Inter-comparison Results (continued)

MAPEP Mixed Analyte Performance Evaluation Program

Department of Energy RESL - 1955 Fremont Ave, MS4149 - Idaho Falls, ID 83415

Laboratory Results For MAPEP-17-MaW37

(CMRC01) Carlsbad Environmental Monitoring and Research Center
1400 University Dr.
Carlsbad, NM 88220

Inorganic								Units: (mg/L)
Analyte	Result	Ref Value	Flag	Notes	Bias (%)	Acceptance Range	Unc Value	Unc Flag
Antimony	NR	18.7				13.1 - 24.3		
Arsenic	NR	0.965				0.676 - 1.255		
Barium	NR	18.0				12.6 - 23.4		
Beryllium	NR	1.80				1.26 - 2.34		
Cadmium	NR					False Positive Test		
Chromium	NR	1.08				0.76 - 1.40		
Cobalt	NR	11.3				7.9 - 14.7		
Copper	NR	18.9				13.2 - 24.6		
Lead	NR	0.898				0.629 - 1.167		
Mercury	NR					False Positive Test		
Nickel	NR	10.1				7.1 - 13.1		
Selenium	NR	0.131				0.092 - 0.170		
Technetium-99	NR	1.07E-5				7.50E-6 - 1.39E-5		
Thallium	NR	3.64				2.55 - 4.73		
Uranium-235	NR	0.000590				4.13E-4 - 7.67E-4		
Uranium-238	NR	0.0836				0.0585 - 0.1087		
Uranium-Total	NR	0.0842				0.0589 - 0.1095		
Vanadium	NR	6.00				4.20 - 7.80		
Zinc	NR	8.08				5.66 - 10.50		

Radiological								Units: (Bq/L)
Analyte	Result	Ref Value	Flag	Notes	Bias (%)	Acceptance Range	Unc Value	Unc Flag
Americium-241	8.34E-01	0.892	A		-6.5	0.624 - 1.160	5.48E-02	A
Cesium-134	1.12E+01	11.5	A		-2.6	8.1 - 15.0	4.38E-01	A
Cesium-137	1.64E+01	16.3	A		0.6	11.4 - 21.2	8.09E-01	A
Cobalt-57	1.12E+01	12.1	A		-7.4	8.5 - 15.7	4.18E-01	A
Cobalt-60	9.88E+00	10.7	A		-7.7	7.5 - 13.9	3.64E-01	A
Hydrogen-3	NR	258				181 - 335		
Iron-55	NR	19.4				13.6 - 25.2		
Manganese-54	1.50E+01	14.9	A		0.7	10.4 - 19.4	6.55E-01	A
Nickel-63	NR					False Positive Test		
Plutonium-238	5.59E-01	0.603	A		-7.3	0.422 - 0.784	3.89E-02	A
Plutonium-239/240	7.20E-01	0.781	A		-7.8	0.547 - 1.015	4.91E-02	A
Potassium-40	4.55E+00		A			False Positive Test	2.44	
Radium-226	NR	0.858				0.601 - 1.115		
Strontium-90	NR	7.77				5.44 - 10.10		

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Figure 9-6: Radiochemistry MAPEP 2017 Inter-comparison Results (continued)

Radiological								Units: (Bq/L)
Analyte	Result	Ref Value	Flag	Notes	Bias (%)	Acceptance Range	Unc Value	Unc Flag
Technetium-99	NR	6.73				4.71 - 8.75		
Uranium-234/233	9.82E-01	1.01	A		-2.8	0.71 - 1.31	7.65E-02	A
Uranium-238	9.88E-01	1.04	A		-5.0	0.73 - 1.35	7.68E-02	A
Zinc-65	1.73E+01	15.5	A		11.6	10.9 - 20.2	1.23	A

Radiological Reference Date: August 1, 2017

Result Flags:

A = Result acceptable Bias <=20%

W = Result acceptable with warning 20% < Bias < 30%

N = Result not acceptable Bias > 30%

RW = Report Warning

NR = Not Reported

Uncertainty Flags:

