Carlsbad Environmental Monitoring and Research Center

2012 Annual Report

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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 exhaust air, ambient air, and water collected at and in the vicinity of the U.S. DOE's Waste Isolation Pilot Plant (WIPP) during calendar year 2012. The WIPP facility became operational in March 26, 1999 for the disposal of transuranic waste, and the WIPP received its first mixed waste shipments on September 9, 2000.

The CEMRC has compared these levels to those measured in the pre-operational phase, prior to receipt of waste. Based on these analyses, the CEMRC concludes that:

a) Levels of the measured radiological and non-radiological constituents in the environment around WIPP during calendar year 2012 are not different from the preoperational baseline levels.
b) The measured levels are similar to those measured by other organizations, where direct comparisons can be made.
c) No measurable radiation dose to the public resulted from WIPP-related operations during calendar year 2012, relative to the estimated baseline dose.

Respectfully submitted,

Russell Hardy
Director, Carlsbad Environmental Monitoring & Research Center

Table of Contents

List of Tables

List of Figures

Acronyms and Abbreviations

μBq	MicroBecquerel
μm	Micrometer
Ag	Silver
Al	Aluminum
Am	Americium
ANSI	American National Standards Institute
As	Arsenic
ASTM	American Society for Testing and Materials
Ba	Barium
Be	Beryllium
Bq	Becquerel
C	Centigrade
Ca	Calcium
CAM	Continuous Air Monitor
CCP	Central Characterization Project
Cd	Cadmium
Ce	Cerium
CEMRC	Carlsbad Environmental Monitoring & Research Center
CEMRP	Carlsbad Environmental Monitoring & Research Program
CFR	Code of Federal Regulations
CH	Contact-handled
Ci	Curie
cm	Centimeter
Cm	Curium
Co	Cobalt
Cr	Chromium
CRM	Certified Reference Materials
Cs	Cesium
Cu	Copper
DL	Detection Limit
DOE	U.S. Department of Energy
DOE/CBFO	U.S. Department of Energy/Carlsbad Field Office
DOELAP	U.S. Department of Energy Laboratory Accreditation Program
EEG	Environmental Evaluation Group
EC	Environmental Chemistry
EM	Environmental Monitoring
EPA	U.S. Environmental Protection Agency
Er	Erbium
ERA	Environmental Research Associates
Eu	Europium
F	Fluoride
FAS	Fixed Air Samples
Fe	Iron
FP	Field Programs
FWHM	Full-Width, Half-Maximum
g	Gram
GC/MS	Gas Chromatograph/Mass Spectrometer
Gd	Gadolinium
Ge	Germanium

GPS	Global Positioning Satellite
HCl	Hydrochloric acid
$HClO_4$	Perchloric acid
HEPA	High Efficiency Particulate Air
HF	Hydrofluoric acid
Hg	Mercury
HNO_3	Nitric acid
H_2O_2	Hydrogen Peroxide
HPGe	High Purity Germanium
hr	Hour
HSG	Headspace Gas
I	Iodine
IC	Ion Chromatography
ICP-MS	Inductively Coupled Plasma-Mass Spectrometry
ID	Internal Dosimetry
IM	Information Management
ISO	International Organization for Standardization
IUPAC	International Union of Pure and Applied Chemistry
K	Potassium
km	Kilometer
L	Liter
La	Lanthanum
LaF_3	Lanthanum Fluoride
LANL	Los Alamos National Labs
lb	Pound
LDBC	"Lie Down and Be Counted"
LCS	Laboratory Control Samples
LFB	Laboratory Fortified Blank
LFM	Laboratory Fortified Matrix
Li	Lithium
LRB	Laboratory Reagent Blanks
m	Meter
MAPEP	Mixed-Analyte Performance Evaluation Program
mb	Millibar
MBL	Mobile Bioassay Laboratory
mBq	MilliBecquerel
MDC	Minimum Detectable Concentration
MDL	Method Detection Limit
Mg	Magnesium
min	Minute
mL	Milliliter
mm	Millimeter
Mn	Manganese
Mo	Molybdenum
M&O	Management and Operations
MTRU	Mixed Transuranic
Na	Sodium
NaOH	Sodium Hydroxide
NCR	Nonconformance
Nd	Neodymium
Ni	Nickel
NIST	National Institute of Standards and Technology
nm	Nanometer
NMED	New Mexico Environment Department

NMSU	New Mexico State University
Np	Neptunium
NRE	Non-Routine Event
NRIP	National Radiochemistry Intercomparison Program
OC	Organic Chemistry
ORNL	Oak Ridge National Laboratory
Pa	Protactinium
Pb	Lead
pH	Scale Indicating Acidity or Alkalinity of a Substance
Ppbv	Parts per Billion Volume
Pu	Plutonium
QA	Quality Assurance
QAP	Quality Assurance Program
QAPD	Quality Assurance Program Document
QC	Quality Control
RC	Radiochemistry
RCRA	Resource Conservation and Recovery Act
RH	Remote-Handled
Ru	Ruthenium
SAB	Science Advisory Board
Sb	Antimony
Sc	Scandium
SD	Standard Deviation
Se	Selenium
SE	Standard Error
sec	Second
SNL	Sandia National Labs
Sr	Strontium
$T_{1/2}$	Half-Life
TCD	Thermal Conductivity Detector
Th	Thorium
Ti	Titanium
Tl	Thallium
TRU	Transuranic
TSP	Total Suspended Particulates
U	Uranium
V	Vanadium
VOC	Volatile Organic Compound
WERC	Waste-management Education & Research Consortium
WHB	Waste Handling Building
WIPP	Waste Isolation Pilot Plant
WIPP-EM	Waste Isolation Pilot Plant Environmental Monitoring
WRES	Washington Regulatory and Environmental Services
WTS	Washington TRU Solutions
XO	Experimental Operations
Y	Yttrium

INTRODUCTION

This report summarizes the Waste Isolation Pilot Plant (WIPP) site environmental monitoring activities conducted by an independent oversight organization, the Carlsbad Environmental Monitoring & Research Center (CEMRC), for calendar year 2012. The CEMRC, an entity of New Mexico State University, was established in 1991 through a financial assistance grant by the U.S. Department of Energy (DOE), to conduct an independent environmental monitoring program of the WIPP site on behalf of the residents of southeast New Mexico. The CEMRC report, published annually since 1998, includes information and summary data to provide an overview of CEMRC's environmental monitoring activities at the DOE's WIPP site. In addition to highlighting CEMRC's environmental monitoring and surveillance activities and results, this report also provides a brief description of the WIPP site and its mission as well as an overview of the long-term history of radionuclides commonly found in the region in order to assess the impact of WIPP (if any) to the local environment. Readers interested in more detailed information can consult the CEMRC website which contains electronic copies of this and prior year annual reports. http://cemrc.org/report/.

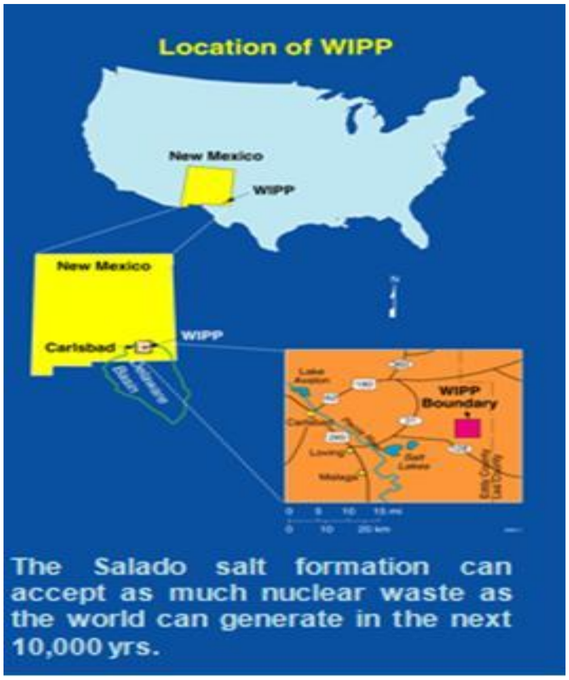
The WIPP Site
AND ITS MISSION

The WIPP site is the nation's first underground repository permitted to safely and permanently dispose of Transuranic (TRU) radioactive and mixed waste generated through defense-related activities and programs. 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]) of alpha-emitting TRU isotopes per gram of waste, with half-lives greater than 20 years. The WIPP mission is to provide for the safe, environmentally sound disposal of defense-related TRU radioactive waste created by the research, development, and production of nuclear weapons. To accomplish this mission, TRU waste is packaged and disposed of 655 m (2,150 ft) below the surface in excavated disposal rooms within the Salado Formation (Salado), which is a thick sequence of Permian Age evaporite salt beds. Prior to final disposal within the repository, the waste is packed and sealed in metal drums and placed within the mined disposal panels. When a panel is filled with waste, the panel is sealed to minimize the release of hazardous or radioactive constituents while a new panel is prepared to accept additional shipments of waste. At the conclusion of the WIPP disposal phase, estimated to occur in 2035, seals will also be placed in the access and ventilation shafts of the repository to further minimize the release of contaminants into the environment. In addition to these manmade barriers, the location and design of the repository were selected to further shield the environment from a release well into the future. This occurs because one of the main attributes of salt, used as a rock formation in which to isolate radioactive waste, is its ability to creep, that is, to deform continuously over time. As a result of this movement, the waste disposal panels into which the waste-filled drums are placed will eventually close allowing the surrounding salt to flow around the drums, virtually encapsulating them within the Salado Formation for many years to come.

SITE DESCRIPTION

Located in Eddy County, New Mexico, at the edge of the Chihuahuan Desert, the WIPP site encompasses 41.4 km^2 (16 mi^2). This part of New Mexico is relatively flat and is sparsely inhabited, with little surface water present. The site is located 42 km (26 mi) east of Carlsbad, New Mexico, in a region known as Los Medaños (the Dunes). The WIPP Land Withdrawal Act (LWA) was signed into law on October 30, 1992, transferring the administration of federal land from the U.S. Department of the Interior to the DOE. With the exception of the facilities located within the boundaries of the posted 1.17 km2 (0.45 mi2) exclusive use area, the surface land uses remain largely unchanged from the 1992 withdrawal, and are managed in accordance with accepted practices for multiple land use.



The Salado salt formation can accept as much nuclear waste as the world can generate in the next 10,000 yrs.

The majority of the lands in the immediate vicinity of the WIPP site are managed by the U.S. Department of the Interior Bureau of Land Management (BLM). Land uses in the surrounding area include livestock grazing, potash mining, oil and gas exploration and production, and recreational activities such as hunting, camping, hiking, and bird watching. In addition, the region is home to diverse populations of animals and plants.

WIPP SITE SNAPSHOT THROUGH SEPTEMBER 2013

- **13+ years of operation.**
- **88,852 cubic meters of TRU waste disposed.**
- **169,339 containers disposed in the underground.**
- **11,629 shipments received.**
- **~ 7 waste panels mined**
- **5 Panels filled and closed.**
- **22 storage sites cleaned of legacy TRU waste.**
- **“0” releases to the environment.**
- **“0” contamination to the WIPP personnel.**

As shown in Figure 1.1 below, the WIPP repository layout currently consists of eight panels, each consisting of seven waste disposal rooms measuring approximately 300 feet (91 meters) long and 33 feet (10 meters) wide. Seven of the planned panels have been excavated; with the first five panels being closed and sealed from repository ventilation air. During 2012, waste disposal was in progress in the sixth panel. Usually three panels are in operation at any given time, with one panel having been already filled with waste and in the process of being closed (closure mode), a second panel already excavated with waste disposal in progress (waste disposal mode), and a third panel being mined (mining mode). As of September 2013, panel 5 is in closure mode, Panel 6 is in waste mode and, Panel 7 is in mining mode and has been certified to begin receiving waste as soon as Panel 6 is full. In addition, the underground mined disposal area is divided into two main areas. The northern part is a research area and is being used by the scientific community for physics and biology experiments requiring low background radiation, while the much more extensive southern part is devoted to waste disposal activities.

Currently, two types of TRU wastes are currently disposed of in the WIPP repository: (1) mixed transuranic waste (MTRU), meaning disposal containers that have both chemically hazardous waste and radioactive waste in them, and (2) non-mixed waste contaminated with just radioactive elements, mostly plutonium. Since its operation in March 1999, more than 88,000 cubic meters of legacy TRU waste have been removed from temporary locations around the nation and shipped to WIPP for permanent disposal.

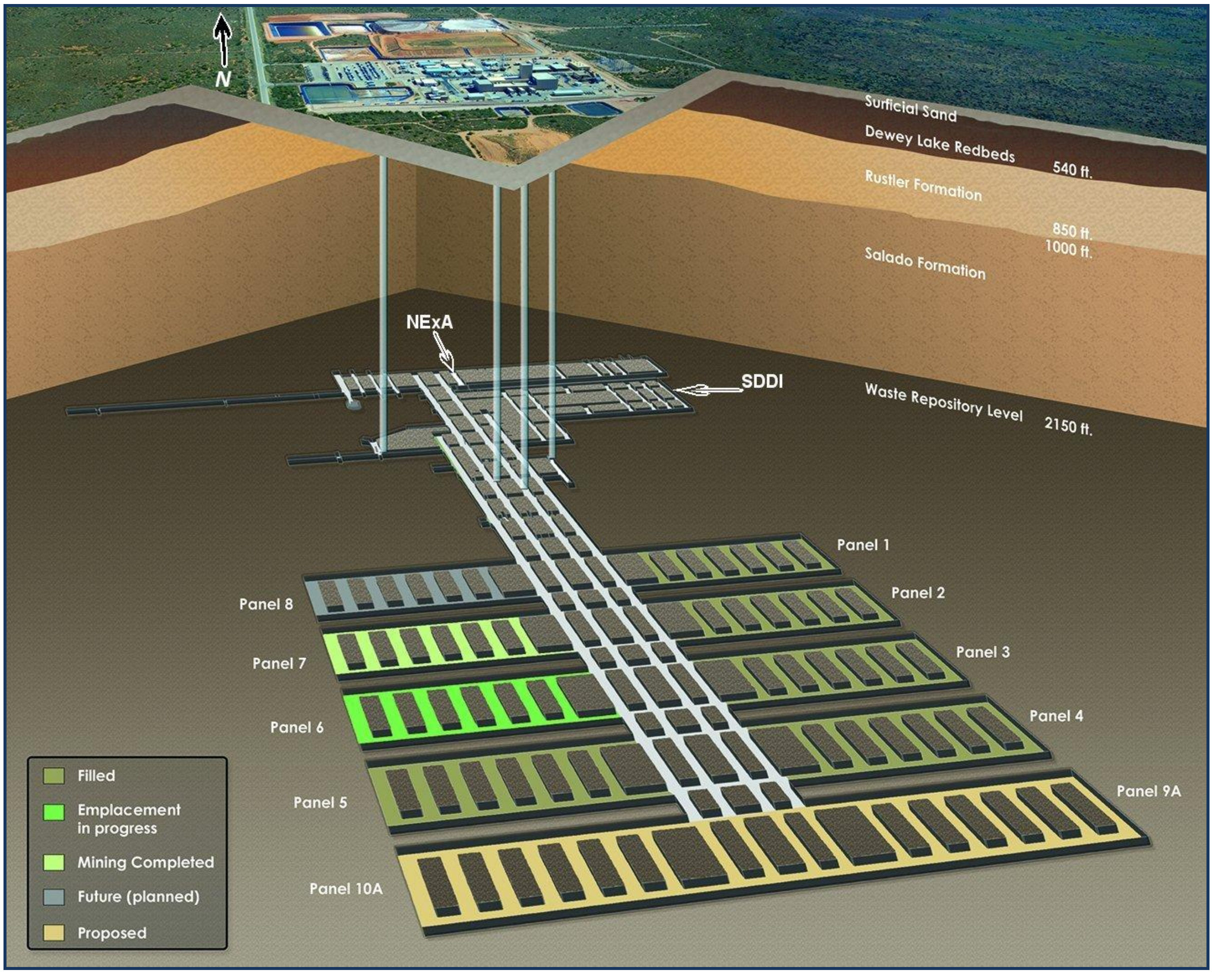


Figure 0.1 WIPP layout

As mandated by the LWA, the WIPP facility can only accept defense-related transuranic waste for disposal within the repository. This waste is shipped to the WIPP from various locations around the US as depicted in Figure 0.2 and has resulted in the successful cleanup of several locations throughout the contiguous states. The green dots in Figure 0.2 show the location of the waste whereas the yellow circle represents the amount of waste generated per location.

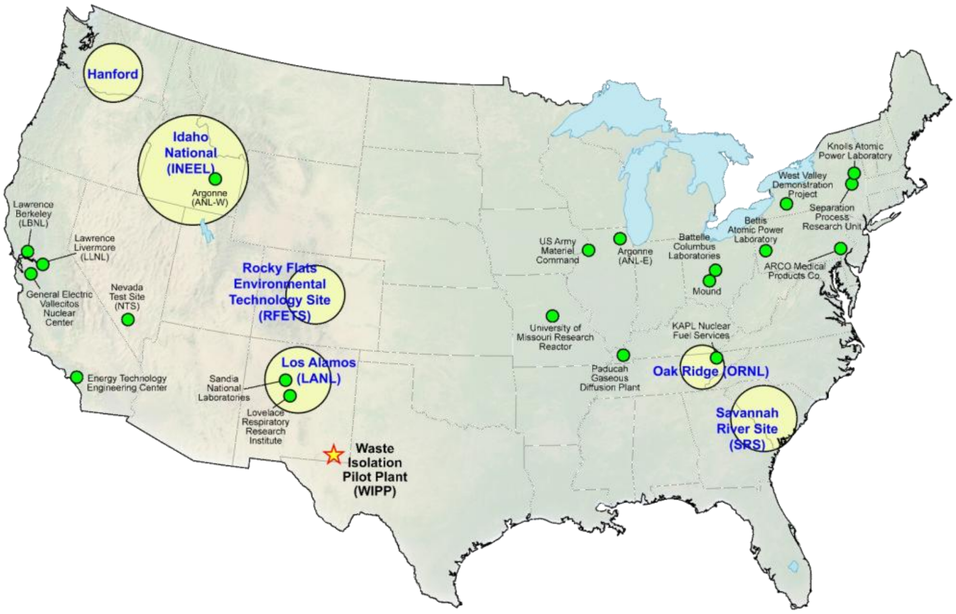


Figure 0.2 TRU Waste Generator Sites

MONITORING OBJECTIVE

The major objective of the CEMRC environmental monitoring program is to evaluate the present, future and sometimes past behavior of radionuclides in the vicinity of the WIPP. The program also has the capabilities to detect radionuclides as quickly as possible in case of accidental releases from within the repository or at the site during waste handling operations. The ambient air, drinking water, surface water, soil, and local population around the WIPP facility as well as air entering and exiting the WIPP underground are analyzed at CEMRC as part of a routine environmental monitoring program. CEMRC has been monitoring the concentration of plutonium (Pu) and americium (Am) in the area around the WIPP sites for many years as isotopes of these elements are the major radioactive constituents in the TRU waste. The source of Pu and Am in and around the WIPP site prior to arrival of the TRU waste at the site can be attributed to several events including: nuclear weapons testing that occurred between the 1950s to 1980s, controlled releases from the operation of nuclear power plants and nuclear reprocessing facilities, and nuclear-related accidents. It has been reported that about 15 pBq of $^{239+240}$Pu and 0.3 pBq of ^{238}Pu have been globally released into the atmosphere from weapons testing and nuclear power-related incidents, whereas 1.3 pBq of ^{238}Pu was injected into the upper atmosphere from satellite burn-up upon reentry. In addition, the Gnome test site, located about 8.8 km (5.5 miles) southwest of the WIPP site, is also a potential source of radionuclides present in the area. At this site, a 3.3 kiloton-yield nuclear underground detonation was conducted in 1961 as part of the Plowshare Program of the Atomic Energy Commission to see if the heat produced from an atomic detonation could be used to produce a sufficient amount of steam to produce electricity. Despite plans to prevent contamination from the atomic detonation, a small release of radioactive constituents escaped into the environment. The site was decontaminated in 1968-1969 and again in 1978; however, despite these clean-up efforts, elevated levels of ^{137}Cs and plutonium have been detected in some of the surface soil samples collected at the Gnome site. As a result, these contaminated soils are a potential source of contamination for environmental samples being collected in the area to monitor for potential release of radionuclides from the WIPP and to maintain the integrity of the WIPP environmental monitoring project. Therefore, knowledge of the levels and behavior of actinides in the WIPP environment is necessary to assess the radiological and ecological effects of radiation on workers and the general public that live and work around the WIPP site.

In this report, samples collected and analyzed during calendar year 2012 are presented. In addition, results from this program are accessible to the public through this report and through the CEMRC website and can be used for evaluating the long-term history of these radionuclides to better assess the impact of WIPP (if any) on the local environment. CEMRC believes this aspect of its mission is important since the public needs to know what is truly happening in the environment and what effect, if any, WIPP activities has on their lives and overall health. Lastly, this type of information is important for assessing the impact of the WIPP on the local environment for public acceptance of this and future waste disposal projects.

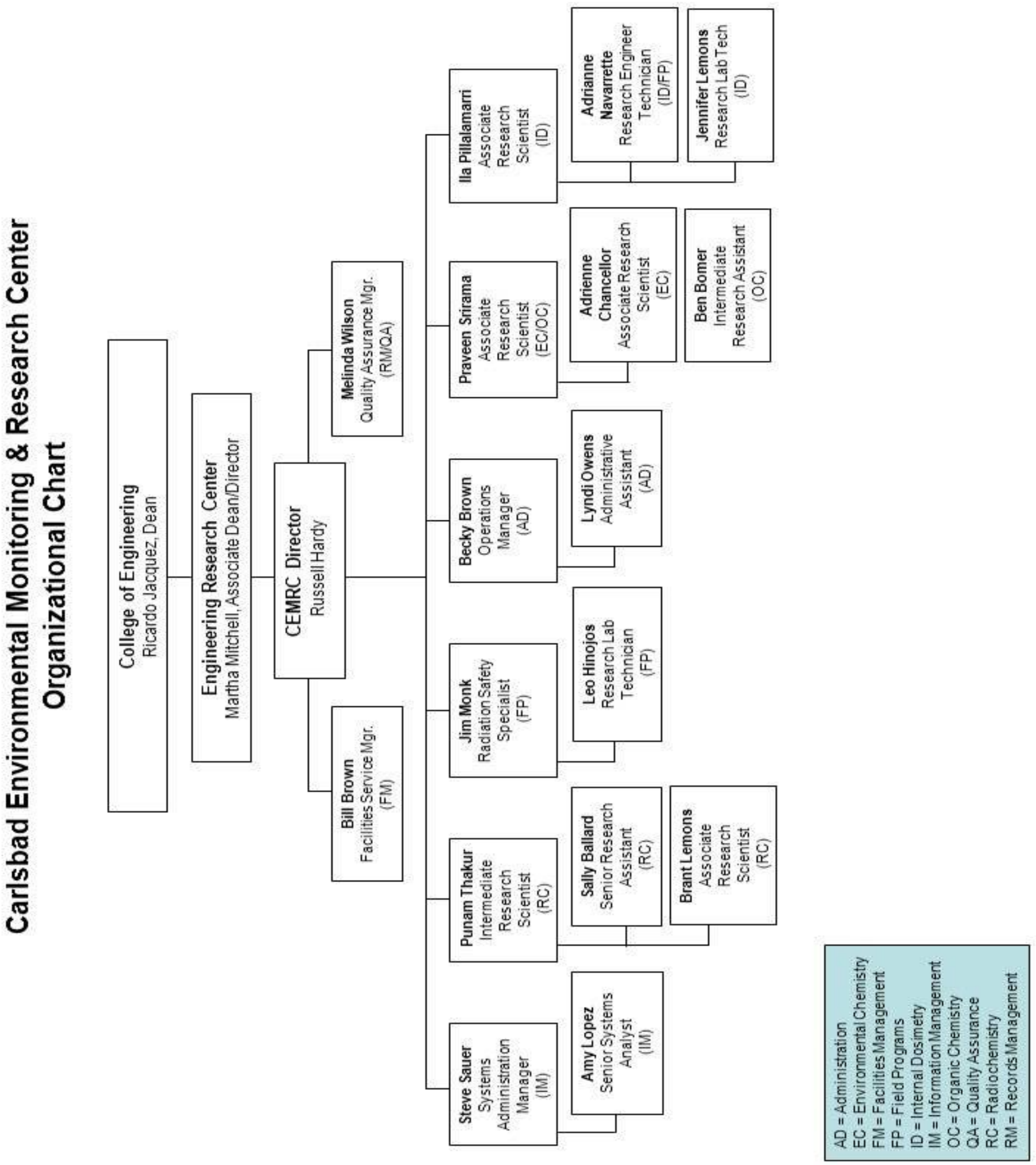


Figure 0.3 CEMRC Organizational Chart

CHAPTER 1

WIPP Exhaust Air Monitoring

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. Three organizations: CEMRC, Nuclear Waste Partnership (NWP) LLC, and NMED (New Mexico State Environment Department) routinely collect samples from a Fixed Air Sampler (FAS) which collects particulates from the unfiltered exhaust air at the top of the exhaust shaft (Station A) at the WIPP before the air is discharged to the environment.

Introduction

The WIPP exhaust air from the underground is measured by four monitoring stations referred to as Stations A, B, C, and D respectively. Each station is equipped with at least one skid-mounted particulate air sampler, called a fixed-air sampler (FAS). Station A is an above-ground air sampling platform that is shared by several other environmental monitoring groups. At this station, unfiltered air is exhausted from the repository to the atmosphere. At station B, HEPA (High Efficiency Particulate Air) filters are first used to filter the exhaust from the repository. While in *filtration mode*, stations A and B are mutually exclusive (i.e., when air is exhausted from station A, none is exhausted from station B and vice versa). However, both stations A and B sample the same air when operating in the *maintenance bypass*, *reduced*, or *minimum* mode. Station C is used to sample the exhaust from the WHB (Waste Handling Building) after the air has passed through a bank of HEPA filters. Lastly, station D is located at the base of the exhaust shaft and occasionally serves as a back-up skid for station A.

The sensitivity of the CEMRC WIPP-EM program at Station A was first 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. This incident was notable because it demonstrated, for the first time, the ability of the monitoring system to detect a non-routine event. A second incident occurred in the second calendar quarter of 2003 when CEMRC's scientists reported that they had detected a small quantity of plutonium ($^{239+240}$ Pu) in a composite aerosol sample. This discovery was later corroborated by both EEG (Environmental Evaluation Group) and WTS (Washington TRU solutions – the management and operations contractor for the WIPP site) through the analyses of samples that were independently collected and analyzed. The detection of Pu in the exhaust air led to the issuance of a CEMRC report to the U.S. Department of Energy (DOE) and a briefing presented to the New Mexico Environment Department (NMED). Although the activity was extremely low and well within historic background, it indicated the ability of the monitoring program to detect radionuclides of interest at any level above the MDC. Similarly, trace concentrations of $^{239+240}$Pu, ^{238}Pu and americium (^{241}Am) were again detected in February, 2008; April, 2009; and July, 2010 composite samples by CEMRC. These detections were also corroborated by both WTS and NMED as well. As both ^{238}Pu and $^{239+240}$Pu were detected above MDC, the activity ratios between ^{238}Pu to $^{239+240}$Pu were calculated in order to better understand the source of these radionuclides in the WIPP exhaust air samples. The mean ^{238}Pu to $^{239+240}$Pu activity ratio of 0.025±0.004 observed in these samples are consistent with the source being largely related to global fallout. Lastly, a release of the fire suppression material, FORAY®, was detected in the WIPP underground in October of 2011. This time the CEMRC was aware of the release and the affected FAS filter was analyzed separately from the other filters collected in October and analyzed for both beta emitter(s) and non-radioactive materials. Since the material FORAY® contains small amounts of Attapulgite Clay (a salt containing magnesium, Mg, and aluminum, Al, and silicate) in the range of 5-7% by weight, slightly higher concentrations for these elements were observed in the affected filter as compared to the average Mg and Al concentrations from October 2011.

With respect to radionuclides, atmospheric nuclear tests have been by far the major source of plutonium in the environment. Since the discovery of plutonium, over 500 atmospheric nuclear tests have been conducted worldwide at a number of locations (Vincent, 1997). Besides atmospheric nuclear tests, satellite accidents and nuclear power plant accidents such as Chernobyl and Fukushima have also injected plutonium into the environment. Additionally, local and regional contamination of plutonium in the environment has resulted from reprocessing of nuclear fuels and from ocean dumping of nuclear wastes. The first injection of plutonium into the atmosphere occurred in July 1945 with the detonation of the first plutonium device at the "Trinity Site" near Alamogordo in New Mexico, USA. Since then approximately 330 TBq (TBq = 1×10^{12} Bq) of ^{238}Pu, 7.4 PBq (PBq = 1×10^{15} Bq) of ^{239}Pu, 5.2 PBq of ^{240}Pu, 170 PBq of ^{241}Pu and 16 TBq of ^{242}Pu have been released into the atmosphere from nuclear weapons testing between 1945 and 1980 with approximately 76% of the fallout accumulating in the Northern Hemisphere and 24% in the Southern Hemisphere (Hardy et al., 1973). The burn-up of plutonium-bearing satellites has also contributed to the global environmental inventory. One satellite in particular, the Systems for Nuclear Auxiliary Power generator (SNAP) satellite in 1964, contributed about 1.3 PBq of ^{238}Pu to the global inventory, and changed the ^{238}Pu to $^{239+240}$Pu ratio from 0.024 to 0.034 in the Northern Hemisphere and to 0.20 in the Southern Hemisphere (Hardy et al., 1973). Additionally, a missile fire at the U.S McGuire Air Force Base in New Jersey in 1960; the B-52 accidents in Palomares, Spain in 1966; and the US aircraft carrying four hydrogen bombs that crashed on the sea ice near Thule, Greenland in 1968, have all resulted in the dispersion of weapons grade plutonium into the environment(UNSCEAR, 2000).. Currently, ^{238}Pu, ^{239}Pu, and ^{240}Pu isotopes can be measured as traces in environmental samples with a ^{238}Pu to $^{239+240}$Pu activity ratio of 0.03 at mean latitudes of 40^{o}-50^{o} N (UNSCEAR, 1982).

Sample Collection

CEMRC commenced sampling of the WIPP exhaust air at Station A on December 12, 1998. Detailed descriptions of the sampling and analytical methods have been included in prior CEMRC Annual Reports which are available on the CEMRC website www.cemrc.org . In brief, the WIPP underground air samples are collected on 47 mm diameter membrane filters with the use of a shrouded probe, commonly referred to as a fixed air sampler or FAS (Figure 1.1). The airflow through the FAS is approximately 170 liters per minute (6.0 cubic feet per minute, cfm) as discussed elsewhere (Rodgers, 1987). The samples at Station A are typically collected daily except for weekends (the weekend samples run from Friday to Monday so the coverage is continuous). However, occasionally more than one sample per day is still collected such as when the flow rate on any of the sampler legs drops below 51 liters per minute. Under these conditions, a low-flow alarm on the sampler is activated and the filters are changed. In 2012, a total of 441 filters were collected from Station A. The number of filters collected each year from station A is shown in Figure 1.2.

After the 2003 Pu detection, CEMRC implemented an additional FAS filter, called the Trip Blank, which is a blank filter that accompanies the sample filter throughout the whole process, including transportation to and from the WIPP site as well as being placed on the collector for approximately 15 seconds before being removed and placed in a sealed container. Unlike the laboratory and reagent blanks, the Trip Blank can reflect sampling errors or field contamination that is independent of laboratory procedures and reagents.

Sample Preparation and Analysis

All analyses of the FAS filters are performed according to the methods detailed in the CEMRC document-controlled, standard operating procedures. A simplified scheme of the sample preparation process is shown in Figure 1.3.

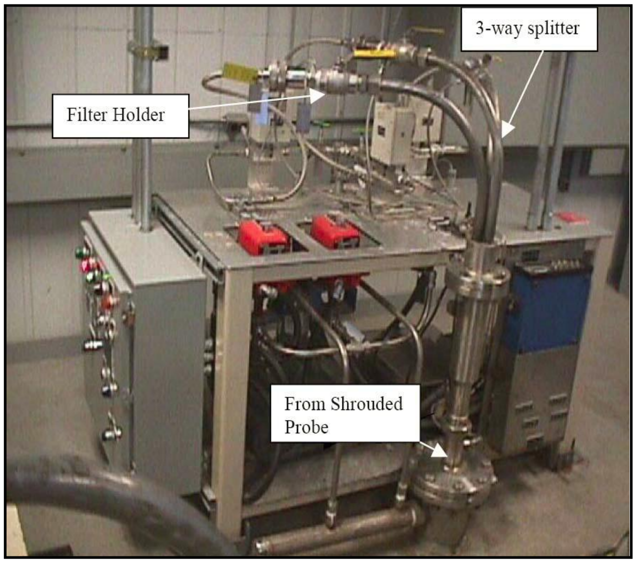


Figure 1.1 Station A Fixed Air Sampler

Once the samples are collected from the field and returned to the laboratory, the individual filters are desiccated for two days to ensure that any moisture on the filters are evaporated and to ensure a complete decay of daughter products of ^{222}Rn and ^{220}Rn. Once dried, the filters are then weighed to determine mass loadings. Following the desiccating and weighing process, the filters are counted for gross alpha/beta activities using a low-background gas proportional counter (Protean MPC9604).

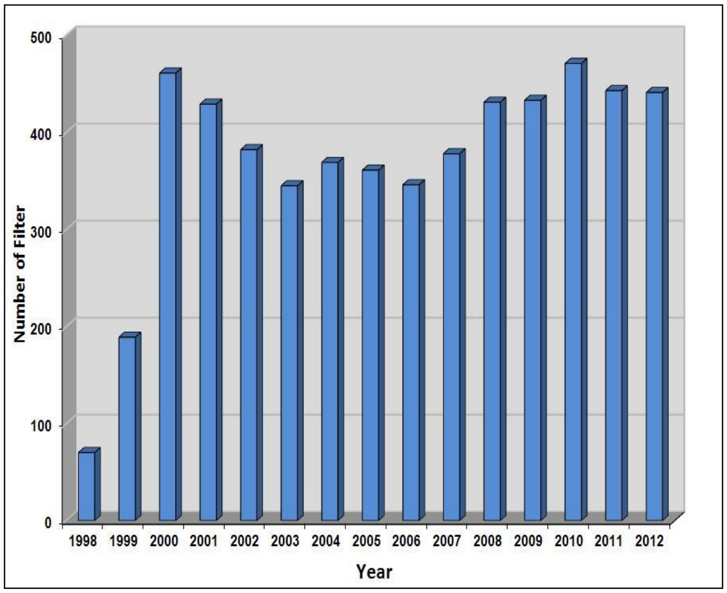


Figure 1.2 Number of Filters Collected from Station A

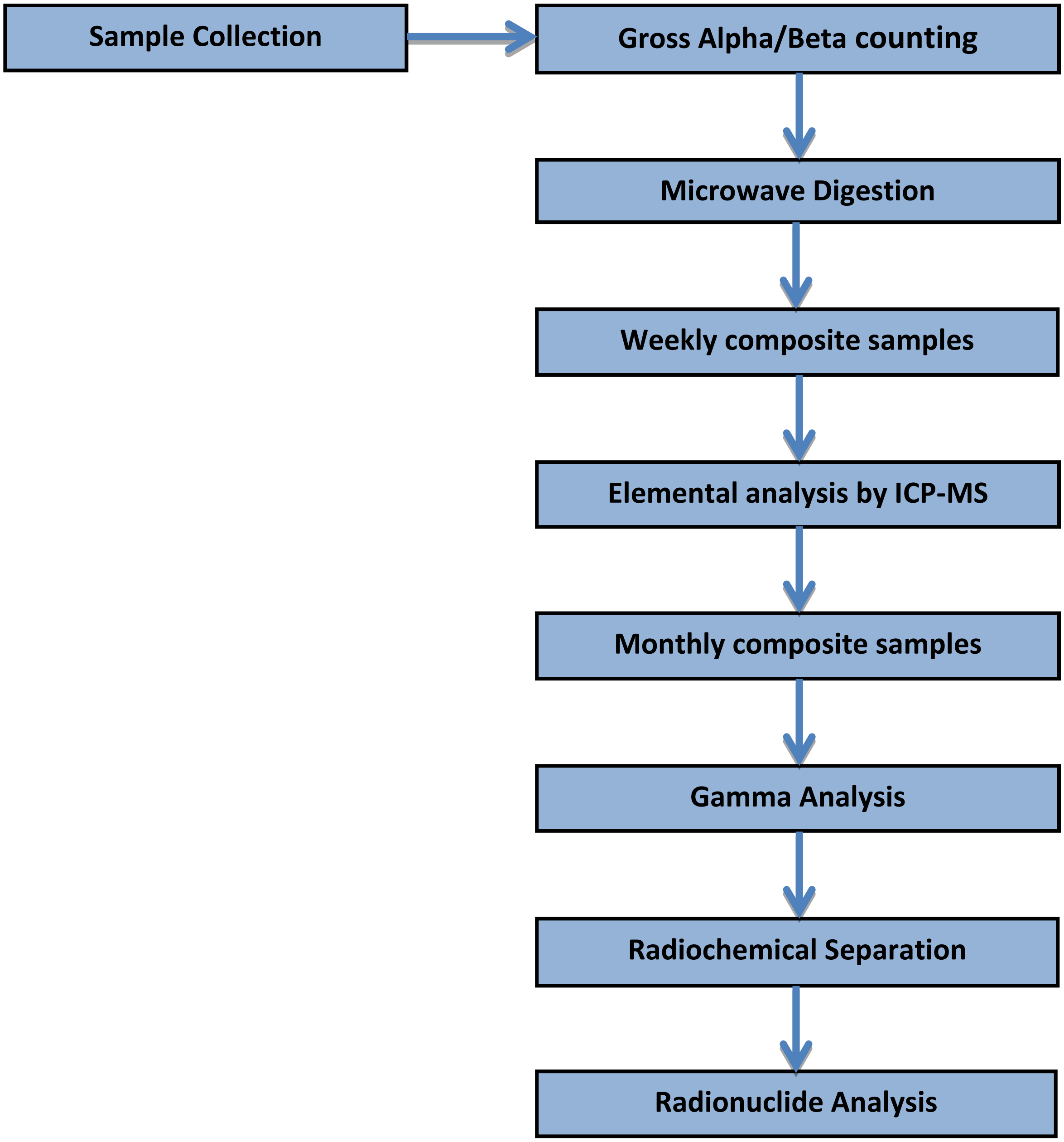


Figure 1.3 Flow Diagram Showing the Handling and Analysis of Station A Filters

The use of such a counter is described in an American National Standards Institute Publication (ANSI 1997). The gas proportional counter can operate in two modes: (1) alpha then beta and (2) alpha/beta (ANSI 1997). Mode (1) is more useful, as it allows simultaneous detection. In this case, the detector operates at the β- plateau, while alpha and beta particles can be distinguished by either pulse height or pulse shape or both (Currie and Lindstrom 1973; Wink et al. 1993). The main interference is from crosstalk or spillover in the case of pulse height or pulse shape, respectively. While gross screening analyses are not as accurate nor as precise as more detailed radiochemical separations, they are intended to provide rapid information associated with a particular action level with minimal chemical preparation. Additionally, these types of analyses are not intended to give "absolute" activity measurements, but rather "order-of magnitude" activity measurements, therefore, its main advantages are relatively low costs and simplicity (Semkow et al., 2004).

In preparation for gross alpha/beta counting, the filter is centered on a stainless steel planchet. The standard planchets for the alpha and beta were prepared from certified solutions of ^{239}Pu and ^{90}Sr/^{90}Y obtained from Analytics, Inc. (Atlanta, GA, USA). The planchet is counted on a low-background gas proportional counter for 1,200 minutes (20 hours). The sample detectors are gas flow window type counters with an ultra-thin window. The counting gas was P-10, which is a mixture of 90% argon and 10% methane. The operating voltage on the detector was selected as 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. 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 ensuring that alpha/beta cross-talk are within limits ($\leq$ 0% α into beta and $\leq$ 0.1% beta into alpha). Sixty-minute background counts are also recorded daily (count must be within the mean background $\pm 3\sigma$) 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 system are found to be around 25% for alpha and 38% for beta.

Since the levels of radioactivity encountered in environmental samples are typically low, a long counting time is often necessary. The detection limit, i.e., minimum detectable concentration (MDC), is calculated from a combination of instrument calibration parameters (efficiency, attenuation factor, background and background counting time) and sample parameters (residual mass, volume and sample counting time). The levels not detected or less than MDC occur when the activity concentration is less than calculated uncertainty.

The gross alpha and beta activities are expressed in the following two ways. First, the *activity concentration* is calculated as the activity per unit volume of air sampled (Bq/m^3). Second, *activity density* is calculated as the activity per unit aerosol mass collected (Bq/g). The flow volume (per cubic meter) and the mass loading (mg) on the monthly composite samples are listed in Table 1.1.

Samples for actinide and elemental analyses are prepared by using microwave acid digestion in a CEM MARS™ Xpress™ microwave unit according to CEMRC procedures. Individual FAS filters are placed in separate Teflon vessels and digested at 195^{o}C using an acid matrix consisting of nitric acid, hydrochloric acid, and hydrofluoric acid. A blank filter and Certified Reference Material (CRM) filter are also digested in the same manner for QC-purposes. All acids used in the digestions are concentrated and purified either by using a Milestone Inc. sub-boiling quartz distillation apparatus or purchased as "trace metal" grade. After digestion, the FAS filter solutions are then combined into weekly composites and a small aliquot of each weekly composite is removed for inorganic analysis by inductively-coupled Plasma Mass Spectrometry (ICP-MS).

The weekly composites are then combined into monthly composite samples for the determination of actinide and gamma measurements. The detection and measurement of gamma radionuclides on filter samples are carried out using a low-background, HPGe co-axial detector with a count time of 48 hours. Only one half of the composite sample is normally used for the determination of the actinide activities and the remaining aliquot is archived. The composite sample is evaporated to dryness, and the residue is digested in perchloric acid ($HClO_4$) to destroy the black residue, which consists mostly of diesel exhaust particulates from within the repository. The actinides are concentrated in an iron hydroxide precipitate as $Fe(OH)_3$. After decantation and centrifugation, the precipitate is dissolved in 10 ml of conc. HNO_3 and diluted to 20 ml to make the solution 8M 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 $NaNO_2$. The sample solutions are then ready for the purification procedure with anion exchange column chromatography. Plutonium is separated from americium and uranium and purified using an anion exchange column. The fraction containing americium and uranium is separated using a TRU extraction chromatography column followed by purification of U on an anion exchange column. The individual actinides are then micro-co-precipitated with a Nd-carrier and counted using alpha spectrometry for 5 days.

The primary purpose of the WIPP-EM plan, including the studies at Station A, has been to compare pre- vs. post-disposal conditions. The WIPP received its first radioactive waste shipments on March 26, 1999. This is considered to be the cut-off date separating the pre-disposal phase from the post-disposal, or operational phase. In addition, the first shipment of mixed waste arrived at the WIPP on September 9, 2000. Data for samples collected prior to this date compose a pre-mixed waste baseline for the elemental data, while those collected afterwards are considered operational. In Figures 1.4 to 1.7 and Figures 1.22 to 1.27 discussed in the Radiological and Non-Radiological sections below, data points are distinguished by color for the pre-operational and operational monitoring phases.

RADIOLOGICAL MONITORING RESULTS

Gross Alpha and Beta Activities and Aerosol Mass Loadings

Gross alpha and beta measurements in airborne particulates collected at Station A are used as a screening technique to provide timely information on levels of radioactivity in the environment around the WIPP site. The gross alpha and beta activity in air filters prior to arrival of waste at WIPP were used as a baseline concentration. The bulk of the activity in those samples results from naturally occurring radioactive materials (NORM), specifically radon daughters. The baseline concentrations of gross alpha and gross beta activities were 1.49 mBq/m^3 and 4.90 mBq/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. In other words, the pre-operational baseline data is compared with the operational data to assess the integrity of the WIPP project. The minimum detectable activity concentrations and densities for the gross alpha emitters are $\approx 1\times10^{-7}$ Bq/m^3 and $\approx$0.7 Bq/g, respectively, while for gross beta emitters the corresponding values were $\approx 2 \times10^{-7}$ Bq/m^3 and $\approx$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 activity densities could either be due to changes in the amount of radioactivity in the sample or the aerosol mass in the samples. As a side note, the volumes of air sampled, which are not shown, have changed little during the course of the program and therefore should have little or no effect on the activity concentrations.

The annual gross alpha and beta activities measured at station A in 1998 through 2012 are plotted in Figures 1.4-1.7 for trend analysis. Summary statistics for mass loading and gross alpha and beta activities are given in Tables 1.2-1.5. As shown in Tables 1.2 and 1.3, the pre-operational gross alpha activity densities and concentrations were both low compared with the annual mean values for the first five years of operation, but have gone back up above the pre-operational levels during 2007-2009. Gross alpha activities exhibit clear seasonal variability with peaks occurring in the winter (Figures 1.4 and 1.5). An especially pronounced annual cycle in alpha activity concentrations, with high values in December and January and low values mid-year, was seen in 2004 to 2005 and again in 2007 to 2008. In 2012, activities appear to be close to pre-operational levels with an overall slightly increasing trend visible over the years from 2003 to 2012. Similar seasonal trends in gross beta data can be seen in Figures 1.6 and 1.7. The pronounced annual cycle in beta activity concentrations, with high values in December and January and low values mid-year, are seen throughout the entire operational monitoring period from 2000 through 2012.

Blank filters are also counted for gross alpha and beta activities so that background corrections (activities present in the blank filters) can be made in the gross alpha and beta measurements of the air samples. The gross alpha and beta activities have not changed greatly since the inception of the studies. The bulk of the activity in pre-operational samples results from naturally occurring radioactive materials, specifically radon daughters. Both gross alpha and gross beta activities exhibit clear seasonal variability with maximum values occurring in December and January and minimum values in mid-year. The two samples with elevated gross beta activity concentrations (0.058 Bq/m^3) observed in early 2001(Figure 1.6) are because of contamination by material released from an underground fire extinguisher. Follow-up measurements verified that the fire retardant containing ^{40}K was the cause of the elevated results and that WIPP waste had not been released. The high beta concentration value in late 2009 is considered a real result but a statistical anomaly.

The gross alpha and beta activity concentrations and densities in the WIPP exhaust air collected from 1998 to 2012 are shown in Figures 1.8 and 1.9 as a function of their ranges (vertical lines), medians (stars), and boxes indicating with horizontal lines the means plus or minus two standard deviations. The interpretation of Figures 1.8 and 1.9 is that activities of the alpha and beta activities have not changed greatly since the WIPP became operational, a time-series plot of the aerosol mass loadings (Figure 1.10) show a trend towards lower sample masses beginning in 2004 and also less scatter in the gravimetric data and then increasing again in late 2007 through 2011. In 2012, aerosol mass loading again decreased towards lower mass. The latter point is also evident in Table 1.6, which shows that the relative standard error, i.e. the standard error divided by the arithmetic mean and expressed as a percentage, was ≤ 8% in 2000 and 2003-2009 of the study compared with 10% to 20% in 1999, 2001, 2002, 2010, and 2011. This decrease in aerosol mass loadings would directly contribute to the high alpha activity densities observed in the more recent years of the WIPP-EM program. The average mass loadings on Station A filters from 1998-2012 are plotted in Figure 1.11 to show the trend.

The weekly and monthly average of gross alpha and gross beta activity concentrations measured in Station A samples for 2012 are shown in Figures 1.12 to 1.15. As can be seen in these figures, gross activity concentrations appear to increase during summer and autumn months. The annual average of gross alpha and beta activity concentration measured in Station A samples for the period 1998-2012 are shown in Figure 1.16. The activity concentrations of alpha and beta emitters have not changed greatly since the inception of the studies; the gross alpha activities appeared to decrease slightly after the WIPP became operational and then in 2007 and 2008 began to increase again to pre-disposal levels, while beta activity remains slightly lower than pre-operational levels. The observed trends may be results of environmental phenomena, changes in WIPP operational practices, or a combination of these factors. The most noticeable decrease in these measurements appeared to coincide with increased mining activity at the WIPP. The maximum detectable concentrations of gross alpha and beta as well as aerosol mass loading in Station A filters from 1998 to 2012 are summarized in Table 1.7. The high mass loading is usually associated with low gross alpha/beta activity. This is consistent with the previous studies in which it has been shown that WIPP salts contain lower amounts of naturally occurring radioactive elements (e.g., U and Th) than crustally-derived materials (USDOE, 2000). This suggests that operations at the WIPP (e.g., salt from the underground mining, construction or road dust) may have generated some aerosols that contributed to the mass loadings but contain less naturally occurring radionuclides than ambient aerosols typically do. Under these conditions, it would be expected that as the proportion of salt per unit of aerosol mass increases, radioactivity per unit mass in WIPP effluents would decrease.