NOT ACCEPTABLE.....RP<2%

ACCEPTABLE.....2%<=RP<=15%

ACCEPTABLE WITH WARNING.....15%<RP<=30%

NOT ACCEPTABLE.....RP>30%

RP = Relative Precision

Issued 11/28/2017 Printed 11/29/2017

Figure 9-6: Radiochemistry MAPEP 2017 Inter-comparison Results (continued)

MAPEP Mixed Analyte Performance Evaluation Program

Department of Energy RESL - 1955 Fremont Ave, MS4149 - Idaho Falls, ID 83415

Laboratory Results For MAPEP-17-RdF37

(CMRC01) Carlsbad Environmental Monitoring and Research Center
1400 University Dr.
Carlsbad, NM 88220

Inorganic								Units: (ug/sample)
Analyte	Result	Ref Value	Flag	Notes	Bias (%)	Acceptance Range	Unc Value	Unc Flag
Uranium-235	NR	0.0507				0.0355 - 0.0659		
Uranium-238	NR	7.00				4.90 - 9.10		
Uranium-Total	NR	7.05				4.94 - 9.17		

Radiological								Units: (Bq/sample)
Analyte	Result	Ref Value	Flag	Notes	Bias (%)	Acceptance Range	Unc Value	Unc Flag
Americium-241	5.75E-02	0.0612	A		-6.0	0.0428 - 0.0796	4.59E-03	A
Cesium-134	9.61E-01	1.00	A		-3.9	0.70 - 1.30	4.83E-02	A
Cesium-137	8.38E-01	0.82	A		2.2	0.57 - 1.07	6.56E-02	A
Cobalt-57	1.24E-02		A			False Positive Test	1.68E-02	
Cobalt-60	6.40E-01	0.68	A		-5.9	0.48 - 0.88	3.60E-02	A
Manganese-54	1.32E+00	1.30	A		1.5	0.91 - 1.69	7.57E-02	A
Plutonium-238	3.19E-02	0.0298	A		7.0	0.0209 - 0.0387	2.82E-03	A
Plutonium-239/240	4.46E-02	0.0468	A		-4.7	0.0328 - 0.0608	3.65E-03	A
Strontium-90	NR	0.801				0.561 - 1.041		
Uranium-234/233	8.78E-02	0.084	A		4.5	0.059 - 0.109	6.77E-03	A
Uranium-238	8.70E-02	0.087	A		0.0	0.061 - 0.113	6.72E-03	A
Zinc-65	1.31E+00	1.08	W		21.3	0.76 - 1.40	1.25E-01	A

Radiological Reference Date: August 1, 2017

Result Flags:

A = Result acceptable Bias <=20%

W = Result acceptable with warning 20% < Bias < 30%

N = Result not acceptable Bias > 30%

RW = Report Warning

NR = Not Reported

Uncertainty Flags:

NOT ACCEPTABLE.....RP<2%

ACCEPTABLE.....2%<=RP<=15%

ACCEPTABLE WITH WARNING.....15%<RP<=30%

Issued 11/28/2017 Printed 11/29/2017

Figure 9-6: Radiochemistry MAPEP 2017 Inter-comparison Results (continued)

Radiological								Units: (Bq/sample)
Analyte	Result	Ref Value	Flag	Notes	Bias (%)	Acceptance Range	Unc Value	Unc Flag
NOT ACCEPTABLE.....RP>30%								

Issued 11/28/2017 Printed 11/29/2017

Figure 9-6: Radiochemistry MAPEP 2017 Inter-comparison Results (continued)

Department of Energy RESL - 1955 Fremont Ave, MS4149 - Idaho Falls, ID 83415

Laboratory Results For MAPEP-17-ScR37

(CMRC01) Carlsbad Environmental Monitoring and Research Center
1400 University Dr.
Carlsbad, NM 88220

Radiological

Sample ID	Nuclide	Known Activity	Experimental Activity	Bias (%)
MAPEP-17-ScR37	Screen alpha	0.74 +/- 0.04 Bq/L	0.8771 +/- 0.6139 Bq/L	18.5
MAPEP-17-ScR37	Screen beta/gamma	3.06 +/- 0.14 Bq/L	3.087 +/- 0.494 Bq/L	0.9

Radiological Reference Date: August 1, 2017

Issued 11/28/2017 Printed 11/29/2017

Figure 9-6: Radiochemistry MAPEP 2017 Inter-comparison Results (continued)