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

Table 1.1 Total Air Flow Volume and Mass Loading Recorded in Monthly Composite Filters in 2012

Month	SID	Air Flow volume (m^3)	Mass Loading (mg)
January	27523	2357.54	416.04
February	27525	2310.55	375.04
March	27527	2392.94	407.67
April	27529	2385.92	276.48
May	27531	2419.44	345.40
June	27533	2305.91	393.60
July	27535	2391.17	326.56
August	27537	2301.98	268.10
September	27539	2321.40	279.58
Sept. BU	28561	2381.99	297.77
October	27541	2423.42	324.74
November	27543	2341.92	265.90
December	27545	2216.50	212.10

BU= Back-up filter

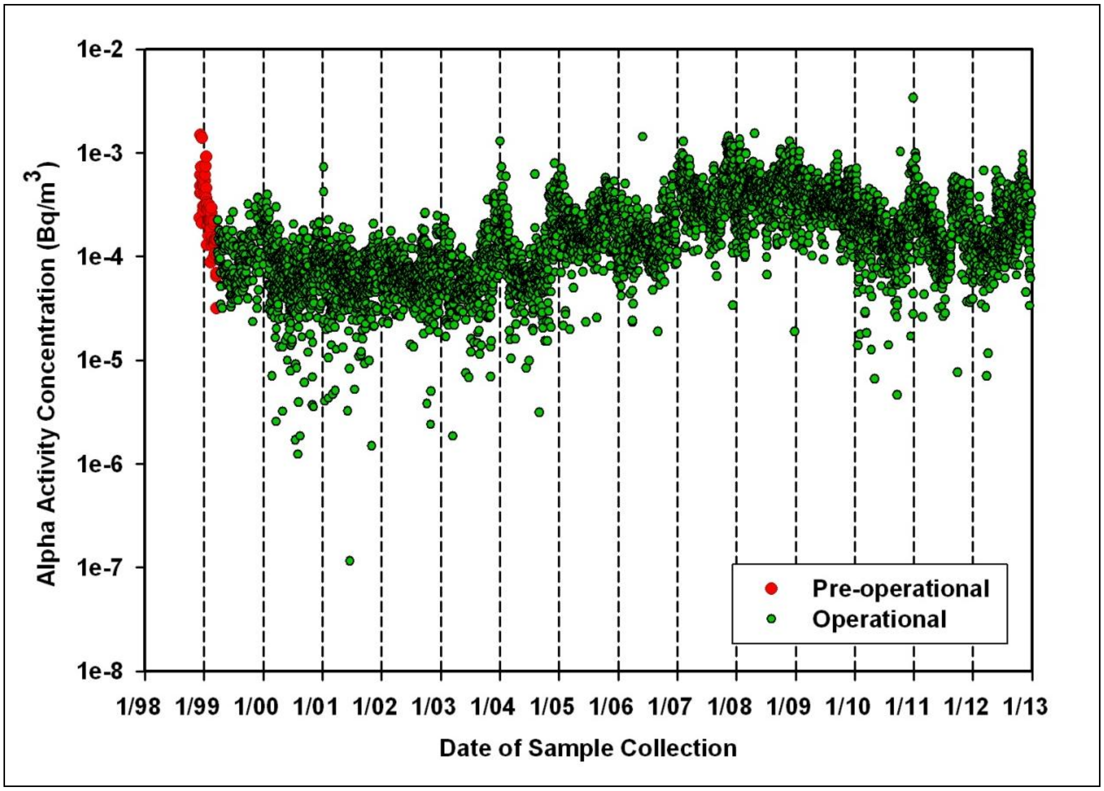


Figure 1.4 Gross Alpha Activity Concentrations measured in Station A Filters

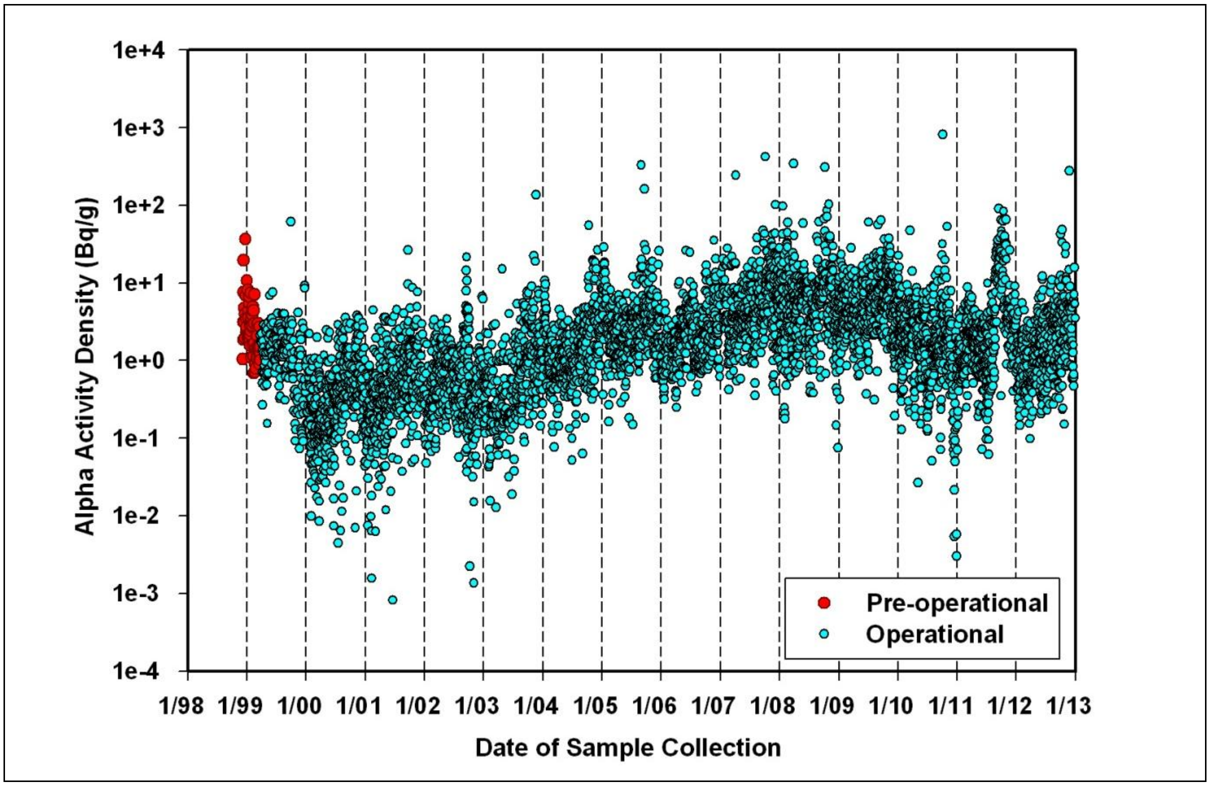


Figure 1.5 Gross Alpha Activity Densities measured in Station A Filters

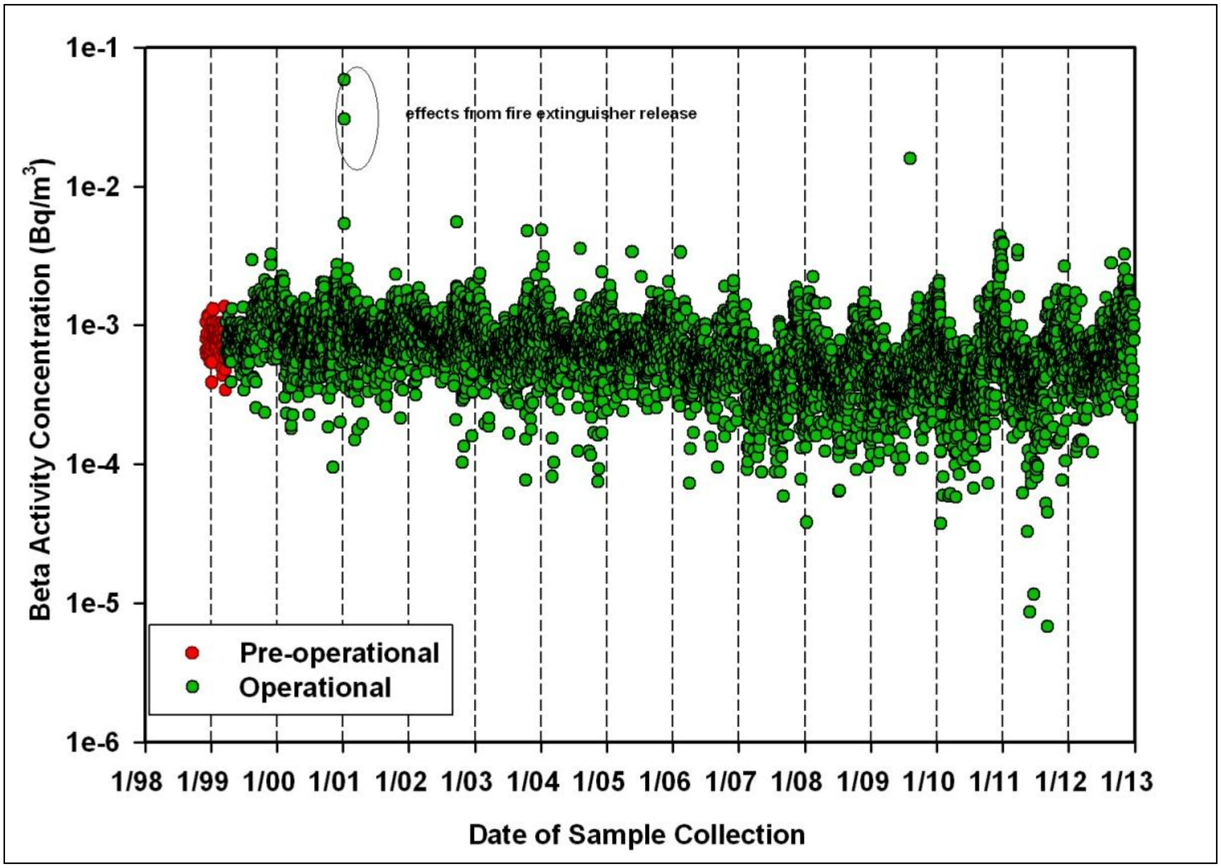


Figure 1.6 Gross Beta Activity Concentrations measured in Station A Filters

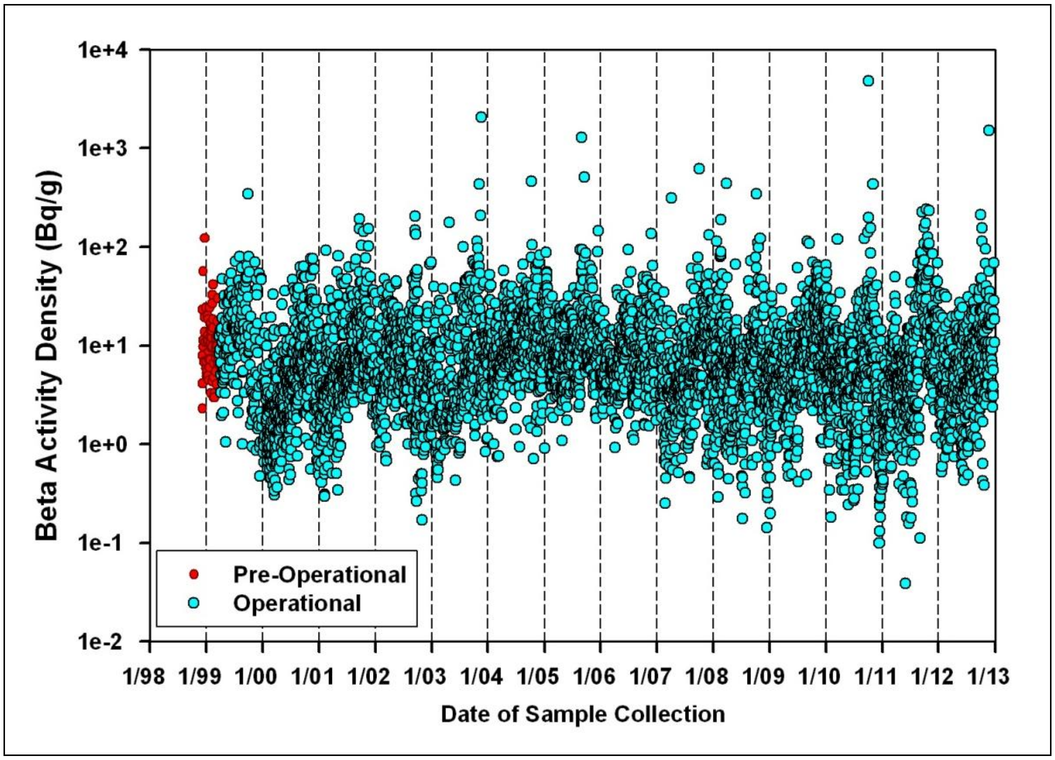


Figure 1.7 Gross Beta Activity Densities measured in Station A Filters

Table 1.2 Summary Statistics for Mass Loading and Gross Alpha Activity Density Analyses of Station A Filters

		Alpha Activity Density (Bq/g)			
Group	N	% <MDC	Mean	Standard Error	Maximum
Pre-Disposal	70	0%	3.6	0.59	36.7
1999*	185	1%	1.9	0.33	61.4
2000	465	67%	1.0	0.07	3.8
2001	428	65%	1.3	0.12	9.6
2002	382	33%	1.0	0.13	21.5
2003	345	35%	2.1	0.61	135.4
2004	370	17%	2.4	0.18	26.6
2005	361	4%	5.6	1.07	327.8
2006	264	3%	3.1	0.21	35.4
2007	378	0%	9.1	1.3	421.2
2008	431	1%	10.1	1.20	345.1
2009	433	4%	7.1	0.35	63.5
2010	471	6%	4.6	1.74	815.0
2011	443	7%	5.2	0.49	89.9
2012	421	2%	3.3	0.06	276.0

Table 1.3 Summary Statistics for Mass Loading and Gross Alpha Activity Concentration Analyses of Station A Filters

		Alpha Activity Concentration (mBq/m^3)			
Group	N	% <MDC	Mean	Standard Error	Maximum
Pre-Disposal	70	0%	0.315	0.031	1.49
1999*	185	1%	0.110	0.005	0.37
2000	465	67%	0.112	0.005	0.39
2001	428	65%	0.082	0.004	0.42
2002	382	34%	0.081	0.002	0.26
2003	345	35%	0.104	0.005	0.40
2004	370	17%	0.144	0.008	1.29
2005	361	4%	0.223	0.006	0.71
2006	264	3%	0.166	0.007	1.43
2007	378	0%	0.444	0.014	1.44
2008	431	1%	0.455	0.011	1.53
2009	433	4%	0.357	0.008	1.03
2010	471	6%	0.199	0.009	3.37
2011	443	7%	0.218	0.007	1.00
2012	421	2%	0.210	0.007	0.967

*From 26 March to 31 December 1999
N = number of filter

Table 1.4 Summary Statistics for Mass Loading and Gross Beta Activity Density Analyses of Station A Filters

		Beta Activity Density (Bq/g)			
Group	N	%	Mean	Standard Error	Maximum
Pre-Disposal	70	0%	14.0	1.90	120
1999*	189	0%	20.0	2.20	350
2000	461	6%	7.7	0.54	76
2001	429	3%	12.0	1.00	190
2002	382	2%	12.0	0.99	200
2003	345	1%	20.0	6.30	2100
2004	369	4%	16.0	1.50	460
2005	361	1%	20.0	3.90	1300
2006	324	1%	9.8	0.57	93
2007	378	2%	11.3	1.89	616
2008	431	3%	12.6	1.53	438
2009	433	6%	11.3	0.64	114
2010	471	3%	20.7	10.2	4780
2011	443	7%	13.9	1.33	241
2012	421	0%	13.5	3.66	1510

Table 1.5 Summary Statistics for Mass Loading and Gross Beta Activity Concentration Analyses of Station A Filters

		Beta Activity Concentration (mBq/m^3)			
Group	**N**	**% <MDC**	**Mean**	**Standard**	**Maximum**
Pre-Disposal	70	0%	1.14	0.09	4.94
1999*	189	0%	0.99	0.03	3.25
2000	461	6%	0.98	0.02	2.73
2001	429	3%	1.14	0.16	58.41
2002	382	2%	0.90	0.02	1.97
2003	345	1%	0.79	0.02	4.77
2004	369	4%	0.81	0.02	4.85
2005	361	1%	0.78	0.02	2.07
2006	324	1%	0.61	0.02	2.10
2007	378	2%	0.50	0.02	1.88
2008	431	3%	0.52	0.01	2.25
2009	433	6%	0.56	0.04	15.84
2010	471	3%	0.65	0.03	4.41
2011	443	7%	0.55	0.02	3.87
2012	421	0%	0.72	0.02	3.26

*From 26 March to 31 December 1999
N = number of filter

Table 1.6 Summary Statistics for Aerosol Mass Loadings on Station A (µg/m^3 per filter)

Group	Number of filter	Mean	Standard Error	RSE (%)
Pre-Disposal	70	125.0	12.2	9.8
1999*	189	171.2	17.1	10.0
2000	461	396.5	20.7	5.2
2001	429	285.4	29.4	10.3
2002	382	274.7	55.5	20.2
2003	345	204.3	12.7	6.2
2004	369	95.7	6.0	6.3
2005	361	90.2	3.9	4.3
2006	324	84.8	3.0	3.5
2007	378	125.2	10.2	8.1
2008	431	143.5	11.2	7.8
2009	433	100.2	6.0	6.0
2010	471	385.5	70.5	18.3
2011	443	176.0	24.5	14.0
2012	421	175.2	9.8	5.6

RSE = Relative Standard Error in percentage (Standard error divided by Mean)
From 26 March to 31 December 1999

Table 1.7 Summary Statistics of Maximum Gross Alpha/Beta Activities and the Corresponding Mass Loading on Station A Filters (1998-2012)

Year	Max. mass loading (mg)	Alpha activity Bq	Beta activity Bq	Max. alpha activity, Bq	Mass Loading (mg)	Max. beta activity, Bq	Mass loading (mg)
1998	26.23	0.036	0.124	0.181	4.94	0.606	4.94
1999	87.66	0.008	0.042	0.067	7.84	0.430	7.98
2000	87.94	0.014	0.073	0.065	24.77	0.759	12.90
2001	307.51	0.016	0.237	0.030	19.32	0.491	3.21
2002	148.85	0.000	0.025	0.029	17.95	0.500	17.95
2003	92.68	0.013	0.156	0.035	69.20	0.248	10.82
2004	79.02	0.041	0.116	0.083	8.45	0.260	8.90
2005	31.73	0.021	0.068	0.106	19.93	0.355	19.93
2006	79.44	0.021	0.057	0.122	4.65	0.282	2.08
2007	76.46	0.037	0.048	0.125	4.22	0.162	4.22
2008	121.58	0.018	0.035	0.161	5.42	0.213	5.42
2009	32.52	0.034	0.036	0.085	10.56	0.301	24.91
2010	321.2	0.0003	0.032	0.188	302.1	0.197	89.5
2011	79.0	0.049	0.115	0.049	79.0	0.310	6.27
2012	47.2	0.015	0.047	0.073	6.04	0.244	6.04

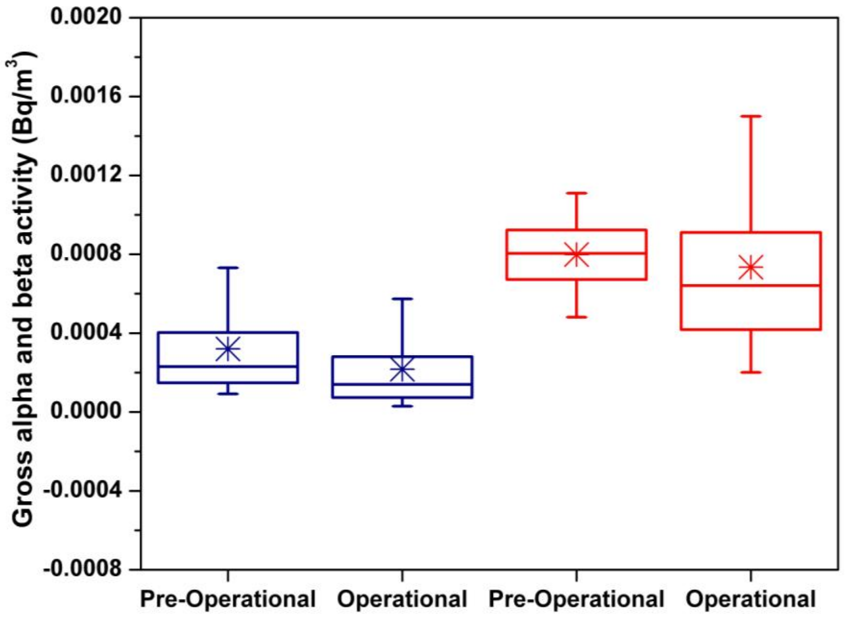


Figure 1.8 Comparison of pre-operational and operational Gross alpha (Navy Box) and beta (red box) activity concentration (Bq/m^3) in the Station A filters.

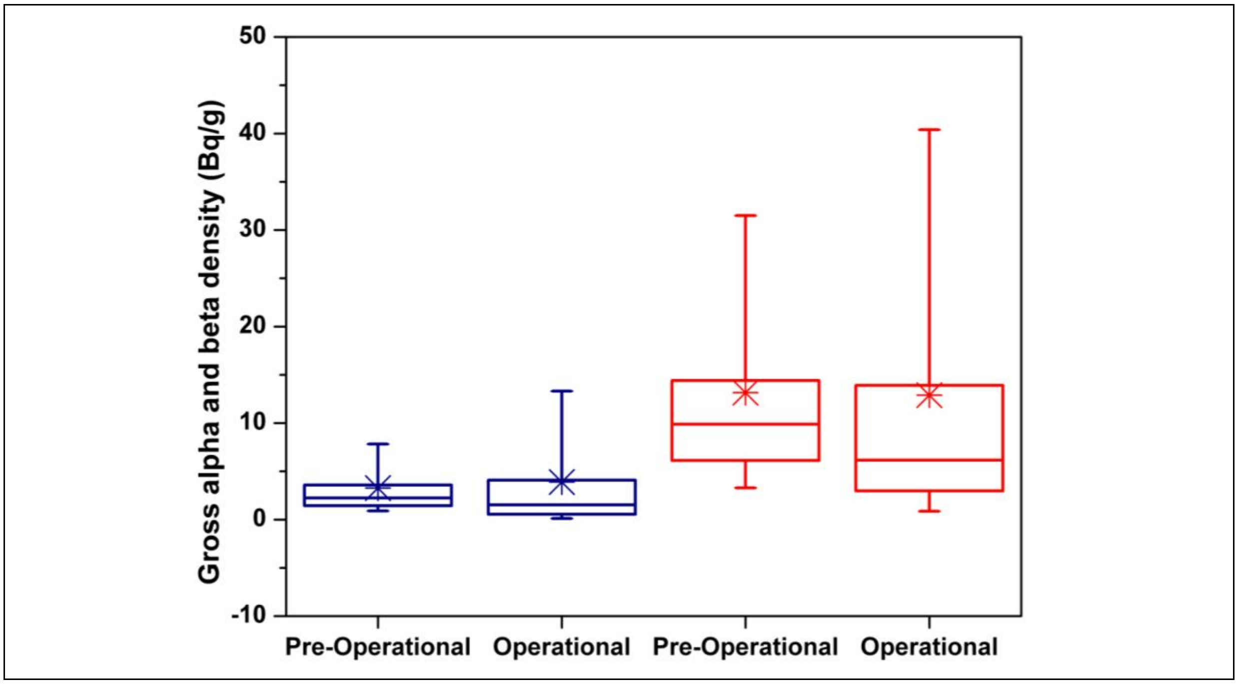


Figure 1.9 Comparison of pre-operational and operational Gross alpha (Navy Box) and beta (red box) activity density (Bq/g) in the Station A filters.

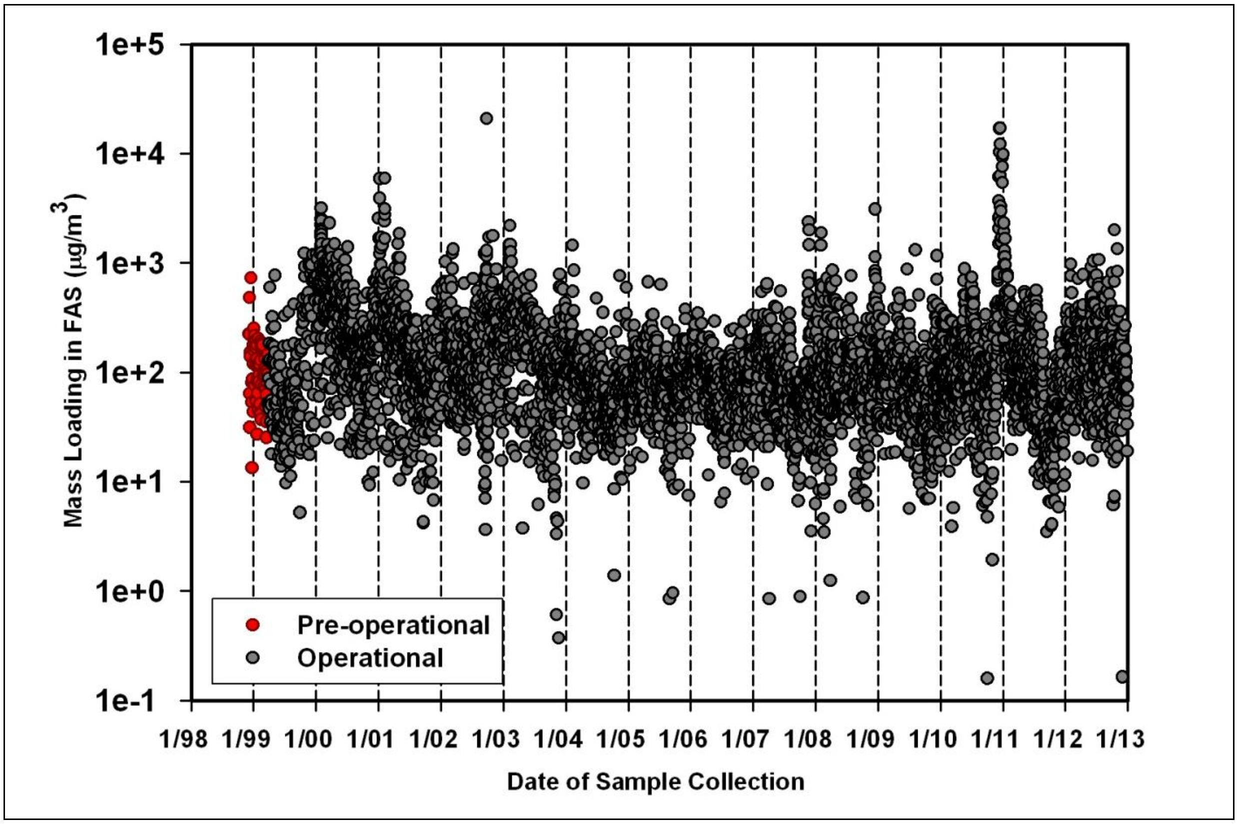


Figure 1.10 Aerosol Mass Loadings on Station A Filters (1998-2012)

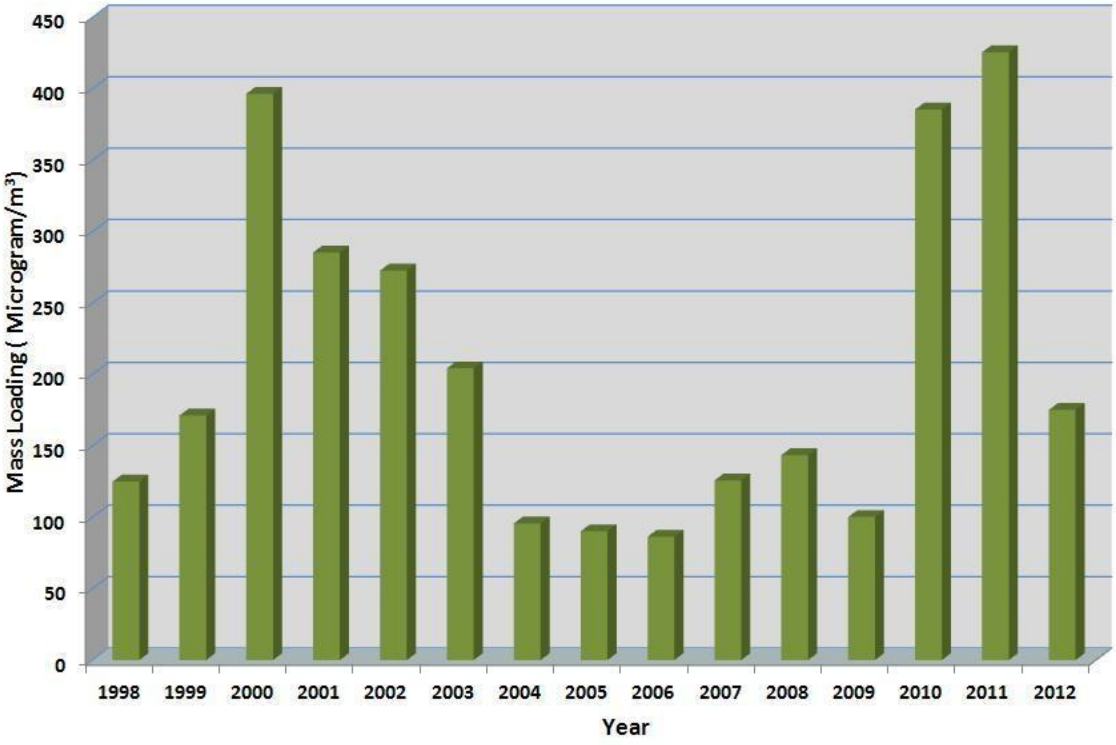


Figure 1.11 Average Mass Loadings on Station A Filters (1998-2012)

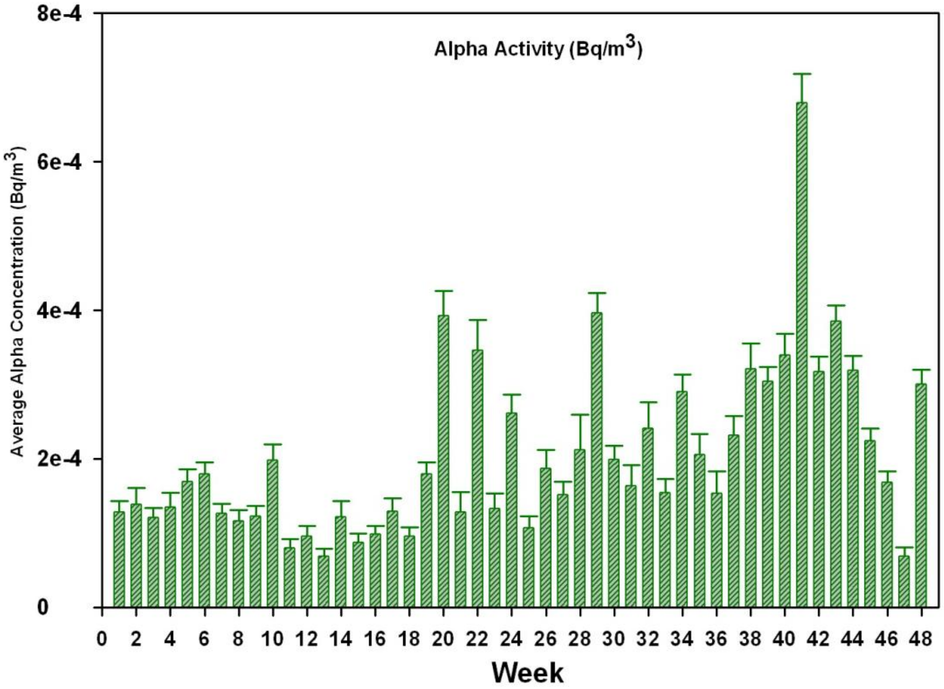


Figure 1.12 Weekly Average Gross Alpha Activity measured in Station A Filters in 2012

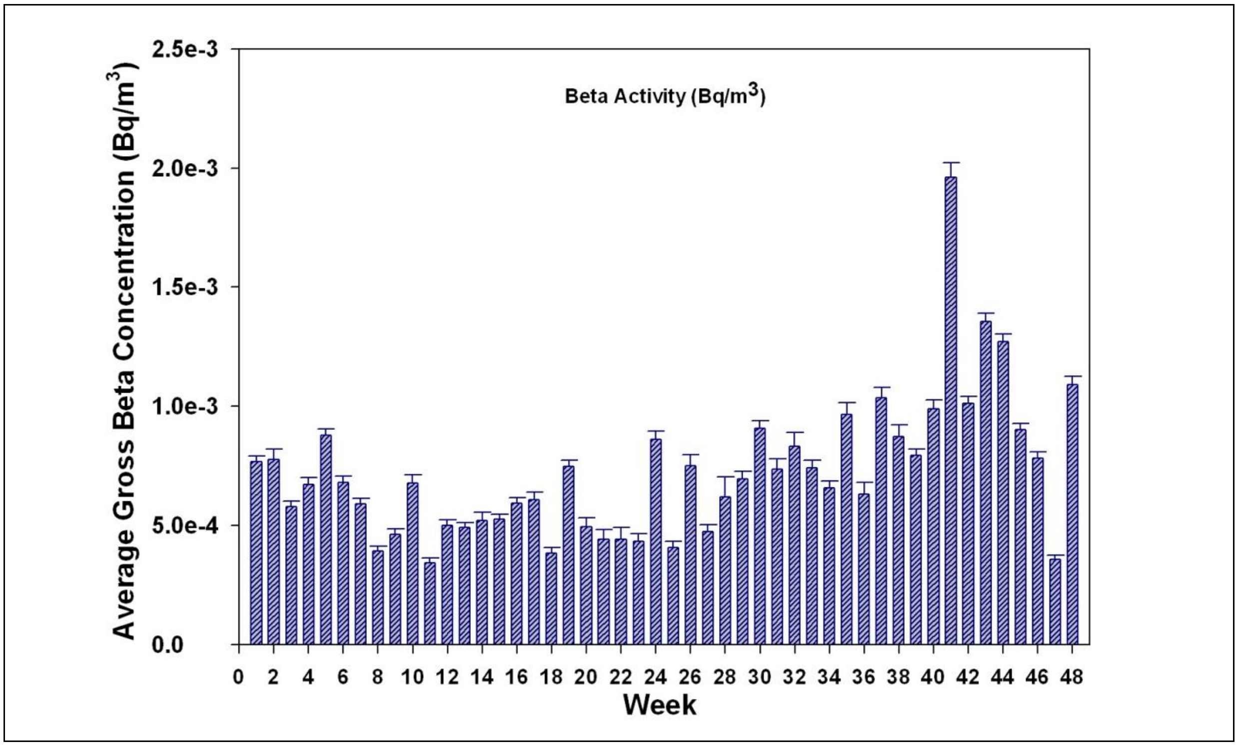


Figure 1.13 Weekly Average Gross Beta Activity measured in Station A Filters in 2012

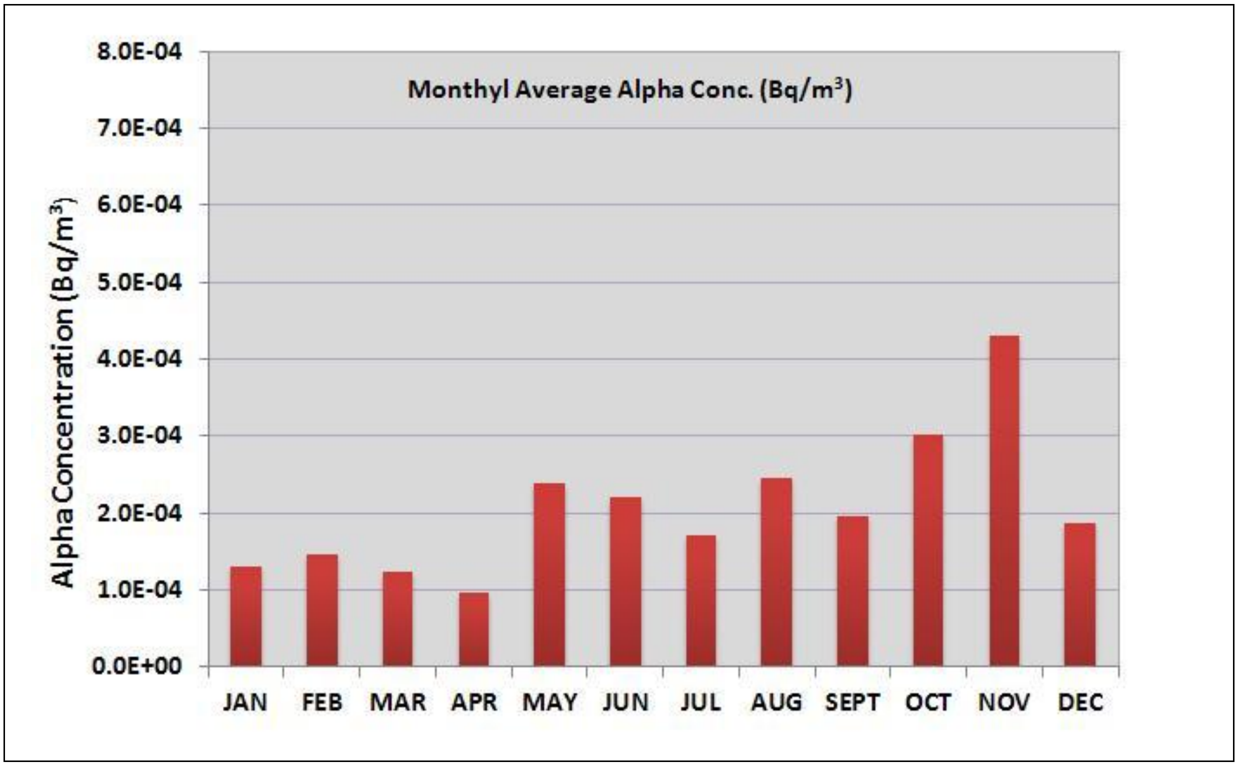


Figure 1.14 Monthly Average Gross Alpha Activity measured in Station A Filters in 2012

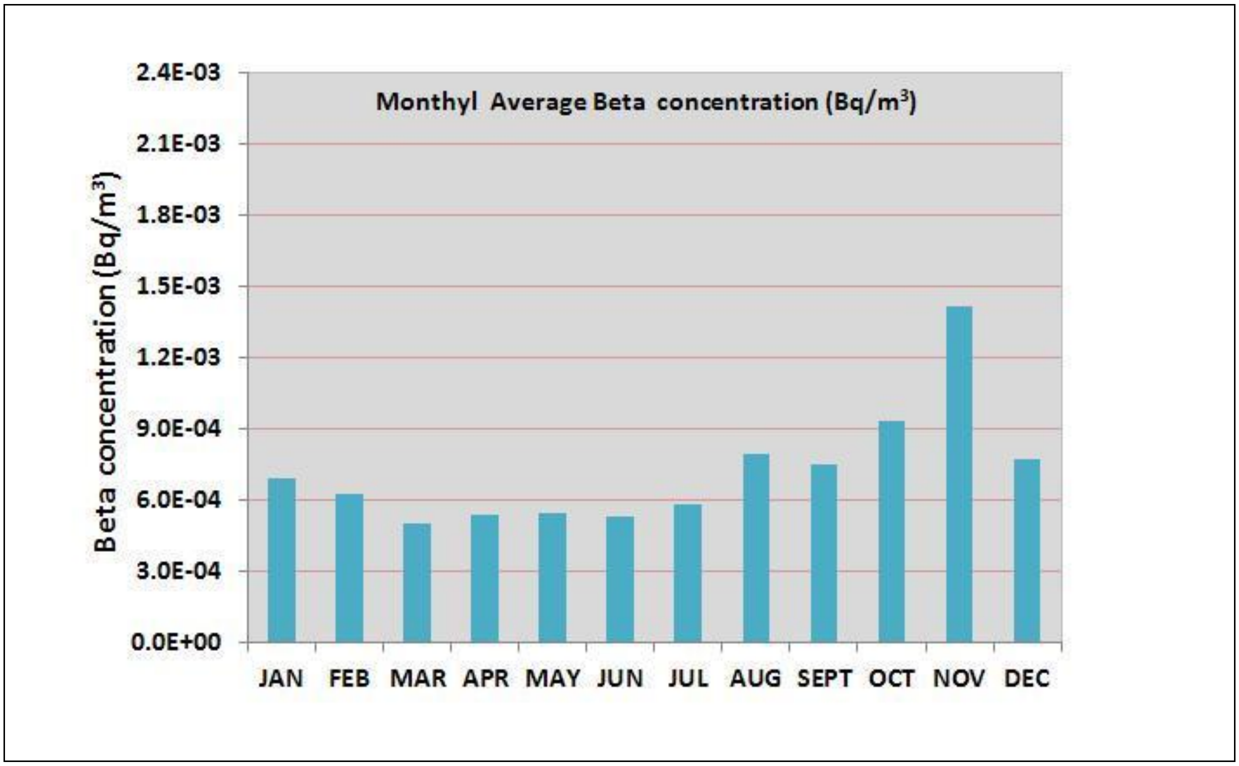


Figure 1.15 Monthly Average Gross Beta Activity measured in Station A Filters in 2012

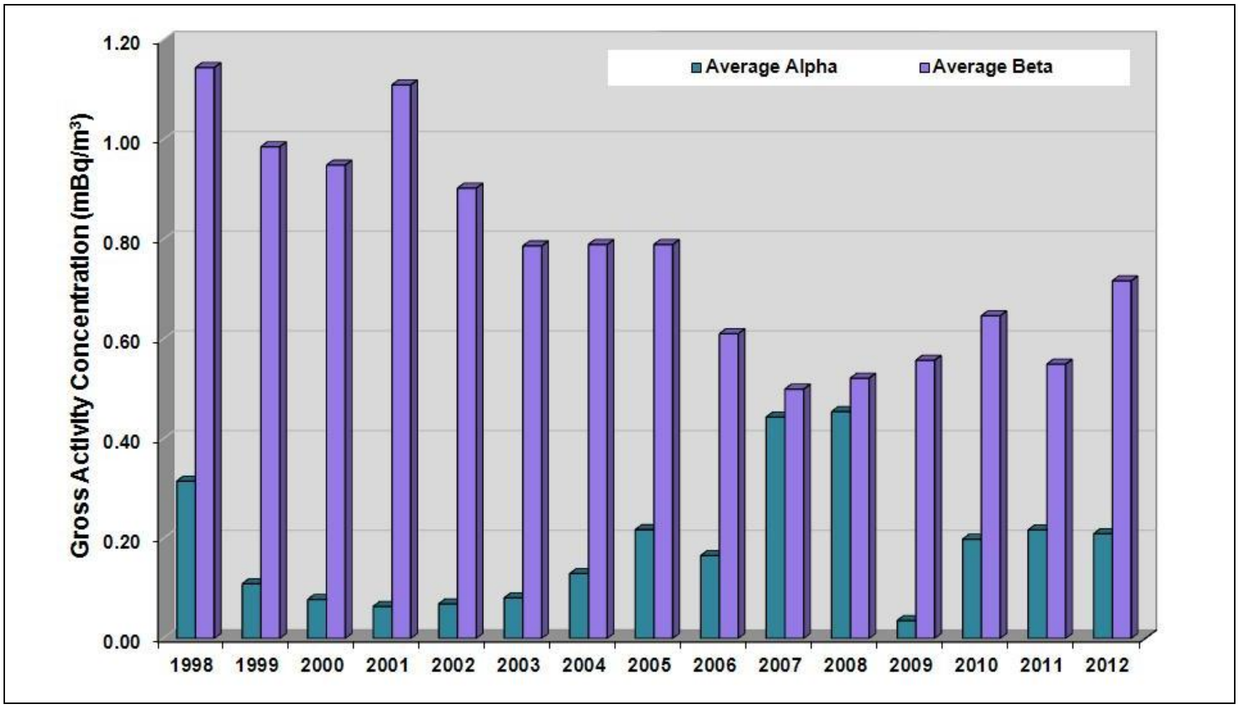


Figure 1.16 Average Annual Gross Alpha and Beta Concentrations in Station A filters

Actinide Data

Results of actinide analyses performed on monthly Station A composite samples are presented in Tables 1.8 and 1.9. Whenever the word "sample" is used in this section, it should be taken to mean "a monthly composite FAS sample".

No detectable concentrations of ^{238}Pu, $^{239+240}$Pu or ^{241}Am were detected in any of the 2012 samples. The activity concentrations of $^{239+240}$Pu, ^{238}Pu, ^{241}Am, ^{134}Cs, ^{137}Cs, and ^{60}Co measured in the 2012 monthly composite samples are illustrated in Figures 1.17 to 1.22. The time series of the $^{239+240}$Pu and ^{241}Am and $^{239+240}$Pu and ^{238}Pu activity concentrations in the WIPP exhaust air from the period from 1999 to 2012 are shown in Figures 1.23 and 1.24, respectively. An analysis of historical operational data indicates occasional detections of trace amount of $^{239+240}$Pu, ^{238}Pu, and ^{241}Am in the exhaust air release from the WIPP. From 2000 until 2012, only ten measurements can be declared as a detection of a radionuclide. These measurements are listed in Table 1.10. For comparison, the values detected above detection limits by WTS/NWP are listed in Table 1.11. The consistency between the CEMRC and WTS/NWP data further reflects high quality and sensitivity of CEMRC's monitoring results. However, it should be noted that these activities were extremely low and well below the action level of 37 Bq/m^3 that triggers the Continuous Air Alarms (CAMs) that are distributed throughout the WIPP. The historical average radionuclide concentrations data of $^{239+240}$Pu, ^{238}Pu, ^{241}Am measured by CEMRC from 2000-2012 are summarized in Tables 1.12 to 1.14.

The naturally occurring isotopes of U were detected in all monthly composites samples in 2012. The average ^{234}U/^{238}U activity ratio of 1.57±0.18 in the WIPP underground air samples indicates the presence of natural U (Table 1.15). The ^{234}U results were similar to those of ^{238}U for activity concentration and density, indicating secular equilibrium between the two isotopes. These results are consistent with those reported in previous CEMRC, reports.

With the exception of occasional detections from ^{40}K, no detectable gamma-emitting radio-nuclides were observed during the monitoring period 2012. The minimum, maximum, and average concentrations of radionuclides for the 2012 FAS composite samples are summarized in Table 1.16.

Relative distance from average

The relative distance from average (RDA) was used for a first impression of mean variation's sequence. For comparability reasons absolute distance from average was normed for every radionuclide to the average itself. The following equation shows how RDA was calculated, with radionuclides (RN) as the value's associated radionuclide.

$$\mathbf{RDA}_{\mathbf{X}} = \frac{\overline{\mathbf{X}}_{\mathbf{RN}} - \mathbf{X}}{\overline{\mathbf{X}}_{\mathbf{RN}}}$$

The RDA's chronological sequence (measured data from 2000 to 2012) is shown in Figure 1.25. In the year 2008 the RDA raises up to almost 100.

Conclusion

The occasional detection of extremely low levels of $^{239+240}$Pu, ^{238}Pu and ^{241}Am in the WIPP exhaust air is largely due to their presence in the global environment, although an occasional higher detection level may well be attributable to minute particles with contamination being released from the surface of a waste container during handling. The sensitivity of the measurements being made make it likely that just a few atoms would be detected; therefore there is no reason to believe that WIPP is a source of environmental contamination that can be considered significant by any health-based standard.

Table 1.8 Activity concentration of Monthly Composite filters from Station A

Activity Concentration (Bq/m^3)			
Radionuclide	**Activity**	**SD**	**MDC**
JANUARY 2012			
^{241}Am	1.61E-08	2.62E-08	3.54E-08
^{238}Pu	3.43E-08	6.41E-08	2.42E-07
$^{239+240}$Pu	1.71E-08	7.07E-08	2.72E-07
^{228}Th	2.86E-07	6.71E-08	1.59E-07
^{230}Th	6.22E-07	8.11E-08	7.39E-08
^{232}Th	4.79E-07	7.39E-08	1.08E-07
^{234}U	4.37E-07	7.23E-08	1.38E-07
^{235}U	7.97E-08	4.11E-08	1.23E-07
^{238}U	3.85E-07	6.50E-08	1.10E-07
^{134}Cs	-5.84E-05	9.75E-06	3.29E-05
^{137}Cs	-1.80E-05	1.27E-05	4.24E-05
^{40}K	1.07E-04	1.44E-04	4.77E-04
^{60}Co	1.82E-06	1.18E-05	3.93E-05
FEBRUARY 2012			
^{241}Am	7.74E-08	5.92E-08	1.85E-07
^{238}Pu	3.79E-08	3.46E-08	1.22E-07
$^{239+240}$Pu	3.39E-08	3.39E-08	1.22E-07
^{228}Th	1.68E-07	5.53E-08	1.49E-07
^{230}Th	5.23E-07	8.07E-08	1.39E-07
^{232}Th	1.78E-07	5.24E-08	1.29E-07
^{234}U	7.10E-07	1.48E-07	3.31E-07
^{235}U	1.64E-07	9.81E-08	3.11E-07
^{238}U	5.83E-07	1.22E-07	2.24E-07
^{134}Cs	-4.03E-05	9.52E-06	3.21E-05
^{137}Cs	6.89E-06	1.25E-05	4.14E-05
^{40}K	2.06E-04	1.45E-04	4.78E-04
^{60}Co	2.30E-05	1.18E-05	3.87E-05
MARCH 2012			
^{241}Am	5.18E-08	3.94E-08	1.19E-07
^{238}Pu	7.16E-08	5.66E-08	1.93E-07
$^{239+240}$Pu	1.30E-07	6.52E-08	1.93E-07
^{228}Th	6.52E-07	8.54E-08	1.31E-07
^{230}Th	9.93E-07	1.02E-07	1.22E-07
^{232}Th	5.10E-07	7.66E-08	1.31E-07
^{234}U	2.76E-07	6.41E-08	1.48E-07
^{235}U	4.90E-08	4.24E-08	1.47E-07
^{238}U	2.26E-07	6.16E-08	1.56E-07
^{134}Cs	-3.81E-05	8.85E-06	2.99E-05
^{137}Cs	2.51E-06	1.22E-05	4.05E-05
^{40}K	-2.49E-06	1.14E-05	3.81E-05
^{60}Co	5.18E-08	3.94E-08	1.19E-07

Table 1.8 Activity concentration of Monthly Composite filters from Station A (continued)

Activity Concentration (Bq/m^3)			
Radionuclide	**Activity**	**SD**	**MDC**
APRIL 2012			
^{241}Am	-3.77E-09	2.33E-08	9.24E-08
^{238}Pu	1.07E-07	5.00E-08	1.44E-07
$^{239+240}$Pu	9.57E-08	4.88E-08	1.52E-07
^{228}Th	4.49E-07	7.20E-08	1.29E-07
^{230}Th	5.12E-07	8.12E-08	1.66E-07
^{232}Th	4.66E-07	7.29E-08	1.29E-07
^{234}U	2.55E-07	7.74E-08	2.14E-07
^{235}U	4.82E-08	3.22E-08	1.01E-07
^{238}U	2.86E-07	6.26E-08	1.19E-07
^{134}Cs	-5.75E-05	9.28E-06	3.13E-05
^{137}Cs	-1.42E-05	1.24E-05	4.14E-05
^{40}K	1.48E-04	1.40E-04	4.61E-04
^{60}Co	2.71E-05	1.12E-05	3.64E-05
MAY 2012			
^{241}Am	6.12E-08	3.79E-08	9.86E-08
^{238}Pu	3.46E-08	3.29E-08	1.16E-07
$^{239+240}$Pu	5.25E-08	3.15E-08	9.83E-08
^{228}Th	4.94E-07	9.59E-08	2.37E-07
^{230}Th	6.81E-07	9.24E-08	1.51E-07
^{232}Th	1.81E-07	4.75E-08	9.36E-08
^{234}U	3.28E-07	6.91E-08	1.36E-07
^{235}U	5.61E-08	5.25E-08	1.84E-07
^{238}U	3.11E-07	6.87E-08	1.43E-07
^{134}Cs	-3.78E-05	1.05E-05	3.54E-05
^{137}Cs	-6.74E-06	1.24E-05	4.11E-05
^{40}K	1.07E-04	1.39E-04	4.61E-04
^{60}Co	8.42E-06	1.19E-05	3.96E-05
JUNE 2012			
^{241}Am	2.62E-09	3.18E-08	1.21E-07
^{238}Pu	4.88E-08	4.23E-08	1.47E-07
$^{239+240}$Pu	-5.45E-08	3.55E-08	1.77E-07
^{228}Th	4.31E-07	1.03E-07	2.85E-07
^{230}Th	7.72E-07	9.58E-08	1.34E-07
^{232}Th	1.12E-07	5.12E-08	1.54E-07
^{234}U	1.85E-06	1.63E-07	1.88E-07
^{235}U	5.33E-07	9.67E-08	1.58E-07
^{238}U	6.62E-07	9.77E-08	1.55E-07
^{134}Cs	-3.08E-05	1.06E-05	3.58E-05
^{137}Cs	1.71E-05	1.28E-05	4.22E-05
^{40}K	2.08E-04	1.45E-04	4.77E-04
^{60}Co	4.27E-06	1.26E-05	4.17E-05

Table 1.8 Activity concentration of Monthly Composite filters from Station A (continued)

Activity Concentration (Bq/m^3)			
Radionuclide	Activity	SD	MDC
JULY 2012			
^{241}Am	1.71E-08	5.37E-08	2.04E-07
^{238}Pu	3.88E-08	2.38E-08	7.14E-08
$^{239+240}$Pu	6.58E-08	4.10E-08	1.32E-07
^{228}Th	6.54E-07	8.96E-08	1.90E-07
^{230}Th	7.63E-07	8.54E-08	1.23E-07
^{232}Th	2.18E-07	5.05E-08	1.14E-07
^{234}U	6.00E-07	8.64E-08	1.36E-07
^{235}U	7.71E-08	4.07E-08	1.19E-07
^{238}U	3.33E-07	7.21E-08	1.64E-07
^{134}Cs	-3.33E-05	1.01E-05	3.39E-05
^{137}Cs	2.50E-05	1.21E-05	3.96E-05
^{40}K	-8.27E-05	1.41E-04	4.71E-04
^{60}Co	1.34E-05	1.18E-05	3.91E-05
AUGUST 2012			
^{241}Am	1.30E-08	2.48E-08	8.17E-08
^{238}Pu	-2.33E-08	4.69E-08	1.89E-07
$^{239+240}$Pu	1.98E-08	4.21E-08	1.57E-07
^{228}Th	3.08E-07	9.62E-08	2.85E-07
^{230}Th	4.86E-07	7.77E-08	1.33E-07
^{232}Th	1.11E-07	3.65E-08	7.43E-08
^{234}U	7.62E-07	1.08E-07	1.47E-07
^{235}U	9.47E-08	6.68E-08	2.22E-07
^{238}U	4.35E-07	8.86E-08	1.78E-07
^{134}Cs	-3.19E-05	1.02E-05	3.44E-05
^{137}Cs	-1.91E-05	1.30E-05	4.33E-05
^{40}K	5.68E-05	1.45E-04	4.79E-04
^{60}Co	1.28E-05	1.20E-05	3.97E-05
SEPTEMBER 2012			
^{241}Am	-3.06E-08	2.35E-08	1.13E-07
^{238}Pu	4.28E-08	3.36E-08	1.14E-07
$^{239+240}$Pu	-5.39E-08	5.05E-08	2.17E-07
^{228}Th	2.90E-07	5.99E-08	1.16E-07
^{230}Th	7.24E-07	8.56E-08	7.10E-08
^{232}Th	2.59E-07	5.53E-08	1.03E-07
^{234}U	1.44E-06	1.52E-07	1.85E-07
^{235}U	1.32E-07	6.46E-08	1.89E-07
^{238}U	1.48E-06	1.50E-07	1.31E-07
^{134}Cs	-3.07E-05	9.04E-06	3.05E-05
^{137}Cs	8.55E-06	1.25E-05	4.14E-05
^{40}K	6.84E-05	1.44E-04	4.76E-04
^{60}Co	4.91E-06	1.17E-05	3.88E-05

Table 1.8 Activity concentration of Monthly Composite filters from Station A (continued)

Activity Concentration (Bq/m^3)			
Radionuclide	**Activity**	**SD**	**MDC**
SEPTEMBER BU 2012			
^{241}Am	2.20E-09	2.70E-08	1.02E-07
^{238}Pu	9.94E-09	3.25E-08	1.31E-07
$^{239+240}$Pu	6.47E-08	4.04E-08	1.30E-07
^{234}U	6.35E-07	9.42E-08	1.76E-07
^{235}U	3.94E-08	3.48E-08	1.22E-07
^{238}U	5.60E-07	8.58E-08	1.49E-07
OCTOBER 2012			
^{241}Am	3.48E-08	3.42E-08	1.11E-07
^{238}Pu	3.64E-08	2.58E-08	8.46E-08
$^{239+240}$Pu	5.88E-08	4.08E-08	1.35E-07
^{228}Th	4.29E-07	9.52E-08	2.51E-07
^{230}Th	5.92E-07	8.99E-08	1.70E-07
^{232}Th	1.84E-07	5.21E-08	1.22E-07
^{234}U	8.74E-07	1.22E-07	2.05E-07
^{235}U	1.85E-07	7.34E-08	2.02E-07
^{238}U	3.54E-07	8.22E-08	1.79E-07
^{134}Cs	-3.90E-05	9.35E-06	3.16E-05
^{137}Cs	1.50E-05	1.19E-05	3.93E-05
^{40}K	1.27E-04	1.37E-04	4.53E-04
^{60}Co	4.84E-06	1.12E-05	3.72E-05
NOVEMBER 2012			
^{241}Am	3.02E-08	2.66E-08	3.22E-08
^{238}Pu	2.18E-08	3.45E-08	1.31E-07
$^{239+240}$Pu	-1.01E-13	3.09E-08	1.31E-07
^{228}Th	4.08E-07	9.45E-08	2.55E-07
^{230}Th	7.16E-07	9.24E-08	1.40E-07
^{232}Th	2.38E-07	5.47E-08	1.07E-07
^{234}U	9.16E-07	1.18E-07	2.07E-07
^{235}U	5.26E-08	4.55E-08	1.58E-07
^{238}U	5.79E-07	9.17E-08	1.55E-07
^{134}Cs	-4.07E-05	9.48E-06	3.20E-05
^{137}Cs	-4.45E-08	1.26E-05	4.19E-05
^{40}K	2.71E-04	1.41E-04	4.61E-04
^{60}Co	2.94E-05	1.15E-05	3.76E-05
DECEMBER 2012			
^{241}Am	8.19E-08	4.94E-08	1.49E-07
^{238}Pu	4.01E-08	4.28E-08	1.46E-07
$^{239+240}$Pu	4.89E-08	6.50E-08	2.18E-07
^{228}Th	3.28E-07	8.87E-08	2.45E-07
^{230}Th	4.93E-07	9.04E-08	2.02E-07
^{232}Th	2.71E-07	6.52E-08	1.48E-07
^{234}U	1.66E-06	1.58E-07	1.28E-07
^{235}U	5.31E-07	1.05E-07	1.85E-07

Table 1.8 Activity concentration of Monthly Composite filters from Station A (continued)

Activity Concentration (Bq/m^3)			
Radionuclide	Activity	SD	MDC
DECEMBER 2012			
^{238}U	8.27E-07	1.15E-07	1.67E-07
^{134}Cs	-3.63E-05	9.69E-06	3.27E-05
^{137}Cs	1.48E-05	1.31E-05	4.32E-05
^{40}K	1.29E-04	1.50E-04	4.97E-04
^{60}Co	5.98E-06	1.21E-05	4.02E-05

BU = back up filter
SD = Standard deviation (1 sigma)
MDC = Minimum Detectable Concentration
Station A = composited monthly due to the large number of samples
NR = Not reported

Table 1.9 Activity density (Bq/g) of Monthly Composite filters from Station A

Activity Density (Bq/g)			
Radionuclide	Activity	SD	MDC
JANUARY 2012			
^{241}Am	9.12E-05	1.48E-04	2.00E-04
^{238}Pu	1.94E-04	3.63E-04	1.37E-03
$^{239+240}$Pu	9.71E-05	4.00E-04	1.54E-03
^{228}Th	1.62E-03	3.80E-04	9.02E-04
^{230}Th	3.53E-03	4.60E-04	4.19E-04
^{232}Th	2.72E-03	4.19E-04	6.09E-04
^{234}U	2.48E-03	4.10E-04	7.81E-04
^{235}U	4.52E-04	2.33E-04	6.95E-04
^{238}U	2.18E-03	3.69E-04	6.23E-04
^{134}Cs	-3.31E-01	5.52E-02	1.87E-01
^{137}Cs	-1.02E-01	7.21E-02	2.40E-01
^{40}K	6.09E-01	8.17E-01	2.70E+00
^{60}Co	1.03E-02	6.69E-02	2.22E-01
FEBRUARY 2012			
^{241}Am	4.77E-04	3.65E-04	1.14E-03
^{238}Pu	2.33E-04	2.13E-04	7.50E-04
$^{239+240}$Pu	2.09E-04	2.09E-04	7.50E-04
^{228}Th	1.04E-03	3.41E-04	9.17E-04
^{230}Th	3.22E-03	4.97E-04	8.58E-04
^{232}Th	1.09E-03	3.23E-04	7.97E-04
^{234}U	4.37E-03	9.14E-04	2.04E-03
^{235}U	1.01E-03	6.04E-04	1.92E-03
^{238}U	3.59E-03	7.52E-04	1.38E-03
^{134}Cs	-2.48E-01	5.86E-02	1.98E-01
^{137}Cs	4.25E-02	7.71E-02	2.55E-01
^{40}K	1.27E+00	8.95E-01	2.95E+00
^{60}Co	1.41E-01	7.28E-02	2.39E-01

Table 1.9 Activity density (Bq/g) of Monthly Composite filters from Station A (continued)

Activity Density (Bq/g)			
Radionuclide	Activity	SD	MDC
MARCH 2012			
^{241}Am	3.04E-04	2.31E-04	7.00E-04
^{238}Pu	4.20E-04	3.32E-04	1.13E-03
$^{239+240}$Pu	7.63E-04	3.83E-04	1.13E-03
^{228}Th	3.83E-03	5.01E-04	7.71E-04
^{230}Th	5.83E-03	6.01E-04	7.14E-04
^{232}Th	2.99E-03	4.50E-04	7.68E-04
^{234}U	1.62E-03	3.76E-04	8.69E-04
^{235}U	2.87E-04	2.49E-04	8.63E-04
^{238}U	1.33E-03	3.62E-04	9.17E-04
^{134}Cs	-2.23E-01	5.20E-02	1.76E-01
^{137}Cs	1.47E-02	7.17E-02	2.38E-01
^{40}K	-1.46E-02	6.71E-02	2.24E-01
^{60}Co	3.04E-04	2.31E-04	7.00E-04
APRIL 2012			
^{241}Am	-3.25E-05	2.01E-04	7.97E-04
^{238}Pu	9.22E-04	4.31E-04	1.24E-03
$^{239+240}$Pu	8.26E-04	4.21E-04	1.31E-03
^{228}Th	3.88E-03	6.22E-04	1.12E-03
^{230}Th	4.42E-03	7.01E-04	1.43E-03
^{232}Th	4.02E-03	6.29E-04	1.11E-03
^{234}U	2.20E-03	6.68E-04	1.85E-03
^{235}U	4.16E-04	2.78E-04	8.70E-04
^{238}U	2.47E-03	5.40E-04	1.02E-03
^{134}Cs	-4.97E-01	8.01E-02	2.70E-01
^{137}Cs	-1.22E-01	1.07E-01	3.57E-01
^{40}K	1.28E+00	1.20E+00	3.97E+00
^{60}Co	2.34E-01	9.62E-02	3.14E-01
MAY 2012			
^{241}Am	4.29E-04	2.66E-04	6.91E-04
^{238}Pu	2.42E-04	2.31E-04	8.14E-04
$^{239+240}$Pu	3.68E-04	2.20E-04	6.89E-04
^{228}Th	3.46E-03	6.71E-04	1.66E-03
^{230}Th	4.77E-03	6.47E-04	1.06E-03
^{232}Th	1.27E-03	3.33E-04	6.55E-04
^{234}U	2.30E-03	4.84E-04	9.51E-04
^{235}U	3.93E-04	3.68E-04	1.29E-03
^{238}U	2.18E-03	4.81E-04	1.00E-03
^{134}Cs	-2.65E-01	7.35E-02	2.48E-01
^{137}Cs	-4.72E-02	8.66E-02	2.88E-01
^{40}K	7.51E-01	9.76E-01	3.23E+00
^{60}Co	5.90E-02	8.37E-02	2.77E-01

Table 1.9 Activity density (Bq/g) of Monthly Composite filters from Station A (continued)

Activity Density (Bq/g)			
Radionuclide	Activity	SD	MDC
JUNE 2012			
^{241}Am	1.53E-05	1.87E-04	7.09E-04
^{238}Pu	2.86E-04	2.48E-04	8.59E-04
$^{239+240}$Pu	-3.19E-04	2.08E-04	1.04E-03
^{228}Th	2.52E-03	6.03E-04	1.67E-03
^{230}Th	4.52E-03	5.61E-04	7.86E-04
^{232}Th	6.59E-04	3.00E-04	8.99E-04
^{234}U	1.08E-02	9.57E-04	1.10E-03
^{235}U	3.12E-03	5.67E-04	9.28E-04
^{238}U	3.88E-03	5.72E-04	9.09E-04
^{134}Cs	-1.81E-01	6.23E-02	2.10E-01
^{137}Cs	1.00E-01	7.51E-02	2.47E-01
^{40}K	1.22E+00	8.49E-01	2.79E+00
^{60}Co	2.50E-02	7.36E-02	2.44E-01
JULY 2012			
^{241}Am	1.25E-04	3.93E-04	1.49E-03
^{238}Pu	2.84E-04	1.74E-04	5.23E-04
$^{239+240}$Pu	4.82E-04	3.01E-04	9.65E-04
^{228}Th	4.79E-03	6.56E-04	1.39E-03
^{230}Th	5.59E-03	6.25E-04	9.03E-04
^{232}Th	1.60E-03	3.70E-04	8.32E-04
^{234}U	4.39E-03	6.33E-04	9.93E-04
^{235}U	5.64E-04	2.98E-04	8.73E-04
^{238}U	2.44E-03	5.28E-04	1.20E-03
^{134}Cs	-2.44E-01	7.36E-02	2.48E-01
^{137}Cs	1.83E-01	8.86E-02	2.90E-01
^{40}K	-6.06E-01	1.03E+00	3.45E+00
^{60}Co	9.78E-02	8.67E-02	2.86E-01
AUGUST 2012			
^{241}Am	1.12E-04	2.13E-04	7.02E-04
^{238}Pu	-2.00E-04	4.03E-04	1.62E-03
$^{239+240}$Pu	1.70E-04	3.61E-04	1.35E-03
^{228}Th	2.64E-03	8.26E-04	2.44E-03
^{230}Th	4.17E-03	6.67E-04	1.14E-03
^{232}Th	9.53E-04	3.13E-04	6.38E-04
^{234}U	6.55E-03	9.31E-04	1.26E-03
^{235}U	8.13E-04	5.73E-04	1.90E-03
^{238}U	3.73E-03	7.60E-04	1.53E-03
^{134}Cs	-2.74E-01	8.77E-02	2.95E-01
^{137}Cs	-1.64E-01	1.11E-01	3.72E-01
^{40}K	4.88E-01	1.24E+00	4.12E+00
^{60}Co	1.10E-01	1.03E-01	3.40E-01

Table 1.9 Activity density (Bq/g) of Monthly Composite filters from Station A (continued)

Activity Density (Bq/g)			
Radionuclide	Activity	SD	MDC
SEPTEMBER 2012			
^{241}Am	-2.54E-04	1.95E-04	9.37E-04
^{238}Pu	3.55E-04	2.79E-04	9.49E-04
$^{239+240}$Pu	-4.48E-04	4.19E-04	1.80E-03
^{228}Th	2.41E-03	4.97E-04	9.66E-04
^{230}Th	6.01E-03	7.11E-04	5.90E-04
^{232}Th	2.15E-03	4.60E-04	8.59E-04
^{234}U	1.20E-02	1.26E-03	1.54E-03
^{235}U	1.10E-03	5.36E-04	1.57E-03
^{238}U	1.23E-02	1.25E-03	1.09E-03
^{134}Cs	-2.55E-01	7.51E-02	2.53E-01
^{137}Cs	7.10E-02	1.04E-01	3.44E-01
^{40}K	5.68E-01	1.19E+00	3.96E+00
^{60}Co	4.08E-02	9.72E-02	3.22E-01
SEPTEMBER BU 2012			
^{241}Am	1.76E-05	2.16E-04	8.19E-04
^{238}Pu	7.95E-05	2.60E-04	1.04E-03
$^{239+240}$Pu	5.18E-04	3.23E-04	1.04E-03
^{234}U	5.08E-03	7.53E-04	1.41E-03
^{235}U	3.15E-04	2.78E-04	9.76E-04
^{238}U	4.48E-03	6.86E-04	1.19E-03
OCTOBER 2012			
^{241}Am	2.59E-04	2.55E-04	8.27E-04
^{238}Pu	2.72E-04	1.92E-04	6.31E-04
$^{239+240}$Pu	4.39E-04	3.04E-04	1.01E-03
^{228}Th	3.20E-03	7.11E-04	1.87E-03
^{230}Th	4.42E-03	6.71E-04	1.27E-03
^{232}Th	1.37E-03	3.89E-04	9.14E-04
^{234}U	6.52E-03	9.12E-04	1.53E-03
^{235}U	1.38E-03	5.47E-04	1.51E-03
^{238}U	2.64E-03	6.13E-04	1.33E-03
^{134}Cs	-2.91E-01	6.98E-02	2.35E-01
^{137}Cs	1.12E-01	8.90E-02	2.93E-01
^{40}K	9.49E-01	1.02E+00	3.38E+00
^{60}Co	3.61E-02	8.38E-02	2.78E-01
NOVEMBER 2012			
^{241}Am	2.66E-04	2.34E-04	2.84E-04
^{238}Pu	1.92E-04	3.04E-04	1.15E-03
$^{239+240}$Pu	-8.90E-10	2.72E-04	1.15E-03
^{228}Th	3.60E-03	8.32E-04	2.24E-03
^{230}Th	6.31E-03	8.14E-04	1.23E-03
^{232}Th	2.10E-03	4.81E-04	9.42E-04

Table 1.9 Activity density (Bq/g) of Monthly Composite filters from Station A (continued)

Activity Density (Bq/g)			
Radionuclide	**Activity**	**SD**	**MDC**
NOVEMBER 2012 (continued)			
^{234}U	8.07E-03	1.04E-03	1.82E-03
^{235}U	4.63E-04	4.01E-04	1.40E-03
^{238}U	5.10E-03	8.07E-04	1.37E-03
^{134}Cs	-3.59E-01	8.35E-02	2.82E-01
^{137}Cs	-3.92E-04	1.11E-01	3.69E-01
^{40}K	2.38E+00	1.24E+00	4.06E+00
^{60}Co	2.59E-01	1.01E-01	3.31E-01
DECEMBER 2012			
^{241}Am	8.56E-04	5.16E-04	1.56E-03
^{238}Pu	4.19E-04	4.48E-04	1.53E-03
$^{239+240}Pu$	5.11E-04	6.79E-04	2.28E-03
^{228}Th	3.43E-03	9.27E-04	2.56E-03
^{230}Th	5.15E-03	9.45E-04	2.11E-03
^{232}Th	2.83E-03	6.81E-04	1.55E-03
^{234}U	1.73E-02	1.65E-03	1.34E-03
^{235}U	5.55E-03	1.10E-03	1.93E-03
^{238}U	8.64E-03	1.20E-03	1.75E-03
^{134}Cs	-3.79E-01	1.01E-01	3.42E-01
^{137}Cs	1.55E-01	1.37E-01	4.51E-01
^{40}K	1.35E+00	1.57E+00	5.19E+00
^{60}Co	6.24E-02	1.27E-01	4.20E-01

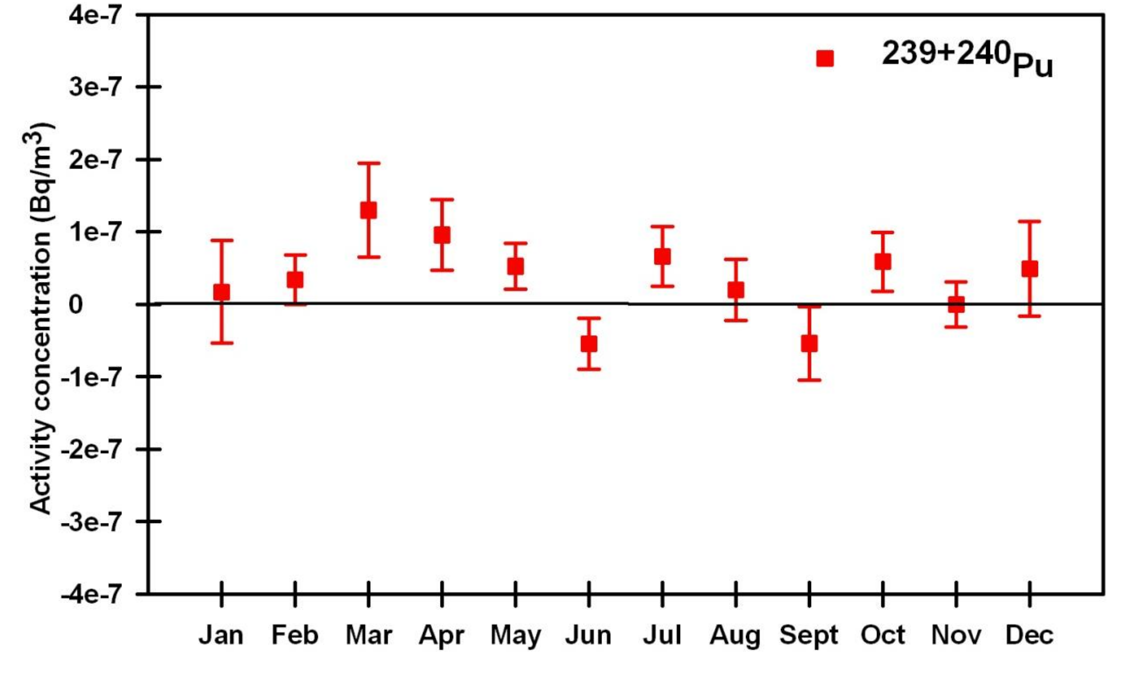


Figure 1.17 $^{239+240}$Pu Concentrations in Station A composites in 2012

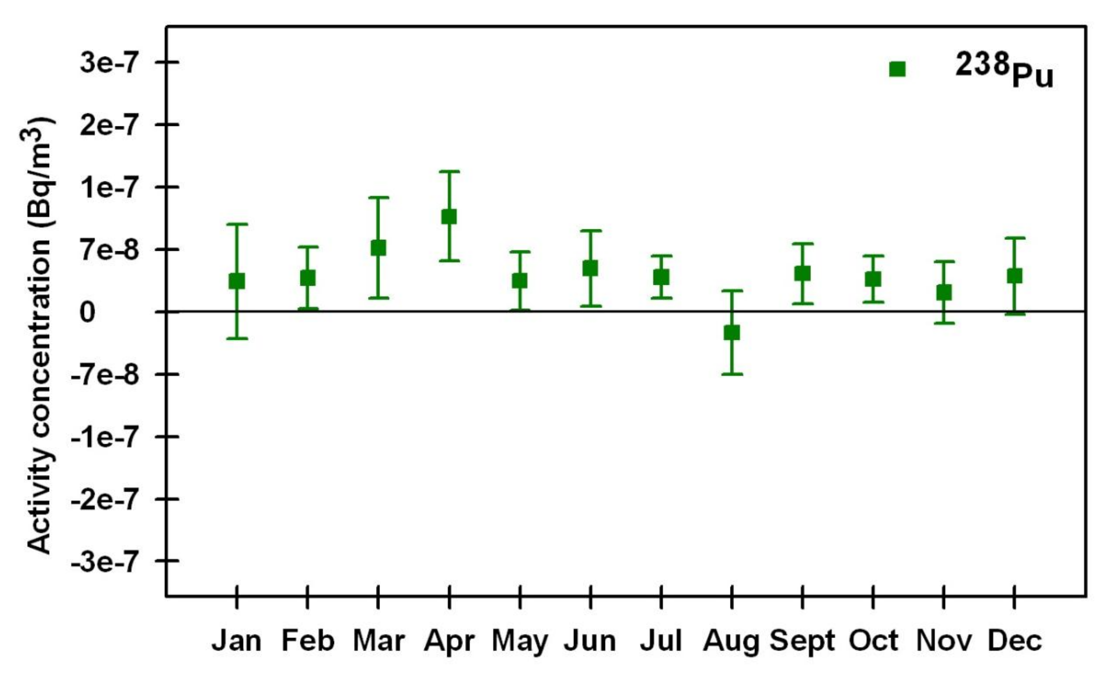


Figure 1.18 ^{238}Pu Concentrations in Station A Composites in 2012

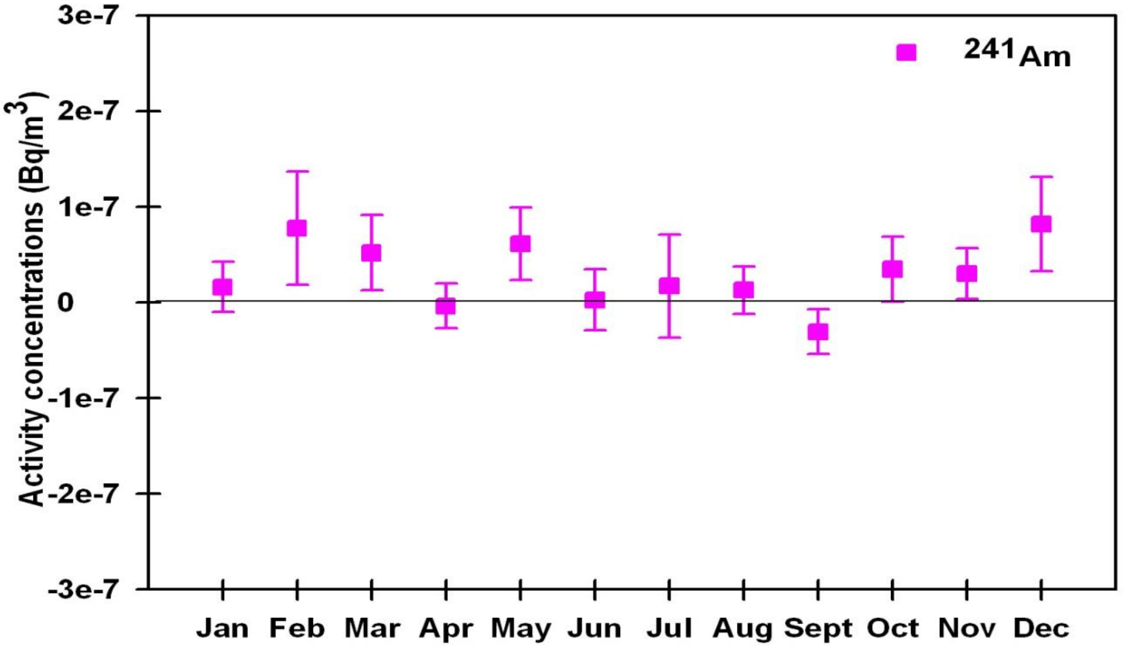


Figure 1.19 ^{241}Am Concentrations in Station A composites in 2012

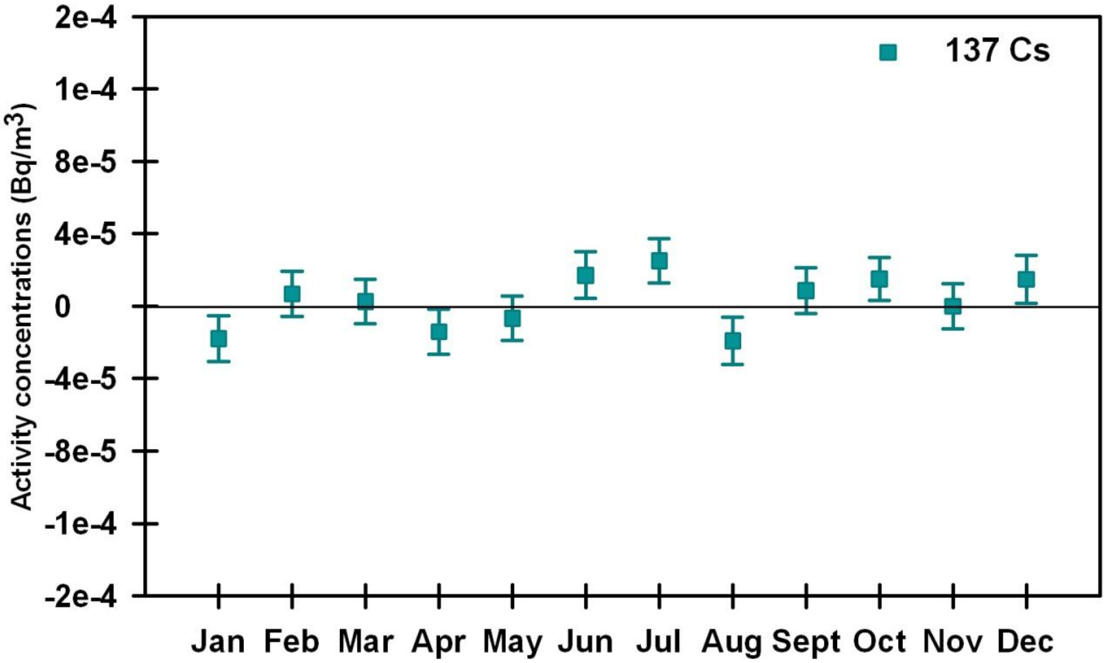


Figure 1.20 ^{137}Cs Concentrations in Station A Composites in 2012

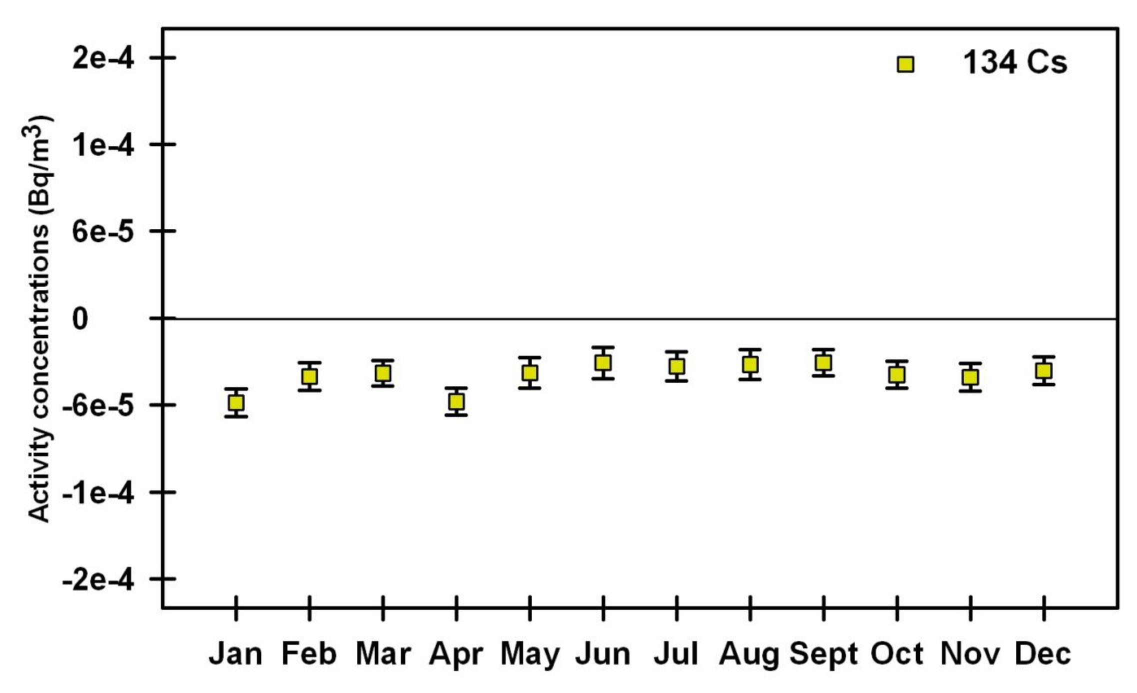


Figure 1.21 ^{134}Cs Concentrations in Station A Composite in 2012

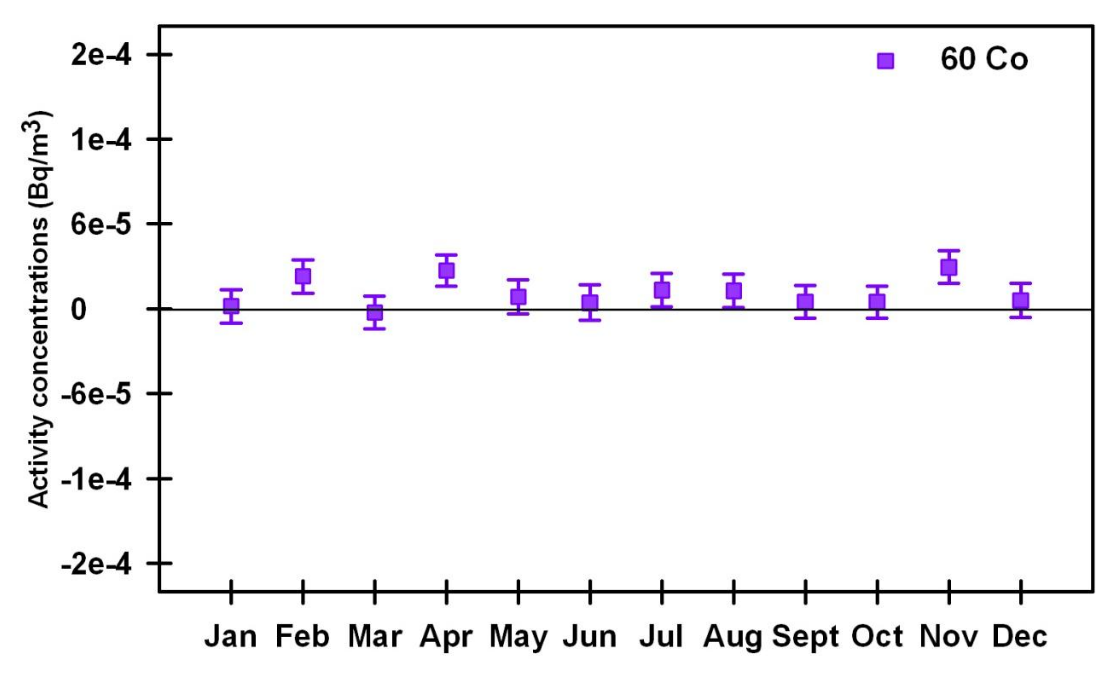


Figure 1.22 ^{60}Co Concentrations in Station A Composite in 2012

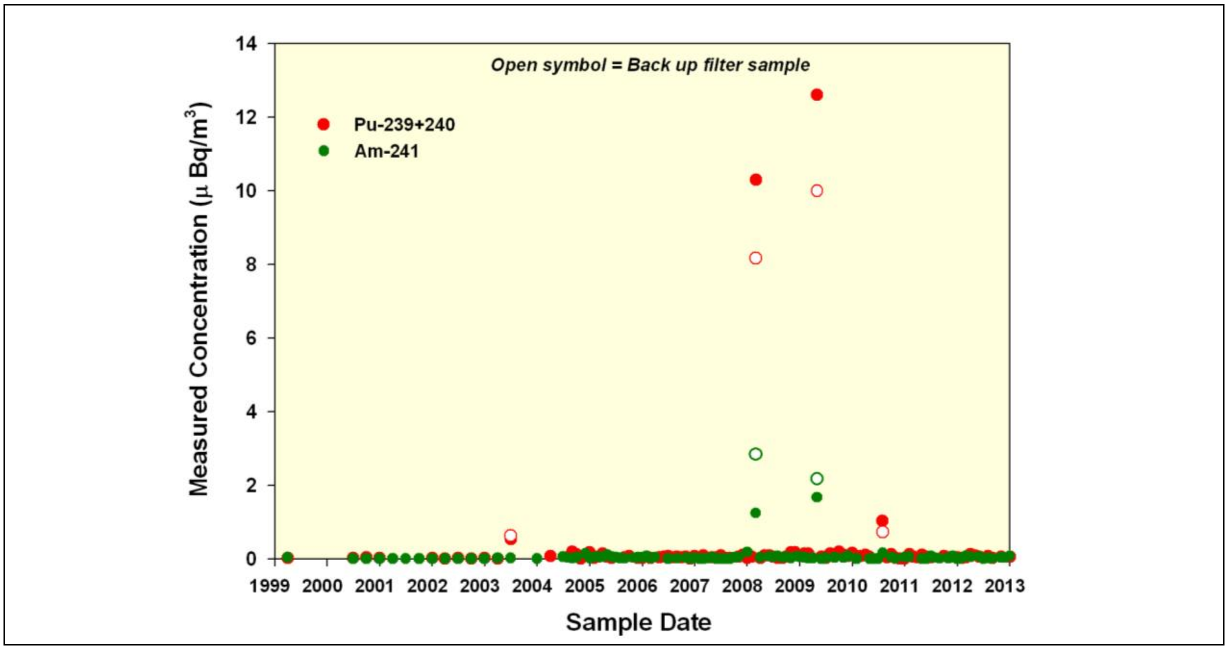


Figure 1.23 Activity Concentrations of $^{239+240}$Pu and ^{241}Am in Station A filters (1999-2012)

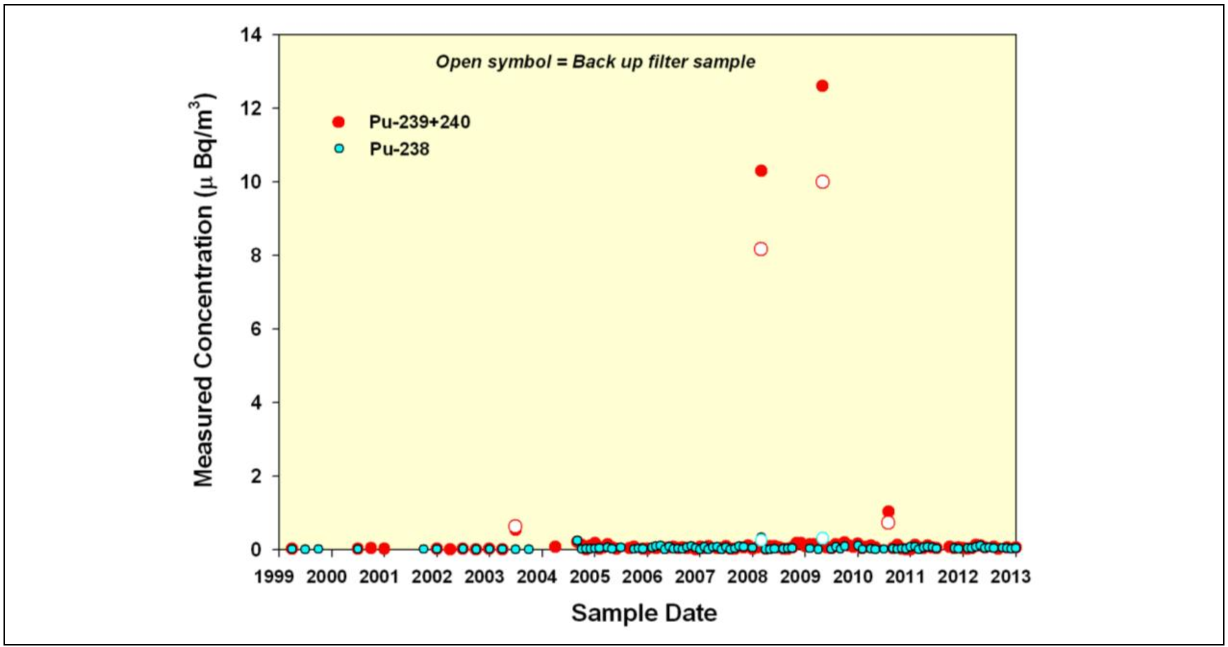


Figure 1.24 Activity Concentrations of $^{239+240}$Pu and ^{238}Pu in Station A filters (1999-2012)

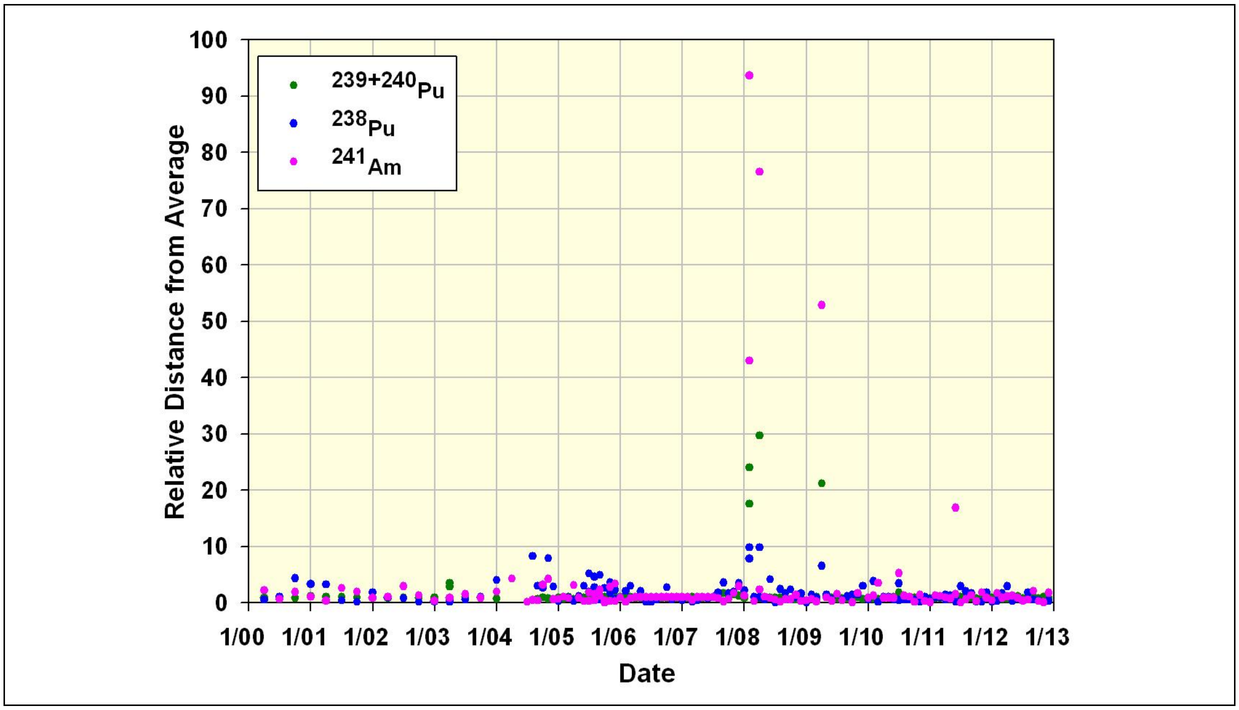


Fig. 1.25 Relative distance from average

Table 1.10 Activities greater than MDC and Uncertainty (2σ) measured by CEMRC during period 1999-2012

Year	Month	Radionuclides	Activity (Bq)	Uncertainty (2σ)	MDC
2003	Mar-Jun	$^{239+240}$Pu	4.76E-03	8.02E-04	2.63E-04
2005	April	^{241}Am	2.72E-04	1.99E-04	2.65E-04
2008	Feb	^{241}Am	6.20E-03	7.92E-04	1.79E-04
2008	Feb	^{238}Pu	7.02E-04	3.52E-04	2.87E-04
2008	Feb	$^{239+240}$Pu	1.78E-02	2.06E-03	2.87E-04
2009	April	^{241}Am	3.53E-03	1.19E-03	3.03E-04
2009	April	^{238}Pu	4.89E-04	2.24E-04	6.61E-05
2009	April	$^{239+240}$Pu	2.13E-02	1.72E-03	6.61E-05
2010	July	$^{239+240}$Pu	2.72E-03	9.04E-04	9.29E-04
2010	July	^{241}Am	4.09E-04	2.48E-04	2.95E-04

Table 1.11 Activities greater than MDC and Uncertainty (2σ) measured by WTS during period 1999-2012

Year	Month	Radionuclides	Activity (Bq)	Uncertainty (2σ)	MDC
2001	Oct	^{241}Am	1.86E-03	1.41E-03	1.52E-03
2003	Jan	^{241}Am	6.85E-04	5.70E-04	3.09E-04
2003	Sep	^{241}Am	4.96E-04	4.51E-04	2.69E-04
2007	Sep	$^{239+240}$Pu	1.71E-03	9.99E-04	4.40E-04
2008	Feb	^{241}Am	4.00E-03	2.53E-03	1.97E-03
2008	Feb	$^{239+240}$Pu	2.20E-02	5.17E-03	1.60E-03
2009*	April	^{241}Am	4.26E-03	1.85E-03	3.23E-03
2009*	April	$^{239+240}$Pu	1.96E-02	4.00E-03	1.83E-03
2010	July	$^{239+240}$Pu	1.88E-03	1.15E-03	5.00E-04

* Re-analyzed resulting in no detection

Table 1.12 Historical Minimum, Maximum, and Average Concentrations of ^{238}Pu (Bq/m^3) measured in Station A.

Year	Minimum	Maximum	Average
2000	-3.62E-08	5.35E-09	-1.23E-08
2001	-2.68E-08	1.08E-08	-8.20E-09
2002	-8.22E-09	2.01E-08	6.47E-09
2003	-2.90E-11	8.00E-09	4.26E-09
2004	9.89E-08	2.76E-07	1.70E-07
2005	-5.94E-08	6.01E-08	4.52E-09
2006	-3.57E-08	7.81E-08	1.87E-08
2007	-6.96E-08	6.83E-08	8.97E-09
2008	-8.62E-08	1.50E-07	1.20E-08
2009	-1.42E-08	2.33E-07	4.07E-08
2010	-6.05E-08	7.19E-08	6.65E-09
2011	-5.12E-08	8.17E-08	1.81E-08
2012	-2.33E-08	1.07E-07	4.09E-08

Table 1.13 Historical Minimum, Maximum, and Average Concentrations of $^{239+240}$Pu (Bq/m^3) measured in Station A.

Year	Minimum	Maximum	Average
2000	2.24E-08	5.86E-08	3.67E-08
2001	-3.34E-08	1.06E-08	-8.83E-09
2002	8.10E-09	1.76E-08	1.23E-08
2003	-7.99E-09	6.39E-07	1.58E-07
2004	3.65E-09	1.25E-07	6.45E-08
2005	-3.82E-08	1.41E-07	3.69E-08
2006	-5.05E-08	1.67E-07	5.82E-08
2007	-2.79E-07	1.09E-07	1.73E-08
2008	8.44E-09	3.81E-06	3.77E-07
2009	-3.48E-08	1.01E-05	9.24E-07
2010	-1.77E-08	1.03E-06	1.28E-07
2011	-4.07E-08	1.63E-07	6.04E-08
2012	-5.45E-08	1.30E-07	3.45E-08

Table 1.14 Historical Minimum, Maximum, and Average Concentrations of ^{241}Am (Bq/m^3) measured in Station A.

Year	Minimum	Maximum	Average
2000	-1.51E-08	3.17E-08	8.02E-09
2001	-1.70E-08	1.36E-08	-3.5E-09
2002	-2.16E-08	1.35E-09	-6.1E-09
2003	-4.73E-09	1.98E-08	7.72E-09
2004	-9.96E-09	5.12E-08	2.66E-08
2005	-1.94E-08	1.13E-07	3.35E-08
2006	-2.20E-08	7.07E-08	2.84E-08
2007	-2.05E-08	1.08E-07	2.97E-08
2008	-3.72E-08	1.32E-06	1.34E-07
2009	-1.61E-08	1.68E-06	1.88E-07
2010	-4.82E-08	1.54E-07	1.66E-08
2011	-1.13E-08	7.50E-08	1.54E-08
2012	-3.06E-08	8.19E-08	2.72E-08

Table 1.15 $^{234}U/^{238}U$ Activity Ratios in Station A Composites in 2012

Month	^{234}U (Bq)	^{238}U (Bq)	$^{234}U/^{238}U$
January	5.15E-04	4.54E-04	1.14
February	8.20E-04	6.74E-04	1.22
March	3.30E-04	2.71E-04	1.22
April	3.04E-04	3.42E-04	0.89
May	3.97E-04	3.76E-04	1.05
June	2.12E-03	7.63E-04	2.78
July	7.18E-04	3.98E-04	1.80
August	8.78E-04	5.01E-04	1.75
September	1.68E-03	1.72E-03	0.97
October	1.06E-03	4.29E-04	2.47
November	1.07E-03	6.79E-04	1.58
December	1.84E-03	9.16E-04	2.01
		Average	1.57
		Std Error	0.18

Table 1.16 Minimum, Maximum, and Average Radionuclide Concentrations (Bq/m^3) in Station A Composites in 2012

		Activity Concentration (Bq/m^3)		
Radionuclides		**Conc.**	**SD**	**MDC**
^{241}Am	Minimum	-3.06E-08	2.33E-08	3.22E-08
	Maximum	8.19E-08	5.92E-08	2.04E-07
	Average	2.93E-08	3.58E-08	1.12E-07
^{238}Pu	Minimum	-2.33E-08	2.38E-08	7.14E-08
	Maximum	1.07E-07	6.41E-08	2.42E-07
	Average	4.09E-08	4.07E-08	1.42E-07
$^{239+240}$Pu	Minimum	-5.45E-08	3.09E-08	9.83E-08
	Maximum	1.30E-07	7.07E-08	2.72E-07
	Average	3.45E-08	4.63E-08	1.67E-07
^{228}Th	Minimum	1.68E-07	5.53E-08	1.29E-07
	Maximum	6.54E-07	1.03E-07	2.85E-07
	Average	4.19E-07	8.57E-08	2.11E-07
^{230}Th	Minimum	4.86E-07	7.77E-08	7.39E-08
	Maximum	9.93E-07	1.02E-07	2.02E-07
	Average	6.50E-07	8.81E-08	1.41E-07
^{232}Th	Minimum	1.11E-07	3.65E-08	7.43E-08
	Maximum	5.10E-07	7.66E-08	1.54E-07
	Average	2.68E-07	5.76E-08	1.19E-07
^{234}U	Minimum	2.55E-07	6.41E-08	1.28E-07
	Maximum	1.85E-06	1.63E-07	3.31E-07
	Average	8.26E-07	1.10E-07	1.80E-07
^{235}U	Minimum	3.94E-08	3.22E-08	1.01E-07
	Maximum	5.33E-07	1.05E-07	3.11E-07
	Average	1.57E-07	6.11E-08	1.71E-07
^{238}U	Minimum	2.26E-07	6.16E-08	1.10E-07
	Maximum	1.48E-06	1.50E-07	2.24E-07
	Average	5.40E-07	8.95E-08	1.56E-07
^{137}Cs	Minimum	-1.91E-05	1.19E-05	3.93E-05
	Maximum	2.50E-05	1.31E-05	4.33E-05
	Average	2.65E-06	1.25E-05	4.15E-05
^{134}Cs	Minimum	-5.84E-05	8.85E-06	2.99E-05
	Maximum	-3.07E-05	1.06E-05	3.58E-05
	Average	-3.96E-05	9.70E-06	3.27E-05
^{60}Co	Minimum	-2.49E-06	1.12E-05	3.64E-05
	Maximum	2.94E-05	1.26E-05	4.17E-05
	Average	1.11E-05	1.18E-05	3.89E-05
^{40}K	Minimum	-8.27E-05	1.37E-04	4.53E-04
	Maximum	2.71E-04	1.50E-04	4.97E-04
	Average	1.13E-04	1.43E-04	4.72E-04

NON-RADIOLOGICAL MONITORING RESULTS

Elemental analysis by Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) is conducted on weekly composites of the FAS filters using a low-resolution Perkin Elmer Elan 6100 ICP-MS, which has a peak resolution of <0.71amu for the mass range reported. The mass calibration value is within 0.1amu of the published true values. The system is configured with a gem-tip^{TM} cross-flow nebulizer and a Scott spray chamber. Triplicate readings were performed on each digestate, with the average result reported. The ICP-MS analyses used at CEMRC can provide data for up to 35 elements in the FAS filters, but in practice the concentrations of some elements, including, but not limited to, As, Be, Cd, Er, Eu, Sc, Se, Sm, Tl and V are often below detectable or quantifiable levels. A second set of elements (notably Ag, Li, and Sn) often have variable concentrations in the blank filters which makes their quantification difficult.

As a result, only the following metals are reported herein: aluminum (Al), cadmium (Cd), magnesium (Mg), lead (Pb), thorium (Th), and uranium (U). Time-series plots from 1998 through 2012 of the trace elemental data for these metals are exhibited in Figures 1.26 through 1.37. Data shown in red represents concentrations measured prior to September 2000 when the WIPP received its first shipment of mixed waste (pre-operational). Different colors are used to represent "post operational" data. Some data is missing from the elemental data plots because of a sample holding time issue in the fourth quarter of 2004. Furthermore, the data presented in these plots only reflect concentrations above MDC. The MDCs are re-calculated annually, and vary slightly from year to year. The concentrations of Cd, Th, and U regularly hover right around the MDC and in 2009, concentrations for these elements never exceeded the MDC.

Among the many inorganic pollutants originating from anthropogenic activities, heavy metals such as arsenic (As), cadmium (Cd), chromium (Cr), and lead (Pb) are of a major concern due to their toxic and potentially carcinogenic characteristics (Melaku, 2008). Cadmium (Cd) and Pb are also components of the WIPP mixed waste, in addition to Th and U. It should be noted that these elements (Cd, Pb, Th, and U) shown in Figure 1.28 through Figure 1.31, respectively, were already present in measurable amounts in the WIPP aerosol effluent prior to the receipt of mixed waste. **Thus, there is no evidence of a long-term increase in the concentrations of these elements that can be linked to the WIPP operations.**

Information about the limits and potential health effects for the metals presented in this chapter are listed in Table 1.17. The US Environmental Protection Agency (EPA) only has National Ambient Air Quality Standards (NAAQS) for six principal pollutants, of which Pb is the only metal listed (U.S. EPA, 2012). In addition, only the EPA limit for Pb is enforceable. The other limits listed in Table 1.17 from the Occupational Safety & Health Administration (O.S.H.A.) are just Recommended Exposure Limits (RELs).

Lead (Pb) is found naturally in the environment as well as in manufactured products. The major sources of Pb emissions have historically been from fuels in on-road motor vehicles (such as cars and trucks) and from industrial sources (U.S. EPA, 2012). The EPA primary standard (established limit to protect the public health, including the health of "sensitive" populations such as asthmatics, children, and the elderly) for Pb in ambient air is 150ng/m^3 (0.15µg/m^3) averaged over a rolling 3-month period. The highest recorded Pb concentration in the WIPP effluent air during 2012 (Figure 1.35) was measured in January at 11.9ng/m^3. Figure 1.29 shows the measured concentrations of Pb from the WIPP exhaust air from 1998 to present. The maximum Pb concentration measured since the CEMRC commenced monitoring FAS samples (in 1998) was recorded in August of 2001 at 79.3ng/m^3 although typically concentrations don't exceed 18.9ng/m^3.

Aluminum is of particular interest because of the correlation between the Al concentrations in ambient aerosols and the activities of $^{239+240}$Pu and ^{241}Am (Arimoto, et. al. 2002, 2005, 2006). Windblown dust is the main source of Al and many other elements (such as Iron (Fe), Magnesium (Mg), Manganese (Mn), Scandium (Sc), and the rare earth elements). Dust is also the main source of naturally occurring radionuclides, including U, and fallout radionuclides such as plutonium (Pu) and Americium (Am). Kirchner, et al. (2002) has also discussed the relationships between Al and various radionuclides, both artificial and naturally occurring, in soils.

Historical studies at Station A have shown that concentrations of hazardous metals and various trace elements can be highly variable over time. This was true even in the samples collected prior to WIPP receiving the mixed waste in September 2000. The concentrations in the FAS samples for 2012 were no exception. Monthly averages for 2012 are shown for Al, Mg, Cd, Pb, Th, and U in Figures 1.32 through Figure 1.37, respectively. A large variation was observed in the Cd levels this year (shown in Figure. 1.34) ranging from values less than the MDC (0.0522ng/m^3) to the highest concentration of 2.45ng/m^3 measured in September. However, the largest concentration measured in the FAS filters since 1998 was in March 2000 of 14.7ng/m^3 which was prior to receiving mixed waste at the WIPP (Figure 1.28). All of these values are well below the Recommended Exposure Limit (REL) of 2000ng/m^3 (0.002mg/m^3) listed for Cd in Table 1.17. During the fourth quarter of 2010 with carry-over into the first quarter of 2011 there was an increase in the mining activity at the WIPP due to additional panel mining as well as mining in the experimental operations (XO) area. The increase in metal concentrations as a result of the increased mining activity for January 2011 could also be augmented by the fact that the winter weather has been noticeably dryer and windier than in recent history. The mining activity is particularly noticeable in the concentrations of Al and Mg (components of dust) concentrations shown in Figure 1.26 and Figure 1.27, respectively.