Table 9-1: Examples of the Daily Performance Tests
ICP-MS, Elan DRC-e

	Acceptable Ranges		05/16/2017			11/09/2017		
	Criteria for Net Intensity Mean of 5 replicate readings	Required Relative Standard Deviation (%)	Measured Intensity Mean	Relative Standard Deviation	Performance Evaluation	Measured Mean Intensity	Relative Standard Deviation	Performance Evaluation
Be	>1,000	0.0 - 5.0%	6,624.2	3.9	Acceptable	8,130.8	3.4	Acceptable
Mg	>40,000	0.0 - 5.0%	68,893.8	4.3	Acceptable	99,694.0	3.6	Acceptable
In	>250,000	0.0 - 5.0%	392,811.6	2.3	Acceptable	449,875.9	1.7	Acceptable
Pb	>100,000	0.0 - 5.0%	201,667.1	1.2	Acceptable	273,300.3	1.6	Acceptable
Ce	<900,000	0.0 - 5.0%	436,861.9	2.1	Acceptable	480,684.3	1.4	Acceptable
CeO	≤3.0%	N/A	2.8%	N/A	Acceptable	3.0%	N/A	Acceptable
Ba	<900,000	0.0 - 5.0%	352,632.1	1.9	Acceptable	386,784.9	1.7	Acceptable
Ba++	≤3.0%	N/A	1.6%	N/A	Acceptable	1.9%	N/A	Acceptable
Bkgd	≤10.0	N/A	0.8	N/A	Acceptable	1.0	N/A	Acceptable

ERA
A Waters Company

WS-249 2009 TNI Evaluation Final Complete Report

Adrienne Chancellor
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1400 University Dr
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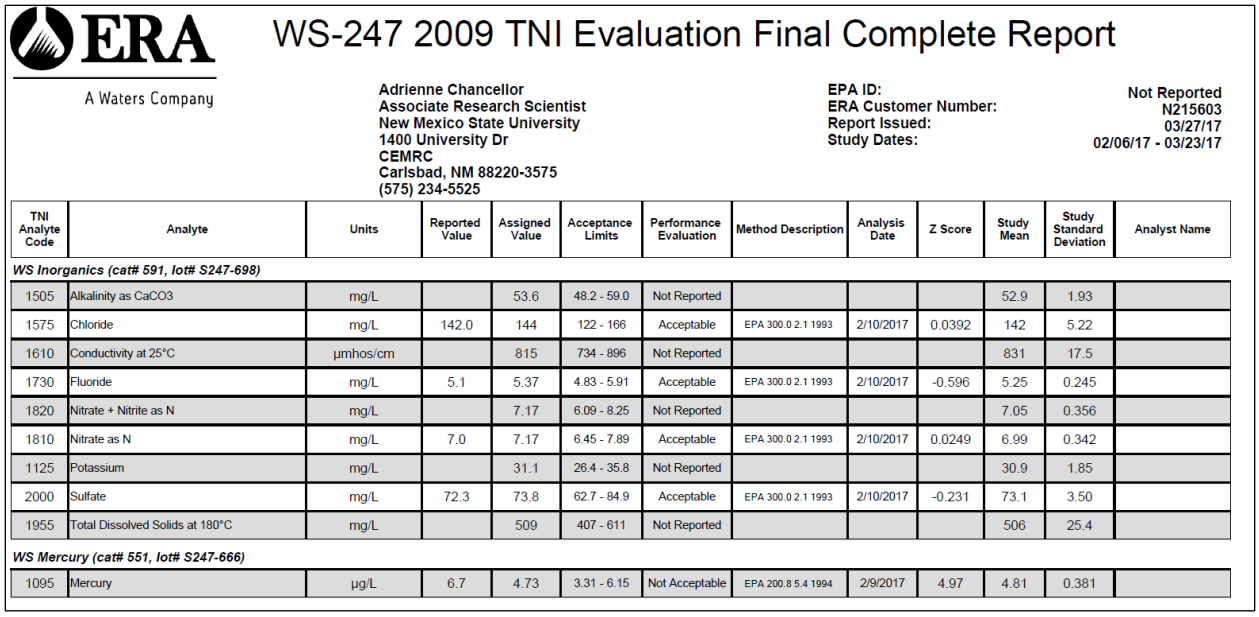
Carlsbad, NM 88220-3575
(575) 234-5525

EPA ID: Not Reported
ERA Customer Number: N215603
Report Issued: 05/30/17
Study Dates: 04/10/17 - 05/25/17

TNI Analyte Code	Analyte	Units	Reported Value	Assigned Value	Acceptance Limits	Performance Evaluation	Method Description	Analysis Date	Z Score	Study Mean	Study Standard Deviation	Analyst Name
WS Metals (cat# 590, lot# S249-697)												
1000	Aluminum	µg/L	622.6	617	524 - 710	Acceptable	EPA 200.8 5.4 1994	5/16/2017	-0.145	628	36.9	
1005	Antimony	µg/L	34.0	34.2	23.9 - 44.5	Acceptable	EPA 200.8 5.4 1994	5/16/2017	-0.0620	34.1	2.19	
1010	Arsenic	µg/L	23.6	21.2	14.8 - 27.6	Acceptable	EPA 200.8 5.4 1994	5/16/2017	1.97	21.3	1.15	
1015	Barium	µg/L	1604.8	1610	1370 - 1850	Acceptable	EPA 200.8 5.4 1994	5/16/2017	0.0484	1600	63.3	
1020	Beryllium	µg/L	16.4	15.7	13.3 - 18.1	Acceptable	EPA 200.8 5.4 1994	5/16/2017	1.17	15.5	0.745	
1025	Boron	µg/L		1020	867 - 1170	Not Reported				1010	56.9	
1030	Cadmium	µg/L	23.9	23.8	19.0 - 28.6	Acceptable	EPA 200.8 5.4 1994	5/16/2017	0.550	23.3	1.06	
1040	Chromium	µg/L	14.6	14.4	12.2 - 16.6	Acceptable	EPA 200.8 5.4 1994	5/16/2017	0.242	14.4	0.946	
1055	Copper	µg/L	1029.8	991	892 - 1090	Acceptable	EPA 200.8 5.4 1994	5/16/2017	0.905	987	46.8	
1070	Iron	µg/L	489.9	458	389 - 527	Acceptable	EPA 200.8 5.4 1994	5/16/2017	0.966	463	28.1	
1075	Lead	µg/L	79.9	81.6	57.1 - 106	Acceptable	EPA 200.8 5.4 1994	5/16/2017	-0.332	81.1	3.67	
1090	Manganese	µg/L	224.8	219	186 - 252	Acceptable	EPA 200.8 5.4 1994	5/16/2017	1.02	214	10.2	
1100	Molybdenum	µg/L	115.4	119	101 - 137	Acceptable	EPA 200.8 5.4 1994	5/16/2017	-0.257	117	5.47	
1105	Nickel	µg/L	69.9	69.0	58.6 - 79.4	Acceptable	EPA 200.8 5.4 1994	5/16/2017	0.251	69.0	3.54	
1140	Selenium	µg/L	34.0	34.6	27.7 - 41.5	Acceptable	EPA 200.8 5.4 1994	5/16/2017	-0.159	34.4	2.41	
1150	Silver	µg/L	214.6	212	148 - 276	Acceptable	EPA 200.8 5.4 1994	5/16/2017	0.457	210	9.57	
1165	Thallium	µg/L	5.0	4.86	3.40 - 6.32	Acceptable	EPA 200.8 5.4 1994	5/16/2017	0.358	4.88	0.348	
1185	Vanadium	µg/L	526.5	487	414 - 560	Acceptable	EPA 200.8 5.4 1994	5/16/2017	1.98	483	21.9	
1190	Zinc	µg/L	1135.8	1110	944 - 1280	Acceptable	EPA 200.8 5.4 1994	5/16/2017	0.284	1120	58.7	

Figure 9-7a: Environmental Chemistry Proficiency Test Results for Select Metal Analyses



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WS-247 2009 TNI Evaluation Final Complete Report