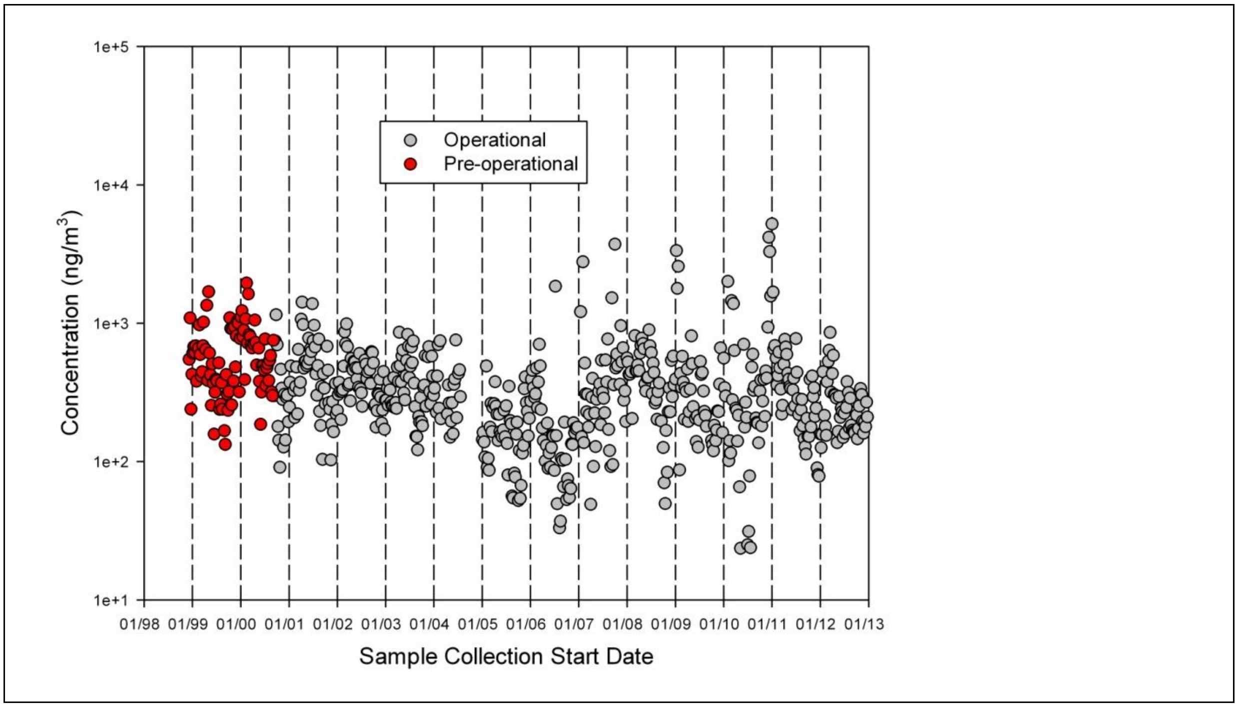


Figure 1.26 Concentrations of Al in WIPP Exhaust Air 1998 – 2012

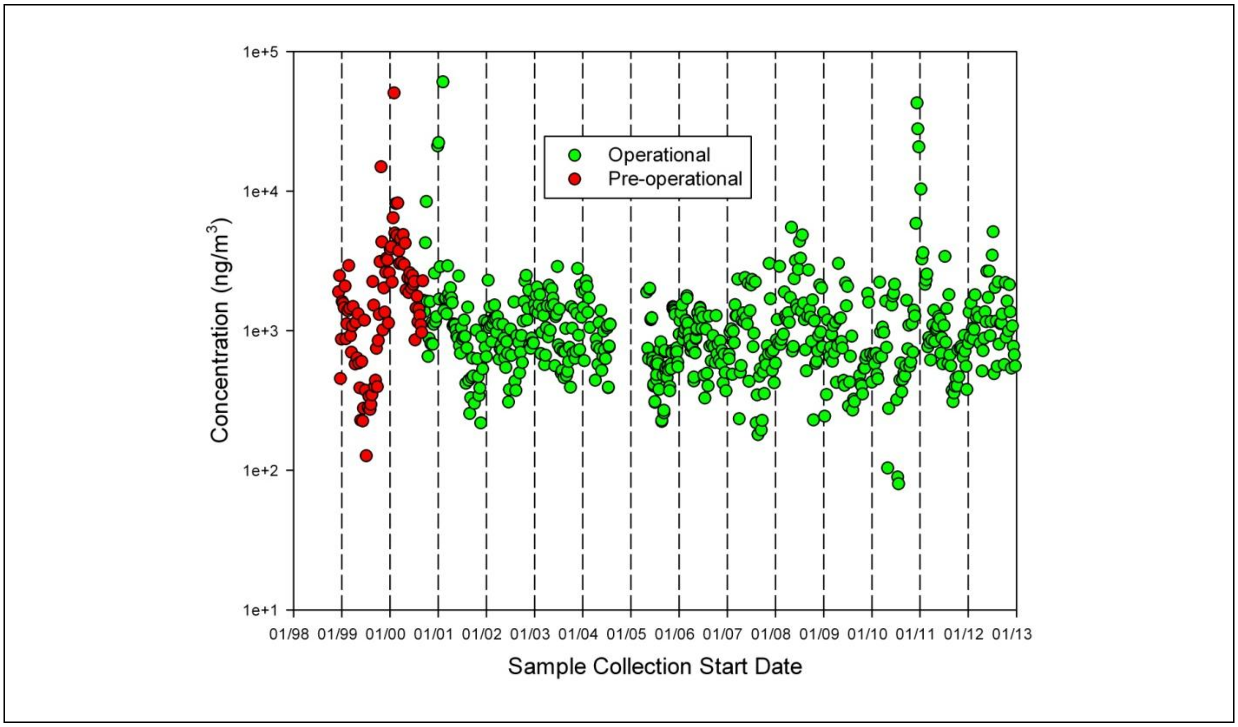


Figure 1.27 Concentrations of Mg in WIPP Exhaust Air from 1998 - 2012

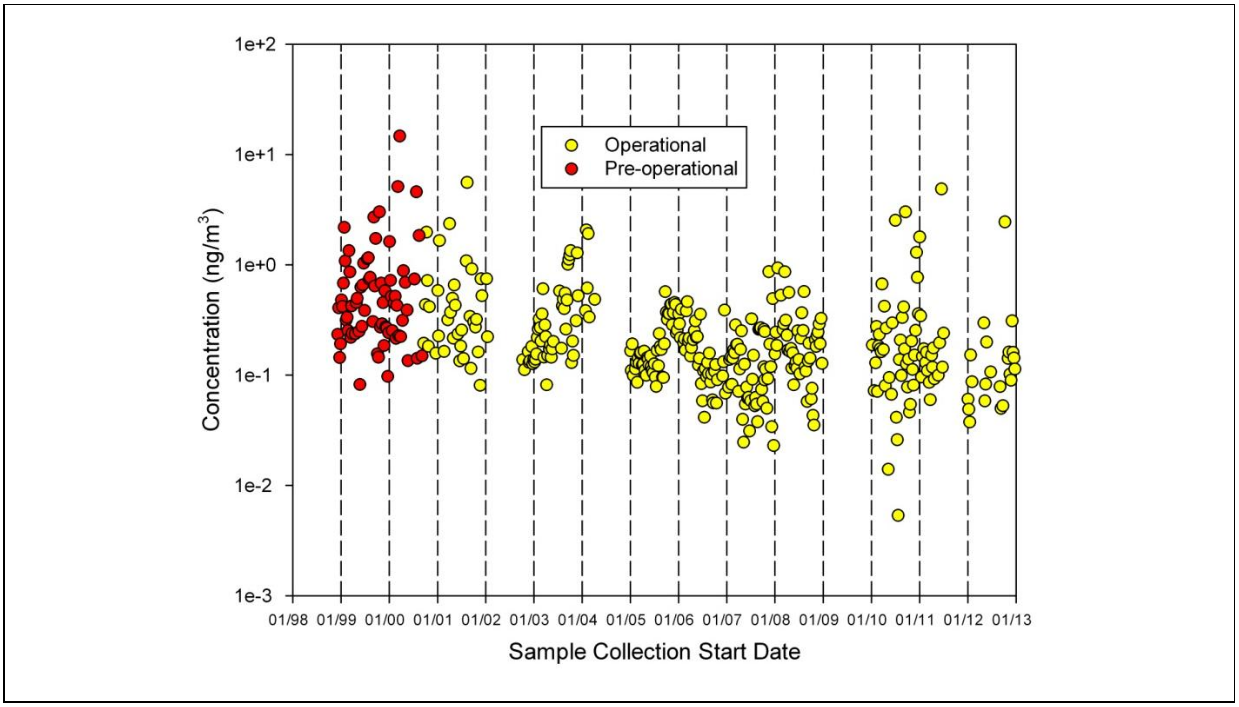


Figure 1.28 Concentrations of Cd in WIPP Exhaust Air from 1998 - 2012

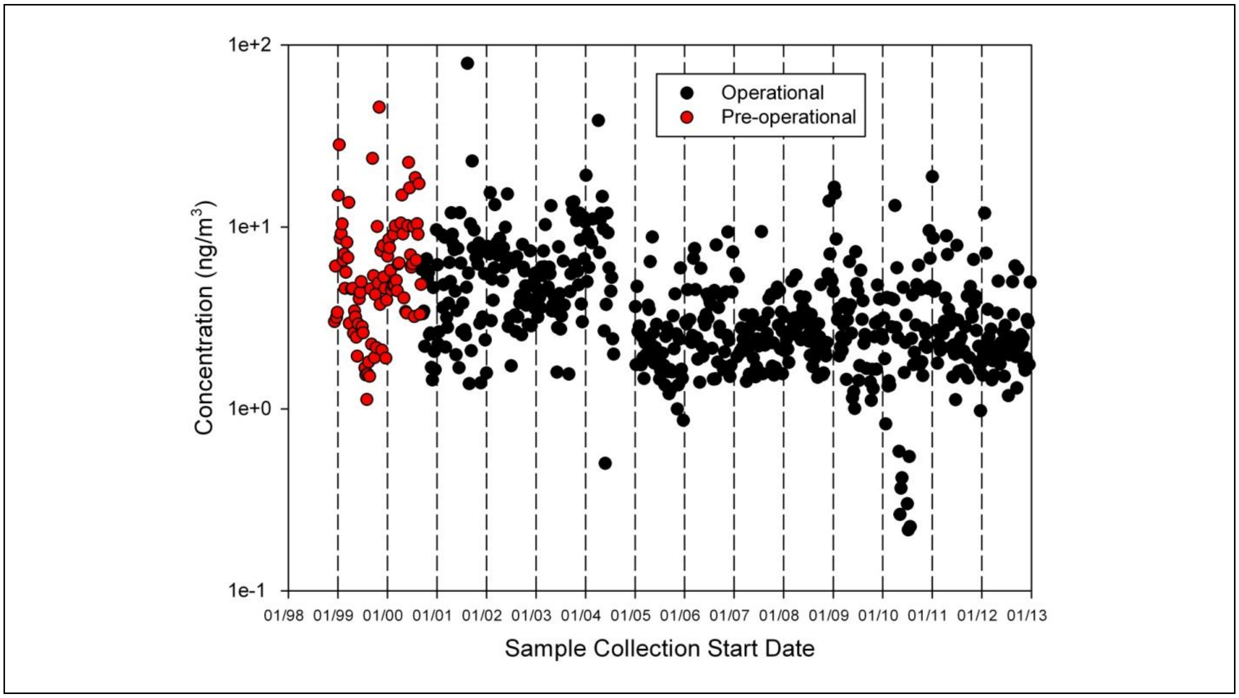


Figure 1.29 Concentrations of Pb in WIPP Exhaust Air from 1998 - 2012

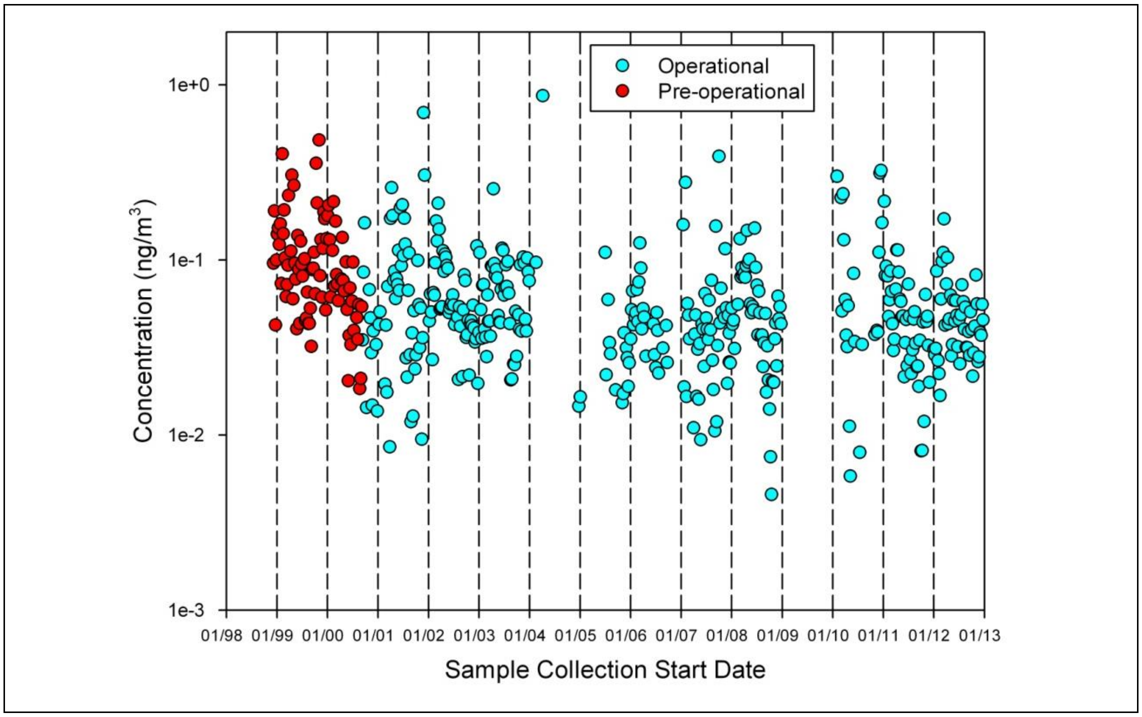


Figure 1.30 Concentrations of Th in WIPP Exhaust Air from 1998 - 2012

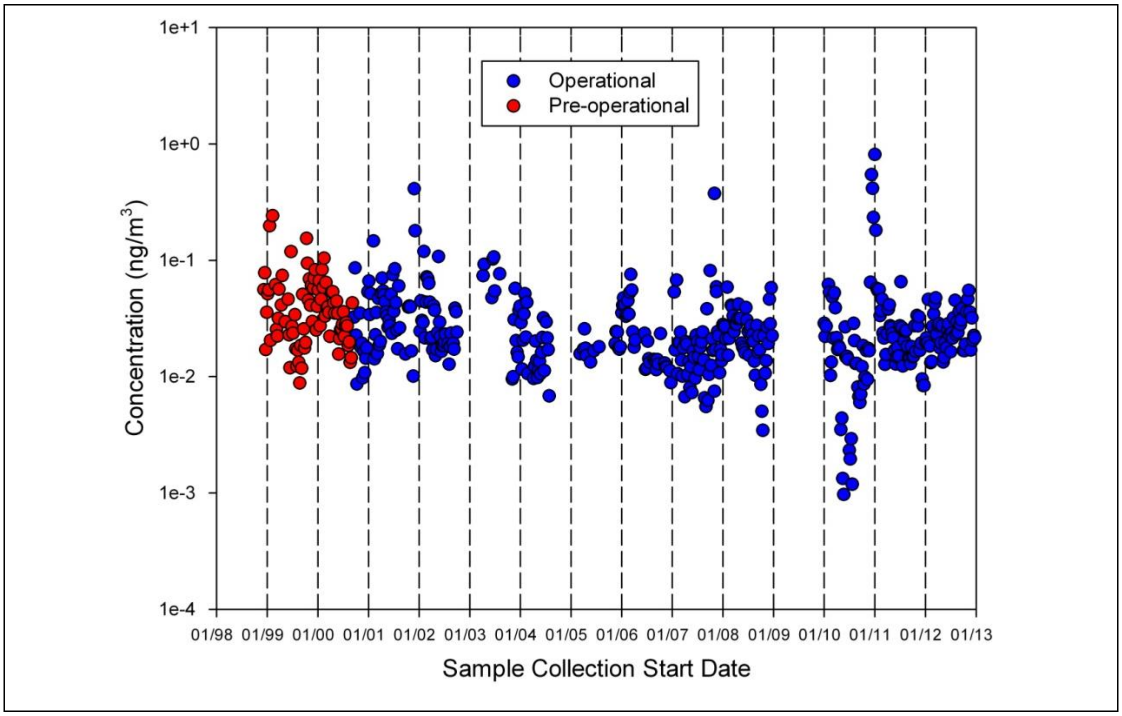


Figure 1.31 Concentrations of U in WIPP Exhaust Air from 1998 - 2012

Table 1.17 General Information about Inorganic Contaminants in Air

Contaminant	Limit	Sources of contaminants	Potential Health Effects from Long Term Exposure	Source
Aluminum (respirable fraction)	5mg/m^3 (8-hour time weighted average)	Dust, solder fumes	Pulmonary fibrosis	NIOSH Recommended Exposure Limit (REL)(2)
Cadmium (respirable dusts)	0.002mg/m^3	Burning fossil fuels, smoking, and incineration of municipal waste materials	Irritation/damage to lungs, kidney damage	EPA(3)
Magnesium	None	N/A	N/A	N/A
Lead (Pb)(1)	0.15µg/m^3	Dust, mining, smelting, refining activities	Neurological effects in children and cardiovascular effects in adults	EPA(4)
Thorium	None	Dust	N/A	EPA(5)
Uranium (insoluble and soluble compounds)	0.2mg/m^3	Dust, uranium mining	Chronic lung disease, cancer	NIOSH Recommended Exposure Limit (REL)(6)

(1) EPA limit is enforceable

(2) http://www.cdc.gov/niosh/npg/npgd0022.html ***and*** http://www.cdc.gov/niosh/npg/nengapdxg.html

(3) American Conference of Governmental Industrial Hygienists (ACGIH). *1999 TLVs and BEIs. Threshold Limit Values for Chemical Substances and Physical Agents. Biological Exposure Indices.* Cincinnati, OH. 1999. ***and*** http://www.epa.gov/ttn/atw/hlthef/cadmium.html

(4) http://www.epa.gov/superfund/lead/health.htm

(5) http://www.epa.gov/superfund/health/contaminants/radiation/pdfs/thorium.pdf

(6) National Institute for Occupational Safety and Health (NIOSH). *Pocket Guide to Chemical Hazards*. U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention. Cincinnati, OH. 1997 ***and*** http://www.epa.gov/ttnatw01/hlthef/radionuc.html

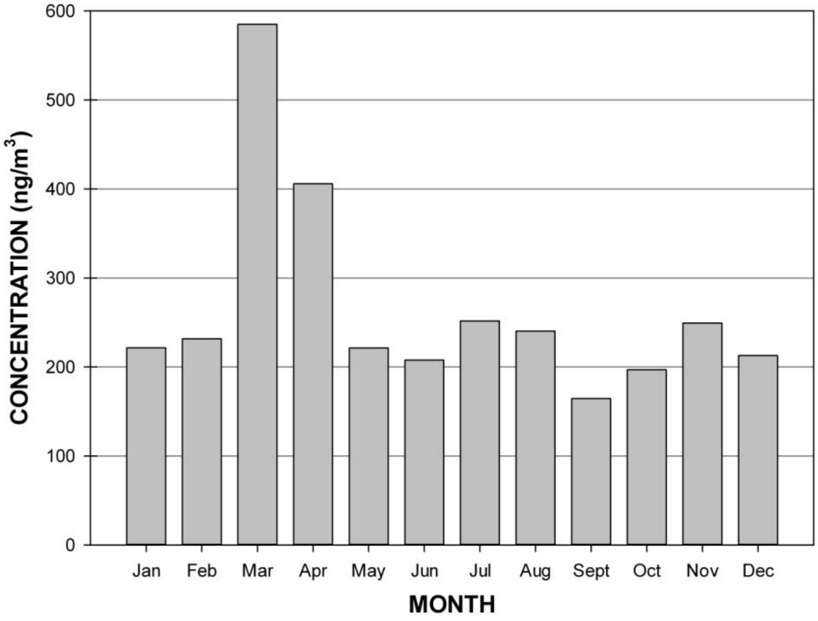


Figure 1.32 Monthly Average Concentrations of Al for 2012

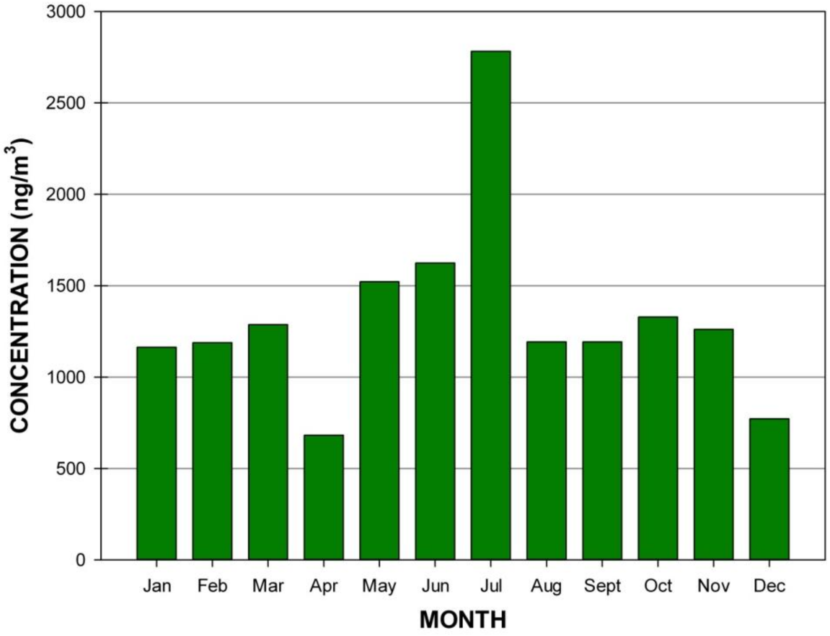


Figure 1.33 Monthly Average Concentrations of Mg for 2012

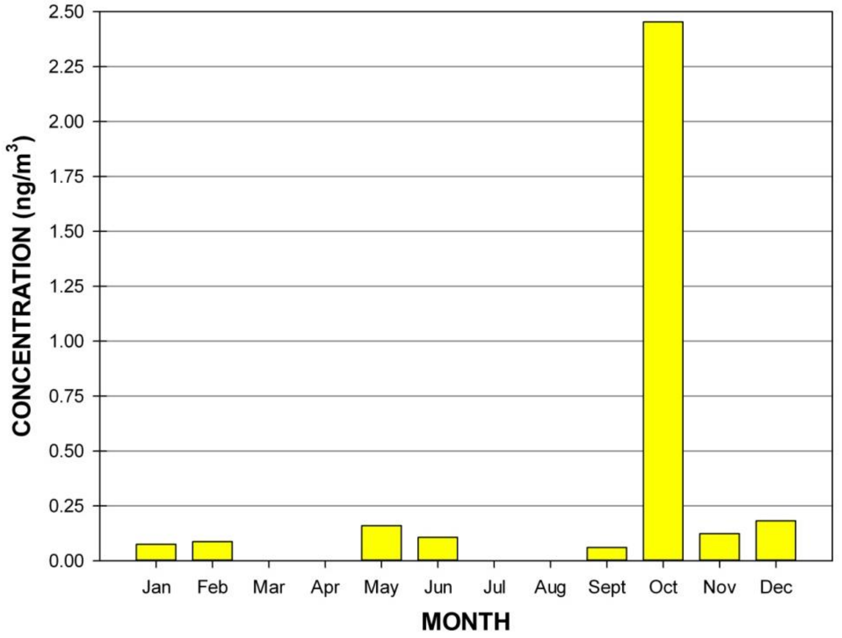


Figure 1.34 Monthly Average Concentrations of Cd for 2012

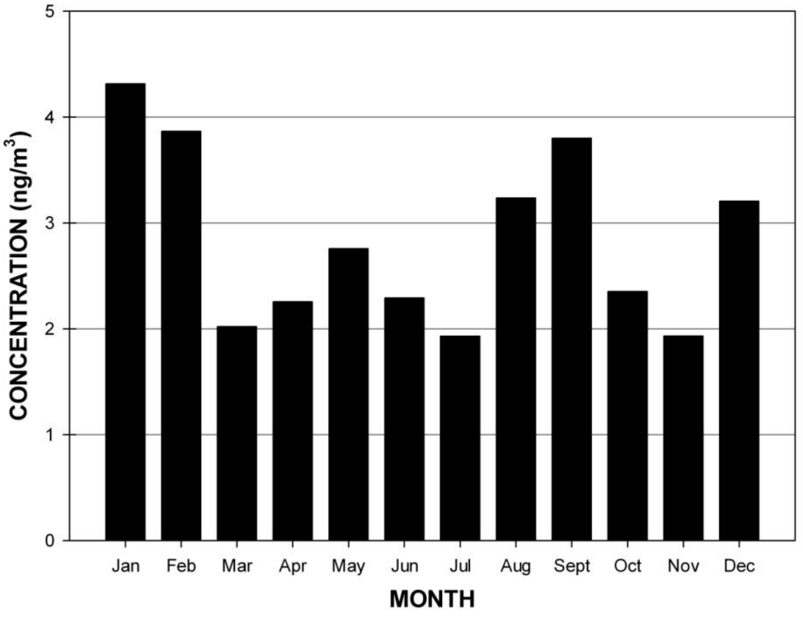


Figure 1.35 Monthly Average Concentrations of Pb for 2012

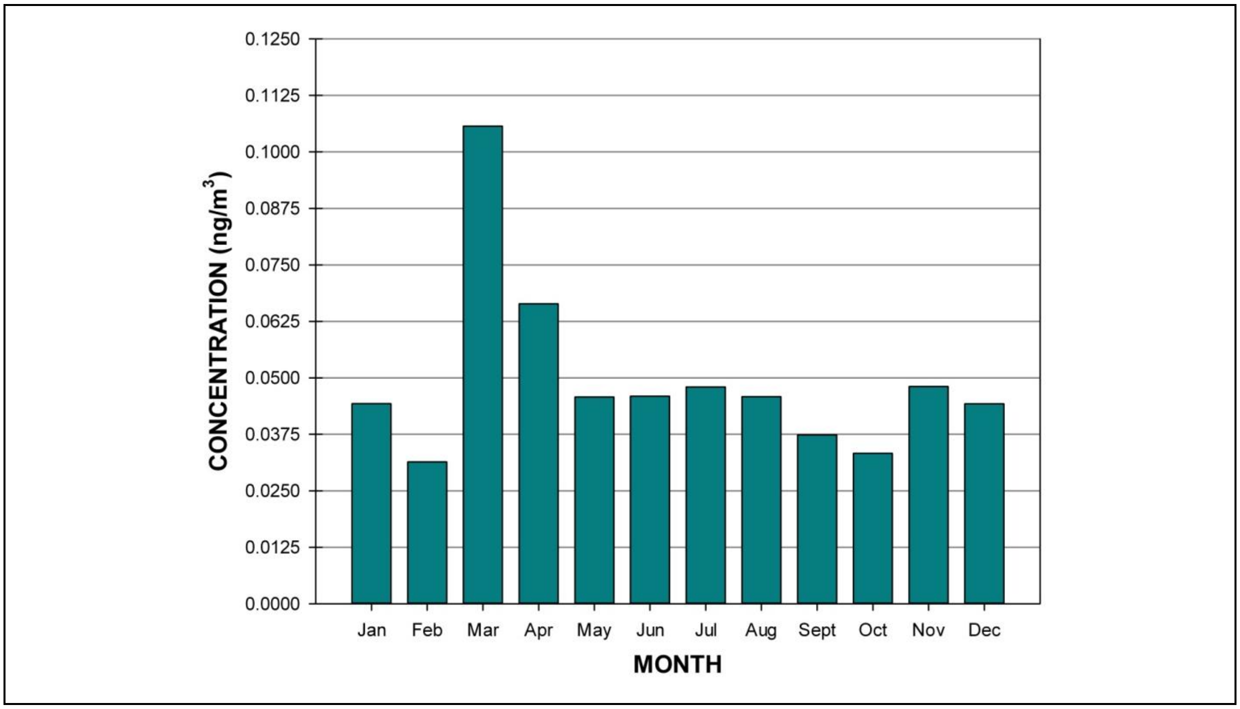


Figure 1.36 Monthly Average Concentrations of Th for 2012

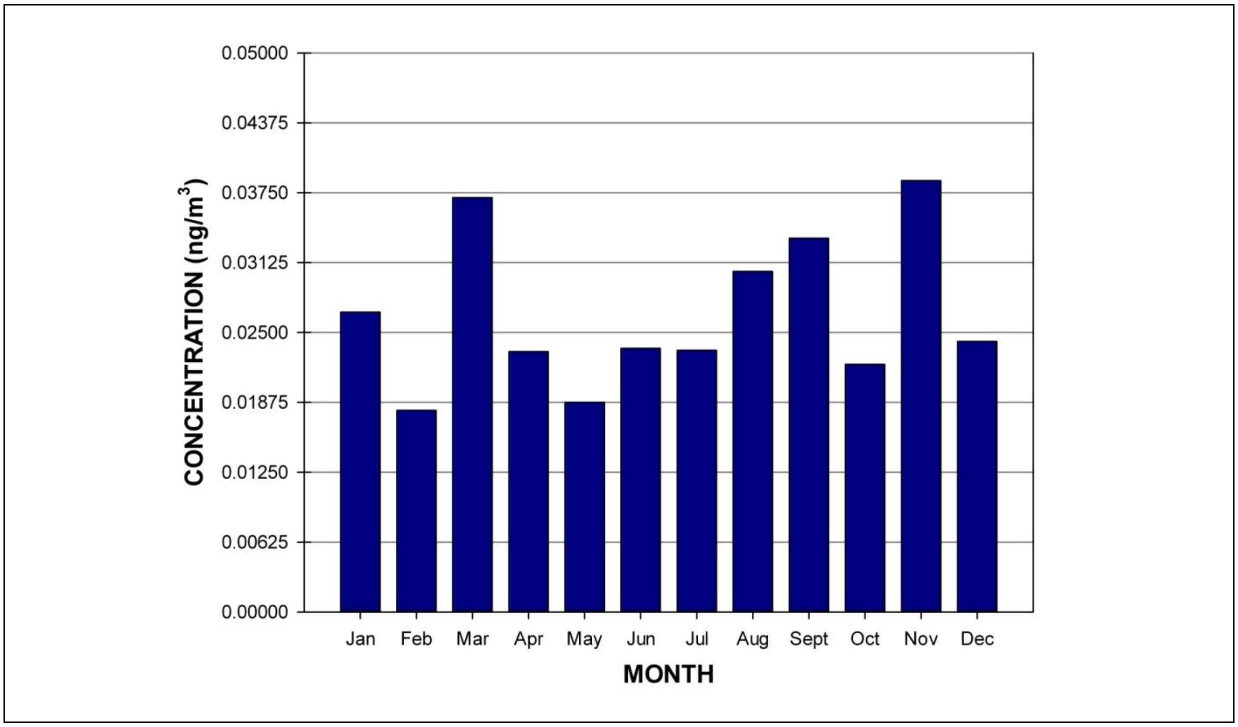


Figure 1.37 Monthly Average Concentrations of U for 2012

CHAPTER 2

Drinking Water Monitoring

The Carlsbad Monitoring and Research Center (CEMRC or the Laboratory) monitors the Drinking water in the vicinity of the WIPP site to evaluate the potential effects associated with transport of legacy contaminants and ongoing TRU waste disposal activities in the WIPP. The Laboratory collects and analyzes drinking water samples annually for a variety of constituents including both radionuclides and inorganic matter. The sampling results are then compared with baseline values to determine the impact of WIPP related activities on human health and the environment. The Laboratory does not monitor for bacteria or disinfection byproducts as testing for these contaminants remains the responsibility of public water systems. The Laboratory'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 WIPP on local water supply systems.*

Introduction

Once a year drinking water samples from the area surrounding the WIPP site are collected by the CEMRC for environmental monitoring studies. Routine testing of public drinking water supplies helps to assure the public that health and environmental standards are met and seeks to identify any changes in water quality which might have a negative impact on public health and the environment. Public drinking water systems are regulated by EPA (Environmental Protection Agency) under the Safe Drinking Water Act and by states and tribes when authority is delegated by EPA. During 2012, water samples were collected for CEMRC environmental monitoring studies from six drinking water sources in the region of the WIPP including the community water supplies of Carlsbad, Double Eagle, Loving, Otis, Hobbs, and Malaga. The drinking water wells in the vicinity of the WIPP provide water primarily for livestock, industrial usage by oil and gas production operations, and are subject to monitoring studies conducted by various groups.

Aquifers in the region surrounding the WIPP include Dewey Lake, Culebra-Magenta, Ogallala, Dockum, Pecos River alluvium, and Capitan Reef. 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 drawn from the Ogallala aquifer, while the Loving, Malaga, and Otis public water supply wells are drawn from deposits that are hydraulically linked to the flow of the Pecos River. The source for a private well CEMRC sampling site is a well seven miles southwest of the WIPP. This water is drawn from the Culebra aquifer, however, this sampling site has been dry since before 2001.

CEMRC began collecting drinking water samples for radiochemical analyses in 1997 and inorganic analyses on drinking water samples commenced in 1998. The results for the five drinking water sources from Carlsbad, Loving, Otis, Hobbs, and WIPP (Double Eagle) have been reported annually since 2001. Drinking water samples were not collected during 2004 and 2006. In addition, this is the second year that drinking water has been sampled from the site in Malaga. Summaries of methods, data, and results from previous samplings were reported in earlier CEMRC reports and can be found on the CEMRC website (www.cemrc.org). Present results as well as the results of previous analyses of drinking water were consistent for each source across sampling periods, and were below levels specified under the Safe Drinking Water Act.

Analyses reported herein for are for 2012 drinking water samples only. These samples were analyzed for radionuclides including alpha and gamma emitting radionuclides of interest to the WIPP. In addition, inorganic studies were performed separately and include elemental analysis as well as an analysis for mercury. ***The 2012 monitoring results show no increase in the levels of radionuclides or inorganics that could be attributed to WIPP-related activities***.

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 two sets: (a) samples from Loving, Otis, and Malaga were collected in October of 2012 and (b) samples from Sheep Draw, Hobbs, Double Eagle and the Trip Blank were collected in December of 2012. 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 2.1. Basic information about contaminants in drinking water is listed in Table 2.2 (US-EPA, 2012).

For radioactive analyses, two aliquots were taken from each 8L sample: (a) 3L 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 3L Marinelli beakers for the measurement of the gamma-emitting radionuclides potassium (^{40}K), cobalt (^{60}Co), and cesium (^{137}Cs), by gamma spectroscopy using a high purity germanium (HPGe) detector. Before collecting the measurements, the gamma system was calibrated for energy and efficiency to enable both qualitative and quantitative analysis of the water samples. The energy and efficiency calibrations were carried out using a mixed standards material from Eckert and Ziegler, Analytics (GA) in the energy range between 60 to 2000keV for a 3L Marinelli geometry. The counting time for each sample was 48 hours.

The second, 1L aliquot, was used for 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 perchloric acid. Next, the samples were heated to dryness again in preparation for isotopic separation. The separation process began with co-precipitation of the target isotopes and corresponding tracers with an iron carrier followed by ion exchange and chromatographic separations of the individual radionuclides. Finally, the separated radionuclides were micro-precipitated using lanthanum fluoride (LaF_3) and deposited onto planchets for counting uranium/transuranics by alpha spectroscopy.

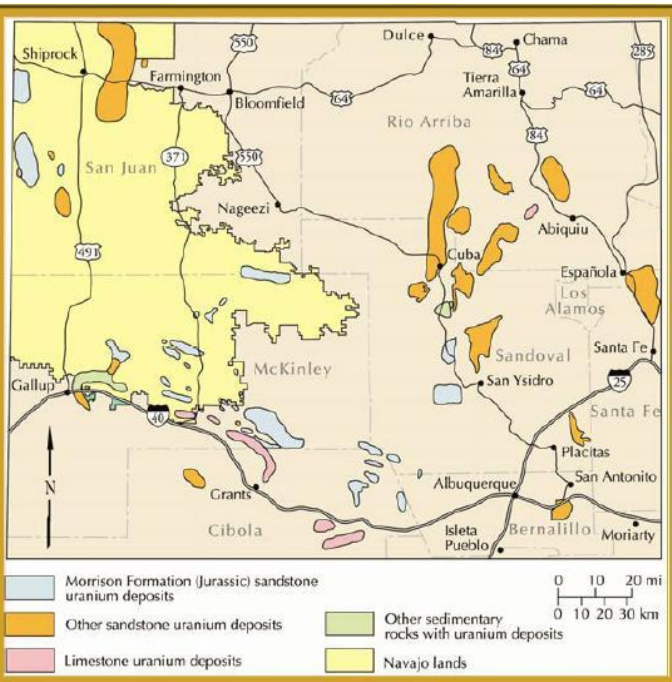
The 1L samples collected for elemental analysis were preserved with distilled nitric acid during sample collection. Samples from Otis, Malaga, and Hobbs were diluted using a similar nitric acid matrix prior to analysis by ICP-MS due to the elevated calcium (Ca) and sodium (Na) levels in these samples. All other 1L samples were analyzed directly. For Mercury analysis, the 500mL samples were preserved with a bromomonochloride solution and analyzed directly by ICP-MS. For each type of inorganic analysis, aliquots were blank-corrected after the application of dilution factors. As per the CEMRC procedure, only concentrations above laboratory MDC values are reported.

RADIOLOGICAL MONITORING RESULTS

Table 2.3 shows the activity concentrations for radionuclides of ^{234}U, ^{235}U, and ^{238}U; ^{238}Pu, $^{239+240}$Pu; ^{241}Am; ^{137}Cs; ^{60}Co; and ^{40}K in regional drinking water samples from 2012. The alpha 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 15pCi/L (0.56Bq/L). This level is over 10,000 times the MDCs used at CEMRC.

Isotopes of naturally occurring uranium were detected in all the drinking water samples in 2012 as shown in Table 2.3. Natural uranium is a mixture of three alpha-emitting isotopes (^{234}U, ^{235}U, and ^{238}U). They have long half-lives, $t_{1/2}$, that allow them to be transported to water supplies. The ^{238}U isotope has a $t_{1/2}$ of 4.5×10^{9} years (99.285% natural abundance), ^{235}U has a $t_{1/2}$ of 7.04×10^{8} years (0.71% natural abundance), and ^{234}U with a $t_{1/2}$ of 2.24×10^{5} years (0.0053% natural abundance; Neghabian et al, 1991). Thus, natural abundances of isotopes and the half-lives give 12.2, 0.6, and 12.2mBq/µg of natural uranium for ^{238}U, ^{235}U, and ^{234}U respectively, or 25mBq/µg in total (Hess et al, 1985). Combined, these isotopes of uranium are found in the earth's crust with a natural abundance of 4×10^{-4} % (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 in some phosphate fertilizers at a level of about 100µg/g or 2.5Bq/g (Hess et al, 1985). All these sources can come in contact with water which influences the amount of natural uranium present in our drinking water. 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. Phosphate fertilizers contain uranium which can leach from the soil to nearby rivers and lakes (Fleischer, 1980; UNSCEAR, 1982).

Uranium contaminated drinking water is a common problem, particularly in the Western United States. The map shown on the right highlights the major uranium deposits in New Mexico. Natural uranium mineral deposits are concentrated in northern Santa Fe County, the Grants-Gallup area, and in other areas within the State. These mineral deposits can leach uranium into ground water.



This image demonstrates distribution of uranium deposits in Northwest New Mexico. ***Source:*** *New Mexico Bureau of Geology and Mineral Resources*

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 in New Mexico with elevated levels of uranium in their groundwater. The Maximum Contaminant Level (MCL) for uranium in drinking Water is 30 ug/l (ppb). Water wells in several New Mexico communities show uranium levels three to six times higher than federal recommended levels for drinking water. Ingesting uranium in drinking water may have both toxicological and radiological health impacts. The primary target organ from chronic (long term) ingestion of uranium is the kidney, but liver and thyroid damage can also result. Radiological impacts from ingestion of uranium are not clear; however, it is still the subject of some research and debate. Bathing in water with elevated levels of Uranium is not considered to be a health risk.

Measured values for the drinking water samples collected around the WIPP site during 2012 ranged between 8.8-44.2 mBq/L for ^{238}U, 0.10-0.84 mBq/L for ^{235}U, and 3.2-160 mBq/L for ^{234}U. The average activity concentrations of ^{234}U, ^{235}U, and ^{238}U in drinking water from the six sources are presented in Figure 2.1. These uranium concentrations are well below the reference concentration level for radiological protection, i.e. 3.0 Bq/L. They are also below the EPA Action level of 0.56 Bq/L and within the range expected in waters from this region. The greatest variations appear in the amounts of ^{235}U. The low concentration of ^{235}U in the water samples is consistent with the lower concentration of ^{235}U in the natural environment as compared to the concentrations of ^{234}U and ^{238}U. The highest activity concentrations were found in Malaga and Otis waters. Figure 2.2 shows the total uranium concentration at each location.

It has been reported that the activity of 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 are 48.9, 2.2, and 48.9 %, respectively (IAEA, 1989). In radiochemical equilibrium, natural activity ratios are typically unity 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 and ^{238}U in the water samples collected around the WIPP site ranged from 0.044-0.078. 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 2.3 shows the average ^{234}U/^{238}U ratios in the drinking water samples in the vicinity of the WIPP site. The results of the activity ratios in this study compared very well with data observed in other countries as shown in Table 2.4. The calculated ^{234}U/^{238}U activity ratio varies between 2.33 to 2.96 which means that two isotopes are not in radioactive equilibrium. The historical activity concentrations of ^{234}U, ^{235}U and ^{238}U measured at well sites in the region of the WIPP site are summarized in Tables 2.5 to 2.9. The historical concentrations of transuranic elements like Plutonium and Americium, (^{238}Pu, $^{239+240}$Pu, and ^{241}Am) are shown in Figures 2.4 through 2.11.

It is important to note that after more than ten 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 well sites around the WIPP site. Although uranium has been found, the levels of uranium detected in regional drinking water are very low and the activity ratio indicates its presence in drinking water 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 1.3μg/day from which the portion from drinking water is 0.2μg/day (UNSCEAR, 2001). Thus drinking water is not usually the main source of ingested uranium.

NON-RADIOLOGICAL MONITORING RESULTS

The CEMRC analyzes samples from the six regional drinking water sources for over 30 different inorganic elements. The results are summarized in Tables 2.10 to 2.15. MDC values are determined annually and are reported as described in the current CEMRC procedure. The results exhibited in these tables are not used in assessing regulatory compliance. However, the CEMRC results for drinking water from the Carlsbad (Sheep Draw) and WIPP (Double Eagle) locations agree well with measurements for the same elements published by the City of Carlsbad (City of Carlsbad Municipal Water System, 2012).

The 2012 inorganic drinking water measurements exhibit a high level of consistency with past results providing a useful characterization of each source. Figures 2.12 through 2.16 compare the history of select inorganic analytes measured in drinking water collected from the surrounding area of WIPP including Carlsbad (Sheep Draw), WIPP (Double Eagle), Loving, Hobbs, and Otis. Only the selected inorganics (listed in Table 2.2) which have been detected regularly above MDCs are shown in these figures. Historical comparisons show that differences of a factor of two or three between one set of successive years is common, as it is for all natural water systems. Additionally, there has been no noticeable increase in the inorganic levels found in the regional drinking water after the WIPP site started accepting mixed waste in August of 2000. It should be noted that drinking water sampling did not take place during the 2004 and 2006 years due to a change in sampling frequency.

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 storm water runoff, industrial or domestic wastewater discharges, oil and gas production, mining, and/or farming, etc. The city of Andrews, TX, has naturally occurring levels of Arsenic and Fluoride in their drinking water (City of Andrews, 2012). The drinking water from this part of TX is supplied from the Ogallala and Dockum formations which are also accessed by the WIPP (Double Eagle) and Hobbs communities. Indeed the 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 MDC) as shown in Figure 2.18. However, the levels determined for Double Eagle and Hobbs are still below the EPA limit of 10µg/L (0.01mg/L) for Arsenic as listed in Table 2.2. Figure 2.17 also includes comparisons of selected analytes which were measured above the corresponding MDC.

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; 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, 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; Zheng et. al, 1968; Palache, 1951;). Therefore, it is to be expected that through leaching and other natural processes, the water in this region should contain significant quantities of potassium (K), magnesium (Mg) and, of course, sodium (Na). Figure 2.18 summarizes the concentrations of common salts measured in the areas surrounding the WIPP site. Currently there are no EPA regulations for salts like K, Mg, and Na in drinking water.

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 2.17). This is likely due to the natural limestone 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 infamous Carlsbad Caverns, located approximately 18 miles southwest of Carlsbad, NM and a likely source of Calcium (Ca) in the drinking water in the area.

Table 2.1 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*
Elemental analysis EPA 200.8	Over 30 different metals	Varies by element**
Anions EPA 300.0	F^-, Cl^-, Br^-, NO_2^-, NO_3^-, PO_4^{3-}, SO_4^{2-}	1.2 – 23.9 µg/L **
Mercury EPA 200.8	Hg	0.015 µg/L**

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

** Detection limits are determined annually.

Table 2.2 Basic Information about Drinking Water Contaminants from the EPA

Contaminant	Minimum Contaminants Level	Potential Health Effects from Long-term Exposure	Sources of Drinking Water Contaminants
Radium-226, Radium-228 (combined)	5pCi/L (1976)	Increased risk of cancer	Erosion of natural deposits of certain minerals that are radioactive and may emit a form of radiation known as alpha radiation.
Gross Alpha	15pCi/L (not including radon or uranium, 1976)	Increased risk of cancer	Decay of natural and man-made deposits of certain minerals that are radioactive and may emit forms of radiation known as photons and beta radiation.
Beta Particle and Photon emitters	4 mrem/year (1976)	Increased risk of cancer	Erosion of natural deposits.
Uranium, U	30μg/L (as of 12/08/03)	Increased risk of cancer; kidney toxicity	Erosion of natural deposits.
Antimony, Sb	0.006mg/L	Increase in blood cholesterol; decrease in blood sugar	Discharge from petroleum refineries; fire retardants; ceramics; electronics; solder
Arsenic, As	0.010mg/L (as of 01/23/06)	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	2mg/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	0.005mg/L	Kidney damage	Corrosion of galvanized pipes; erosion of natural deposits; discharge from metal refineries; runoff from waste batteries and paints.
Chromium, Cr (total)	0.1mg/L	Allergic dermatitis	Discharge from steel and pulp mills; erosion of natural deposits.
Copper, Cu	1.3mg/L	**Short term exposure**: gastrointestinal distress. **Long term exposure**: liver or kidney damage. People with Wilson's Disease should consult their doctor	Corrosion of household plumbing systems; erosion of natural deposits
Fluoride, F^-	4.0	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	0.015mg/L	**Infants and children**: delays in physical or mental development; children could show slight deficits in attention span and learning abilities. **Adults**: kidney problems; high blood pressure	Corrosion of household plumbing systems; erosion of natural deposits

Table 2.2 Basic Information about Drinking Water Contaminants from the EPA (continued)

Contaminant	Minimum Contaminants Level	Potential Health Effects from Long-term Exposure	Sources of Drinking Water Contaminants
Mercury, Hg	0.002mg/L	Kidney damage	Erosion of natural deposits; discharge from refineries; runoff from landfills and croplands
Nitrate (measured as N)	10mg/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)	1mg/L		
Selenium, Se	0.05mg/L	Hair or fingernail loss; numbness in fingers or toes; circulatory problems	Discharge from petroleum refineries; erosion of natural deposits; discharge from mines
Thallium, Tl	0.002mg/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	30µg/L	Increased risk of cancer; kidney toxicity	Erosion of natural deposits

Table 2.3 Radionuclide Activity Concentrations in Drinking Water in 2012

Location/sample collection date	Radionuclide	Activity[a] Bq/L	SD[b] (Bq/L)	MDC[c] (Bq/L)
Carlsbad 12/04/2012	$^{239+240}$Pu	-3.03E-05	1.56E-05	7.54E-05
	^{238}Pu	-2.16E-05	1.30E-05	6.50E-05
	^{241}Am	1.03E-05	1.15E-05	3.56E-05
	^{234}U	9.20E-03	2.85E-04	7.63E-05
	^{235}U	1.85E-04	3.87E-05	7.58E-05
	^{238}U	3.26E-03	1.46E-04	8.05E-05
	^{137}Cs	-4.07E-03	2.95E-02	9.78E-02
	^{40}K	1.33E-01	3.39E-01	1.12E+00
	^{60}Co	2.31E-02	3.13E-02	1.04E-01
Carlsbad (DUP) 12/04/2012	$^{239+240}$Pu	5.19E-06	1.56E-05	6.23E-05
	^{238}Pu	1.04E-05	1.04E-05	3.82E-05
	^{241}Am	-4.52E-06	1.29E-05	5.15E-05
	^{234}U	3.21E-02	8.44E-04	1.15E-04
	^{235}U	8.37E-04	8.14E-05	5.42E-05
	^{238}U	1.42E-02	4.31E-04	6.38E-05
	^{137}Cs	4.26E-03	2.93E-02	9.70E-02
	^{40}K	-1.46E-01	3.41E-01	1.14E+00
	^{60}Co	2.55E-02	3.01E-02	9.94E-02

Table 2.3 Radionuclide Activity Concentrations in Drinking Water in 2012 (continued)

Location/sample collection date	Radionuclide	Activity[a] Bq/L	SD[b] (Bq/L)	MDC[c] (Bq/L)
Double Eagle 12/05/2012	$^{239+240}$Pu	1.94E-05	1.19E-05	3.57E-05
	^{238}Pu	1.45E-05	1.61E-05	5.82E-05
	^{241}Am	3.35E-05	1.57E-05	3.47E-05
	^{234}U	8.75E-03	2.44E-04	6.84E-05
	^{235}U	3.55E-04	4.56E-05	5.45E-05
	^{238}U	3.22E-03	1.31E-04	6.82E-05
	^{137}Cs	1.01E-02	4.64E-02	1.54E-01
	^{40}K	9.15E-02	5.43E-01	1.80E+00
	^{60}Co	-1.31E-02	4.89E-02	1.63E-01
Otis 10/22/2012	$^{239+240}$Pu	1.34E-05	1.18E-05	4.13E-05
	^{238}Pu	4.45E-06	9.95E-06	4.13E-05
	^{241}Am	1.65E-05	1.34E-05	3.94E-05
	^{234}U	3.94E-02	9.87E-04	1.08E-04
	^{235}U	1.00E-03	9.92E-05	9.58E-05
	^{238}U	1.39E-02	4.31E-04	8.60E-05
	^{137}Cs	-3.05E-02	2.94E-02	9.79E-02
	^{40}K	2.94E-01	3.31E-01	1.09E+00
	^{60}Co	1.25E-02	3.04E-02	1.01E-01
Loving 10/22/2012	$^{239+240}$Pu	8.26E-06	1.36E-05	5.27E-05
	^{238}Pu	-1.22E-05	1.54E-05	6.95E-05
	^{241}Am	4.31E-06	1.16E-05	4.08E-05
	^{234}U	2.53E-02	7.30E-04	9.67E-05
	^{235}U	4.93E-04	7.32E-05	7.50E-05
	^{238}U	7.58E-03	3.04E-04	1.23E-04
	^{137}Cs	1.34E-02	2.88E-02	9.51E-02
	^{40}K	-4.67E-01	3.40E-01	1.14E+00
	^{60}Co	-1.29E-03	3.06E-02	1.01E-01
Hobbs 12/06/2012	$^{239+240}$Pu	4.46E-05	2.62E-05	8.18E-05
	^{238}Pu	-7.59E-06	1.70E-05	8.18E-05
	^{241}Am	-1.43E-05	1.77E-05	7.52E-05
	^{234}U	1.61E-02	4.96E-04	1.24E-04
	^{235}U	4.31E-04	6.64E-05	8.56E-05
	^{238}U	5.82E-03	2.45E-04	1.04E-04
	^{137}Cs	-3.53E-03	3.67E-02	1.22E-01
	^{40}K	1.09E-01	3.41E-01	1.13E+00
	^{60}Co	-1.00E-02	1.17E-01	3.89E-01

Table 2.3 Radionuclide Activity Concentrations in Drinking Water in 2012 (continued)

Location/sample collection date	Radionuclide	Activity[a] Bq/L	SD[b] (Bq/L)	MDC[c] (Bq/L)
Malaga 10/22/2012	$^{239+240}Pu$	3.21E-05	1.69E-05	4.97E-05
	^{238}Pu	9.47E-06	1.16E-05	4.40E-05
	^{241}Am	2.64E-05	1.52E-05	4.23E-05
	^{234}U	4.42E-02	8.79E-04	7.13E-05
	^{235}U	6.40E-04	6.28E-05	6.70E-05
	^{238}U	1.61E-02	3.85E-04	4.83E-05
	^{137}Cs	-7.08E-03	2.98E-02	9.89E-02
	^{40}K	1.17E-01	3.38E-01	1.12E+00
	^{60}Co	3.51E-03	3.26E-02	1.08E-01

* Values are overestimated because of poor separation.