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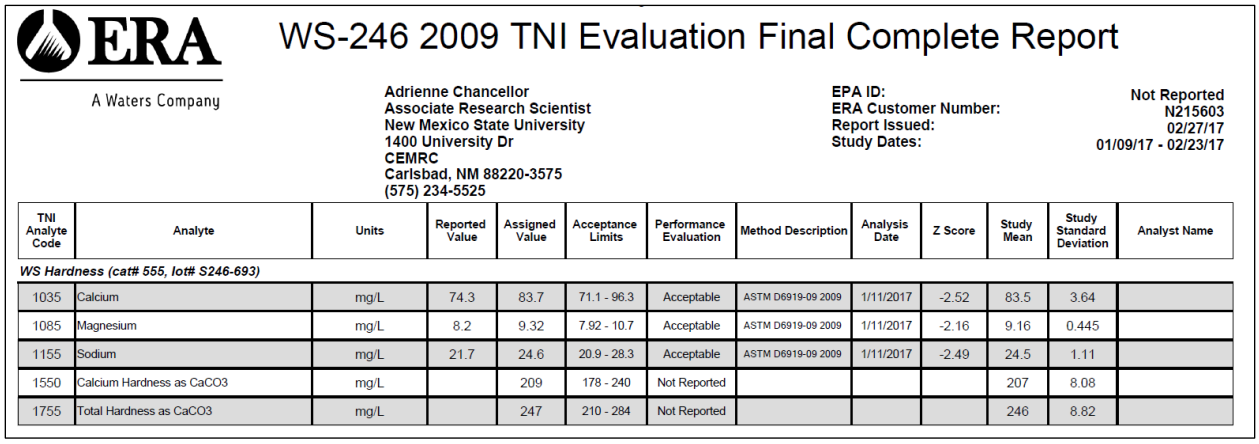
EPA ID: Not Reported
ERA Customer Number: N215603
Report Issued: 03/27/17
Study Dates: 02/06/17 - 03/23/17

TNI Analyte Code	Analyte	Units	Reported Value	Assigned Value	Acceptance Limits	Performance Evaluation	Method Description	Analysis Date	Z Score	Study Mean	Study Standard Deviation	Analyst Name
WS Inorganics (cat# 591, lot# S247-698)												
1505	Alkalinity as CaCO3	mg/L		53.6	48.2 - 59.0	Not Reported				52.9	1.93	
1575	Chloride	mg/L	142.0	144	122 - 166	Acceptable	EPA 300.0 2.1 1993	2/10/2017	0.0392	142	5.22	
1610	Conductivity at 25°C	µmhos/cm		815	734 - 896	Not Reported				831	17.5	
1730	Fluoride	mg/L	5.1	5.37	4.83 - 5.91	Acceptable	EPA 300.0 2.1 1993	2/10/2017	-0.596	5.25	0.245	
1820	Nitrate + Nitrite as N	mg/L		7.17	6.09 - 8.25	Not Reported				7.05	0.356	
1810	Nitrate as N	mg/L	7.0	7.17	6.45 - 7.89	Acceptable	EPA 300.0 2.1 1993	2/10/2017	0.0249	6.99	0.342	
1125	Potassium	mg/L		31.1	26.4 - 35.8	Not Reported				30.9	1.85	
2000	Sulfate	mg/L	72.3	73.8	62.7 - 84.9	Acceptable	EPA 300.0 2.1 1993	2/10/2017	-0.231	73.1	3.50	
1955	Total Dissolved Solids at 180°C	mg/L		509	407 - 611	Not Reported				506	25.4	
WS Mercury (cat# 551, lot# S247-666)												
1095	Mercury	µg/L	6.7	4.73	3.31 - 6.15	Not Acceptable	EPA 200.8 5.4 1994	2/9/2017	4.97	4.81	0.381	

Figure 9-7b: Environmental Chemistry Proficiency Test Results for Mercury and Inorganics (Anions)



ERA
A Waters Company

WS-246 2009 TNI Evaluation Final Complete Report

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EPA ID: Not Reported
ERA Customer Number: N215603
Report Issued: 02/27/17
Study Dates: 01/09/17 - 02/23/17

TNI Analyte Code	Analyte	Units	Reported Value	Assigned Value	Acceptance Limits	Performance Evaluation	Method Description	Analysis Date	Z Score	Study Mean	Study Standard Deviation	Analyst Name
WS Hardness (cat# 555, lot# S246-693)												
1035	Calcium	mg/L	74.3	83.7	71.1 - 96.3	Acceptable	ASTM D6919-09 2009	1/11/2017	-2.52	83.5	3.64	
1085	Magnesium	mg/L	8.2	9.32	7.92 - 10.7	Acceptable	ASTM D6919-09 2009	1/11/2017	-2.16	9.16	0.445	
1155	Sodium	mg/L	21.7	24.6	20.9 - 28.3	Acceptable	ASTM D6919-09 2009	1/11/2017	-2.49	24.5	1.11	
1550	Calcium Hardness as CaCO3	mg/L		209	178 - 240	Not Reported				207	8.08	
1755	Total Hardness as CaCO3	mg/L		247	210 - 284	Not Reported				246	8.82	

Figure 9-7c: Environmental Chemistry Proficiency Test Results for Hardness (Cations)

CONCLUSION

On February 14, 2014, the Waste Isolation Pilot Plant (WIPP) experienced its first minor accident involving an underground radiological release. A waste container in the repository underwent a chemical reaction that caused the container to overheat and breach, releasing its contents into the underground. Following a lengthy recovery process, on December 23, 2017, the facility was authorized by the DoE to resume waste disposal operations. The accident released radioactivity into the disposal room and adjacent exhaust drifts and although no one was present in the underground at the time of the release, a total of 22 workers tested positive for very low levels of radiation, presumably from some of the radioactive material that was released above ground. The dominant radionuclides released were ^{241}Am and $^{239+240}$Pu in a ratio that matched the content of the drum from the Los Alamos National Laboratory (LANL) that was eventually identified as the breached container. From the air particulate monitoring and plume modeling conducted by the DOE through their contract with the National Atmospheric Release Advisory Center (NARAC), it was concluded that the dose, at the nearest location accessible to the general public, from this radiation release event would have been less than 0.01 mSv (<1 mrem/year). This level is well below the 0.1 mSv/year (10 mrem/year) regulatory limit for DOE facilities established by the U.S. Environmental Protection Agency (US-EPA).

This contamination was detected by the CEMRC approximately one kilometer away from the facility a few days after the incident. The highest activities detected outside were 115.2 µBq/m^3 for ^{241}Am and 10.2 µBq/m^3 for $^{239+240}$Pu at a sampling station located 91 meters away from the underground air exhaust point and 81.4 µBq/m^3 of ^{241}Am and 5.8 µBq/m^3 of $^{239+240}$Pu at a monitoring station located approximately one kilometer northwest of the WIPP facility. A week after the event, the radiation at these stations had decreased by a hundred times, and two weeks later the radiation levels at these stations were back to the pre-release levels, sometimes not even detectable, demonstrating no continuing or long-term environmental contamination. According to source-term estimates, the actual amount of radioactivity released from the WIPP site was less than 1.5 millicurie (mCi).

In the wake of the underground radiation release incident of February 14, 2014, the CEMRC conducted an extensive monitoring and measurement campaign to assess the level of risk to anyone as a result of the WIPP underground radiation release event and/or from the on-going WIPP-related activities in general. Moving forward, the CEMRC has continued its efforts to conduct analyses of the WIPP underground air filters collected from Stations A and B, as well as ambient air samples, and other environmental samples collected in and around the WIPP facility in 2017. Sampling during 2017 was in large part returned to the pre-event schedule, with no detections of radioactivity found to be attributable to WIPP-related operations. CEMRC continue to make monitoring results available on its website to assure the local public that the potential

health impacts of radiation from the WIPP facility are being independently evaluated and to provide the public with a basis for judging the continued acceptability of this facility.

The CEMRC program called "Lie Down and Be Counted" uses a state-of-the-art, whole-body counting system that can measure the body burden of radioactive elements at extremely low levels and has operated over the past 20 years with over 1,400 local residents participating to form a baseline. Following the radiation release event, the CEMRC continued to offer this free lung and whole body counting service to adult citizens living within a 100-mile radius of the WIPP facility seven days a week. Concerned citizens were encouraged to be measured to see what radiation might exist in their lungs and whole-body. Even though there was not a substantial upsurge in the number of citizens who took advantage of this valuable service, just the mere availability of such a service, provided a sense of security to concerned citizens after the event.