[a] Activity concentration as defined in CEMRC Report 1997

[b] SD = Standard Deviation as defined in CEMRC Report 1997

[c] MDC = Minimum Detectable Concentration as defined in CEMRC Report 1997

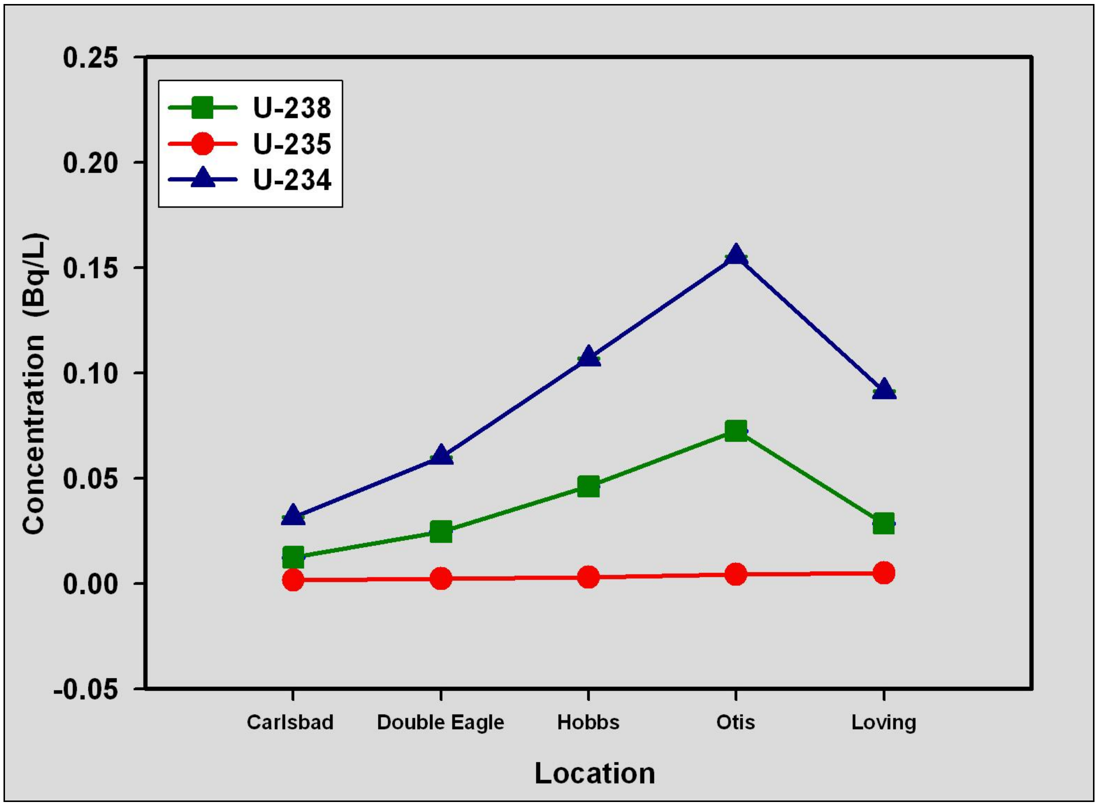


Figure 2.1 Average ^{234}U, ^{235}U, and ^{238}U concentrations (Bq/L) in Regional Drinking Water in 2012

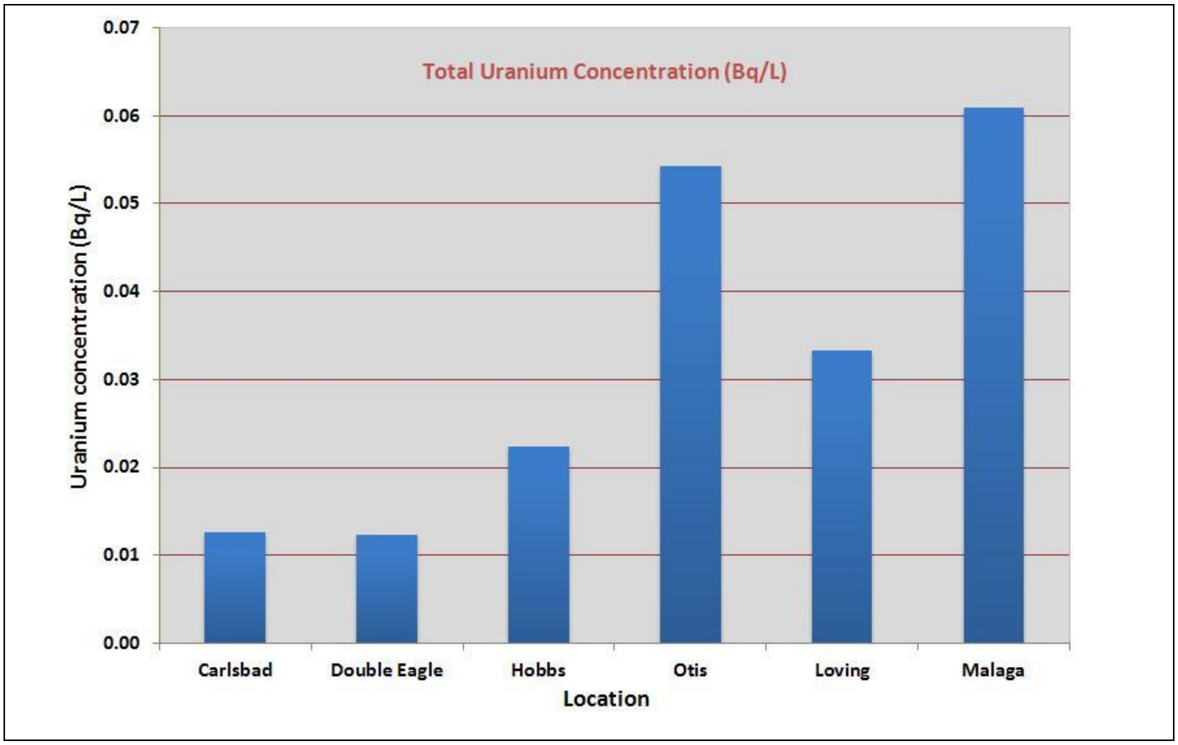


Figure 2.2 Total Uranium Concentrations in Bq/L in Regional Drinking Water Collected in 2012

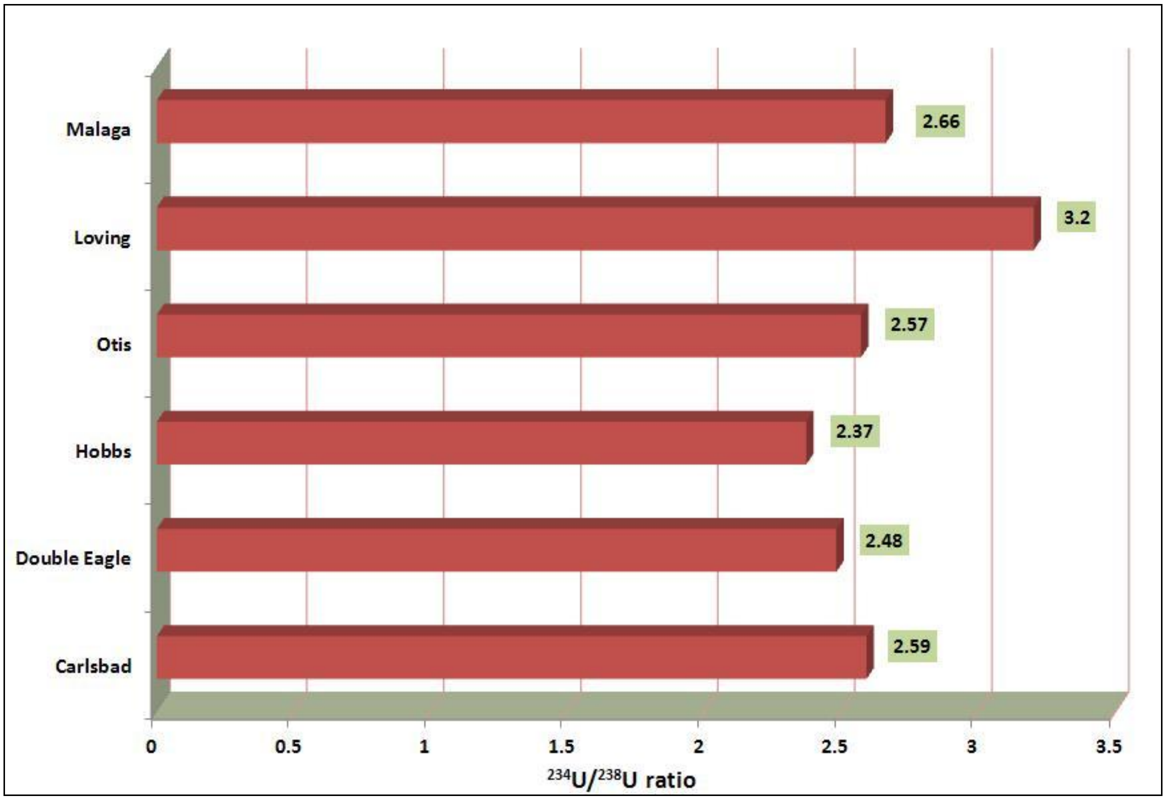


Figure 2.3 Average $^{234}U/^{238}U$ Activity Ratio in Regional Drinking Water from 1998 - 2012

Table 2.4 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	2.59	0.072	Present work
Double Eagle	Drinking water	2.48	0.078	Present work
Hobbs	Drinking water	2.37	0.063	Present work
Otis	Drinking water	2.57	0.059	Present work
Loving	Drinking water	3.2	0.058	Present work
Malaga	Drinking water	2.66	0.044	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 2.5 Historical Activity Concentrations of ^{234}U, ^{235}U and ^{238}U (Bq/L) measured in Carlsbad Drinking Water

Year	^{234}U	^{235}U	^{238}U
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

NR = not reported

Table 2.6 Historical Activity Concentrations of ^{234}U, ^{235}U and ^{238}U (Bq/L) measured in Double Eagle Drinking Water

Year	^{234}U	^{235}U	^{238}U
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	3.22E-03	3.22E-03

NR = not reported

Table 2.7 Historical Activity Concentrations of ^{234}U, ^{235}U and ^{238}U (Bq/L) measured in Hobbs Drinking Water

Year	^{234}U	^{235}U	^{238}U
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	5.82E-03	4.31E-04	1.61E-02

NR = not reported

Table 2.8 Historical Activity Concentrations of ^{234}U, ^{235}U and ^{238}U (Bq/L) measured in Otis Drinking Water

Year	^{234}U	^{235}U	^{238}U
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

NR = not reported

Table 2.9 Historical Activity Concentrations of ^{234}U, ^{235}U and ^{238}U (Bq/L) measured in Loving Drinking Water

Year	^{234}U	^{235}U	^{238}U
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

NR = not reported

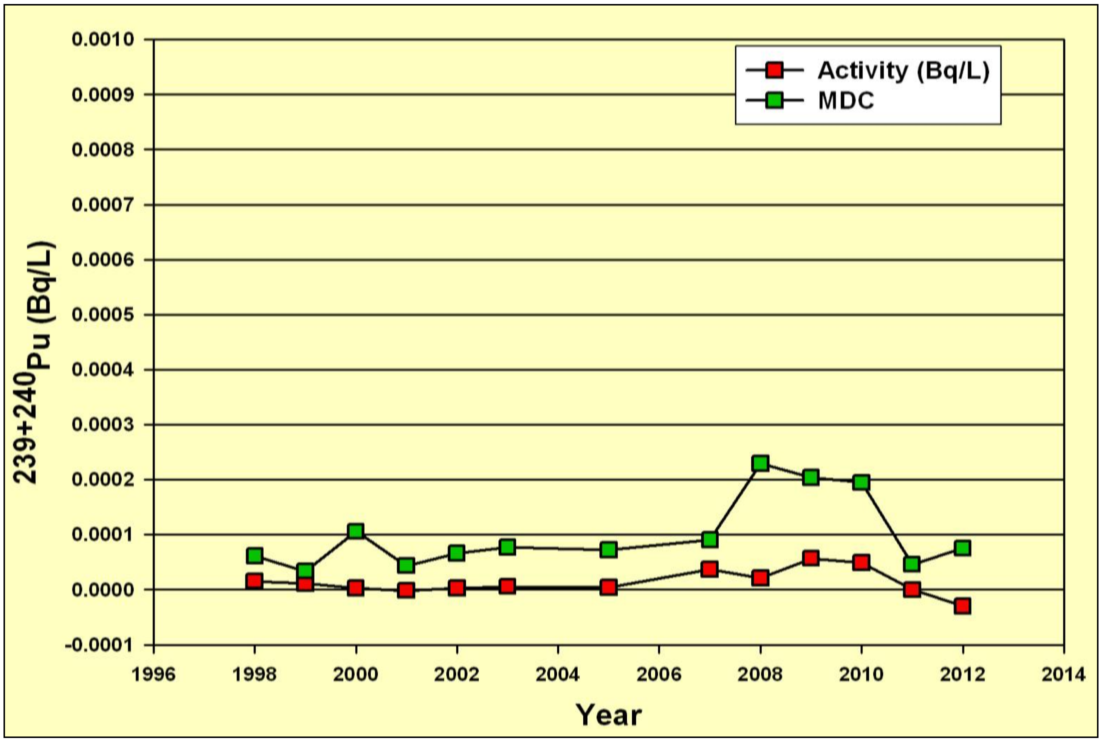


Figure 2.4 $^{239+240}$Pu in Carlsbad Drinking Water from 1998 - 2012

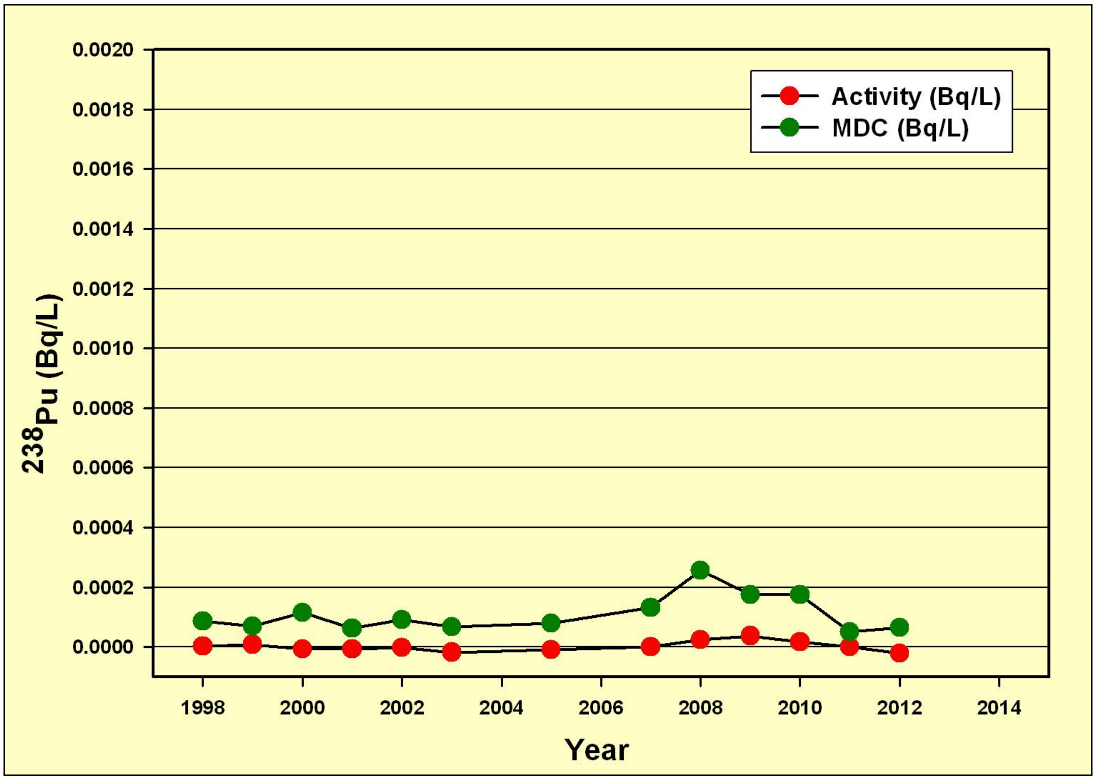


Figure 2.5 ^{238}Pu in Carlsbad Drinking Water from 1998 - 2012
EPA action level for all alpha emitters is 15pCi/L (0.56 Bq/L)

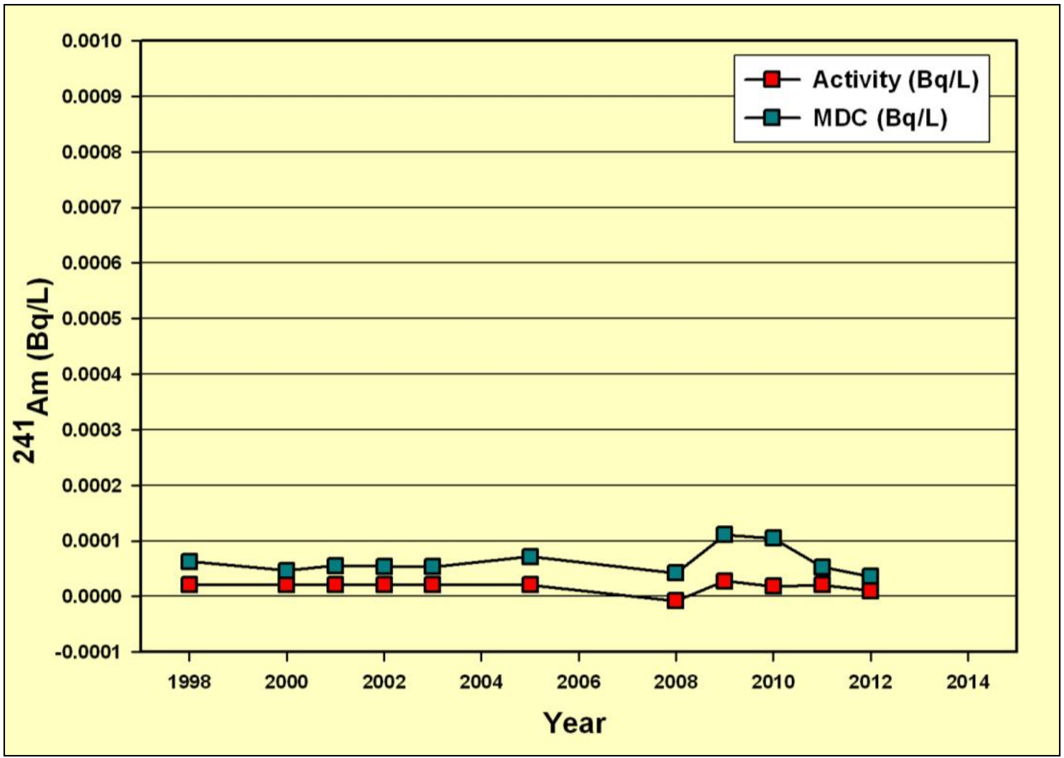


Figure 2.6 ^{241}Am in Carlsbad Drinking Water from 1998 - 2012
EPA action level for all alpha emitters is 15pCi/L (0.56 Bq/L)

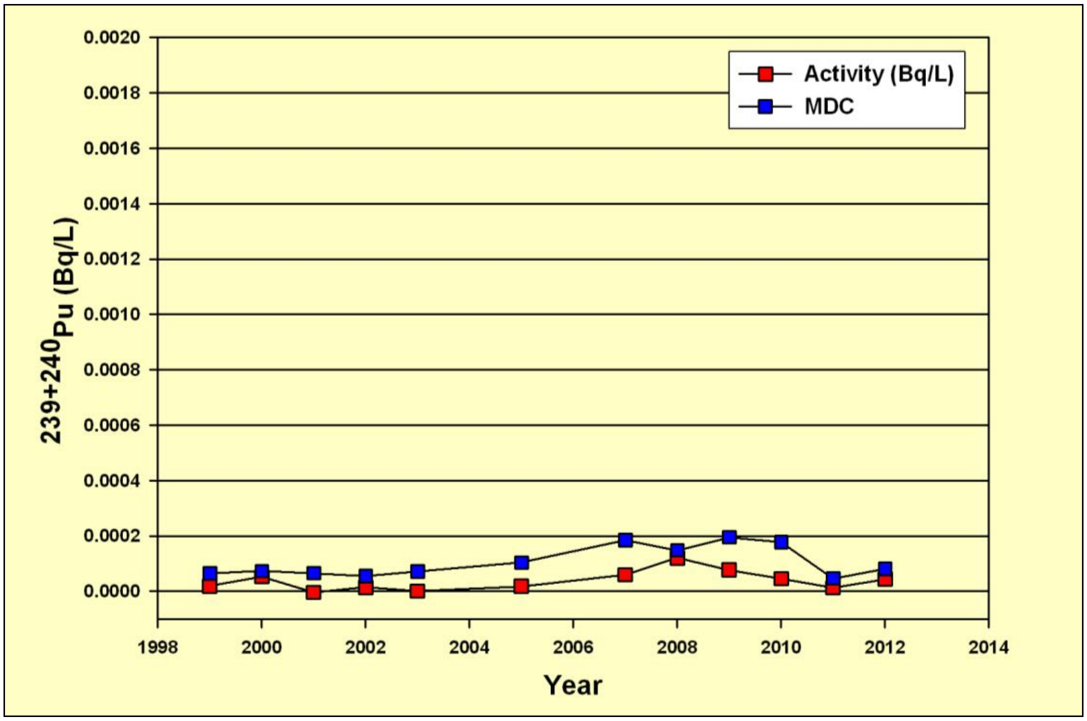


Figure 2.7 $^{239+240}$Pu in Hobbs Drinking Water from 1999-2012

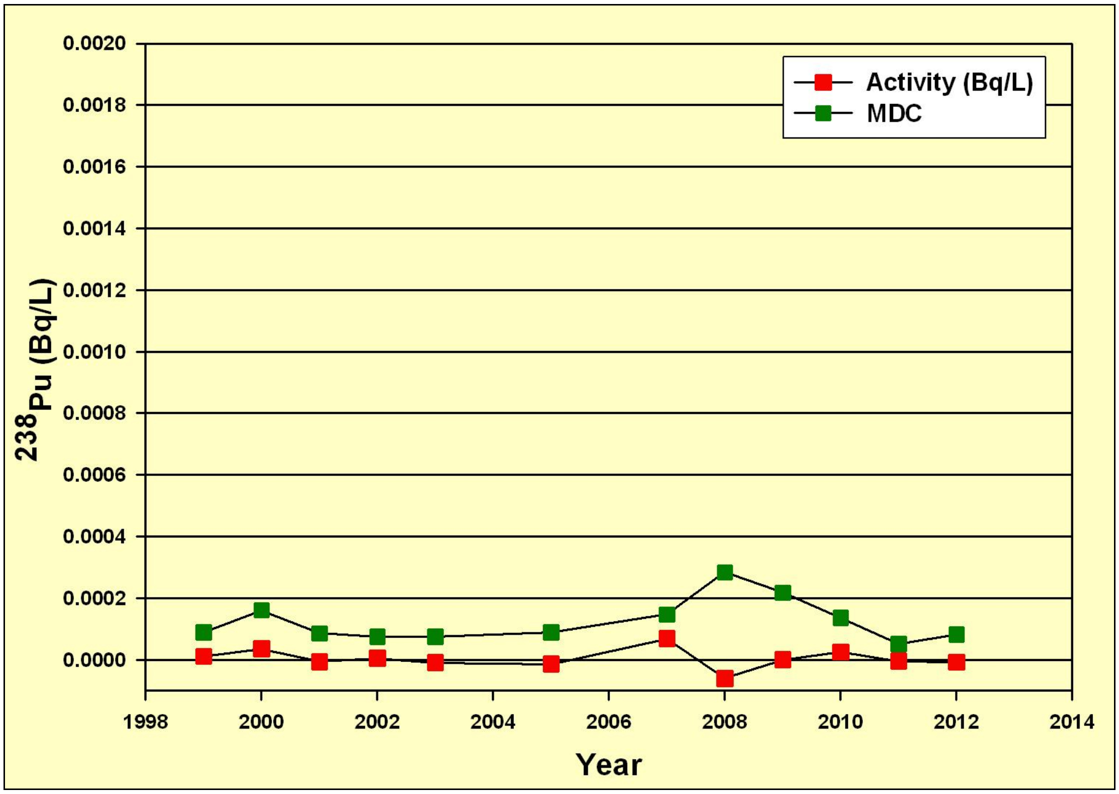


Figure 2.8 ^{238}Pu in Hobbs Drinking Water from 1998 – 2012

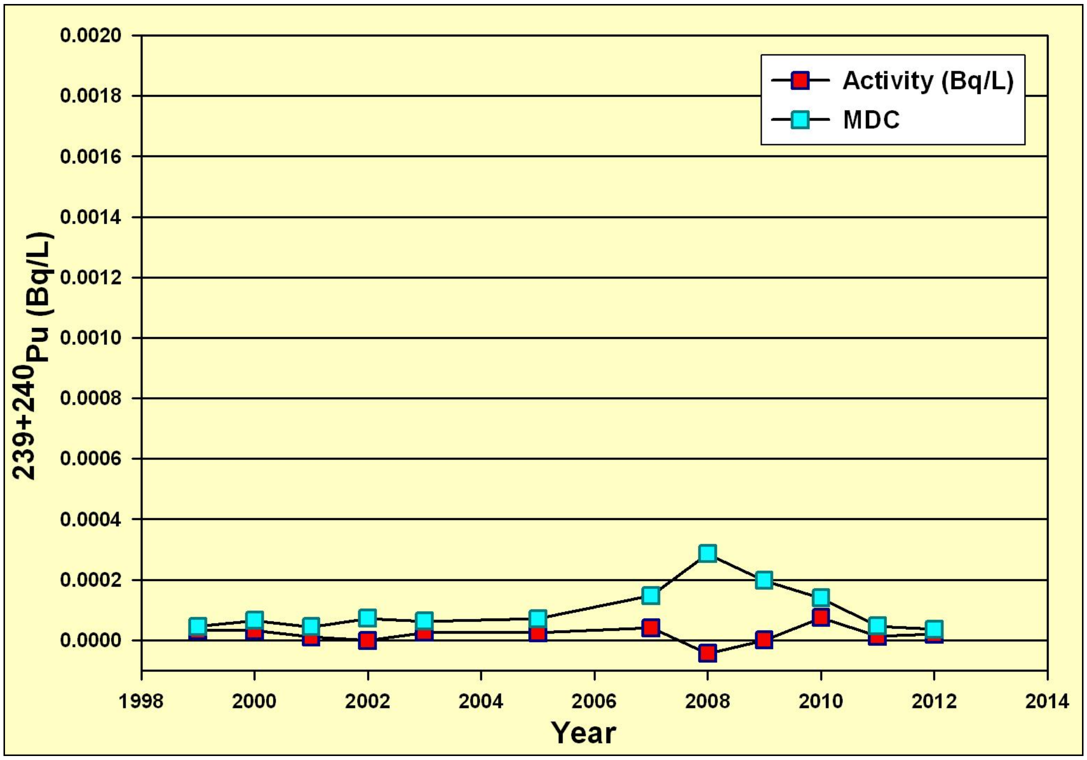


Figure 2.9 $^{239+240}$Pu in Double Eagle Drinking Water from 1999-2012

EPA action level for all alpha emitters is 15pCi/L (0.56 Bq/L)

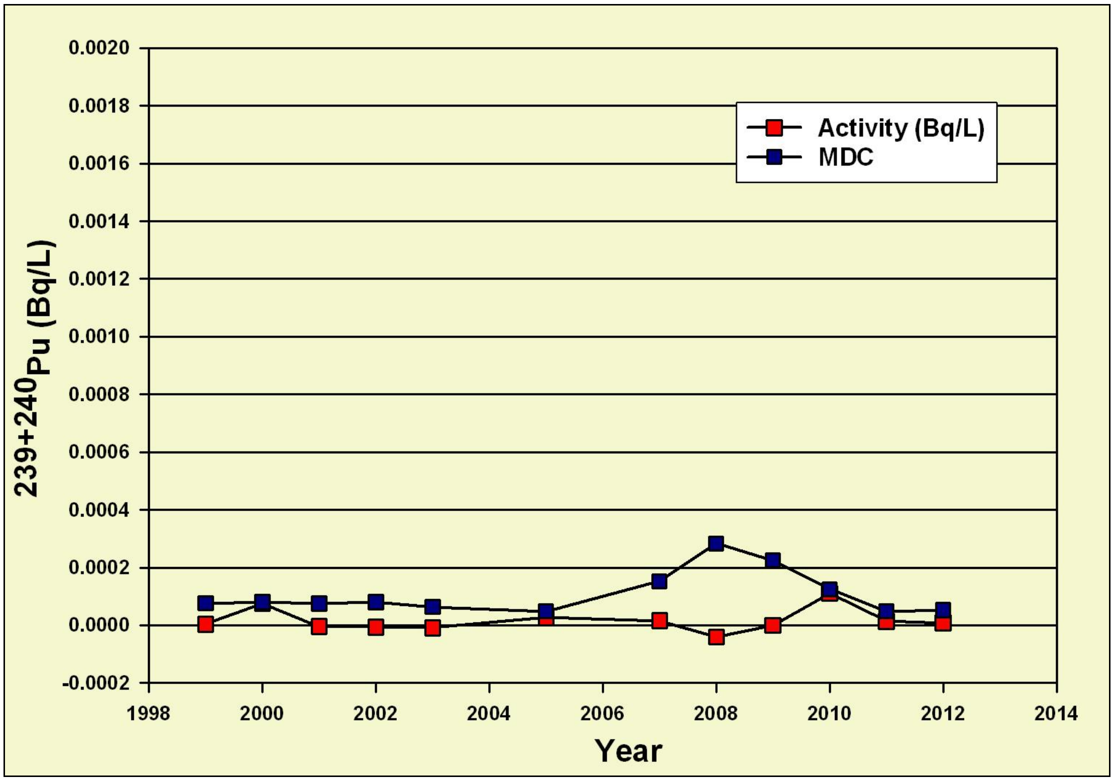


Figure 2.10 $^{239+240}$Pu in Loving Drinking Water from 1999-2012

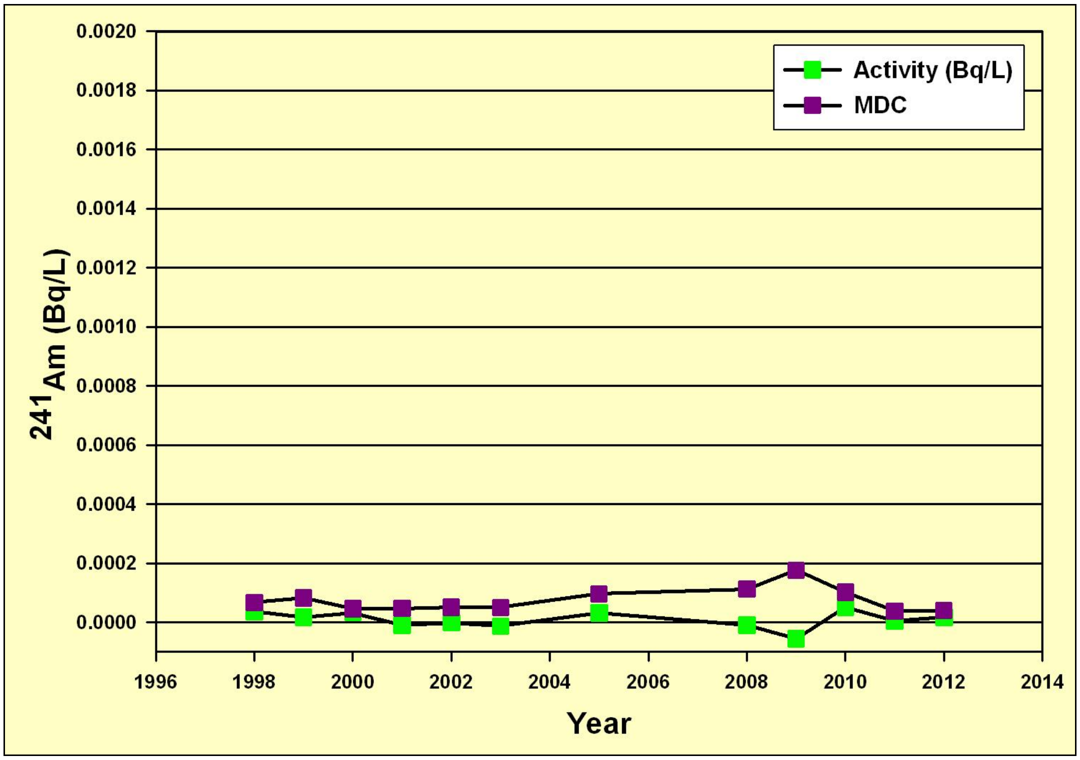


Figure 2.11 ^{241}Am in Otis Drinking Water from 1998 - 2012

Table 2.10 Measured Concentration of Selected Inorganic Analytes in Carlsbad Drinking Water from 1998-2012

Carlsbad							
1998-2011					2012		
EL[1]	N[2]	N_{DET}[2]	Min[3]	Max[3]	MDC[4] (µg/L)	Blank Conc. (µg/L)	Sample Conc. (µg/L)[5]
Ag	9	1	1.75E-02	1.75E-02	8.10E-03	-6.44E-04	<MDC
Al	10	3	1.83E+00	4.11E+01	3.00E+00	2.56E-01	5.56E+00
As	12	8	2.94E-01	1.42E+00	3.40E-01	3.22E-01	1.00E+00
B	3	3	2.89E+01	4.44E+01	N/A	N/A	N/A
Ba	9	9	6.64E+01	8.19E+01	N/A	N/A	N/A
Be	9	N/A	N/A	N/A	5.40E-02	-3.26E-02	<MDC
Ca	5	5	5.90E+04	7.26E+04	5.85E+02	1.52E+01	7.01E+04
Cd	8	N/A	N/A	N/A	1.30E-01	-8.98E-02	<MDC
Ce	9	2	8.31E-03	3.42E-02	6.80E-03	3.46E-04	1.37E-02
Co	10	8	8.80E-02	3.41E-01	1.80E-02	3.59E-03	9.33E-02
Cr	11	9	1.24E+00	6.96E+00	1.50E-01	-1.20E-01	9.54E+00
Cu	10	9	1.30E+00	1.67E+01	5.30E-01	4.93E-03	3.21E+00
Dy	10	1	3.56E-03	3.56E-03	7.20E-03	-4.07E-04	<MDC
Er	10	2	3.32E-03	3.38E-03	8.90E-03	3.24E-04	<MDC
Eu	9	6	1.35E-02	2.42E-02	5.50E-03	1.03E-03	1.96E-02
Fe	7	4	7.10E-01	2.24E+02	1.23E+01	-8.42E-01	1.77E+02
Ga	1	1	3.25E+00	3.25E+00	N/A	N/A	N/A
Gd	8	1	3.80E-03	3.80E-03	5.90E-03	1.05E-03	<MDC
Hg	4	N/A	N/A	N/A	1.50E-02	1.25E-02	3.14E-02
K	9	9	1.04E+03	3.56E+03	2.20E+01	3.03E+01	1.02E+03
La	9	5	5.81E-03	4.42E-02	1.10E-02	1.17E-03	<MDC
Li	8	8	5.14E+00	8.86E+00	1.30E-02	6.03E-03	6.43E+00
Mg	8	8	2.73E+04	3.47E+04	8.80E+00	1.57E-01	3.10E+04
Mn	11	7	5.50E-02	2.04E+00	3.00E-01	8.21E-03	5.56E-01
Mo	7	6	8.93E-01	1.22E+00	1.00E-01	3.54E-02	1.22E+00
Na	10	10	8.16E+03	4.55E+04	4.90E-01	4.33E-01	9.26E+03
Nd	10	N/A	N/A	N/A	6.10E-03	7.61E-04	9.35E-03
Ni	10	9	1.46E+00	3.14E+00	3.30E-02	2.16E-02	1.75E+00
P	4	3	1.61E+01	2.29E+01	4.00E+00	5.12E+00	2.08E+01
Pb	9	7	1.68E-01	1.44E+00	6.90E-02	1.18E-03	1.20E-01
Pr	10	1	3.72E-03	3.72E-03	5.60E-03	4.97E-04	<MDC
Sb	9	4	3.60E-02	1.99E-01	6.00E-03	1.50E-02	3.14E-02
Sc	8	7	1.32E+00	3.03E+00	1.20E-01	6.42E-02	1.20E+00
Se	9	6	-8.83E-02	1.22E+00	1.30E+00	1.21E+00	1.93E+00
Si	6	6	5.39E+03	6.87E+03	5.63E+01	-5.97E+00	6.10E+03
Sr	9	9	2.61E+02	3.62E+02	1.60E-01	7.02E-03	2.98E+02
Th	7	2	6.32E-03	1.76E-02	9.50E-03	2.22E-03	<MDC
Tl	9	9	8.97E-02	1.62E-01	8.50E-03	1.31E-03	1.01E-01
U	10	10	8.21E-01	1.05E+00	4.00E-03	-6.57E-04	9.62E-01
V	11	11	3.54E+00	5.80E+00	1.20E-01	-2.22E-02	6.38E+00
Zn	10	9	2.13E+00	1.52E+01	8.90E-01	-1.73E-02	8.74E+00

[1] El = Element analyzed;
[2] N = Total number of samples analyzed; N_{det} = number of samples with detectable (above MDC) values;
[3] Min = the lowest value measured above MDC; Max = the highest value measured;
[4] MDC = Minimum detectable concentration;
[5] Concentrations below the MDC are reported as <MDC;
N/A = Not Applicable

Table 2.11 Measured Concentration of Selected Inorganic Analytes in Double Eagle Drinking Water from 1998-2012

Double Eagle							
1998-2011					2012		
EL[1]	N[2]	N_{DET}[2]	Min[3]	Max[3]	MDC[4] (µg/L)	Blank Conc. (µg/L)	Sample Conc. (µg/L)[5]
Ag	11	2	3.62E-03	1.78E-01	8.10E-03	-6.44E-04	<MDC
Al	12	6	1.93E+00	7.22E+01	3.00E+00	2.56E-01	5.63E+00
As	11	10	4.43E+00	7.80E+00	3.40E-01	3.22E-01	8.90E+00
B	3	3	2.98E+01	8.55E+01	N/A	N/A	N/A
Ba	9	9	3.82E+01	1.25E+02	3.40E-01	5.16E-03	9.25E+01
Be	10	1	3.63E-02	3.63E-02	5.40E-02	-3.26E-02	6.76E-02
Ca	5	5	4.15E+04	5.61E+04	5.85E+02	1.52E+01	5.94E+04
Cd	9	1	1.87E-02	1.87E-02	1.30E-01	-8.98E-02	<MDC
Ce	10	2	3.63E-03	3.22E-02	6.80E-03	3.46E-04	1.02E-02
Co	11	8	6.48E-02	1.12E+00	1.80E-02	3.59E-03	8.17E-02
Cr	12	11	1.29E+00	3.25E+01	1.50E-01	-1.20E-01	5.40E+00
Cu	11	10	8.09E-01	5.69E+00	5.30E-01	4.93E-03	1.05E+00
Dy	11	N/A	N/A	N/A	7.20E-03	-4.07E-04	<MDC
Er	11	N/A	N/A	N/A	8.90E-03	3.24E-04	<MDC
Eu	10	7	1.68E-02	2.86E-02	5.50E-03	1.03E-03	1.79E-02
Fe	8	6	3.01E-02	9.32E+02	1.23E+01	-8.42E-01	1.21E+02
Ga	1	1	4.46E+00	4.46E+00	N/A	N/A	N/A
Gd	10	N/A	N/A	N/A	5.90E-03	1.05E-03	<MDC
Hg	3	N/A	N/A	N/A	1.50E-02	1.25E-02	<MDC
K	10	10	2.22E+03	2.94E+04	2.20E+01	3.03E+01	3.09E+03
La	10	5	1.19E-02	6.26E-02	1.10E-02	1.17E-03	<MDC
Li	9	9	9.97E+00	1.90E+01	1.30E-02	6.03E-03	1.95E+01
Mg	8	8	8.51E+03	1.25E+04	8.80E+00	1.57E-01	1.14E+04
Mn	12	10	2.22E-01	6.04E+00	3.00E-01	8.21E-03	<MDC
Mo	8	8	1.42E+00	6.70E+00	1.00E-01	3.54E-02	1.93E+00
Na	11	11	3.84E+03	4.04E+04	4.90E+00	4.33E-01	3.83E+04
Nd	11	N/A	N/A	N/A	6.10E-03	7.61E-04	<MDC
Ni	11	10	1.16E+00	4.03E+00	3.30E-02	2.16E-02	1.22E+00
P	4	1	1.04E+01	1.04E+01	4.00E+00	5.12E+00	1.36E+01
Pb	10	9	2.56E-01	1.56E+00	6.90E-02	1.18E-03	4.38E-01
Pr	11	1	9.05E-04	9.05E-04	5.60E-03	4.97E-04	<MDC
Sb	10	6	2.41E-02	1.39E-01	6.00E-03	1.50E-02	4.47E-02
Sc	8	7	1.40E+00	6.59E+00	1.20E-01	6.42E-02	2.87E+00
Se	9	7	-4.16E-02	5.30E+00	1.30E+00	1.21E+00	4.91E+00
Si	6	6	7.37E+03	1.81E+04	5.63E+01	-5.97E+00	1.63E+04
Sr	10	10	5.06E+01	5.53E+02	1.60E-01	7.02E-03	5.68E+02
Th	9	2	2.07E-03	9.23E-03	9.50E-03	2.22E-03	8.38E-02
Tl	10	1	-1.23E-02	-1.23E-02	8.50E-03	1.31E-03	<MDC
U	11	11	1.17E+00	2.38E+00	4.00E-03	-6.57E-04	1.60E+00
V	12	12	7.71E+00	3.26E+01	1.20E-01	-2.22E-02	3.01E+01
Zn	11	10	1.46E+00	1.25E+01	8.90E-01	-1.73E-02	2.95E+00

[1] El = Element analyzed;

[2] N = Total number of samples analyzed; N_{det} = number of samples with detectable (above MDC) values;

[3] Min = the lowest value measured above MDC; Max = the highest value measured;

[4] MDC = Minimum detectable concentration;

[5] Concentrations below the MDC are reported as <MDC;

N/A = Not Applicable

Table 2.12 Measured Concentration of Selected Inorganic Analytes in Hobbs Drinking Water from 1998 - 2012

Hobbs							
1998-2011					2012		
EL^1	N^2	N_{DET}^2	Min^3	Max^3	MDC^4 (µg/L)	Blank Conc. (µg/L)	Sample Conc. (µg/L)^5
Ag	11	2	3.86E-03	1.04E-01	1.62E-02	-6.44E-04	<MDC
Al	12	9	3.03E+00	1.14E+02	6.00E+00	2.56E-01	8.73E+00
As	11	10	4.51E+00	8.56E+00	6.80E-01	3.22E-01	7.38E+00
B	3	3	1.41E+02	1.97E+02	N/A	N/A	N/A
Ba	9	9	5.83E+01	6.79E+01	6.80E-01	5.16E-03	5.63E+01
Be	10	1	5.39E-02	5.39E-02	1.08E-01	-3.26E-02	<MDC
Ca	5	5	7.63E+04	9.20E+04	2.93E+03	1.52E+01	1.05E+05
Cd	9	N/A	N/A	N/A	2.60E-01	-8.98E-02	<MDC
Ce	10	7	5.10E-03	3.56E-02	1.36E-02	3.46E-04	2.50E-02
Co	11	9	9.78E-02	3.61E-01	3.60E-02	3.59E-03	1.62E-01
Cr	12	11	6.44E-01	1.13E+01	3.00E-01	-1.20E-01	6.74E+00
Cu	11	10	1.06E+00	6.93E+00	1.06E+00	4.93E-03	5.12E+00
Dy	11	1	4.18E-03	4.18E-03	1.44E-02	-4.07E-04	<MDC
Er	11	N/A	N/A	N/A	1.78E-02	3.24E-04	<MDC
Eu	10	7	1.31E-02	1.97E-02	1.10E-02	1.03E-03	1.12E-02
Fe	8	6	3.64E+01	4.44E+02	2.46E+01	-8.42E-01	2.16E+02
Ga	1	1	2.56E+00	2.56E+00	N/A	N/A	N/A
Gd	10	N/A	N/A	N/A	1.18E-02	1.05E-03	<MDC
Hg	3	N/A	N/A	N/A	1.50E-02	1.25E-02	<MDC
K	10	10	2.11E+03	2.52E+04	4.40E+01	3.03E+01	2.68E+03
La	10	5	1.25E-02	5.01E-02	2.20E-02	1.17E-03	<MDC
Li	9	9	2.65E+01	3.21E+01	2.60E-02	6.03E-03	3.66E+01
Mg	8	8	1.90E+04	2.67E+04	4.40E+01	1.57E-01	2.48E+04
Mn	12	11	3.79E-01	3.62E+00	6.00E-01	8.21E-03	2.13E+00
Mo	8	8	2.46E+00	3.31E+00	2.00E-01	3.54E-02	2.66E+00
Na	11	11	4.97E+03	5.80E+04	2.45E+01	4.33E-01	5.23E+04
Nd	11	3	3.01E-03	1.28E-02	1.22E-02	7.61E-04	1.44E-02
Ni	11	11	1.67E+00	4.78E+00	6.60E-02	2.16E-02	2.17E+00
P	4	3	1.76E+01	2.53E+01	8.00E+00	5.12E+00	3.93E+01
Pb	10	8	9.44E-02	1.19E+00	1.38E-01	1.18E-03	1.09E+00
Pr	11	1	1.57E-03	1.57E-03	1.12E-02	4.97E-04	<MDC
Sb	10	6	3.88E-02	7.78E-02	1.20E-02	1.50E-02	6.76E-02
Sc	8	8	3.06E+00	1.05E+01	2.40E-01	6.42E-02	4.31E+00
Se	9	7	-1.70E-01	1.23E+01	2.60E+00	1.21E+00	9.88E+00
Si	6	6	2.41E+04	2.86E+04	1.13E+02	-5.97E+00	2.60E+04
Sr	10	10	7.89E+01	1.10E+03	8.00E-01	7.02E-03	1.12E+03
Th	9	2	2.29E-03	4.56E-03	1.90E-02	2.22E-03	<MDC
Tl	9	2	9.45E-03	2.24E-02	1.70E-02	1.31E-03	<MDC
U	11	11	2.90E+00	4.30E+00	8.00E-03	-6.57E-04	4.20E+00
V	12	12	3.11E+01	3.71E+01	2.40E-01	-2.22E-02	3.59E+01
Zn	11	8	8.44E-01	4.37E+00	1.78E+00	-1.73E-02	1.96E+00

[1] El = Element analyzed;
[2] N = Total number of samples analyzed; N_{det} = number of samples with detectable (above MDC) values;
[3] Min = the lowest value measured above MDC; Max = the highest value measured;
[4] MDC = Minimum detectable concentration;
[5] Concentrations below the MDC are reported as <MDC;
N/A = Not Applicable

Table 2.13 Measured Concentration of Selected Inorganic Analytes in Loving Drinking Water from 1998 - 2012

Loving							
1998-2011					2012		
EL[1]	N[2]	N_{DET}[2]	Min[3]	Max[3]	MDC[4] (µg/L)	Blank Conc. (µg/L)	Sample Conc. (µg/L)[5]
Ag	12	4	2.55E-03	2.17E-01	8.10E-03	2.32E-03	<MDC
Al	12	7	1.43E+00	3.76E+02	3.00E+00	-5.77E-02	4.40E+00
As	11	8	7.82E-01	2.01E+00	3.40E-01	2.71E-01	1.94E+00
B	3	3	7.55E+01	1.12E+02	N/A	N/A	N/A
Ba	9	9	2.96E+01	3.47E+01	3.40E-01	4.04E-03	3.14E+01
Be	10	1	9.35E-02	9.35E-02	5.40E-02	2.84E-02	<MDC
Ca	5	5	6.71E+04	1.00E+05	5.85E+02	-1.57E+01	8.65E+04
Cd	10	N/A	N/A	N/A	1.30E-01	-1.98E-01	<MDC
Ce	11	3	9.74E-04	2.53E-01	6.80E-03	-1.07E-04	7.23E-03
Co	11	9	1.02E-01	4.04E-01	1.80E-02	-5.46E-04	1.17E-01
Cr	12	10	1.12E+00	7.44E+00	1.50E-01	-1.66E-01	1.06E+01
Cu	11	9	1.20E+00	5.59E+00	5.30E-01	1.52E-03	9.60E-01
Dy	11	N/A	N/A	N/A	7.20E-03	6.29E-04	<MDC
Er	12	N/A	N/A	N/A	8.90E-03	7.65E-04	<MDC
Eu	11	7	7.00E-03	1.01E-02	5.50E-03	1.32E-03	1.04E-02
Fe	8	5	3.60E+00	2.57E+02	1.23E+01	2.27E+00	1.82E+02
Ga	1	1	1.26E+00	1.26E+00	N/A	N/A	N/A
Gd	11	2	2.15E-03	1.04E-02	5.90E-03	-5.02E-04	<MDC
Hg	3	N/A	N/A	N/A	1.50E-02	2.18E-02	<MDC
K	10	10	1.69E+03	1.98E+04	2.20E+01	3.20E+01	1.86E+03
La	11	4	6.66E-03	2.22E-02	1.10E-02	9.65E-04	<MDC
Li	9	9	1.66E+01	2.03E+01	1.30E-02	4.67E-02	1.86E+01
Mg	8	8	3.02E+04	4.21E+04	8.80E+00	1.76E-01	3.52E+04
Mn	12	8	1.43E-02	1.77E+00	3.00E-01	-1.60E-02	<MDC
Mo	8	7	1.28E+00	1.67E+00	1.00E-01	3.54E-02	1.66E+00
Na	11	11	2.33E+03	2.82E+04	4.90E+00	2.90E-01	2.37E+04
Nd	12	1	3.37E-03	3.37E-03	6.10E-03	6.55E-04	7.68E-03
Ni	11	10	1.91E+00	3.38E+00	3.30E-02	-6.47E-04	2.24E+00
P	4	3	2.46E+01	3.37E+01	4.00E+00	-4.64E+00	3.87E+01
Pb	10	6	1.73E-01	1.67E+00	6.90E-02	-2.93E-04	8.03E-02
Pr	12	N/A	N/A	N/A	5.60E-03	2.29E-04	<MDC
Sb	10	5	3.51E-02	1.84E-01	6.00E-03	6.46E-03	3.78E-02
Sc	8	7	1.91E+00	4.72E+00	1.20E-01	-2.28E-01	1.50E+00
Se	9	6	-2.89E+00	1.51E+00	1.30E+00	1.05E+00	<MDC
Si	6	6	9.23E+03	1.09E+04	5.63E+01	-8.02E+00	9.71E+03
Sr	10	10	7.60E+01	9.37E+02	1.60E-01	7.04E-04	7.64E+02
Th	10	2	5.69E-03	7.38E-03	9.50E-03	1.23E-03	<MDC
Tl	11	2	2.24E-03	4.32E-02	8.50E-03	7.22E-04	<MDC
U	11	11	1.98E+00	2.30E+00	4.00E-03	5.10E-05	2.29E+00
V	12	12	1.11E+01	1.44E+01	1.20E-01	-1.05E-01	1.52E+01
Zn	11	10	4.79E+00	2.01E+01	8.90E-01	-1.17E-01	9.65E+00

[1] El = Element analyzed;
[2] N = Total number of samples analyzed; N_{det} = number of samples with detectable (above MDC) values;
[3] Min = the lowest value measured above MDC; Max = the highest value measured;
[4] MDC = Minimum detectable concentration;
[5] Concentrations below the MDC are reported as <MDC;
N/A = Not Applicable

Table 2.14 Measured Concentration of Selected Inorganic Analytes in Otis Drinking Water from 1998 - 2012

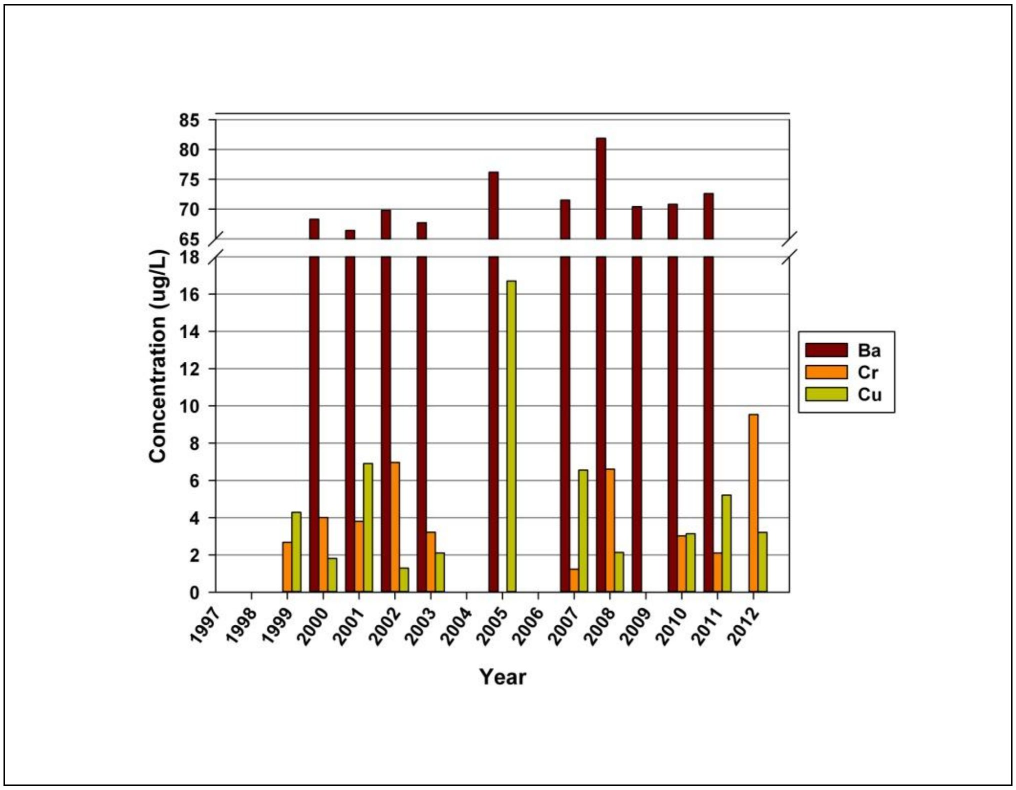
Otis							
1998-2011					2012		
EL[1]	N[2]	N_{DET}[2]	Min[3]	Max[3]	MDC[4] (µg/L)	Blank Conc. (µg/L)	Sample Conc. (µg/L)[5]
Ag	9	1	2.63E-02	2.63E-02	4.05E-02	2.32E-03	<MDC
Al	10	3	5.74E+00	1.06E+03	1.50E+01	-5.77E-02	<MDC
As	11	7	6.53E-01	2.34E+00	1.70E+00	2.71E-01	<MDC
B	3	3	1.46E+02	2.39E+02	N/A	N/A	N/A
Ba	8	7	1.39E+01	1.75E+01	1.70E+00	4.04E-03	1.41E+01
Be	9	N/A	N/A	N/A	2.70E-01	2.84E-02	<MDC
Ca	5	5	2.42E+05	2.81E+05	5.85E+03	-1.57E+01	1.89E+05
Cd	8	N/A	N/A	N/A	6.50E-01	-1.98E-01	<MDC
Ce	9	1	2.75E-02	2.75E-02	3.40E-02	-1.07E-04	<MDC
Co	10	8	3.21E-01	9.51E-01	9.00E-02	-5.46E-04	2.44E-01
Cr	11	9	8.76E-01	6.67E+00	7.50E-01	-1.66E-01	6.64E+00
Cu	10	9	2.43E+00	6.02E+00	2.65E+00	1.52E-03	4.59E+00
Dy	10	1	3.39E-03	3.39E-03	3.60E-02	6.29E-04	<MDC
Er	10	N/A	N/A	N/A	4.45E-02	7.65E-04	<MDC
Eu	9	3	3.42E-03	9.48E-03	2.75E-02	1.32E-03	<MDC
Fe	8	7	2.87E+00	1.02E+03	6.15E+01	2.27E+00	4.35E+02
Ga	1	1	6.54E-01	6.54E-01	N/A	N/A	N/A
Gd	9	N/A	N/A	N/A	2.95E-02	-5.02E-04	<MDC
Hg	3	N/A	N/A	N/A	1.50E-02	2.18E-02	<MDC
K	9	9	2.85E+03	4.01E+03	1.10E+02	3.20E+01	2.41E+03
La	9	2	3.36E-03	6.30E-03	5.50E-02	9.65E-04	<MDC
Li	8	8	3.74E+01	6.79E+01	6.50E-02	4.67E-02	3.37E+01
Mg	8	8	5.16E+04	1.08E+05	8.80E+01	1.76E-01	6.21E+04
Mn	10	4	2.00E-01	2.32E+00	1.50E+00	-1.60E-02	<MDC
Mo	7	7	2.25E+00	3.13E+00	5.00E-01	3.54E-02	3.00E+00
Na	9	9	1.02E+05	1.97E+05	4.90E+01	2.90E-01	5.35E+04
Nd	10	3	4.80E-03	3.97E-02	3.05E-02	6.55E-04	<MDC
Ni	10	9	2.62E+00	1.11E+01	1.65E-01	-6.47E-04	4.65E+00
P	4	4	4.54E+01	1.32E+02	2.00E+01	-4.64E+00	7.92E+01
Pb	9	4	1.08E-01	5.04E-01	3.45E-01	-2.93E-04	4.03E-01
Pr	10	N/A	N/A	N/A	2.80E-02	2.29E-04	<MDC
Sb	9	5	3.69E-02	4.10E-01	3.00E-02	6.46E-03	3.66E-02
Sc	8	6	2.57E+00	5.35E+00	6.00E-01	-2.28E-01	6.55E-01
Se	9	6	-2.43E-02	1.19E+00	6.50E+00	1.05E+00	<MDC
Si	6	6	9.30E+03	1.39E+04	2.82E+02	-8.02E+00	9.56E+03
Sr	8	8	2.41E+03	4.62E+03	1.60E+00	7.04E-04	2.20E+03
Th	7	2	1.19E-03	2.67E-02	4.75E-02	1.23E-03	5.11E-02
Tl	9	1	-6.30E-03	-6.30E-03	4.25E-02	7.22E-04	<MDC
U	10	10	3.73E+00	5.88E+00	2.00E-02	5.10E-05	3.98E+00
V	11	10	1.05E+01	1.29E+01	6.00E-01	-1.05E-01	1.26E+01
Zn	9	6	1.54E+00	1.16E+01	4.45E+00	-1.17E-01	8.93E+00