The CEMRC's recent monitoring data show that the concentration levels of the radionuclides of concern present in the environment have returned to normal background levels and in many instances, are not even detectable, demonstrating no long-term environmental impacts of the recent radiation release event at the WIPP. *Further, an evaluation of 2017 environmental monitoring data indicates that WIPP operations have been safe and that the levels of radiation that escaped to the environment from the 2014 radiation release event were very low and did not, and will not, harm anyone or have any long-term environmental consequence.*

For an established radioactive waste management or disposal facility, the challenge is to maintain that public support as generations pass and as local populations change. To ensure the continued public support for the operation of nuclear facilities, it is necessary to increase public trust by actions that lead to a generalized improvement in the safety at nuclear facilities and by a better risk communication with the public. An accident tests the facility's relationship with the public. Following the radiation release event at WIPP, the information and outreach provided to local citizens by the CEMRC played a crucial role in allaying the concerns of local citizens residing in Carlsbad about the recent radiation release from their nearby repository. It is unlikely they would have had the same level of trust in an outside agency's assurances of safety. Over the years of its existence, the CEMRC's independence and its extensive monitoring program and public engagement have aided the continuing acceptance of this nearby nuclear facility. The credibility that the CEMRC has established over time is such that there would have been confidence in the public that if the release levels had posed a risk to the local or regional public, as the CEMRC would have told them so. This timely dissemination of information was and remains important for assuring the local public that the potential health impacts of the recent radiation release from the WIPP are being independently evaluated, and provides the public a basis for judging the continued acceptability of this facility. Therefore, a community currently considering hosting an interim storage or permanent disposal site should include an independent monitoring and communications program as part of the infrastructure needed to assure local acceptance of planned repositories elsewhere in the nation or the world.

APPENDICES

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

Total Propagated Analytical Uncertainty

For samples that are prepared or manipulated in the laboratory prior to counting (counting the rate of radioactive emissions from a sample), the total propagated analytical uncertainty includes both the counting uncertainty and the uncertainty associated with sample preparation and chemical separations. For samples that are not manipulated (e.g., ashed, dried, or chemically treated) in the laboratory before counting, the total propagated analytical uncertainty only accounts for the uncertainty associated with counting the sample. The uncertainty associated with samples that are analyzed but not counted (e.g., chemical or water quality measurements) includes only the analytical process uncertainty. In this situation, the total propagated analytical uncertainty is assumed to be the nominal detection limit.

Standard Error of the Mean

Just as individual values are accompanied by counting uncertainties, the mean of mean values (averages) is accompanied by ±2 times the standard error of the calculated mean. Two times the standard error of the mean implies that approximately 95% of the time the next calculated mean will fall somewhere between the reported value minus two times the standard error and the reported value plus two times the standard error.