[1] El = Element analyzed;
[2] N = Total number of samples analyzed; N_{det} = number of samples with detectable (above MDC) values;
[3] Min = the lowest value measured above MDC; Max = the highest value measured;
[4] MDC = Minimum detectable concentration;
[5] Concentrations below the MDC are reported as <MDC;
N/A = Not Applicable

Table 2.15 Measured Concentration of Selected Inorganic Analytes in Malaga Drinking Water from 1998 - 2012

Malaga							
1998-2011					2012		
EL[1]	N[2]	N$_{DET}$[2]	Min[3]	Max[3]	MDC[4] (µg/L)	Blank Conc. (µg/L)	Sample Conc. (µg/L)[5]
Ag	1	N/A	N/A	N/A	4.05E-02	2.32E-03	<MDC
Al	1	N/A	N/A	N/A	1.50E+01	-5.77E-02	<MDC
As	1	N/A	N/A	N/A	1.70E+00	2.71E-01	5.44E+00
B	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ba	1	1	1.66E+01	1.66E+01	1.70E+00	4.04E-03	1.53E+01
Be	1	N/A	N/A	N/A	2.70E-01	2.84E-02	3.04E-01
Ca	1	1	2.41E+05	2.41E+05	5.85E+03	-1.57E+01	3.09E+05
Cd	1	N/A	N/A	N/A	6.50E-01	-1.98E-01	<MDC
Ce	1	N/A	N/A	N/A	3.40E-02	-1.07E-04	<MDC
Co	1	1	8.57E-01	8.57E-01	9.00E-02	-5.46E-04	3.54E-01
Cr	1	1	1.95E+00	1.95E+00	7.50E-01	-1.66E-01	5.59E+00
Cu	1	1	3.66E+00	3.66E+00	2.65E+00	1.52E-03	<MDC
Dy	1	N/A	N/A	N/A	3.60E-02	6.29E-04	<MDC
Er	1	N/A	N/A	N/A	4.45E-02	7.65E-04	<MDC
Eu	1	N/A	N/A	N/A	2.75E-02	1.32E-03	<MDC
Fe	1	1	8.94E+02	8.94E+02	6.15E+01	2.27E+00	5.90E+02
Ga	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Gd	1	N/A	N/A	N/A	2.95E-02	-5.02E-04	<MDC
Hg	1	N/A	N/A	N/A	1.50E-02	2.18E-02	<MDC
K	1	1	2.57E+03	2.57E+03	1.10E+02	3.20E+01	3.06E+03
La	1	N/A	N/A	N/A	5.50E-02	9.65E-04	<MDC
Li	1	1	4.39E+01	4.39E+01	6.50E-02	4.67E-02	4.87E+01
Mg	1	1	6.98E+04	6.98E+04	8.80E+01	1.76E-01	8.92E+04
Mn	1	N/A	N/A	N/A	1.50E+00	-1.60E-02	<MDC
Mo	N/A	N/A	N/A	N/A	5.00E-01	3.54E-02	3.98E+00
Na	1	1	7.53E+04	7.53E+04	4.90E+01	2.90E-01	9.38E+04
Nd	1	N/A	N/A	N/A	3.05E-02	6.55E-04	<MDC
Ni	1	1	1.04E+01	1.04E+01	1.65E-01	-6.47E-04	6.84E+00
P	1	1	5.64E+01	5.64E+01	2.00E+01	-4.64E+00	1.22E+02
Pb	1	N/A	N/A	N/A	3.45E-01	-2.93E-04	3.68E-01
Pr	1	N/A	N/A	N/A	2.80E-02	2.29E-04	<MDC
Sb	1	N/A	N/A	N/A	3.00E-02	6.46E-03	6.38E-02
Sc	N/A	N/A	N/A	N/A	6.00E-01	-2.28E-01	1.54E+00
Se	1	N/A	N/A	N/A	6.50E+00	1.05E+00	1.65E+01
Si	1	1	9.12E+03	9.12E+03	2.82E+02	-8.02E+00	9.72E+03
Sr	1	1	3.80E+03	3.80E+03	1.60E+00	7.04E-04	3.71E+03
Th	1	N/A	N/A	N/A	N/A	N/A	N/A
Tl	1	N/A	N/A	N/A	4.25E-02	7.22E-04	<MDC
U	1	1	5.38E+00	5.38E+00	2.00E-02	5.10E-05	5.35E+00
V	1	1	8.70E+00	8.70E+00	6.00E-01	-1.05E-01	9.63E+00
Zn	1	1	1.52E+01	1.52E+01	4.45E+00	-1.17E-01	4.64E+01

[1] El = Element analyzed;
[2] N = Total number of samples analyzed; N$_{det}$ = number of samples with detectable (above MDC) values;
[3] Min = the lowest value measured above MDC; Max = the highest value measured;
[4] MDC = Minimum detectable concentration;
[5] Concentrations below the MDC are reported as <MDC;
N/A = Not Applicable



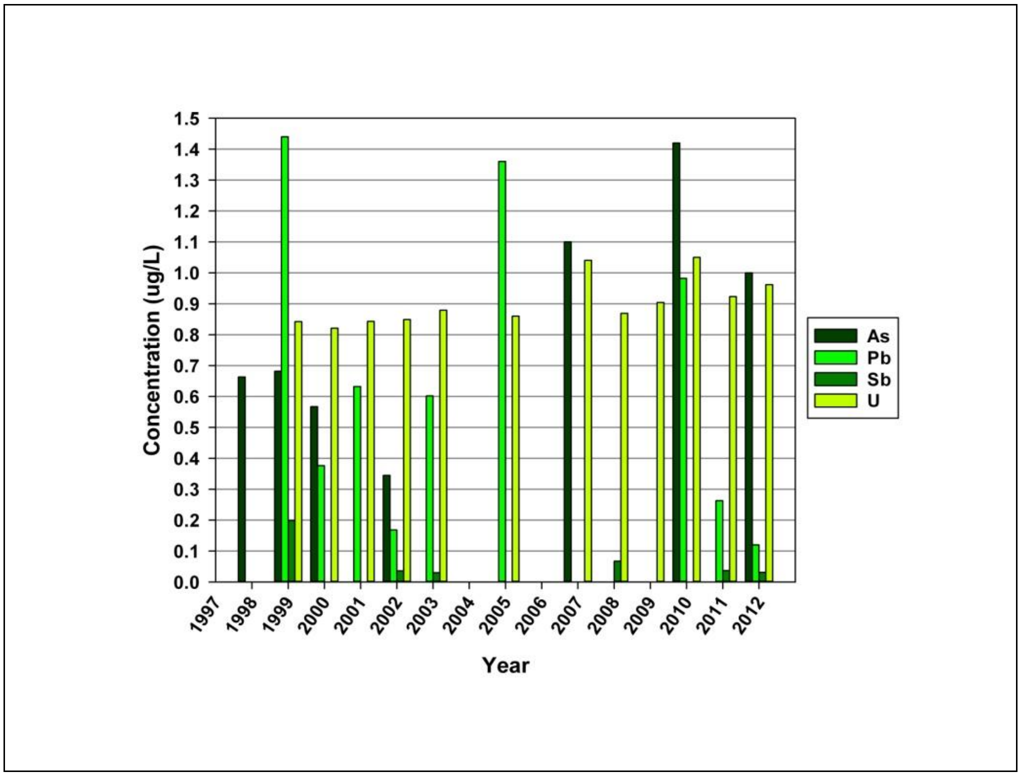
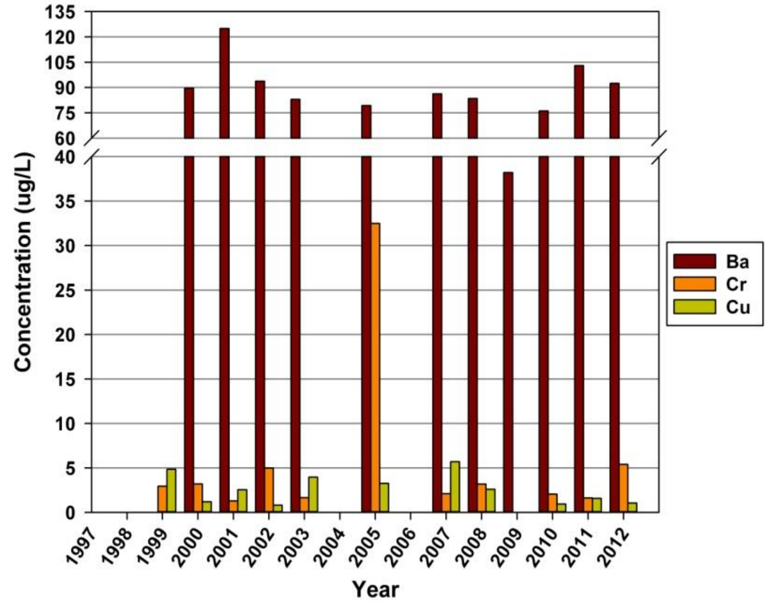


Figure 2.12 Concentrations (μg/L) of Select Inorganic Analytes Measured in Carlsbad Drinking Water from 1998 - 2012



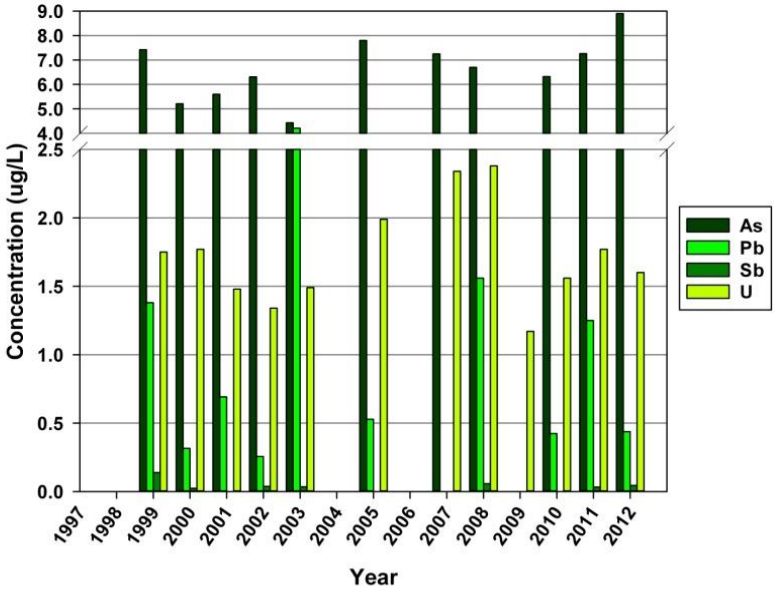
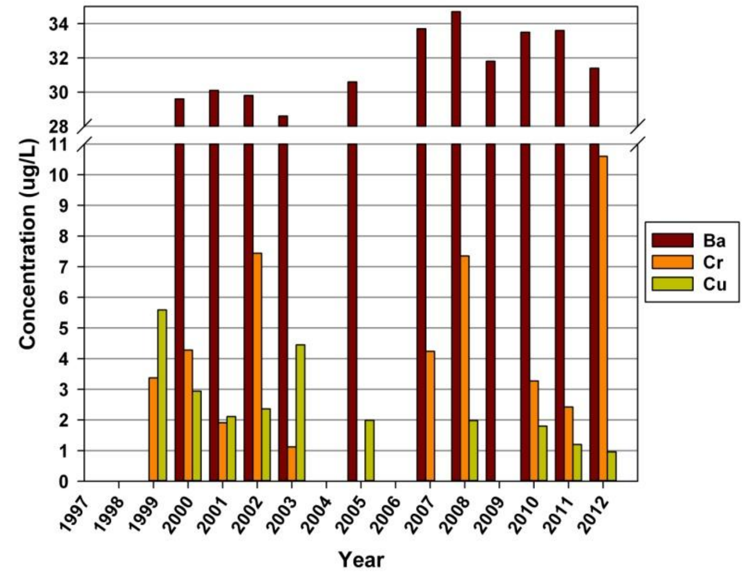


Figure 2.13 Concentrations (µg/L) of Select Inorganic Analytes Measured Near the WIPP site (Double Eagle) from 1998 - 2012



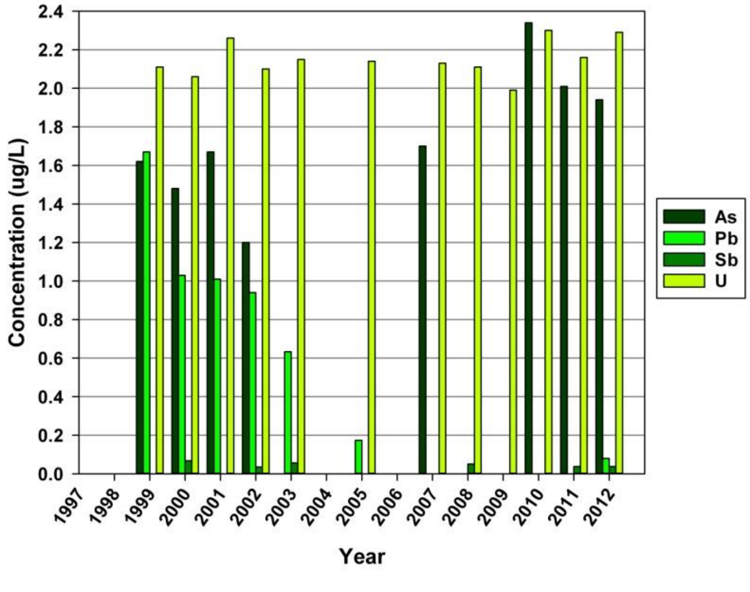
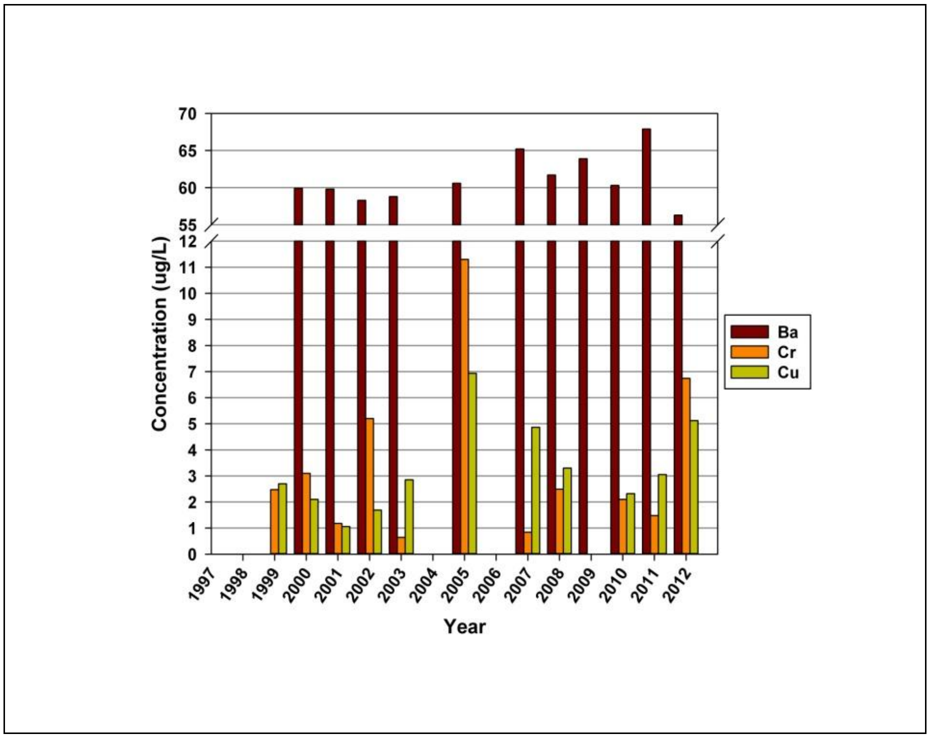


Figure 2.14 Concentrations (µg/L) of Select Inorganic Analytes Measured in Loving Drinking Water from 1998 - 2012



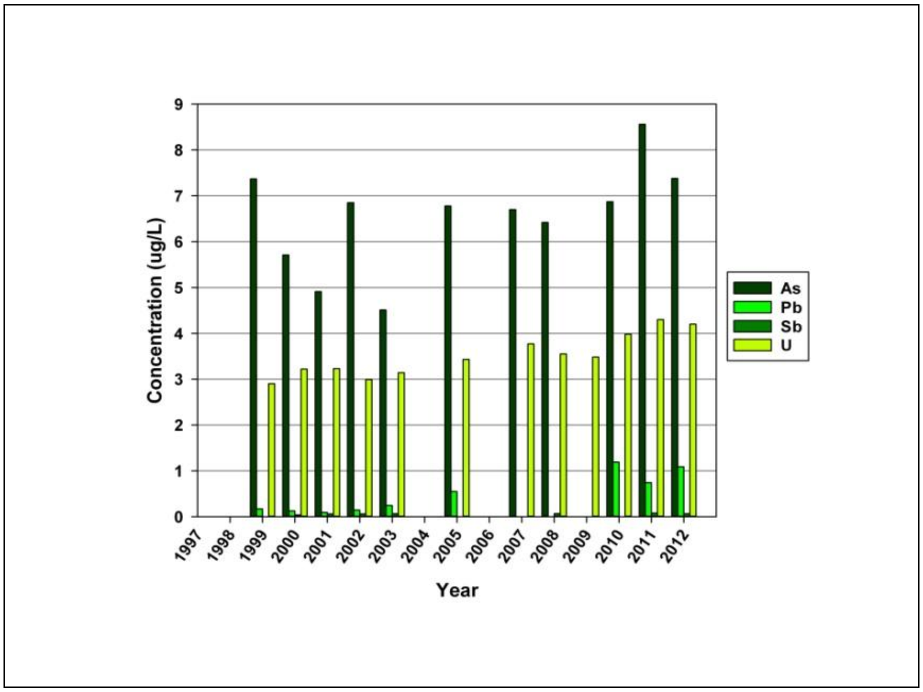
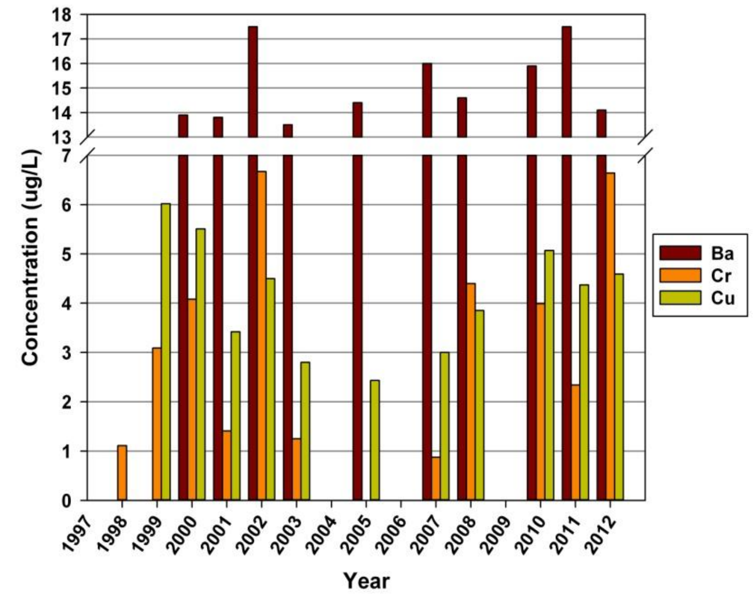


Figure 2.15 Concentrations (µg/L) of Select Inorganic Analytes Measured in Hobbs Drinking Water from 1998 - 2012



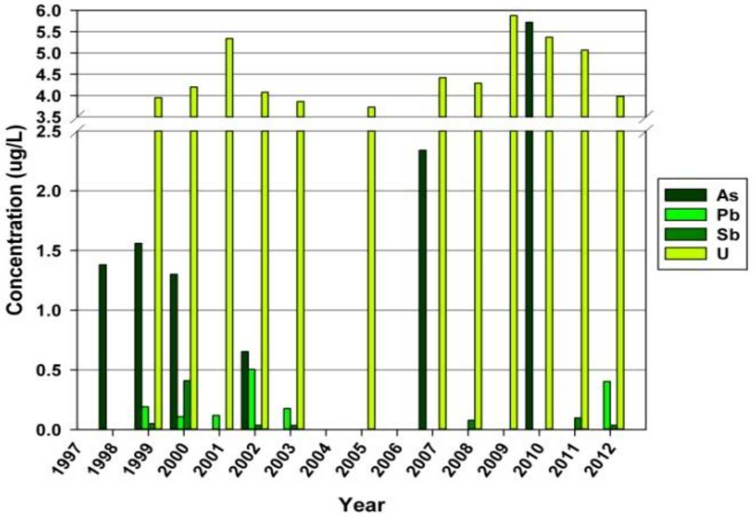


Figure 2.16 Concentrations (µg/L) of Select Inorganic Analytes Measured in Otis Drinking Water from 1998 - 2012

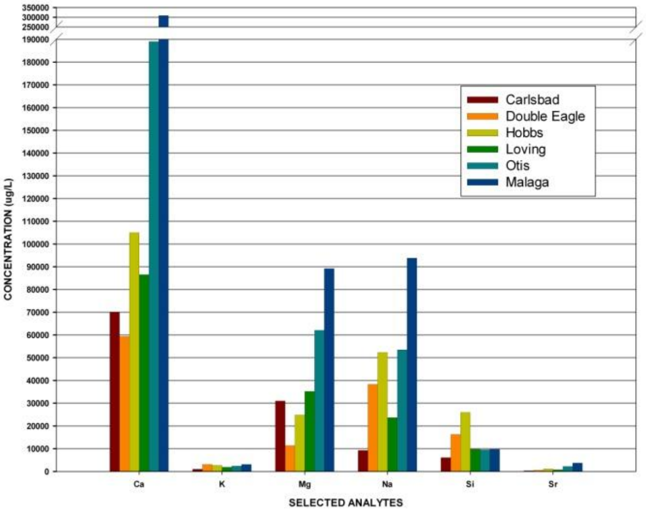


Figure 2.17 Select Analytes with Measured Concentrations >MDC in 2012 Drinking Water

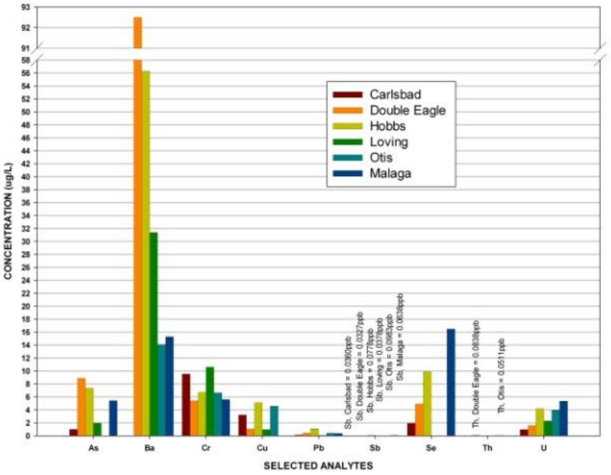


Figure 2.18 Concentrations of Common Salts in 2012 Drinking Water

CHAPTER 3

Whole Body and Lung *In Vivo* Measurement of Occurrence of Radionuclides in Residents of the Carlsbad, New Mexico Area and Other Possible Uses

INTRODUCTION

To better understand how low-level nuclear waste disposed at the WIPP site may impact the residents living near the repository, citizen volunteers from the area are monitored for the presence of internally deposited radionuclides through a project entitled "Lie Down and Be Counted" (LDBC). This project is provided free of charge to residents living within a 100-mile radius of the WIPP site as an outreach service to the public and to support education about naturally occurring and man-made radioactivity present in people, especially those who live in the vicinity of the Waste Isolation Pilot Plant (WIPP). The data collected prior to the opening of the WIPP facility (March 26, 1999) serve as a baseline for comparisons with periodic follow-up measurements that are slated to continue throughout the approximate 35-year operational phase of the WIPP project. It is important to note that the data presented in this report represent an interim summary (through December 31, 2012) of an ongoing study.

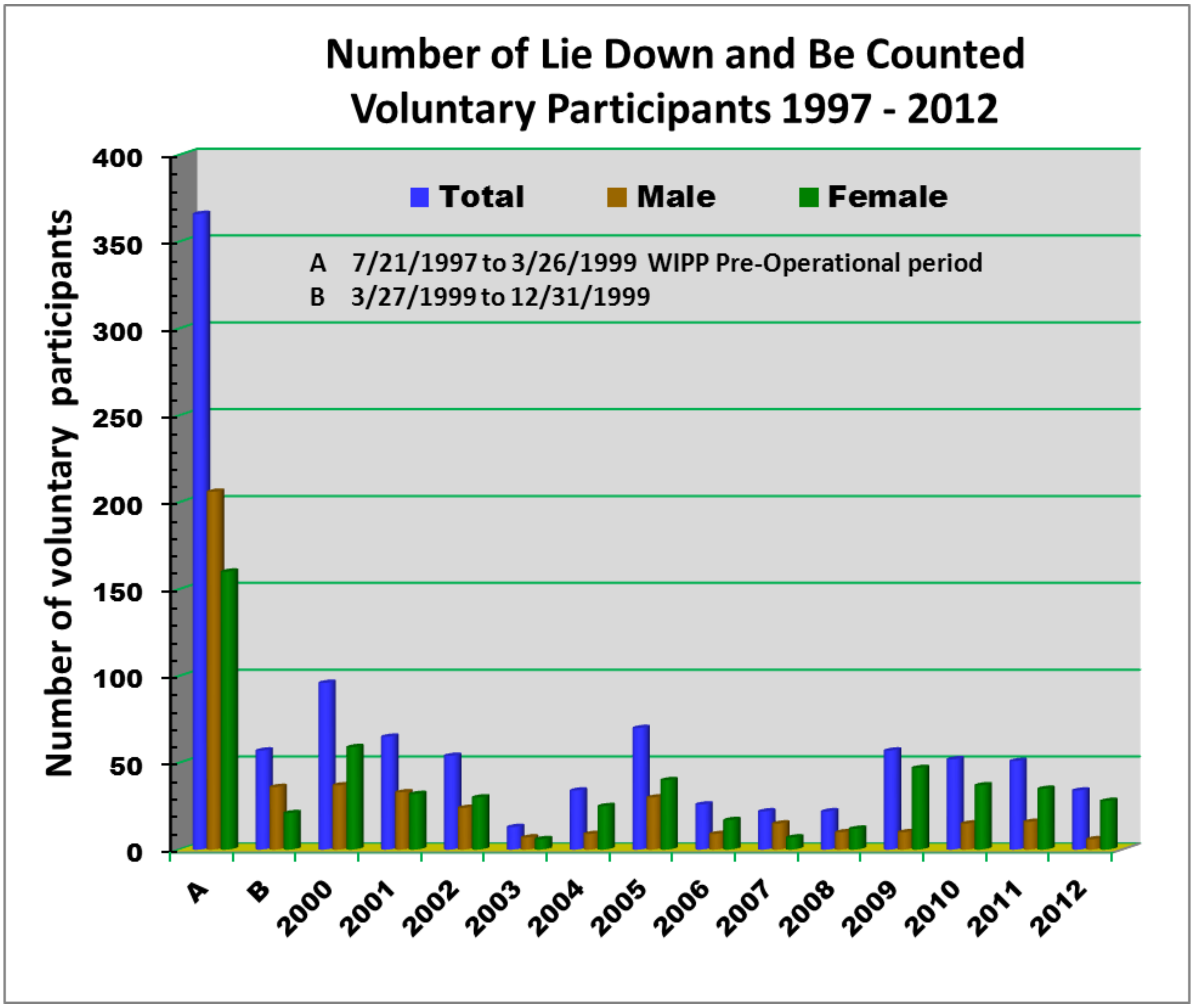
Participating in the LDBC consists of having a lung and whole body count, also referred to as internal dosimetry. The internal dosimetry activity is an *In Vivo* concept, a Latin term that means “within the living” and refers to an experimental concept that uses live organisms as opposed to dead or partial organisms. To solicit volunteers for the LDBC activity, CEMRC staff conduct presentations to local community groups and businesses and solicit volunteers via community events such as the Carlsbad Chamber of Commerce’s Shop Carlsbad Business Fair. The entire measurement process takes approximately one hour and culminates with the volunteer receiving a detailed report showing the results from the whole body count. A detailed description of the measurement protocol, analysis and instrument detection limits is provided in the CEMRC 1998 Report. In addition, the status of the project and results along with more detailed information are available on the CEMRC website (http://www.cemrc.org).

The Department of Energy Laboratory Accreditation Program (DOELAP) maintains the competency of dosimetry measurement laboratories by conducting performance evaluation test measurements, calibration inter-comparisons programs, and site assessments to ensure that the performance of dosimetry and radiobioassay measurements are adequate and meet the standards of Title 10, Code of Federal Regulations, Part 835, “Occupational Radiation Protection,” and related requirements and guidance. In conjunction with the WIPP site and its management and operations contractor, the CEMRC Internal Dosimetry lung and whole body counting laboratory has been DOELAP accredited since 1999.

IN VIVO BIOASSAY RESULTS

As of December 31, 2012, 1019 individuals had participated in the LDBC project. At the time the WIPP opened, 366[1] individuals had been measured using the *in vivo* protocol. 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. Figure 3.1 shows the yearly number of male, female and total number of voluntary participants counted thus far in the program period (7/21/1997 to 12/31/2012).

In addition to the LDBC program, CEMRC conducts *In* Vivo internal dosimetry counting services for radiation control workers in the area and has performed about 3661 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 radiation trained workers in the region. Current contracts for internal dosimetry services include WIPP, Waste Control Specialists (WCS) of Andrews, TX; the Nuclear Enrichment Facility (NEF) of Eunice, NM; and Los Alamos National Laboratory (LANL), Carlsbad, NM; as well as CEMRC radiation workers.



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[1] This number was previously reported at 367 but that number included one test that was not part of the subject population.

Figure 3.1 Number of LDBC voluntary participants (total and by gender) counted during the period 1997 – 2012.

Demographic characteristics (Table 3.1) of the current LDBC cohort are statistically[2] unchanged from those reported in previous CEMRC reports and are generally consistent with those reported in the 2010 census for citizens living in Carlsbad. The largest deviation between the LDBC cohort and 2010 census is under-sampling of Latinos. 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.

For the purposes of the LDBC program, baseline monitoring is held constant and includes only the initial count of individuals made prior to March 26, 1999. Seven people were recounted during the baseline interval but these data are not reported in order to remain consistent with previous reports. Likewise, operational monitoring includes the counting of new volunteers and the recounting of previously measured participants that have occurred since the repository began accepting waste on March 27, 1999. ***Based on the data reported herein, there is no evidence of any increase in the frequency of detection of internally deposited radionuclides for citizens living within the vicinity of the WIPP since the WIPP began receiving radioactive waste***.

As discussed in detail in the CEMRC 1998 Report and elsewhere (Webb and Kirchner, 2000), the criterion, L_C, was used to evaluate whether a result exceeded background as the use of this criterion will result in a statistically inherent 5% false-positive error rate per pair-wise comparison (i.e. 5% of all measurements will be determined to be positive when there is no activity present in the person). The radionuclides being investigated by the CEMRC Internal Dosimetry group and their minimum detectable activities are listed in Table 3.2 for the 2010-2013 timeframe which coincides with the current DOELAP accreditation period.

For the baseline measurements (see Table 3.3, 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 (see Table 3.2). 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 monitoring counts (see Table 3.3, N = 951), 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

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[2] The statistics reported for the bioassay program assume that the individuals participating are a random sample of the population. Given that the bioassay program relies on voluntary participation, randomness of the sample cannot be assured and, as is discussed later, sampling appears to be biased by ethnicity.

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 and are likely due to the replacement of aluminum (tends to contain Th and U) in some of the detector cryostat components with those manufactured from low radiation background steel.

^{40}K results were positive for all participants through December 2012 and ranged from 925 to 5559 Bq per person with an overall average (± Std. Err.) of 2467 (± 23) Bq per person. 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 (± Std. Err.), was 3062 (± 19) Bq per person for males, which was significantly greater ($p < 0.0001$) than that of females, which was 1898 (± 12) Bq per person. This result was expected since; in general, males tend to have larger body sizes and greater muscle content than females.

Detectable ^{137}Cs is present in 21.4 % (20.3% to 22.5% with 95% confidence level for baseline and operational monitoring counts through December 2012) of citizens living in the Carlsbad area. These results are in the same range with findings previously reported in CEMRC reports and elsewhere (Webb and Kirchner, 2000). Detectable ^{137}Cs body burdens ranged from 4.9 to 77.5 Bq per person with an overall average (± Std. Err.) of 10.2 (± 0.4) Bq per person. The average ^{137}Cs body burden (± Std. Err.), was 11.0 (± 0.7) Bq for males per person, which was greater ($p = 0.002$) than that of females, which was 8.7 (± 0.3) Bq per person. Reports such as previous CEMRC Reports and Webb & Kirchner (2000), provide 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. A follow-up analysis of over 15 years of accumulated data is currently under progress and will be reported in a future CEMRC annual report.

K-40 and Cs-137 results of LDBC voluntary participants through December 2012 are shown in Figures 3.2 through 3.5.

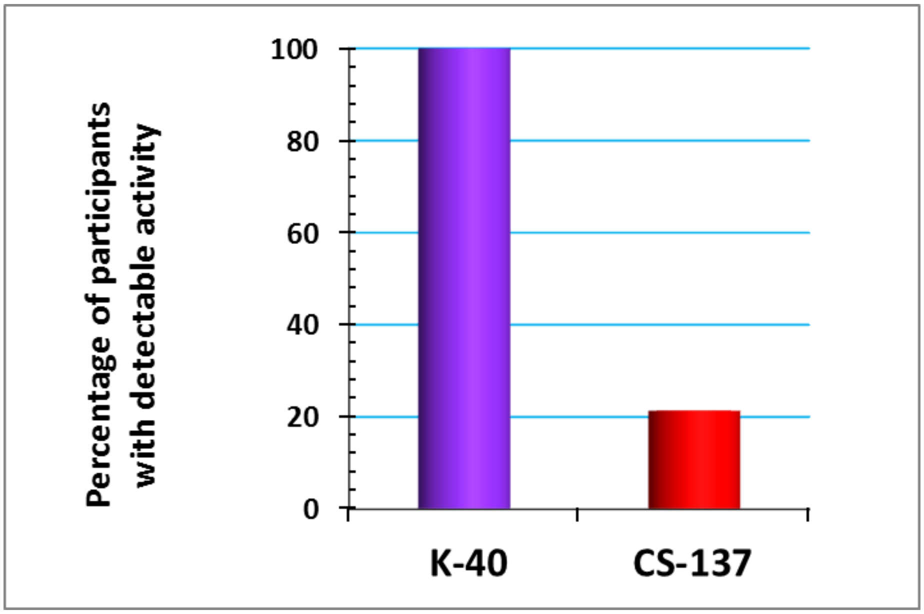


Figure 3.2 Percentage of voluntary participants with detectable ^{40}K and ^{137}Cs activities through December 2012

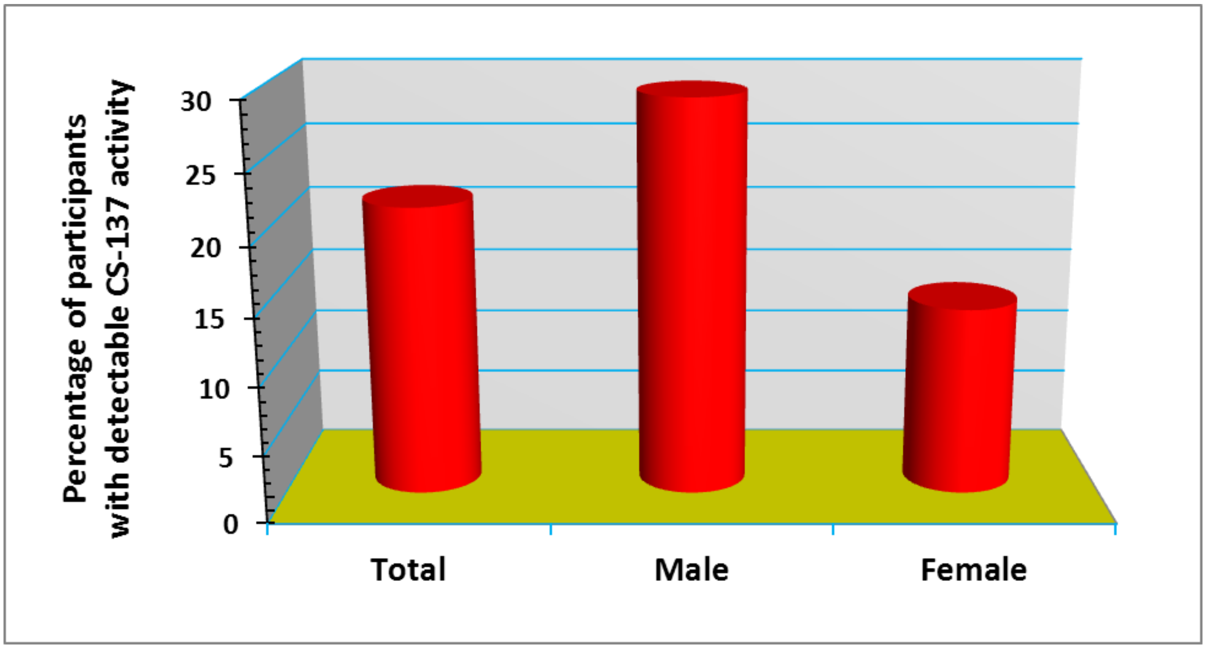


Figure 3.3 Percentage of voluntary participants with detectable ^{137}Cs activity through December 2012 (This figure displays the total percentage of participants with ^{137}Cs activity and the percentage of participants with ^{137}Cs activity by gender).

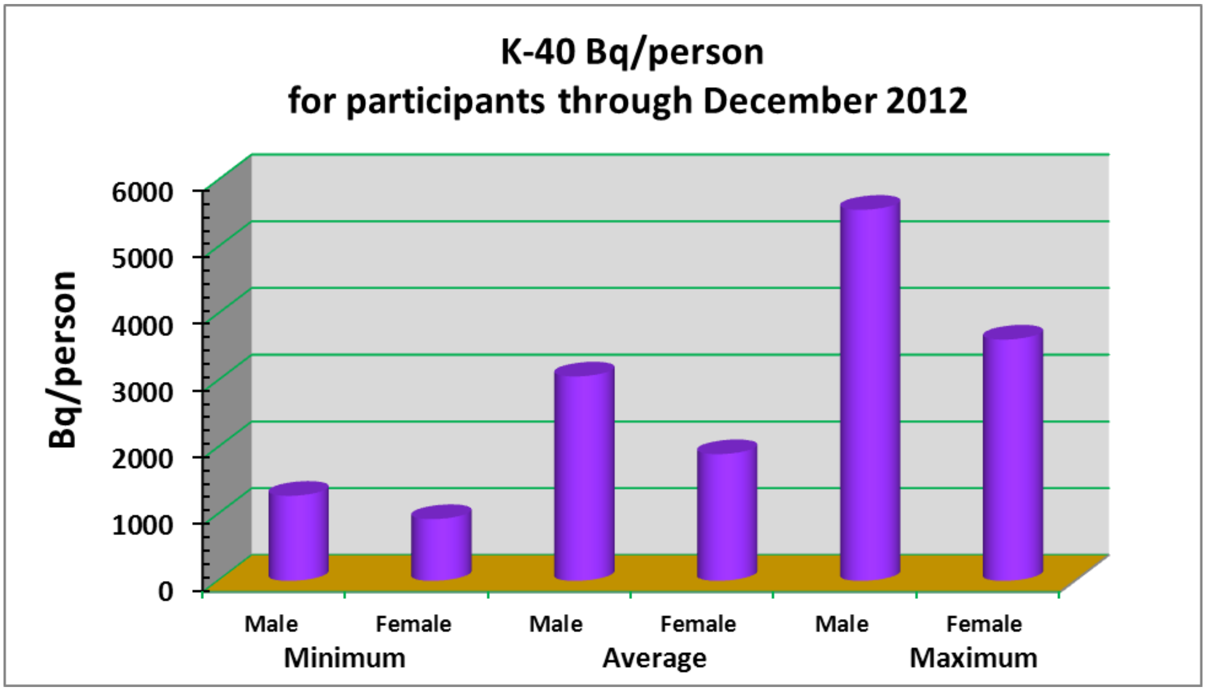


Figure 3.4 Minimum, average, and maximum ^{40}K activity for participants, separated by gender, through December 2012

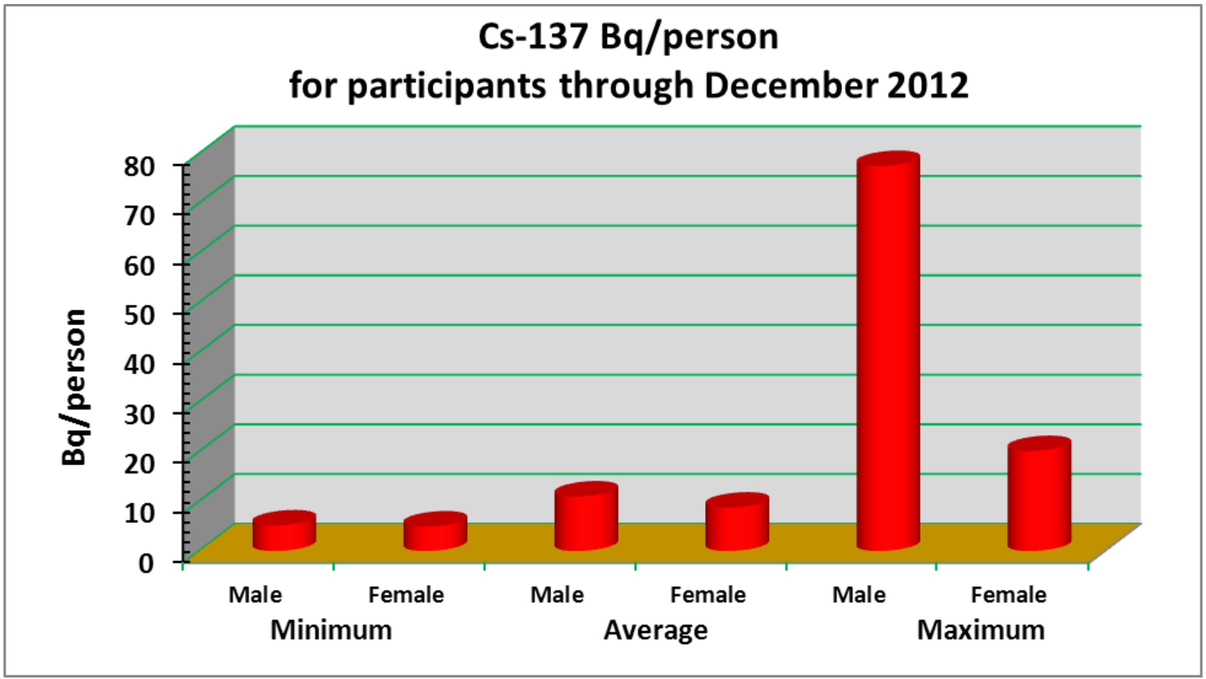


Figure 3.5 Minimum, average, and maximum ^{137}Cs activity for participants, separated by gender, through December 2012

As reported in previous CEMRC reports, the percentage of results greater than L_C for ^{235}U/^{226}Ra (11 %) are 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. This finding shows the necessity of further research and procedural development needed to further enhance the detection capability of the CEMRC Internal Dosimetry group.

Lastly, these results, particularly with no significant variation in the percentage of public participants with detectable levels of plutonium, suggest that there have been no observable health-related effects from WIPP on the citizens living within a 100-mile radius of the WIPP repository.

Table 3.1 Demographic Characteristics of the "Lie Down and Be Counted" Population Sample through December 31, 2012

Characteristic		2012 Sample Group[a] (margin of error)	Census 2010[b]		Census 2012[e,f] Estimates	
			NM	US	NM	US
Gender	Male	45.4% (43.9 to 47.0%)	49.4%	49.1%	49.5%	49.1%
	Female	54.6% (53.0 to 56.1%)	50.6 %	50.9%	50.5%	50.9%
Ethnicity	Latino	19.8% (18.6 to 21.0%)	46.3 %	16.3 %	47.0%	16.9%
	Non-Latino	80.2% (79.0 to 81.4%)	53.7 %	83.7%	53.0%	83.1%
Age 65 years or over		27.5% (26.1 to 28.8%)	13.2 %[g]	13.0%	14.1%	13.7%
Currently or previously classified as a radiation worker		7.5% (6.7 to 8.3%)	NA	NA	NA	23.0%[d]
Consumption of wild game within 3 months prior to count		20.6% (19.4 to 21.9%)	NA	NA	NA	NA
Medical treatment other than X-rays using radionuclides		7.2% (6.4 to 8.0%)	NA	NA	NA	NA
European travel within 2 years prior to the count		4.0% (3.4 to 4.6%)	NA	NA	NA	NA
Current smoker		16.2% (15.1 to 17.3%)	N/A	NA	18.9%[h]	19.3%[h]

[a] 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.

[b] http://2010.census.gov/2010census/popmap/ipmtext.php?fl=35 US Census 2010, New Mexico State.

[c] http://www.census.gov/prod/cen2010/briefs/c2010br-03.pdf US Census 2010, US.

[d] http://www.bls.gov/00h/a-zindex.htm#R US Bureau of Labor Statistics, 2013, US.

[e] http://www.census.gov/popest/data/national/totals/2012/index.html

[f] http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?src=bkmk

[g] In CEMRC 2011 Report this number was reported as 19.6 which was for the age group 50-64.

[h] http://www.cdc.gov/vitalsigns/Adultsmoking/index.html#StateInfo US Center for Disease Control, 2013, US

Table 3.2 Minimum Detectable Activities

2010-2011 Calibration

Radionuclides Deposited in the Lungs

Radionuclide	Energy (keV)	CWT = 1.6 MDA (nCi)	CWT = 2.22 MDA (nCi)	CWT = 3.01 MDA (nCi)	CWT = 3.33 MDA (nCi)	CWT = 4.18 MDA (nCi)	CWT = 5.10 MDA (nCi)	CWT = 6.0 MDA (nCi)
Am-241	59.50	0.18	0.23	0.31	0.35	0.48	0.67	0.93
Ce-144	133.50	0.47	0.57	0.72	0.79	1.01	1.33	1.74
Cf-252	19.20	17.98	35.53	84.73	120.80	307.52	847.33	2286.97
Cm-244	18.10	16.81	35.78	93.35	137.65	387.66	1185.62	3546.51
Eu-155	105.30	0.28	0.34	0.44	0.48	0.64	0.86	1.16
Np-237	86.50	0.49	0.61	0.80	0.90	1.20	1.66	2.26
Pu-238	17.10	18.46	42.54	123.50	189.02	594.43	2045.16	6876.17
Pu-239	17.10	45.94	105.85	307.28	470.28	1478.98	5088.44	17108.17
Pu-240	17.10	18.05	41.59	120.72	184.75	581.03	1999.03	6721.07
Pu-242	17.10	21.77	50.17	145.63	222.88	700.92	2411.53	8107.95
Ra-226	186.10	1.65	1.94	2.37	2.57	3.21	4.07	5.14
Th-232 via Pb-212	238.60	0.15	0.17	0.21	0.23	0.29	0.38	0.48
Th-232	59.00	34.41	43.09	57.62	64.83	88.56	124.16	172.65
Th-232 via Th-228	84.30	4.88	6.09	7.98	8.92	11.99	16.48	22.54
U-233	440.30	0.65	0.75	0.91	0.98	1.21	1.51	1.88
U-235	185.70	0.10	0.12	0.15	0.16	0.20	0.25	0.32
Nat U via Th-234	63.30	1.64	2.04	2.72	3.06	4.17	5.82	8.08

Radionuclides Deposited in the Whole Body

Radionuclide	Energy (keV)	MDA (nCi)
Ba-133	356	0.79
Ba-140	537	1.53
Ce-141	145	1.70
Co-58	811	0.37
Co-60	1333	0.36
Cr-51	320	4.56
Cs-134	604	0.36
Cs-137	662	0.42
Eu-152	344	1.63
Eu-154	1275	0.95
Eu-155	105	3.92
Fe-59	1099	0.67
I-131	365	0.48
I-133	530	0.43
Ir-192	317	0.56
Mn-54	835	0.45
Ru-103	497	0.40
Ru-106	622	3.34
Sb-125	428	1.37
Th-232 via Ac-228	911	1.25
Y-88	898	0.38
Zn-65	1116	1.12
Zr-95	757	0.59

Table 3.2 Minimum Detectable Activities (continued)

2011-2012 Calibration

Radionuclides Deposited in the Lungs

Radionuclide	Energy (keV)	CWT = 1.6 MDA (nCi)	CWT = 2.22 MDA (nCi)	CWT = 3.01 MDA (nCi)	CWT = 3.33 MDA (nCi)	CWT = 4.18 MDA (nCi)	CWT = 5.10 MDA (nCi)	CWT = 6.0 MDA (nCi)
Am-241	59.50	0.17	0.22	0.30	0.34	0.46	0.64	0.89
Ce-144	133.50	0.49	0.57	0.72	0.79	1.02	1.34	1.76
Cf-252	19.20	19.09	34.70	84.51	121.18	315.90	891.15	2454.73
Cm-244	18.10	17.16	35.01	93.70	139.72	402.23	1264.15	3875.50
Eu-155	105.30	0.26	0.33	0.43	0.48	0.63	0.85	1.15
Np-237	86.50	0.45	0.59	0.78	0.87	1.16	1.60	2.19
Pu-238	17.10	17.52	41.27	121.80	190.25	611.99	2179.54	7529.31
Pu-239	17.10	43.60	102.69	303.04	473.35	1522.65	5422.77	18733.21
Pu-240	17.10	17.13	40.34	119.05	185.96	598.18	2130.37	7359.48
Pu-242	17.10	20.66	48.67	143.62	224.33	721.62	2569.98	8878.10
Ra-226	186.10	1.81	1.94	2.40	2.61	3.26	4.16	5.28
Th-232 via Pb-212	238.60	0.15	0.17	0.21	0.23	0.29	0.37	0.48
Th-232	59.00	31.88	41.97	55.90	62.88	85.81	120.21	166.78
Th-232 via Th-228	84.30	4.43	5.87	7.67	8.61	11.57	15.92	21.77
U-233	440.30	0.65	0.76	0.92	0.99	1.23	1.53	1.91
U-235	185.70	0.11	0.12	0.15	0.16	0.20	0.26	0.33
Nat U via Th-234	63.30	1.49	1.99	2.65	2.97	4.04	5.64	7.80

Radionuclides Deposited in the Whole Body

Radionuclide	Energy (keV)	MDA (nCi)
Ba-133	356	0.80
Ba-140	537	1.55
Ce-141	145	1.70
Co-58	811	0.37
Co-60	1333	0.36
Cr-51	320	4.61
Cs-134	604	0.36
Cs-137	662	0.43
Eu-152	344	1.66
Eu-154	1275	0.97
Eu-155	105	3.84
Fe-59	1099	0.68
I-131	365	0.49
I-133	530	0.43
Ir-192	317	0.56
Mn-54	835	0.46
Ru-103	497	0.41
Ru-106	622	3.36
Sb-125	428	1.38
Th-232 via Ac-228	911	1.29
Y-88	898	0.38
Zn-65	1116	1.13
Zr-95	757	0.60

Table 3.2 Minimum Detectable Activities (continued)

2012-2013 Calibration

(Using 4 Lung detectors and 3 Whole Body detectors data from 12/1/2011 to 11/22/2012)

Radionuclide	Energy (keV)	CWT = 1.6 MDA (nCi)	CWT = 2.22 MDA (nCi)	CWT = 3.01 MDA (nCi)	CWT = 3.33 MDA (nCi)	CWT = 4.18 MDA (nCi)	CWT = 5.10 MDA (nCi)	CWT = 6.0 MDA (nCi)
Am-241	59.50	0.16	0.20	0.26	0.29	0.40	0.57	0.79
Ce-144	133.50	0.39	0.48	0.60	0.66	0.86	1.13	1.48
Cf-252	19.20	14.65	29.52	71.94	103.26	268.22	754.87	2082.40
Cm-244	18.10	12.32	26.56	71.03	105.33	303.18	947.13	2902.13
Eu-155	105.30	0.22	0.27	0.35	0.39	0.51	0.69	0.93
Np-237	86.50	0.37	0.46	0.61	0.68	0.91	1.25	1.71
Pu-238	17.10	15.48	36.16	106.71	165.93	530.97	1876.69	6440.71
Pu-239	17.10	38.52	89.97	265.51	412.83	1321.06	4669.28	16024.74
Pu-240	17.10	15.13	35.35	104.31	162.18	518.99	1834.36	6295.44
Pu-242	17.10	18.26	42.64	125.83	195.65	626.08	2212.88	7594.49
Ra-226	186.10	1.30	1.53	1.89	2.06	2.58	3.29	4.18
Th-232 via Pb-212	238.60	0.11	0.13	0.16	0.17	0.22	0.28	0.36
Th-232	59.00	24.03	30.13	40.40	45.50	62.31	87.74	122.54
Th-232 via Th-228	84.30	3.54	4.40	5.79	6.47	8.69	11.98	16.38
U-233	440.30	0.54	0.63	0.77	0.83	1.03	1.29	1.62
U-235	185.70	0.08	0.09	0.12	0.13	0.16	0.20	0.26
Nat U via Th-234	63.30	1.24	1.56	2.08	2.34	3.19	4.47	6.22

Radionuclides Deposited in the Whole Body

Nuclide	Energy (keV)	MDA (nCi)
Ba-133	356	0.74
Ba-140	537	1.56
Ce-141	145	1.23
Co-58	811	0.39
Co-60	1333	0.39
Cr-51	320	3.74
Cs-134	604	0.33
Cs-137	662	0.49
Eu-152	344	1.42
Eu-154	1275	1.05
Eu-155	105	2.63
Fe-59	1099	0.68
I-131	365	0.43
I-133	530	0.46
Ir-192	317	0.42
Mn-54	835	0.50
Ru-103	497	0.40
Ru-106	622	3.36
Sb-125	428	1.26
Th-232 via Ac-228	911	1.37
Y-88	898	0.39
Zn-65	1116	1.31
Zr-95	757	0.61

Table 3.3 "Lie Down and Be Counted" Results through December 31, 2012

Radionuclide	*In Vivo* Count Type	Baseline Counts [c](margin of error) (data prior to 27 March 1999) [a]N = 366	Operational Monitoring Counts[e] (margin of error) (27 March 1999 – 31 December 2012) N = 951
		% of Results ≥ [b]L_C	% of Results ≥ L_C
^{241}Am	Lung	5.2 (4.0 to 6.4)	4.31 (3.7 to 5)
^{144}Ce	Lung	4.6 (3.5 to 5.7)	4.10 (3.5 to 4.7)
^{252}Cf	Lung	4.1 (3.1 to 5.1)	5.99 (5.2 to 6.7)
^{244}Cm	Lung	5.7 (4.5 to 7.0)	4.73 (4.1 to 5.4)
^{155}Eu	Lung	7.1 (5.8 to 8.4)	4.94 (4.3 to 5.6)
^{237}Np	Lung	3.6 (2.6 to 4.5)	3.68 (3.1 to 4.3)
^{210}Pb	Lung	4.4 (3.3 to 5.4)	6.22 (5.5 to 7)
Plutonium Isotope	Lung	5.7 (4.5 to 7.0)	5.47 (4.7 to 6.2)
[d] ^{232}Th via ^{212}Pb	Lung	34.2 (31.7 to 36.6)	31.96 (30.5 to 33.4)
^{232}Th	Lung	4.9 (3.8 to 6.0)	5.27 (4.6 to 6)
^{232}Th via ^{228}Th	Lung	4.1 (3.1 to 5.1)	4.96(4.3 to 5.6)
^{233}U	Lung	5.7 (4.5 to 7.0)	9.15 (8.2 to 10.1)
^{235}U/^{226}Ra	Lung	10.7 (9.0 to 12.3)	11.57 (10.6 to 12.6)
Natural Uranium via ^{234}Th	Lung	5.2 (4.0 to 6.4)	5.99(5.2 to 6.7)
^{133}Ba	Whole Body	3.6 (2.6 to 4.5)	2.84 (2.3 to 3.4)
^{140}Ba	Whole Body	5.2 (4.0 to 6.4)	3.89 (3.3 to 4.5)
^{141}Ce	Whole Body	3.6 (2.6 to 4.5)	4.84 (4.2 to 5.5)
^{58}Co	Whole Body	4.4 (3.3 to 5.4)	2.84 (2.3 to 3.4)
[d] ^{60}Co	Whole Body	54.6 (52.0 to 57.2)	25.24 (23.9 to 26.6)
^{51}Cr	Whole Body	5.7 (4.5 to 7.0)	4.21 (3.6 to 4.8)
^{134}Cs	Whole Body	1.6 (1.0 to 2.3)	2.63 (2.1 to 3.1)
^{137}Cs	Whole Body	28.4 (26.1 to 30.8)	18.72 (17.5 to 20)
^{152}Eu	Whole Body	7.4 (6.0 to 8.7)	6.41 (5.6 to 7.2)
^{154}Eu	Whole Body	3.8 (2.8 to 4.8)	3.47 (2.9 to 4.1)
^{155}Eu	Whole Body	3.8 (2.8 to 4.8)	3.59 (3 to 4.2)
^{59}Fe	Whole Body	3.8 (2.8 to 4.8)	5.99(5.2 to 6.7)
^{131}I	Whole Body	5.2 (4.0 to 6.4)	4.21 (3.6 to 4.8)
^{133}I	Whole Body	3.3 (2.3 to 4.2)	4.10 (3.5 to 4.7)
^{192}Ir	Whole Body	4.1 (3.1 to 5.1)	4.22 (3.6 to 4.9)
^{40}K	Whole Body	100.0 (100.0 to 100.0)	100 (100 to 100)
[d] ^{54}Mn	Whole Body	12.3 (10.6 to 14.0)	12.20 (11.2 to 13.2)
^{103}Ru	Whole Body	2.2 (1.4 to 3.0)	1.79 (1.4 to 2.2)
^{106}Ru	Whole Body	4.4 (3.3 to 5.4)	4.42 (3.8 to 5.1)
^{125}Sb	Whole Body	5.2 (4.0 to 6.4)	4.31 (3.7 to 5)
^{232}Th via ^{228}Ac	Whole Body	34.7 (32.2 to 37.2)	25.53(24.1 to 26.9)
^{88}Y	Whole Body	7.7 (6.3 to 9.0)	6.12 (5.4 to 6.9)
^{95}Zr	Whole Body	6.6 (5.3 to 7.9)	4.10 (3.5 to 4.7)

[a] N = number of individuals. Baseline counts include only the initial counts during this baseline period.

[b] 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 that results 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.

[c] 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.

[d] These radionuclides are present in the shield background, so they are expected to be detected periodically. [e] Operational monitoring counts include the counting of new individuals and the recounting of previously measured participants.

Further considerations for the measurement of pCi level radioactivity using a Ge detector in a deep underground science laboratory:

Because of its capabilities to detect minute levels of radiation, *In Vivo* internal dosimetry counting is very sensitive to background radiation. Thus, the detection sensitivity of a surface *In Vivo* counting facility, built with existing low background counting concepts and techniques, can be further improved by developing an *In Vivo* low background facility underground whereby the earth acts as an added shield in terms of reducing the amount of background radiation.

One of the most contemplated subjects in life sciences research involves low dose radiation effects on the living, especially doses delivered at low rates characteristic of most human exposures to environmental levels of radioactivity. Naturally occurring radioactive sources internal to the human body provide the closest exposure to high linear energy transfer (LET) radiation from alpha-radionuclides. The most important short-lived radioactive sources of interest appear to be those derived from radon and its immediate decay products such as ^{210}Pb which is a part of the chain of radon decay products. One of the latest research interests in cranium internal dosimetry involves the study of ^{210}Pb activity by *In Vivo* gamma-ray spectrometry, especially considering its relation to Alzheimer's disease (AD), Parkinson's disease (PD) and multiple sclerosis (MS).

The United Nations Scientific Committee on the Effects of Atomic Radiation, (UNSCEAR) 1982 Report [1] concludes that 70 % of the body content of ^{210}Pb resides in the skeleton and estimates the typical ^{210}Pb concentration in the skeleton to be 3 Bq/kg (80 pCi/kg). However, the ^{210}Pb concentrations measured by researchers such as Holtzman (1963) in samples of bone ash ranged from 37 to 454 pCi/kg with an average observed value of 146 pCi/kg. As a result of this study, the concentration in bone ash was approximately twice that observed in the skeleton (wet weight). In addition, researchers Jagam (2007) and Lykken et. al, (2001) have estimated the ^{210}Pb activity for a 1.5 L human cranium with a 75-year lifetime exposure to an ambient radon concentration of 150 Bq m^{-3} to be about 0.04 Bq (1 pCi/kg) from the solubility of radon in body fluids alone. On this basis, minimum detectable activity (MDA) of 0.004 Bq (0.1 pCi/kg) of ^{210}Pb becomes the required design specification needed for in-vivo counting of the cranium in an underground low background counting facility[4].

Moreover, proof-of-concept experiments with the above specification for the MDA for *In Vivo* ^{210}Pb counting in a human cranium in a low background counting system have been set-up by Jagam and Lykken in the underground facility at the WIPP facility in Carlsbad, New Mexico (NM). The proof-of-concept experiment was approved by the Institutional Review Board (IRB) of the Research Development and Compliance Division of Research at the University of North Dakota (UND) located in Grand Forks, ND. Additional safety approvals were granted by WIPP safety and operations personnel. Data from these proof-of-concept experiments also contributed to the ongoing NMSU Low Background Radiation Experiment (LBRE) efforts by extending the understanding of the radiation field inside and outside the steel chamber underground at WIPP from the perspective of dosimetry. Lastly, preliminary considerations for instrumentation needs were studied and communicated to the peer reviewed journal *Radiation Protection Dosimetry* by Pillalamarri et al, 2012. As a result, one of the CEMRC Internal Dosimetry department's long-term goals is to develop a deep underground, ultra-low background cranium counter as a tool to investigate the causes for the early onset of brain diseases.

This cutting edge experimental development will contribute significantly to the latest world-wide research interests in cranium internal dosimetry and will benefit relevant health fields in the understanding and possible early detection of debilitating brain diseases such as AD, PD and MS. In addition, the development of this low-background counting technology will further build upon the synergy established by the UND's epigenetic research in its formative stage of COBRE as well as the Wielopolski et al, 2004 research interests in cranium dosimetry for MS investigations.

CHAPTER 4

Analysis of Volatile Organic Compounds, Hydrogen and Methane

Introduction

The WIPP Hazardous Waste Treatment Facility (HWTF) permit, 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 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, nine (9) target VOCs are actively monitored as they represent 99% risk to safety due to air emissions while any other compounds consistently detected in air samples may be added to the list of compounds of interest. In addition to VOC monitoring, the HWTF permit, Attachment N1, describes the monitoring plan for hydrogen and methane generated from underground panels as well.

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 ambient air samples in six liter passivated canisters and deliver to CEMRC for analysis 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 annually. 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). CEMRC purchased an Entech 7100 Preconcentrator for use as the sample concentration and introduction system, and an Entech 3100 Canister Cleaning System for cleaning and evacuation of canisters after analysis.

VOC Project Expansion

The original VOC laboratory was set up in room 149 in the science laboratory wing at CEMRC and only included the equipment necessary for Confirmatory VOCs analysis. In late 2003, the Department of Energy (DOE) requested that CEMRC expand its capabilities to prepare for the analysis of headspace gas (HSG) samples collected from waste drums as required under the WIPP Permit, Attachment B. In preparation for this expansion of scope, CEMRC purchased an HSG analysis system consisting of a 6890/5973N Agilent GC/MS with a loop injection system and three (3) Entech 7032 auto-samplers installed in series. Also included in this purchase was an Entech 3100A oven-based canister cleaning system, an Entech 4600 Dynamic Diluter for automatic preparation of VOCs calibration standards, and fifty 400 mL Silonite-coated mini-canisters with Nupro valves and attached pressure gauges.

After a few months of VOCs Confirmatory Analyses, it became critical to expand the laboratory to accommodate the addition of a backup analysis system. This shortcoming was noted by auditors for the next two years. CEMRC did purchase a backup Preconcentrator to minimize system downtime; however, there was no available space in which to set up the backup GC/MS instrument.

With the addition of headspace gas analysis, it was decided in July 2005 to move the VOCs Confirmatory Analysis and Headspace Gas Analysis programs from the EC group into the newly created Organic Chemistry (OC) Group. The reason for the shift was because the primary management focus for the EC group was research oriented, whereas the functions of the OC group were regulatory in nature and required different QA/QC measures and documentation.

Analyses were originally conducted by manually changing the sample attached to the preconcentrator for each sample. However, due to the need to maximize efficiency, an Entech 7016 canister autosampler was obtained in June 2005. This autosampler device allows for up to sixteen samples to be run in sequence with minimal operator supervision.

In addition, funding was obtained in mid-2005 through a DOE baseline change request to remodel the old CEMRC garage into a functional GC/MS Laboratory. The design for the remodel was completed in late 2005, and construction began in January 2006. Construction was completed in April 2006 and the OC Group moved into the new laboratory.

Around this time, a backup Agilent 6890/5973 GC/MS system was transferred to CEMRC by the Central Characterization Project (CCP) for use in headspace gas analysis and a backup autosampler for HSG analysis was also purchased by CEMRC. Shortly thereafter a new Agilent 6890/5975 GC/MS was obtained to be used as a backup analysis system for the Confirmatory VOCs Monitoring.

The VOC Monitoring expanded from 353 samples in 2005 to 430 samples in 2006. Analysis of closed room samples for VOCs, hydrogen, and methane began in 2007 as well and continues to the present. In 2007, 2008, 2009, 2010, and 2011, CEMRC analyzed a total of 749, 608, 571, 711, and 615 samples for VOCs and 182, 254, 339, 441, and 398 samples, respectively, for hydrogen and methane. In 2012, CEMRC analyzed a total of 559 samples for VOCs and 376 samples for hydrogen and methane. Figure 4.1 shows the total VOC and H/M samples processed by the OC lab since its inception.

Although CEMRC performed well on the DOE audit for the headspace gas analysis project, a decision was made not to submit these samples for analysis at CEMRC. However, some equipment obtained for this project remained at CEMRC and is currently being used for analysis of closed room samples for VOCs and percent levels of hydrogen and methane.

METHODS FOR VOLATILE ORGANIC COMPOUND MONITORING

Confirmatory VOCs Monitoring requires method detection limits at low parts per billion volume (ppbv) range. This type of analysis requires preconcentration of a given volume of ambient air into a much smaller volume prior to introduction into the GC column. In order to maintain 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 then are diluted to working concentrations with Ultra-High Purity (UHP) Nitrogen using the Entech 4600 Dynamic Diluter. Additionally, 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. Lastly, 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 are 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 are 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 4.1 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 now 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 4.2 summarizes the nine permit specified target compounds and their required reporting limits for different types of samples. In early 2011, 9 other compounds were requested to be included in the list of target analytes as "Additional Requested Analytes". 'm-Xylene' & 'p-Xylene' co-elute together as a single compound so they are reported as 'p,m-Xylene'. In September 2012, 7 out of the 9 additional requested compounds were removed from analysis on request; with Trichloroethylene and 1,2,4-Trimethylbenzene being the only remaining additionally requested analytes. Table 4.3 lists the additional analytes, over time, and their required reporting limits.

METHODS FOR HYDROGEN AND METHANE ANALYSIS

The analysis of hydrogen and methane in closed room samples began in August 2007. Under the analysis scheme used at CEMRC, sample canisters are 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 GCMS. The sampling system incorporates three auto-samplers in series to allow for the analysis of two complete batches of six 6L 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 hydrogen and methane analysis results are reported in separate data packages from the VOCs results. Quality assurance requirements for these activities are 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-duplicates are analyzed at a rate of once per batch, or once each ten samples, whichever is applicable, to verify instrument calibration and quantitative analytical accuracy. LCS is a standard that contains compounds of interest which has 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 ± 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. During 2012, the laboratory achieved the precision limit for all the target compounds. Figures 4.2-4.7 show an example of laboratory precision through LCS % recovery and RPD for the target analytes Carbon tetrachloride, 1,1,2,2-Tetrachloroethane and Hydrogen. The data in the figures is for the analyses done in the year 2012.

RESULTS AND DISCUSSION

The OC lab analyzed a total of 935 samples in 2012. All of the samples were analyzed and reported in a timely manner under an extensive quality assurance (QA) / quality control (QC) program. The 935 samples consisted of 559 samples for VOCs measurement (511 routine air samples, 44 blank and recovery gas samples) and 376 samples for hydrogen and methane analysis. All of these samples achieved 100% completeness. Blank and recovery gas samples were collected by Shaw Environmental and were part of the sampler cleaning and certification program; they were analyzed in expedited turnaround batches (7 calendar days) at various times throughout the years.

The OC lab also received a number of canisters and passivated sampling kits (sample trains) for cleaning and certification at various times throughout the year. All of the canisters and sample trains were cleaned and certified with appropriate QA/QC procedures in place. The lab cleaned and certified 908 canisters from batches which had been analyzed and reported. In addition, the lab also cleaned and certified 193 canisters and 134 sample trains in 2012.

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, as detailed in the QAP.

SUMMARY STATEMENTS

Due to the proprietary nature of the VOC data, none are reported herein. However, the success of the VOCs Monitoring Program and the successful HSG Program audit demonstrate CEMRC's ability to initiate new programs to successfully perform regulatory monitoring tasks in accordance with specific QA/QC requirements. At the time both programs were proposed, CEMRC did not have qualified staff with experience in similar programs. Existing staff gained knowledge and skills necessary to perform these tasks appropriately in order to pass strict audit criteria.

CEMRC presently has the capability to analyze over 2,000 VOC and hydrogen/ methane samples per year. As a public service to the local community, CEMRC analyzed a grab sample in March 2012 from a potash mine owned by Mosaic Inc. for any VOCs or hydrogen/methane buildup due to an event within the mine. Also, CEMRC analyzed a grab sample from a Carlsbad Municipal School facility in November 2012. No compounds of concern above EPA or indoor air quality regulation limits were found. In addition, CEMRC has the instrumentation and facilities to analyze air samples for VOCs from and around Carlsbad which might be affected due to the ever increasing mining, oil and gas industries.

Table 4.1 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
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 4.2 Compounds of Interest for WIPP Confirmatory Volatile Organic Compounds Monitoring Program

Compound	Repository Sample Reporting Limit (ppbv)	Closed Room Sample Reporting Limit (ppbv)
1,1-Dichloroethylene	5	500
Carbon tetrachloride	2	500
Methylene chloride	5	500
Chloroform	2	500
1,1,2,2-Tetrachloroethane	2	500
1,1,1-Trichloroethane	5	500
Chlorobenzene	2	500
1,2-Dichloroethane	2	500
Toluene	5	500

Table 4.3 Additional Requested Compounds for WIPP Confirmatory Volatile Organic Compounds Monitoring Program

Compound	Repository Sample Reporting Limit (ppbv)	Closed Room Sample Reporting Limit (ppbv)
Benzene	2	500
Trichloroethylene	2	500
Tetrachloroethylene	5	500
Chloromethane	2	500
trans-1,2-Dichloroethylene	2	500
1,2,4-Trimethylbenzene	2	500
p,m-Xylene	5	500
Trichloromonofluoromethane	2	500

Note: From September 2012 onwards, only Trichloroethylene and 1,2,4-Trimethylbenzene are being reported as additional requested compounds.

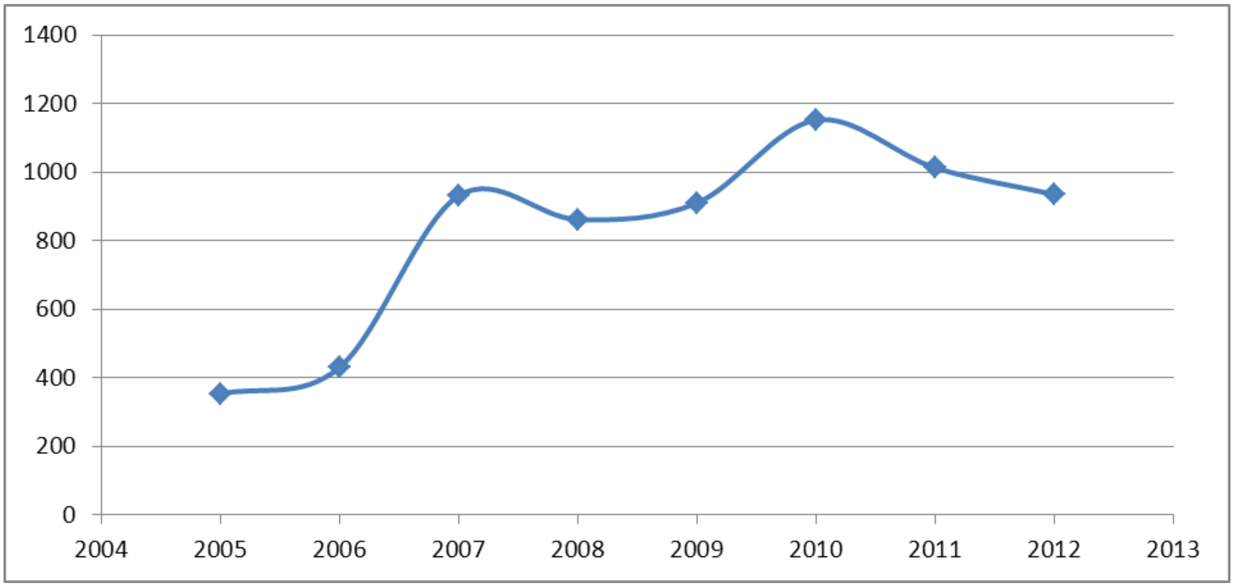


Figure 4.1 Number of Samples Analyzed by Year. (Note: Analysis of Hydrogen and Methane samples began in 2007.)

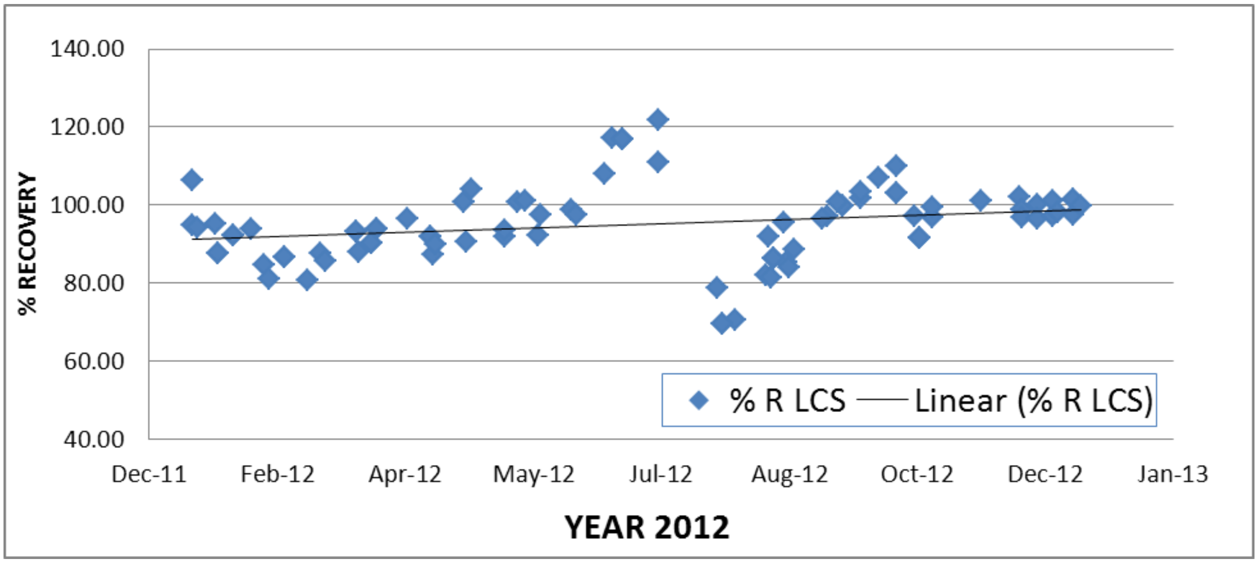


Figure 4.2 Percent Recovery of Carbon Tetrachloride in LCS (Recovery range: 60-140%).

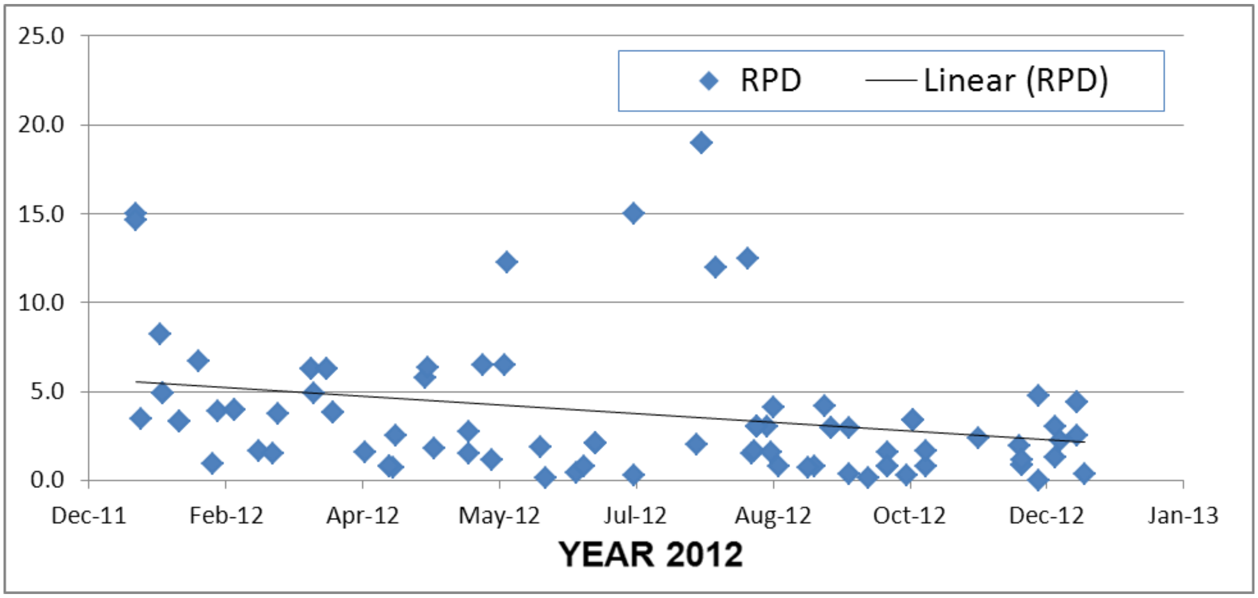


Figure 4.3 Relative Percent Deviation (RPD) between LCS and LCS-Duplicate for Carbon Tetrachloride (RPD range: 25%).

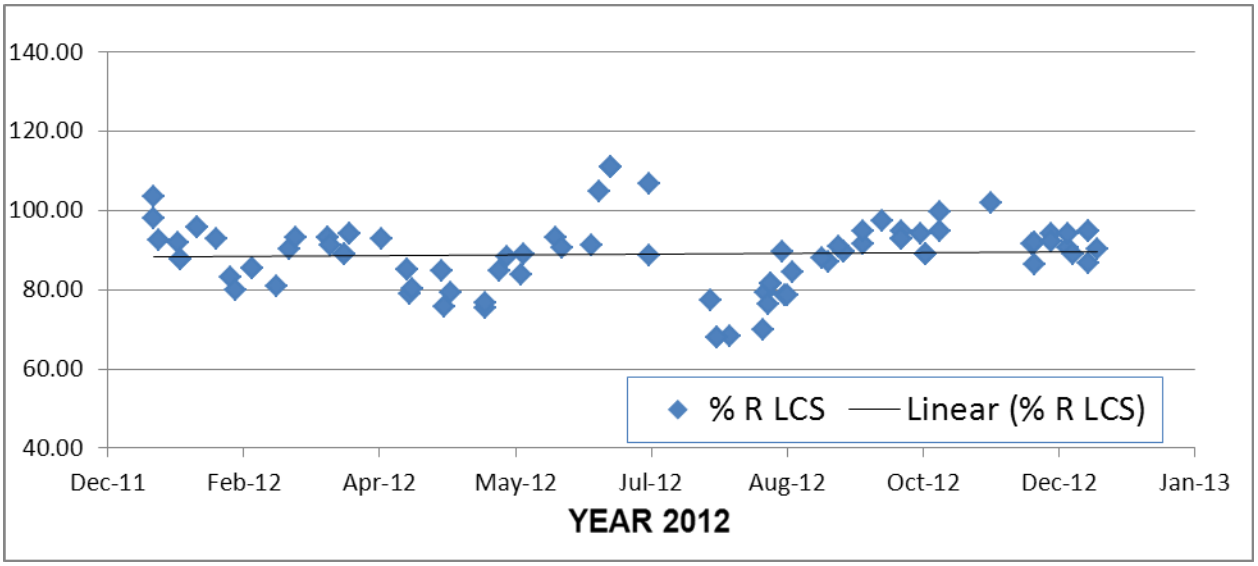


Figure 4.4 Percent Recovery of 1,1,2,2-Tetrachloroethane in LCS (Recovery range: 60-140%).

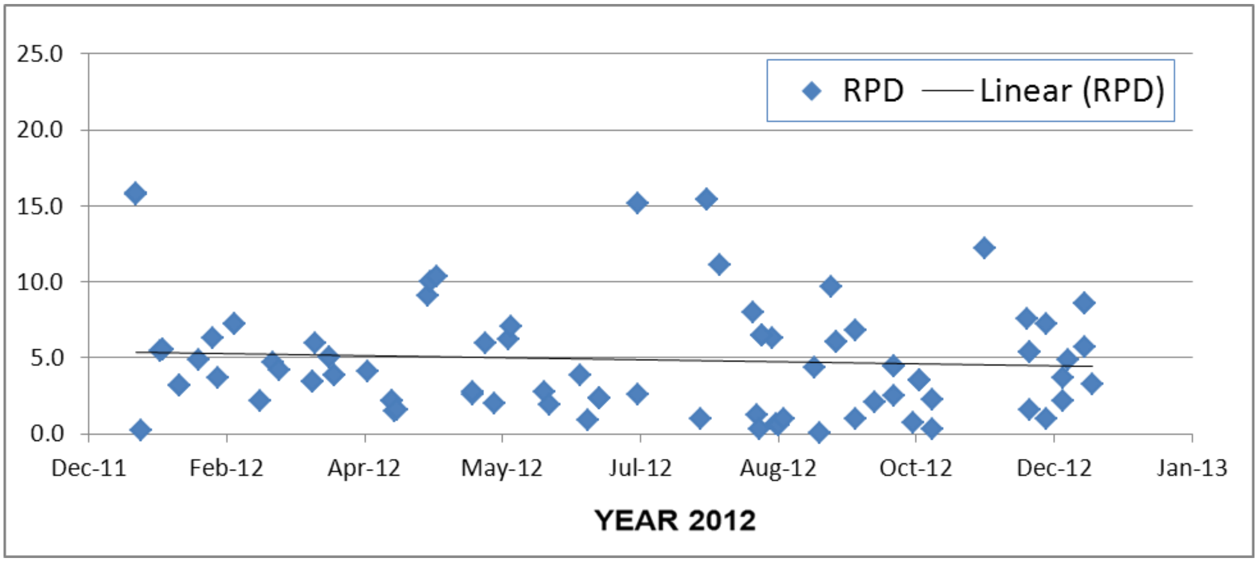


Figure 4.5 Relative Percent Deviation (RPD) between LCS and LCS-Duplicate for 1,1,2,2-Tetrachloroethane (RPD range: 25%).

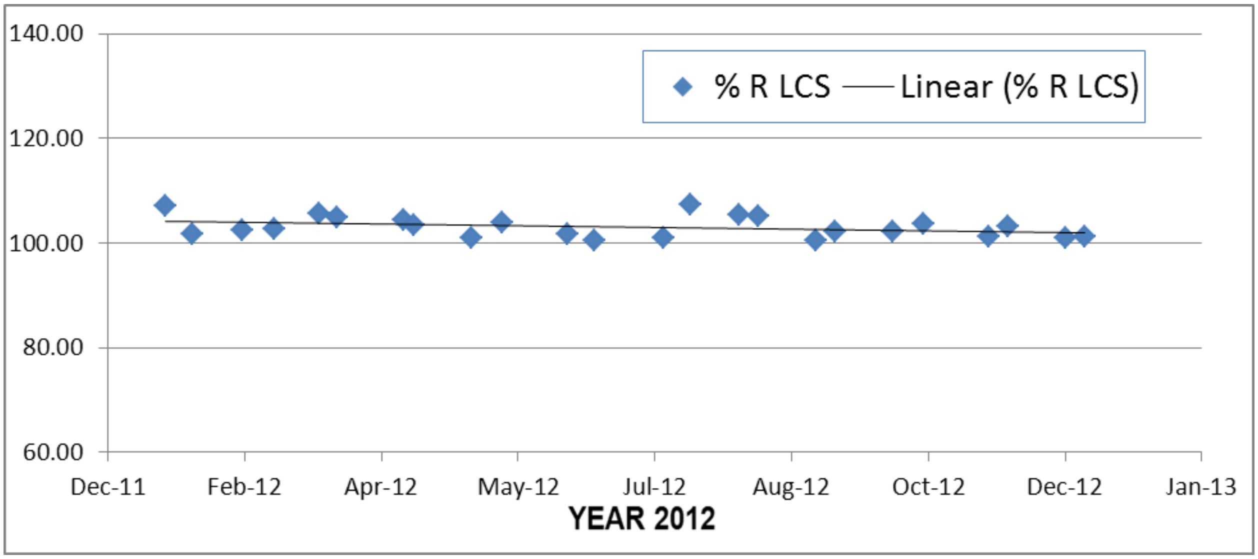


Figure 4.6 % Recovery of Hydrogen in LCS (Recovery range: 60-140%).

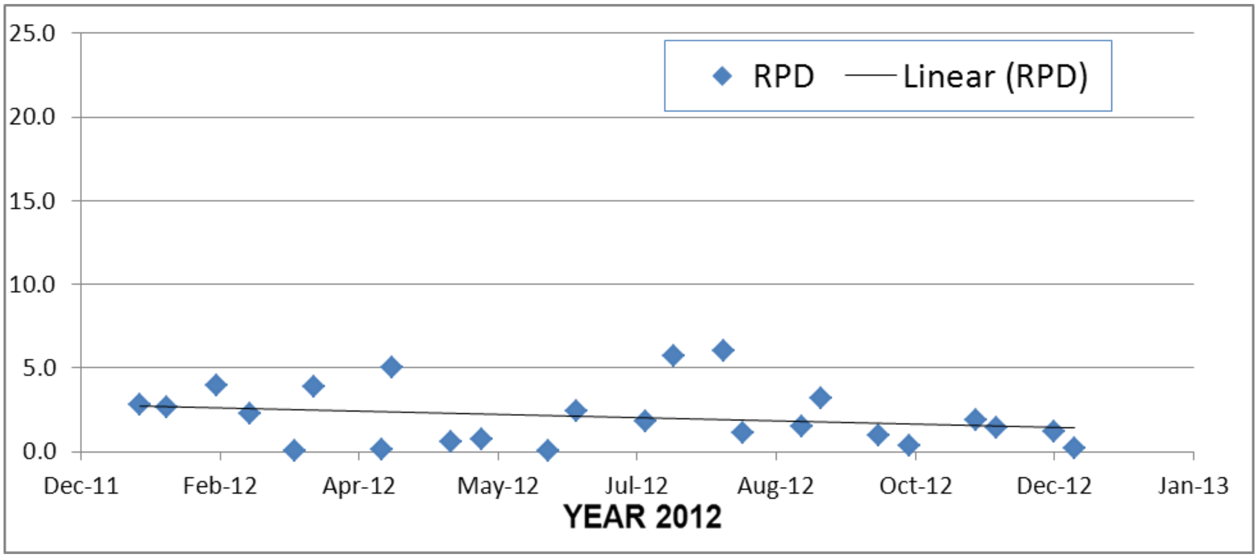


Figure 4.7 Relative Percent Deviation (RPD) between LCS and LCS-Duplicate for Hydrogen (RPD range: 25%)

CHAPTER 5

Ambient Air Monitoring

The Carlsbad Environmental Monitoring and Research Center (CEMRC) operates a network of continuously operating samplers at three locations in the vicinity of the WIPP Site to monitor radioactive constituents in the ambient air. The program is designed to detect radioactive materials in the air in case of an emergency response situation. Conducting air quality measurements are an important aspect of the CEMRC environmental monitoring program that seek 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.

Introduction

The CEMRC ambient aerosol monitoring studies focus on both man-made and naturally-occurring radionuclides, with special emphasis given to plutonium (Pu) and americium (Am) as isotopes of these elements are the major radioactive constituents in the TRU waste stored at the WIPP. In fact, the vast majority of radionuclides within TRU waste are 239Pu, 240Pu and 241Am, which account for more than 99% of the total radioactivity for most of the 10,000-year regulatory period. In this context, the variation in concentrations of these two radionuclides in the WIPP environment is important not only because they are the main component of the WIPP wastes, but also because of their global background activity. Atmospheric nuclear tests have been the major source of radiological contamination to date in the global environment. Approximately 6 tons of 239Pu were introduced into the environment from more than 500 atmospheric weapon tests conducted between 1945 and 1980. Fallout from these tests was distributed globally at an approximately 3:1 ratio between the northern hemisphere and the southern hemisphere (UNSCEAR 2000).

The main objective of the aerosol studies presented here and for the WIPP Environmental Monitoring (WIPP-EM) Program in general, has been to determine whether the nuclear waste handling and storage operations at the WIPP have released radionuclides into the environment around the WIPP. Summaries of the WIPP-EM aerosol studies have been included in prior CEMRC annual reports since 1997, and two articles specifically based on the WIPP-EM aerosol research program have been published in peer-reviewed journals (Arimoto et al. 2002 and 2005).

Currently, 238Pu, 239Pu and 240Pu isotopes can be measured as traces in environmental samples with a 238Pu/239+240Pu activity ratio of 0.03 at mean latitudes of 40o-50o N tracing their global origin (UNSCEAR, 2000). At present, almost all plutonium being introduced into the atmosphere can be found in the surface soil. As a result, plutonium can migrate vertically at various rates depending on meteorological conditions, physiochemical properties of soil, and human activity. In addition, it can also be taken up by plants or be re-suspended into the air with eroded soil particles. The importance of resuspension in recycling radionuclides from the soil back into the atmosphere has been pointed out in many publications (Rosner et al., 1997; Pavlotskaya et al., 1994; Arimoto et al., 2005; Sehmel, 1987).

Additionally, in the Carlsbad area, where WIPP is located, there is a potential local source of anthropogenic radioactivity from an underground nuclear test conducted during the Plowshare project. One particular test occurred in 1961 at the Gnome site, about 8.8 km southwest of the WIPP site, when an underground test of a 3.3-kiloton 239Pu device vented radioactive materials to the surface (USAEC, 1973). 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 risk-based action levels. However, 137Cs and plutonium have been detected in some samples of surface soils at the Gnome site (Kenney 1995). These contaminated soils are of practical concern because they are a potential source of contamination for environmental samples being collected to monitor potential release of radionuclides from the WIPP. Consequently, it is very important to understand factors controlling the distribution of contaminants in the WIPP area.

An important finding of the earlier studies was that the activity of Pu and the concentration of Al in aerosols were correlated and this was driven by the resuspension 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+240Pu (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. In addition to the environmental aerosol studies, aerosol particles also have been and continue to be collected using a fixed air sampler (FAS) in the WIPP exhaust shaft. Results of the FAS studies are presented in Chapter 1 of this report.

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 still 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). Concentrations of plutonium in surface air were not systematically monitored during 1959-1964, a period of time in which the heaviest contributions from global fallout occurred. The global fallout pattern of 90Sr is similar to that of plutonium isotopes, with an average 239+240Pu to 90Sr global activity ratio of about 0.025 (decay corrected to 2000) based on the normalized production rate for 90Sr and plutonium isotopes in nuclear explosions (UNSCEAR, 2000). As a result, the 239+240Pu to 90Sr ratio method (Bennett 1978) is generally utilized to make good estimates of the plutonium concentrations in air.

The current concentration of 239+240Pu in ambient air is about ~1000 times lowered than levels measured during the early 1960s and 1970s. During these earlier decades, plutonium concentrations in surface air were highly variable for a number of reasons such as continued contributions from weapons testing and recycling of deposited plutonium back into the atmosphere via re-suspension of contaminated soil. Furthermore, the fallout radionuclides were not deposited evenly over the earth and tend to vary with latitude with the highest levels being observed in the middle latitudes of the northern hemisphere. In addition, measurements of soil inventories have 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 removes radioactive particles from the atmosphere than dry deposition (Hardy et al., 1973). The Chernobyl accident in April 1986, which released about 70 TBq of the plutonium isotopes, increased the concentration of 239+240Pu 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+240Pu have been shown to decrease continuously. In order to establish an environmental baseline of 239+240Pu deposition, time series data of plutonium is important as it provides information about the factors that controls the past and present concentrations of plutonium present in the atmosphere. Such data are also important in terms of 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) was associated with enhanced transport of radioactive aerosols from the stratosphere-to the troposphere. However, following the cessation of nuclear weapons testing in 1980 and considering only a comparatively small additional input from the Chernobyl incident, the bulk of plutonium in the air today is associated with re-suspended soil which is contaminated from previous weapons-related fallout. As mentioned earlier, re-suspension is considered to be the predominant mechanism for maintaining the small residual level of 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). While a general discussion on transuranic re-suspension has been thoroughly reviewed by Sehmel (1987), Nicholson (1988) has reviewed re-suspension of radionuclides including plutonium in contaminated areas, which are usually found in arid or semiarid regions. Based on his findings, re-suspension appears to be dependent upon current meteorological conditions. For instance, windy, dry days can increase the soil re-suspension, whereas precipitation (rain or snow) can wash particulate matter out of the air, thereby decreasing the rate of re-suspension.

METHODS

Ambient Air Sampling Stations

During 2012, a network of continuously operating samplers at three locations in the vicinity of the WIPP Site was used to monitor radioactive materials in air. The locations of the three (3) air sampling stations are depicted in Figure 5.1. The high volume sampler utilized for ambient aerosol monitoring, filter holder and the type of filter used to collect total suspended particles (TSP) are shown in Figures 5.2 and 5.3. The samplers were primarily located in the prevailing downwind direction and were selected on the basis of the most probable scenario for radioactivity release in the event of an accident that occurred during the operation of the WIPP. In establishing these sites, it was recognized that there was no ideal “control” location from which to collect samples, that is, a site far enough from the WIPP to ensure complete isolation from aerosol releases while adequately replicating key ecological features, aerosol composition, soil topology, biota and weather conditions, etc. One particular site, the cactus flats station, was used as a reference location because it represents a reasonable compromise based on these considerations. Airborne particle samples are collected at each location by drawing air through a glass-fiber filter using a high volume samplers, commonly referred to as "hivols,", which have a flow rate of ~1.13 m3 min-1.

The three (3) hivol stations are designated as follows:

Station #106 (On Site Station): located in a primarily downwind position about 0.1 km northwest of the WIPP exhaust shaft.
Station #107 (Near Field Station): located about 1 km northwest of the WIPP site.
Station #108 (Cactus Flats Station): located about 19 km southeast (upwind) of the WIPP site.

Sampling Background

The sampling design for the ambient aerosol studies has changed over the course of the project, and detailed information regarding the sampling design has been presented in previous CEMRC reports starting in 1998. In prior years, the Near Field and Cactus Flats stations also supported a second hivol sampler for studies of PM10 samples (particulate matter less than 10 µm aerodynamic equivalent diameter), but the PM10 sampling was terminated in December 2000. The decision to use TSP samplers rather than the PM10 samplers was based on the overall objective of the WIPP-EM program, which is to evaluate any possible impacts of the WIPP. In particular this decision was made because it could be argued that the PM10 samplers would not capture any releases of the largest aerosol particles as effective as the TSP samplers. In addition, a fourth set of samples was collected at a site in Hobbs over a period of approximately a year and a half, but the sampling there was discontinued in April 2002 since WIPP is located approximately 61 km (38 miles) from Hobbs and an ambient air baseline had been established for the vicinity of Hobbs during prior years of WIPP-related monitoring studies.

Sample filters are weighed before and after sampling to determine the weight of solid material collected on the filters. Aerosols were sampled on 20x25 cm A/ETM glass-fiber filters (Pall Gelman Laboratory, Ann Arbor, MI), taken over a period of 3 to 6 weeks depending on the levels of particulate matter that accumulated on the filters. Gravimetric measurements of the glass fiber filters were made to determine the mass of aerosol material that accumulated over the sampling interval.

In addition to glass fiber filters, operational aspects of the ambient aerosol component of the WIPP-EM program have changed since the 2003 Annual Report with Whatman 41 sampling beginning on 1/4/2007. These 8 inch by 10 inch filters are being used on Hi-Q Hi-Vol HVP-3800AFC samplers. These samplers are located at sites 107 (Near Field) and 108 (Cactus Flats) and are positioned directly across from the Hi-Vol glass fiber sampler. The samplers are set at 20 SCFM and are changed approximately every 2 weeks and in conjunction with the glass fiber filers. No gravimetric data is collected from the Whatman 41 filters. It is anticipated that these filters may be used to more directly compare trace and major elemental concentrations to actinide and mass concentrations collected at the same locations. A summary of the latest ambient aerosol sampling program is given in Table 5.1.

Prior to the end of March 2002, both low-volume samplers ("low vols," 10 L min-1) and Graseby-Anderson dichotomous samplers (dichots) were used for collection of aerosols for the studies of non-radioactive, inorganic constituents, specifically trace elements and selected water soluble ions. However, the WIPP-EM program underwent a major restructuring in FY 2002 and afterwards, sampling for the non-radiological aerosol analytes was done using dichots exclusively. Further, in November 2004, the collection of aerosols by dichots was discontinued.

Sample Preparation

The high-volume samples were analyzed for selected radionuclides, including 238Pu, 239+240Pu, 241Am and recently 235U, 234U and 238U following 6 hours of heating in a muffle furnace at 500° C to drive off organics. The tracers and the iron carrier are added and each filter is treated with HF+HNO3 up to the complete decomposition of silica. Then each filter is digested with a strong acid mixture of HCl+HF+HClO4. Subsequently, 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 (AG1-X8, Bio-Rad, 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 Oxford Oasis alpha spectroscopy for five days. Gamma-emitting nuclides in the air filters are measured by Gamma spectrometry for 48 hours. Additionally, a known amount of tracer (242Pu, 243Am or 232U) is added to determine the actinide recovery in each sample. Typical chemical recoveries are in the range of "40-80%" for Pu and of "90-105%" for Am. For counting times of 72,000 min, the detection limits of 239+240Pu, 238Pu and 241Am are 2.6x10-9, 3.9x10-9 and 3.1x10-9 Bq/m3, respectively.

Data Reporting

The activities of the actinides in the air samples are reported as activity concentration (Bq/m3) and activity density (Bq/g). Activity concentration is calculated as the activity of radionuclides detected in Becquerel (Bq) divided by the volume of air in cubic meters, while activity density is calculated as the radionuclides activity divided by the aerosol mass in grams collected on the filter.

RESULTS AND DISCUSSION

Average air concentrations of actinides in the aerosol samples during the period from 1998 to 2012 are summarized in Table 5.2. The average air concentrations of actinides after WIPP became operational are not statistically different than those measured prior to waste disposal operations. During most years studied, the peak 239+240Pu activities generally occur in the March to June timeframe, which is when strong and gusty winds in the area frequently give rise to blowing dust. Some samples taken at Cactus Flats (station 108) in 1999 and 2000, at On Site (station 106) in 2004, and at Near field (station 107) in 2008 exhibited slightly higher 239+240Pu activity concentrations as well as densities (Figures 5.4 and 5.5) than surrounding data points. The observed seasonality in Pu activity concentration is attributed to the re-suspension of contaminated soil dust plus the local precipitation to some extent. Studies conducted prior to the end of the atmospheric weapons testing showed that Pu activities varied seasonally, being highest in spring and summer because of the springtime enhanced transportation of radioactive aerosols from the stratosphere to troposphere. However, with the cessation of nuclear weapons tests and considering the fact that 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 assumed to be the main source of Pu in the aerosol samples around the WIPP.

Methods for determining the activity of 241Am were developed by the CEMRC radiochemistry group in 2001. Most notably, strong springtime peaks in 241Am activity concentrations were evident in the samples from 2001 through 2002 and 2004 through 2012. A time series plot for 241Am activity concentrations and densities are presented in (Figures 5.6 and 5.7). A strong correlation between aerosol 241Am and 239+240Pu activity concentrations exists (r2 = 0.71, 0.67, and 0.68 respectively, for OnSite, Near Field and Cactus Flats stations) even though neither 239Pu nor 240Pu are immediate progeny of 241Am (Figures 5.8 - 5.10). Furthermore, the relative activities of 241Am and 239+240Pu were similar at all aerosol stations. The mean activity ratios of 241Am/239+240Pu (decay corrected to Jan 2010) at three aerosol stations were found to be 0.37±0.05 (On Site), 0.37±0.02 (Near Field), and 0.41±0.04 (Cactus Flats). These values are in agreement with the mean activity ratio of these radionuclides, originating from the atmospheric nuclear tests in soils and sediments reported in different studies: 0.32, 0.35 (Jia et al., 1999), 0.30 (Bunzl et al., 1995), 0.34, 0.37, 0.39, 0.42 (Mitchell, et al., 1992), 0.43 (Sha et al., 1991). Taking into account the contribution of 241Am from 241Pu decay, the observed 241Am/239+240Pu activity ratio again strongly indicates global fallout as its origin. The seasonal fluctuation for 238Pu is not as pronounced as for 239+240Pu and 241Am. The 239+240Pu and 241Am are frequently detected, whereas 238Pu is detected infrequently in aerosol filters, presumably because 238Pu is not primarily from weapons fallout, but instead was released by the burn-up of nuclear satellites such as the SNAP-9A satellite which broke apart upon re-entry to the atmosphere in 1964 (Hardy et al., 1973)

The average activity concentration (activity per unit volume air sampled) for 239+240Pu ranges from 5.5-18.3 nBq/m3 at On Site, 4.9-19.4 nBq/m3 at Near Field, 2.9-20.3 nBq/m3 at Cactus Flat. For 241Am the average activity concentrations ranged from 1.9-5.5 nBq/m3 for On Site station, 1.9-7.1 nBq/m3 for Near Field and 1.7-7.7 nBq/m3 for Cactus Flats. However, the 241Am concentrations were consistently lower than those of 239+240Pu. The average 239+240Pu, 241Am, and 238Pu concentrations in these three stations are shown in Figures (5.11-5.13). The average 239+240Pu activity density (activity per unit mass aerosol collected) ranges from 0.26-0.41 mBq/g at On Site, 0.26-0.77 mBq/g at Near Field, 0.23-0.59 mBq/g at Cactus Flats (Figures 5.14-5.16) while that of 241Am ranged from 0.08-0.16 mBq/g for On Site, 0.06-0.23 mBq/g for Near Field and 0.10-0.38 mBq/g for Cactus Flats.

The highest levels of activity both in terms of activity concentrations and activity densities, occurred not at the OnSite station, which is where one would expect any emission from the WIPP to be most evident, but rather at Cactus Flats, the reference station farthest from WIPP. The Pu activity concentration follows the order: Cactus Flats>Near Field>OnSite (Table 5.2). In contrast to actinide data, the aerosol mass loadings follow the trend: On Site (39.22±20.51 µg/m3)> Cactus Flat (31.37±17.65 µg/m3) > Near Field (29.66±16.14 µg/m3). Furthermore, aerosol mass loading shows a linear relationship with the 239+240Pu activity concentrations for the Near Field and Cactus Flats stations. However, such linearity is not observed for the OnSite station (Figure 5.18).The mass loading is usually high with low 239+240Pu activity concentration at On Site station. This suggests that operations at the WIPP such as underground salt mining, construction or road dust may have generated some aerosols that contributed to the mass loadings but contain less 239+2340Pu than ambient aerosols typically do.