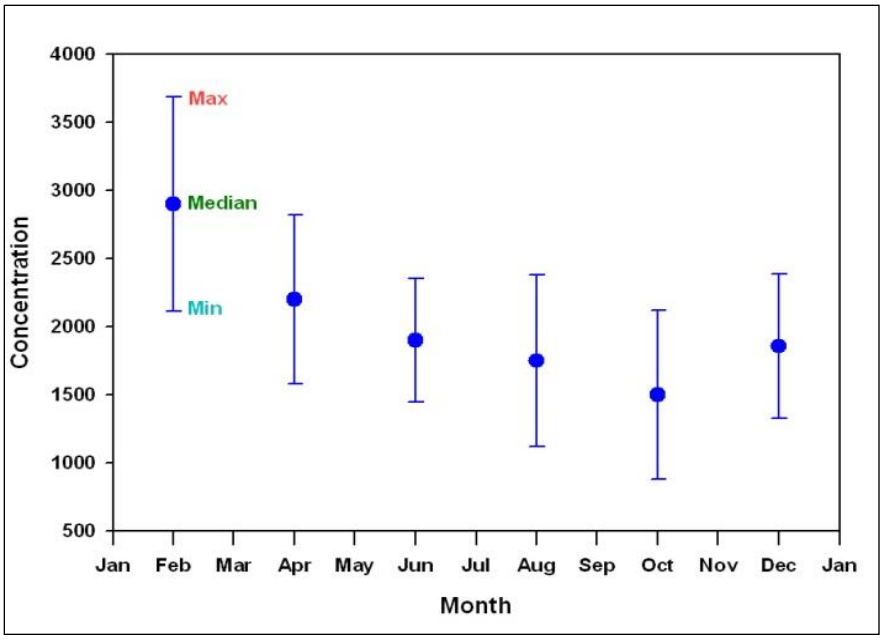

Figure A-1: Graphical representation of maximum, median and minimum values

Median, Maximum, and Minimum Values

Median, maximum, and minimum values are reported in some sections of this report. A median value is the middle value of an odd-numbered set and the average of the two central values in an even-numbered set. For example, the median value in the odd-numbered series of numbers - 1, 2, 3, 3, 4, 5, 5, 5, 6 is 4. The maximum value would be 6 and the minimum value would be 1. Median, maximum, and minimum values are reported when there are too few analytical results to accurately determine the average with a ± statistical uncertainty or when the data do not follow a bell-shaped (i.e., normal) distribution. Figure A-1 provides a graphical representation of median, maximum, and minimum values. The upper line is the maximum value, the center dot is the median value, and the lower line is the minimum value.

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 radioactive 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.

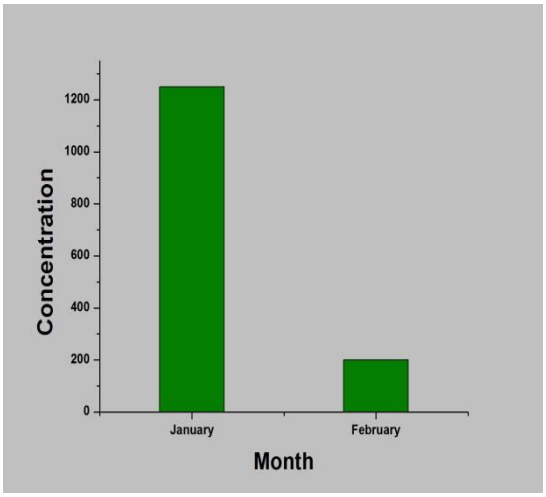

Figure A-2: Data plotted using a linear scale

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 A-2). A logarithmic plot of these same two numbers allows the reader to see both data points clearly (Figure A-3).

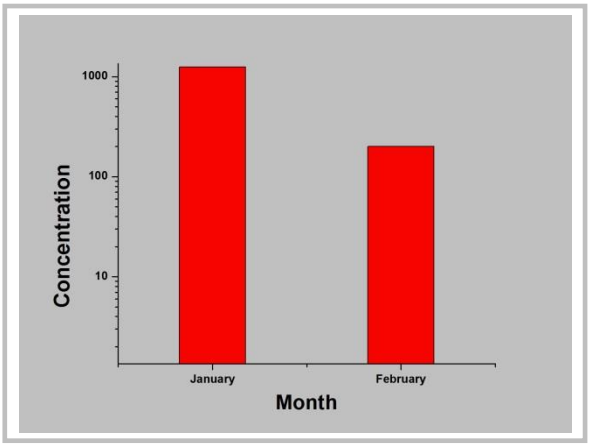

Figure A-3: Data plotted using a logarithmic

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.

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 A-4, 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

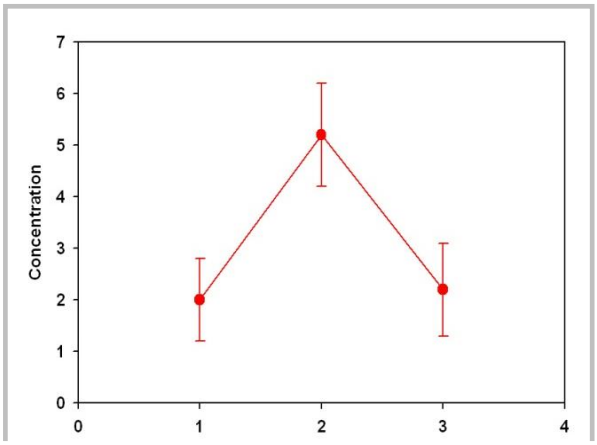

Figure A-4: Data with error bars plotted using a linear scale

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 statistically. Lastly, when vertical lines are used with median values, the lower end of each bar represents the minimum concentration measured while the upper end of each bar represents the maximum concentration measured (see Figure A-1).

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