The suspension of soil particles typically exhibits a threshold with respect to wind velocity. Thresholds typically range from 6 to 13 m s-1 at 0.3 m and, they are related to the force required to cause the saltation of large soil particles. The regression analysis (r2 = 0.5 for threshold velocity >8 m s-1; Arimoto et al., 2005) demonstrates that activity of 239+240Pu increases as a function of wind speed, supporting the theory that the activities of 239+240Pu are controlled by resuspension. Further, threshold wind velocity studies for sand movement in southeastern New Mexico demonstrate that the dispersal of contaminated soils from the Gnome site is likely to occur only when winds are greater than ~10 to 10.5 m s-1 (Stout and Arimoto, 2010). This occurs generally in the months of April through May when winds are strong, precipitation is low, and the air is drier. In addition, the results show that saltation activity is favored at certain times of the day, especially from noon to mid-afternoon.

The concentrations of 239+240Pu, 238Pu, 241Am, 137Cs, 134Cs, 60Co and 40K measured in ambient aerosol samples collected in 2012 are presented in Figures 5.19 - 5.25. The individual radionuclide concentrations measured in the filters are listed in Tables 5.3 to 5.5. The minimum, maximum, and average concentrations of radionuclides for all sampling locations combined are reported in Tables 5.6 to 5.8. As can be seen in the Tables 239+240Pu and 241Am were detected in some samples. Additionally, concentrations of 40K were detected in most of the samples. 40K is ubiquitous in the earth's crust and thus would be expected to show up in environmental air samples. However, there was no significant difference in the concentrations of 40K among locations. Lastly, 137Cs, 134Cs and 60Co were not detected in any of the samples.

SUMMARY STATEMENTS

The source and level of plutonium in and around the WIPP environment prior to arrival of the TRU waste and after it became operational were compared to assess if there is any evidence of an increase in radionuclide activity concentrations in the region that could be attributed to releases from WIPP. After fourteen years of continuous operations, there is no evidence of increases in radiological contaminants in the region that could be attributed to releases from WIPP. 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 remain a possibility during high wind seasons, the activity and the atomic ratio measurements indicates that deposited plutonium in the aerosol mainly results from global fallout. Resuspension 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.

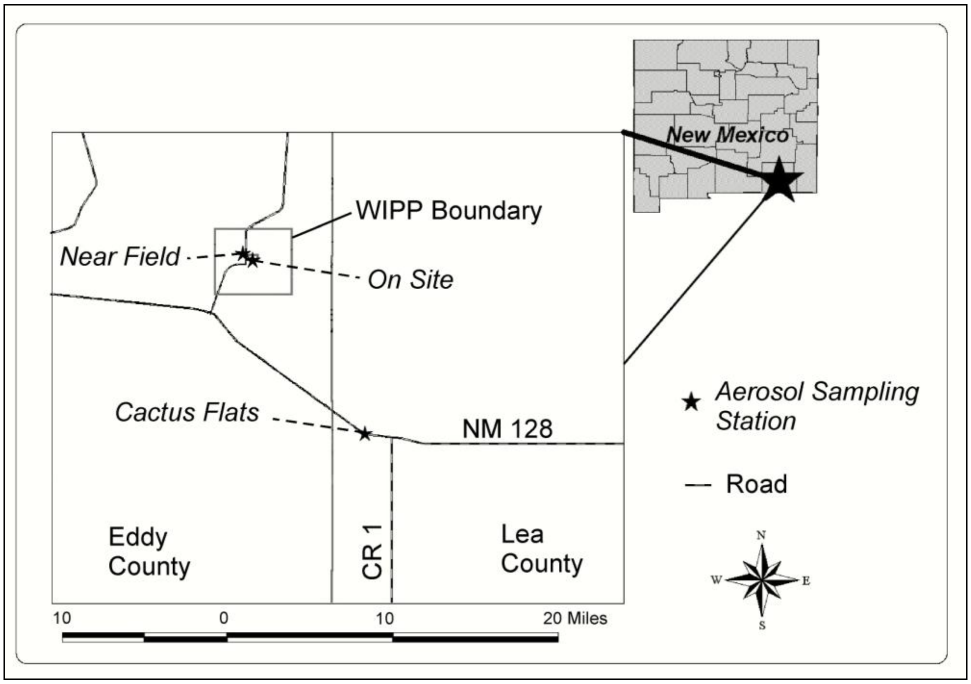


Figure 5.1 WIPP-EM Ambient Aerosol Sampling Locations

Figure 5.2 High Volume Air sampler for TSP Monitoring around the WIPP Site

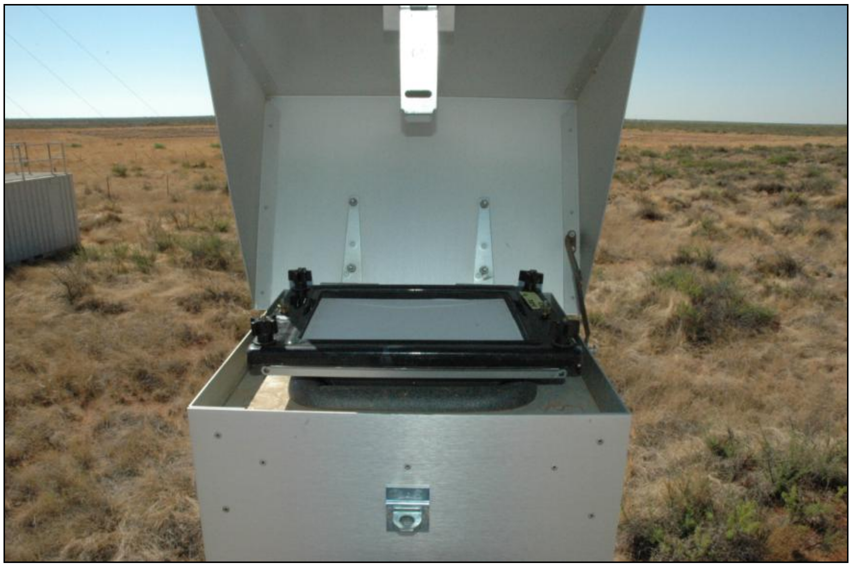


Figure 5.3 Aerosol Sampling Filter Holder
Filter Type Used: 8×10 inches Glass Fiber

Table 5.1 Aerosol Sampling Status for the WIPP-EM

Site	[a]Sampler	Analyses	Frequency	Comments
Station A (Exhaust Shaft)	PM_{10}-Shrouded Probe	Mass, Gross Alpha and Beta Activities, Trace Elements, Gamma Emitters, Actinides	Daily	Monthly Composites
Station B (Post Filtration)		Gross Alpha and Beta Activities, Actinides	Weekly	Monthly Composites
Cactus Flats **Near Field** **On Site**	TSP-HI VOL Glass Fiber Filter	Mass & Radionuclides	[b]Variable	Continuous
	[c]TSP-HI VOL Whatman 41Filter	Elemental	Variable	Continuous

[a] Sampler types are as follows: PM_{10}-Shrouded Probe = particles greater than 10 µm diameter (50% cut-size)
TSP-HI VOL = High Volume Total Suspended Particles.

[b] Samples are changed when the flow drops to 90% of original for the 2-stage pumps.

[c] TSP-HI VOL Whatman 41 Filters are collected at Cactus Flats and Near Field.

Table 5.2 Summary Statistics for Aerosol Mass Loadings and Actinide Activities in High Volume Aerosol Samples Around WIPP Site

Station		Cactus Flats	Near Field	On Site
Type of Sample		TSP	TSP	TSP
Number of Samples		**150**	**151**	**152**
Aerosol Mass, micrograms per cubic meter	N	150	151	152
	Mean	31.37	29.66	39.22
	StdDev	17.65	16.14	20.51
^{241}Am Activity Concentration, Bq/m^3	N	58	60	63
	Mean	6.44E-09	5.47E-09	1.21E-07
	StdDev	5.19E-09	4.42E-09	9.20E-07
^{241}Am Activity Density, Bq/g	N	58	60	64
	Mean	2.53E-04	1.92E-04	5.16E-03
	StdDev	2.37E-04	1.08E-04	4.00E-02
$^{239+240}$Pu Activity Concentration, Bq/m^3	N	101	121	116
	Mean	1.66E-08	1.46E-08	1.43E-08
	StdDev	1.33E-08	1.01E-08	1.02E-08
$^{239+240}$Pu Activity Density, Bq/g	N	101	122	118
	Mean	5.22E-04	5.12E-04	3.66E-04
	StdDev	2.11E-04	2.30E-04	1.90E-04
^{234}U Activity Concentration, Bq/m^3	N	51	50	49
	Mean	2.48E-06	2.57E-06	2.72E-06
	StdDev	1.30E-06	1.39E-06	1.50E-06
^{234}U Activity Density, Bq/g	N	51	50	49
	Mean	6.54E-02	6.68E-02	5.78E-02
	StdDev	2.55E-02	2.71E-02	2.28E-02
^{235}U Activity Concentration, Bq/m^3	N	51	50	49
	Mean	1.34E-07	1.52E-07	1.52E-07
	StdDev	8.02E-08	1.51E-07	1.05E-07
^{235}U Activity Density, Bq/g	N	51	50	49
	Mean	3.54E-03	3.82E-03	3.29E-03
	StdDev	1.70E-03	3.25E-03	2.04E-03
^{238}U Activity Concentration, Bq/m^3	N	51	50	49
	Mean	2.38E-06	2.45E-06	2.72E-06
	StdDev	1.24E-06	1.29E-06	1.73E-06
^{238}U Activity Density, Bq/g	N	51	50	49
	Mean	6.29E-02	6.41E-02	5.78E-02
	StdDev	2.44E-02	2.62E-02	3.10E-02
^{238}Pu Activity Concentration, Bq/m^3	N	9	3	10
	Mean	6.13E-09	2.42E-09	1.00E-08
	StdDev	1.14E-08	2.14E-09	2.34E-08
^{238}Pu Activity Density, Bq/g	N	9	3	11
	Mean	2.69E-04	9.15E-05	2.24E-04
	StdDev	5.45E-04	9.35E-05	4.71E-04

[a] N stands for number of samples with masses or activities above detection limits.

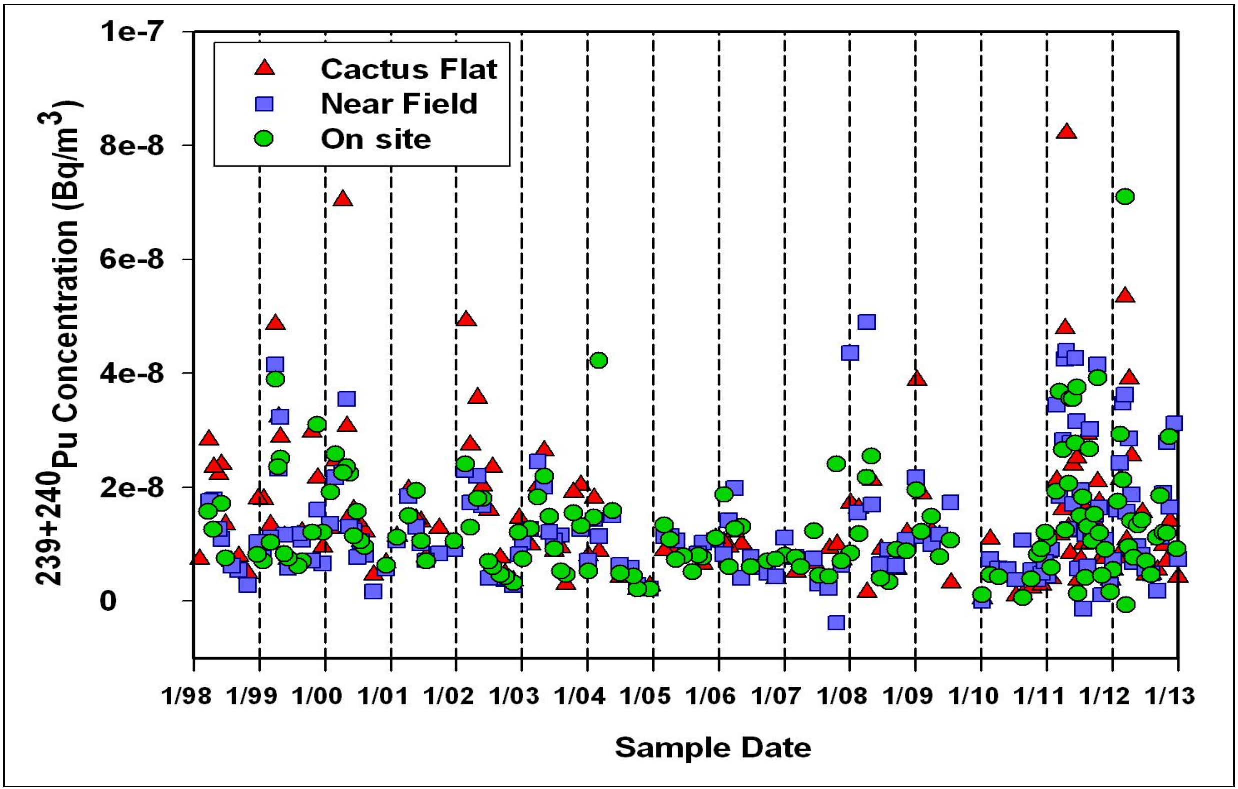


Figure 5.4 High Volume Ambient Aerosol $^{239+240}$Pu Activity Concentrations

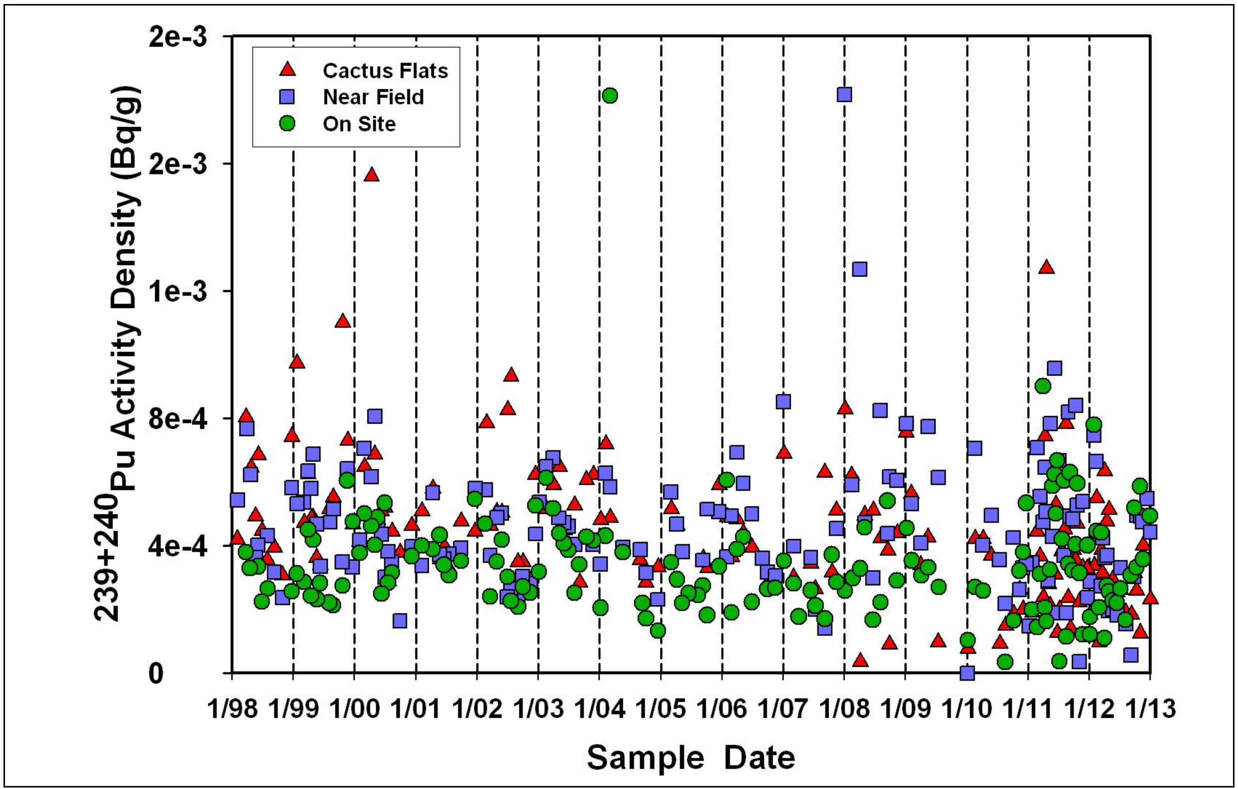


Figure 5.5 High Volume Ambient Aerosol $^{239+240}$Pu Activity Densities

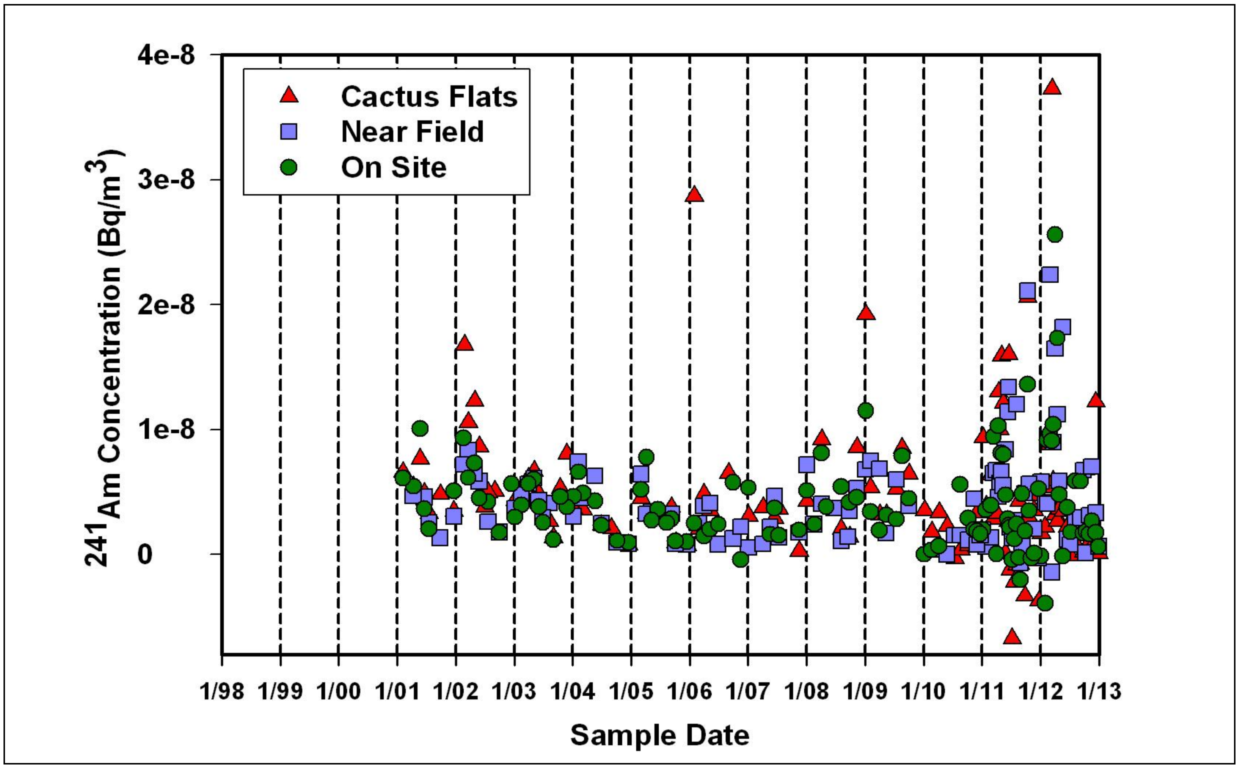


Figure 5.6 High Volume Ambient Aerosol ^{241}Am Activity Concentrations

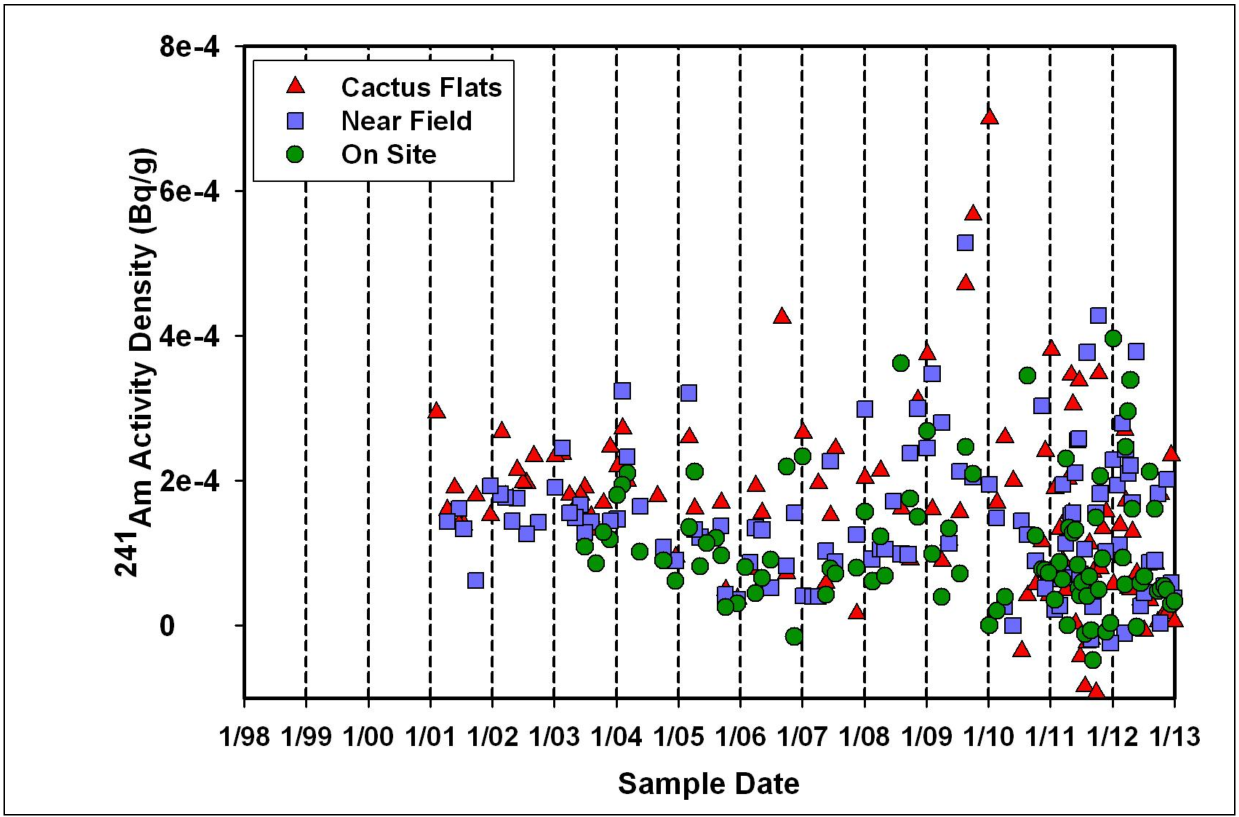


Figure 5.7 High Volume Ambient Aerosol ^{241}Am Activity Densities

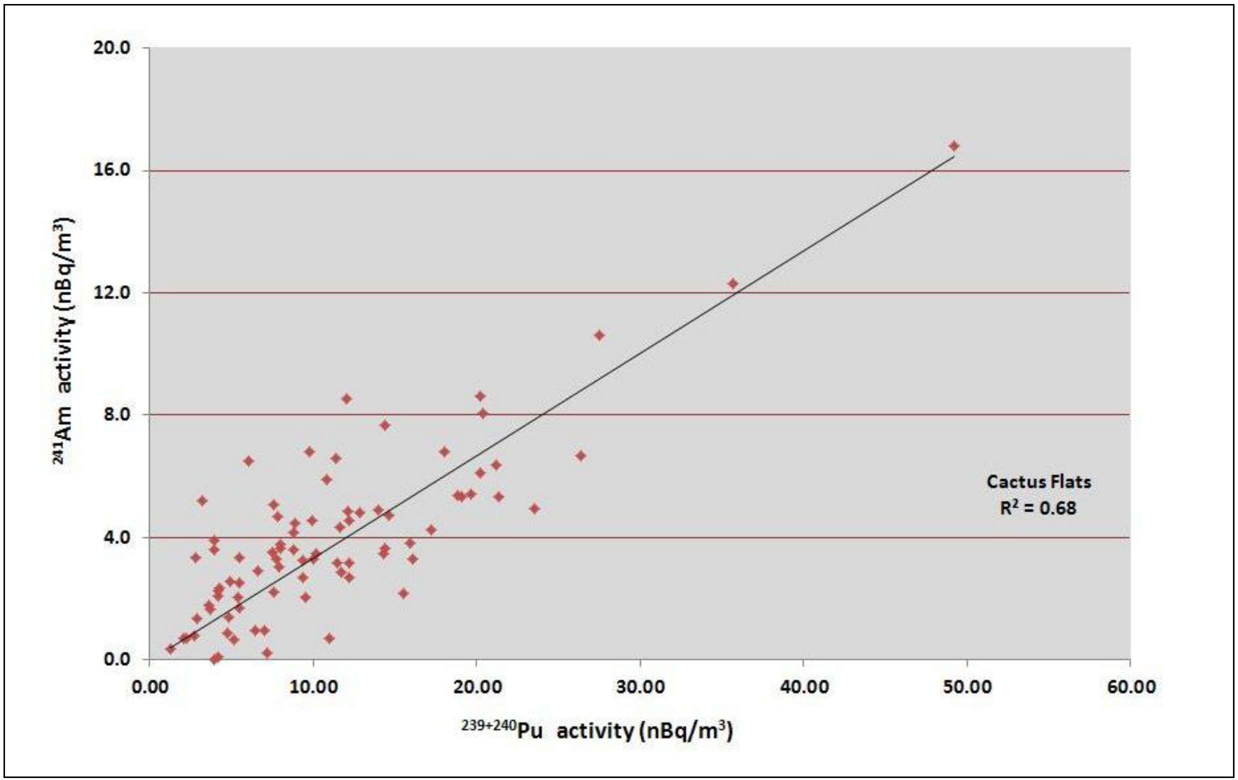


Figure 5.8 Correlation between $^{239+240}$Pu and ^{241}Am Activity Concentrations in Aerosol Samples Collected from Cactus Flats Station

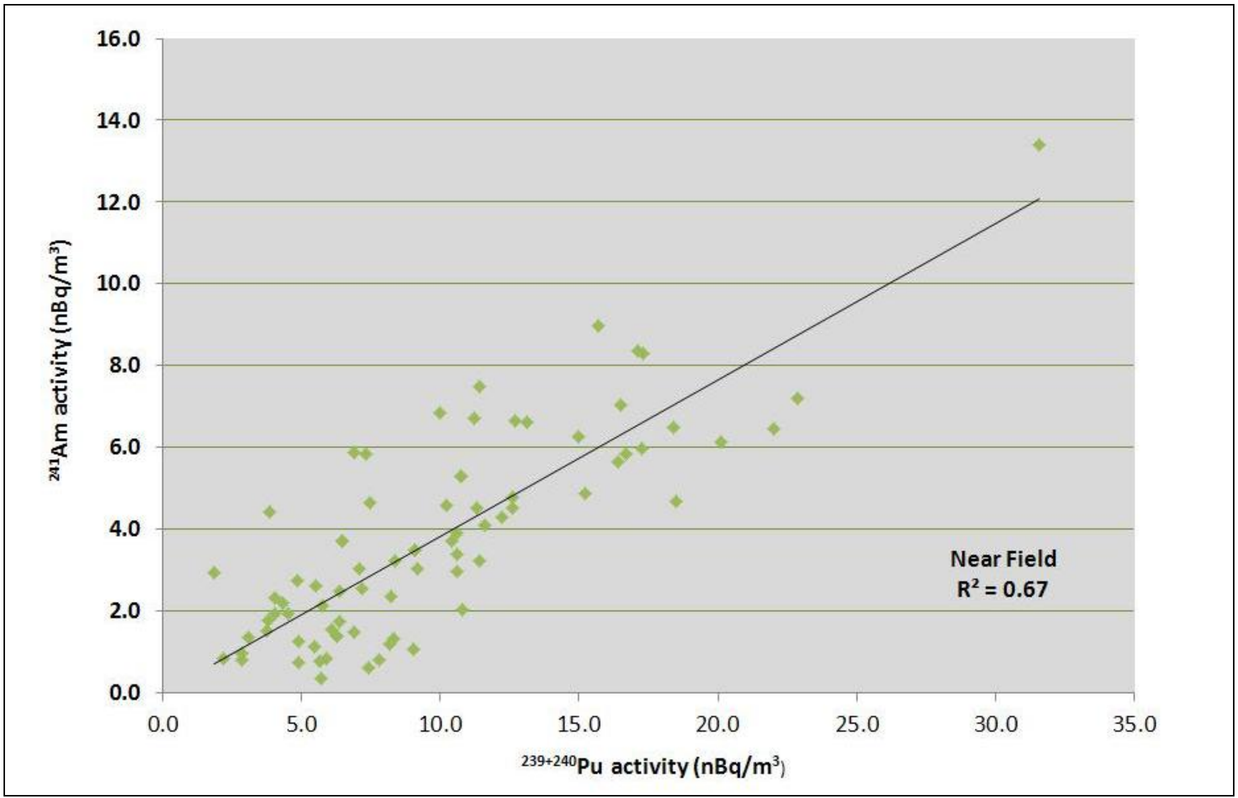


Figure 5.9 Correlation between ^{241}Am and $^{239+240}$Pu Activity Concentrations in Aerosol Samples Collected from Near Field Station

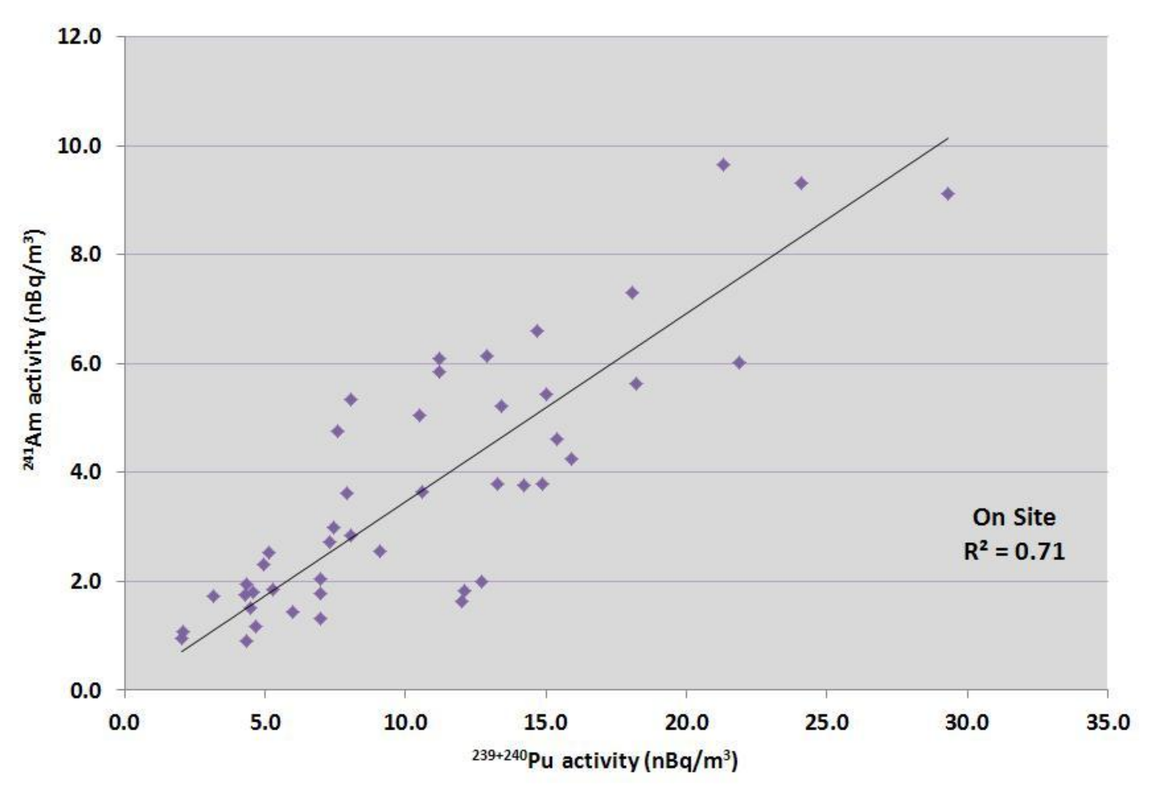


Figure 5.10 Correlation between ^{241}Am and $^{239+240}$Pu Activity Concentrations in Aerosol Samples Collected from On Site Station

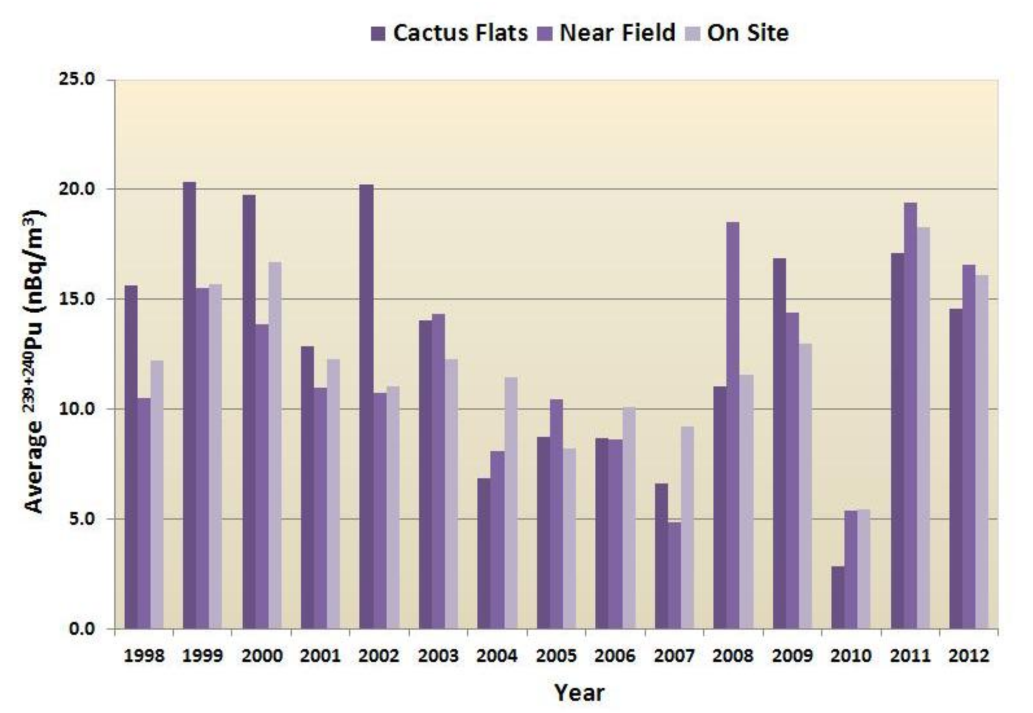


Figure 5.11 Average High Volume Ambient Aerosol $^{239+240}$Pu Activity Concentrations in the Vicinity of WIPP Site

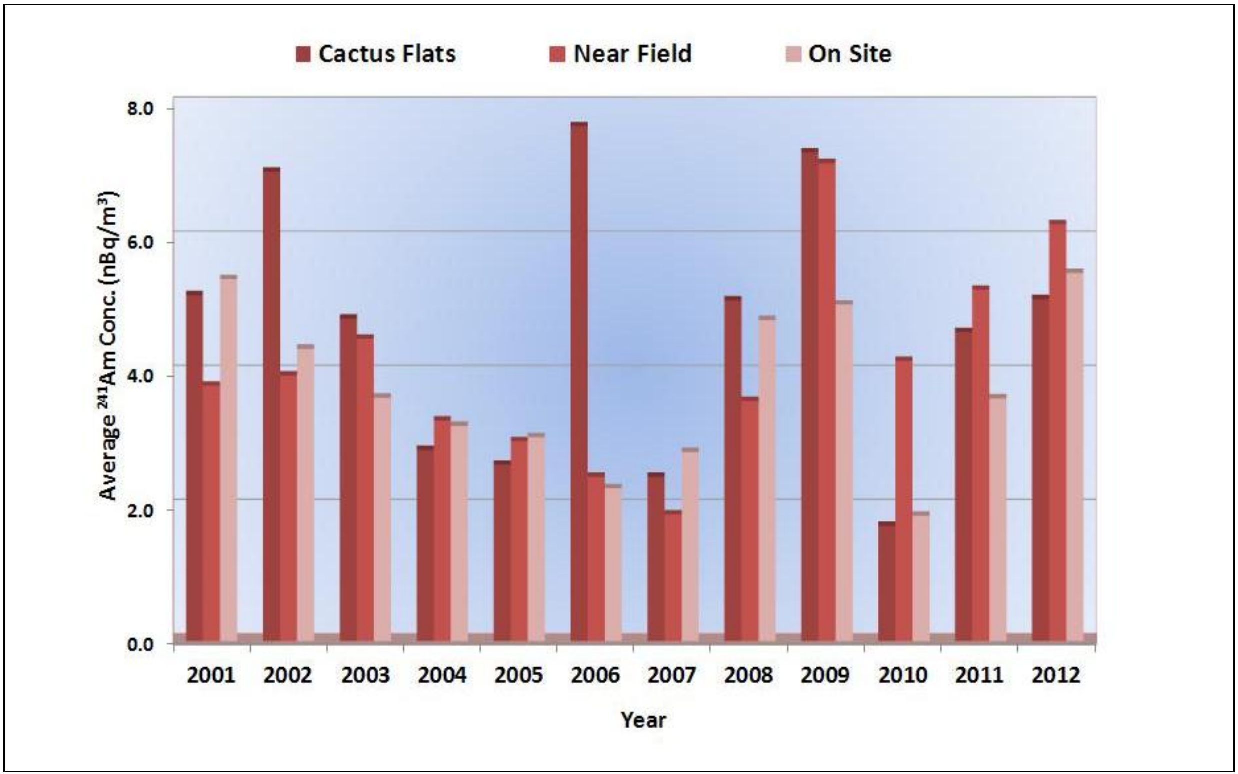


Figure 5.12 Average High Volume Ambient Aerosol ^{241}Am Activity Concentrations in the Vicinity of the WIPP Site

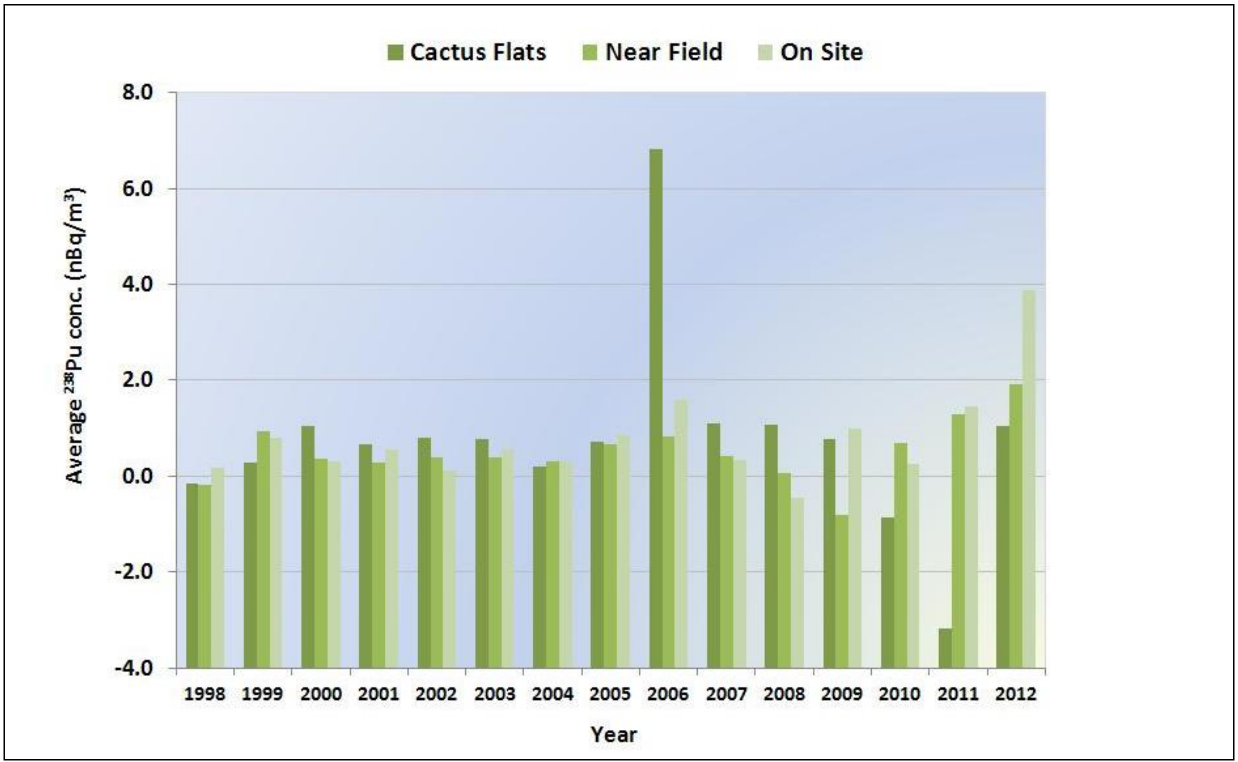


Figure 5.13 Average High Volume Ambient Aerosol ^{238}Pu Activity Concentrations in the vicinity of the WIPP Site

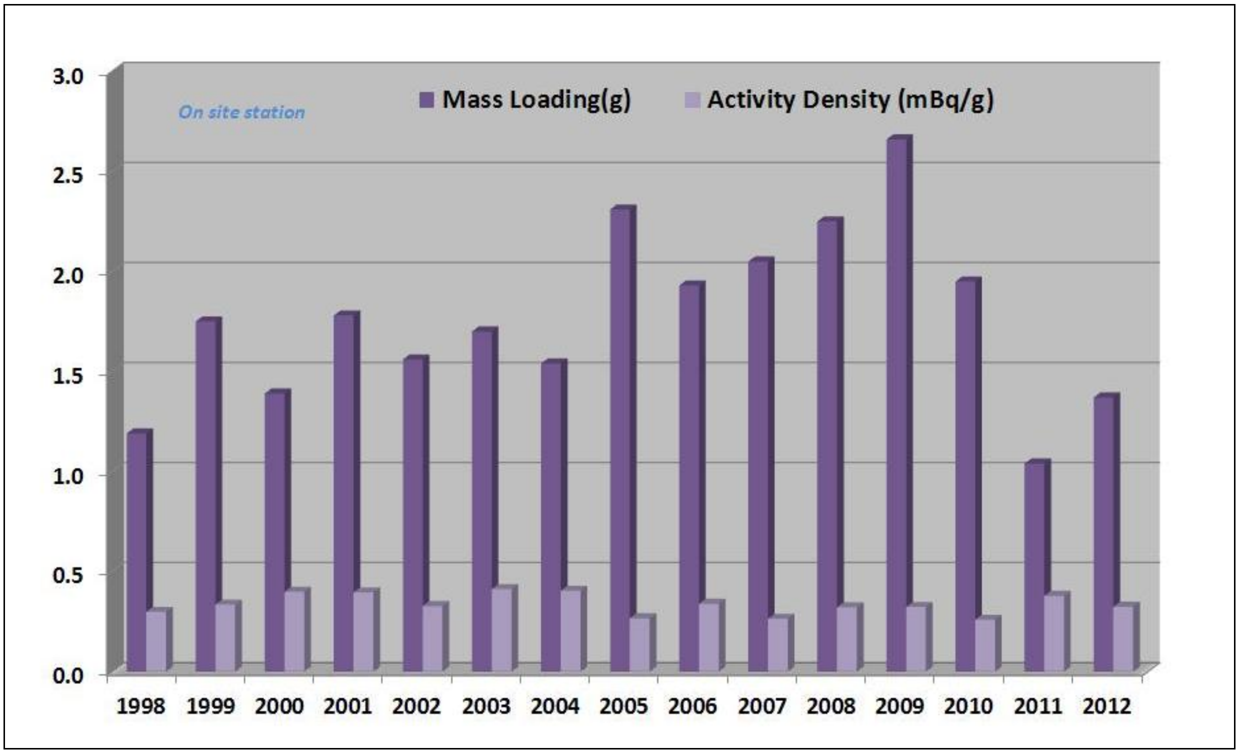


Figure 5.14 Average High Volume Ambient Aerosol Mass Loading and $^{239+240}$Pu Activity Density at On Site Station

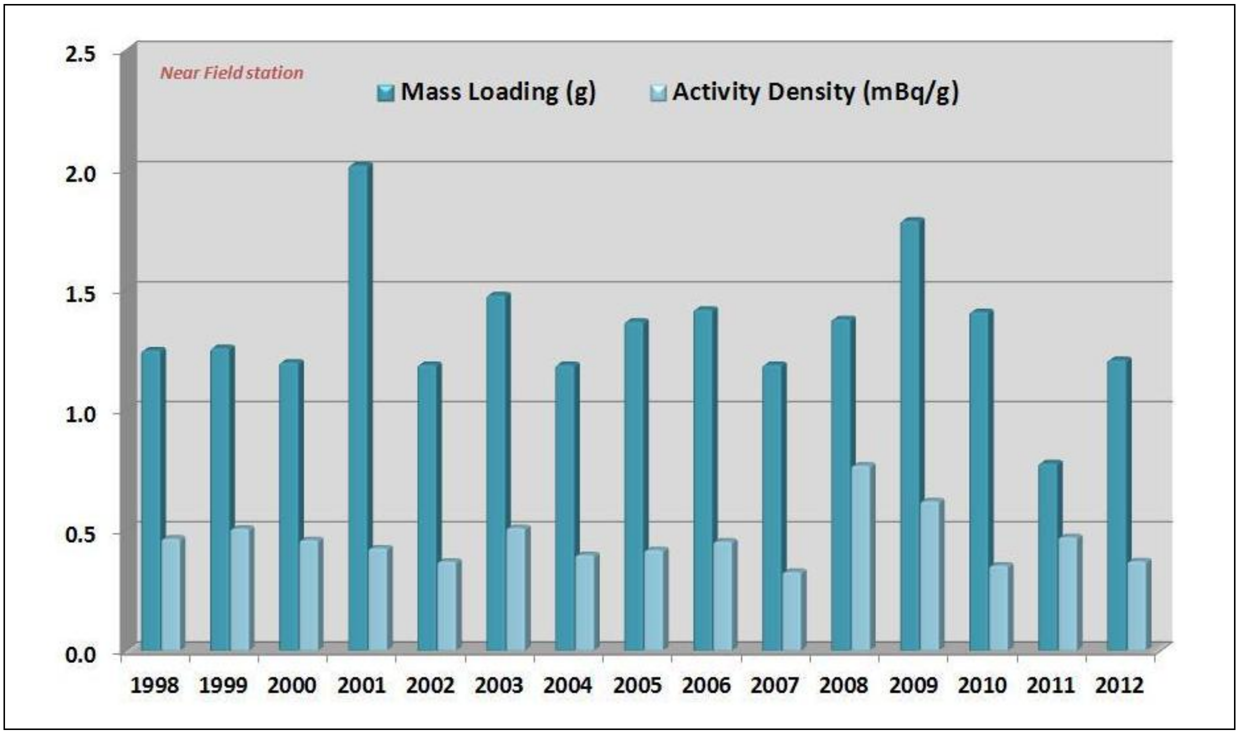


Figure 5.15 Average High Volume Ambient Aerosol Mass Loading and $^{239+240}$Pu Activity Density at Near Field Station

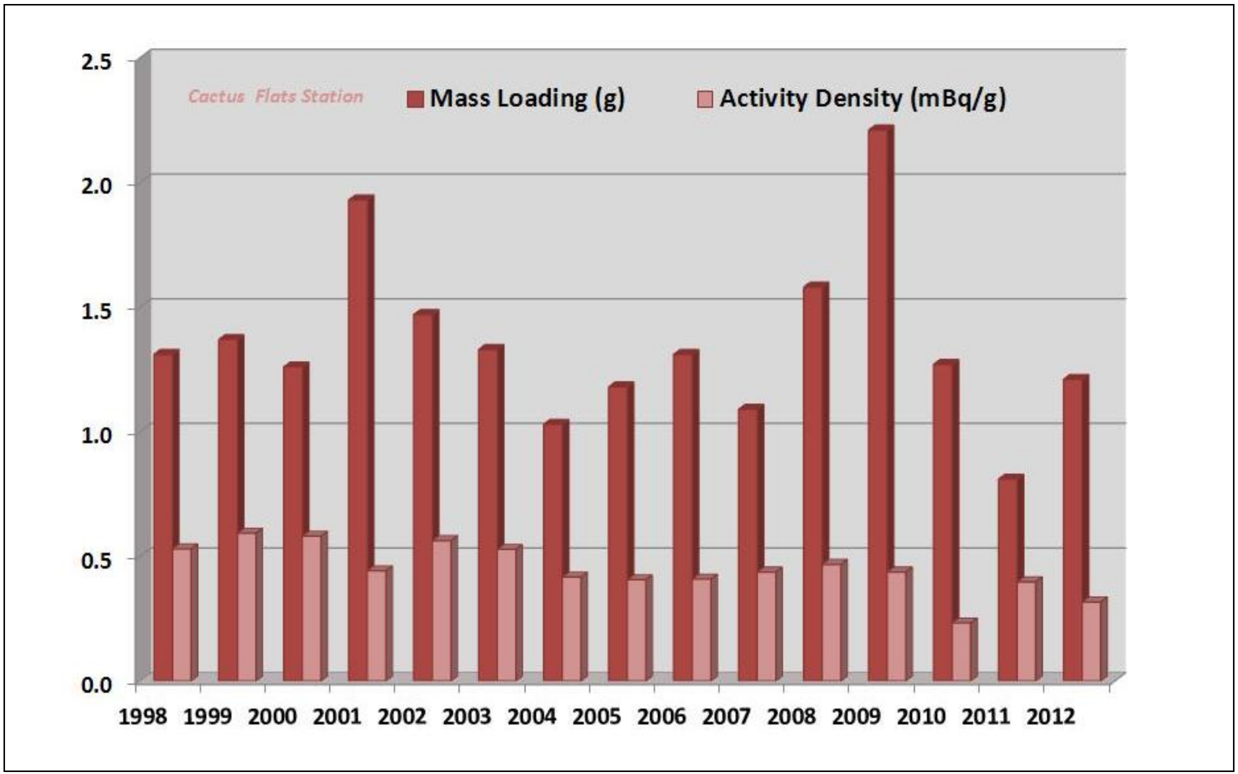


Figure 5.16 Average High Volume Ambient Aerosol Mass Loading and $^{239+240}$Pu Activity Density at Cactus Flats Station

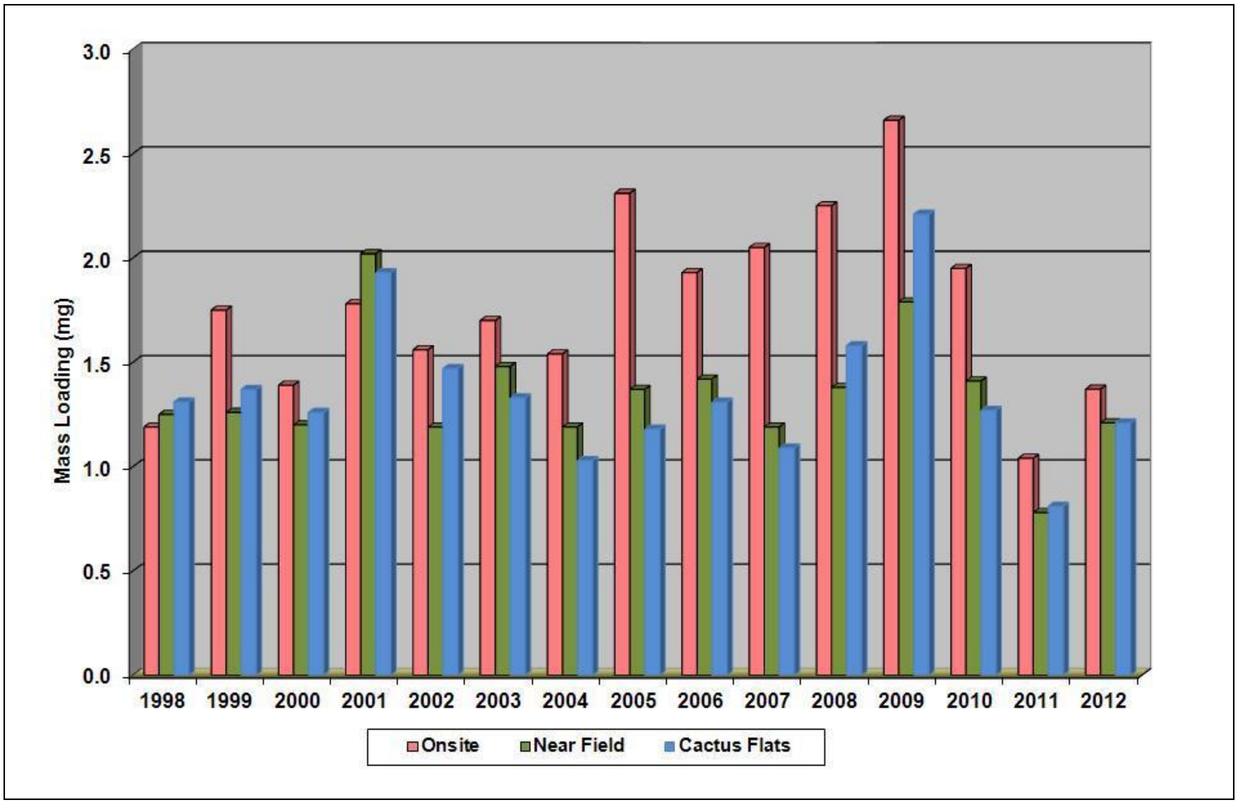


Figure 5.17 Average Ambient Aerosol Mass Loading in Aerosol Air Filters near the WIPP Site

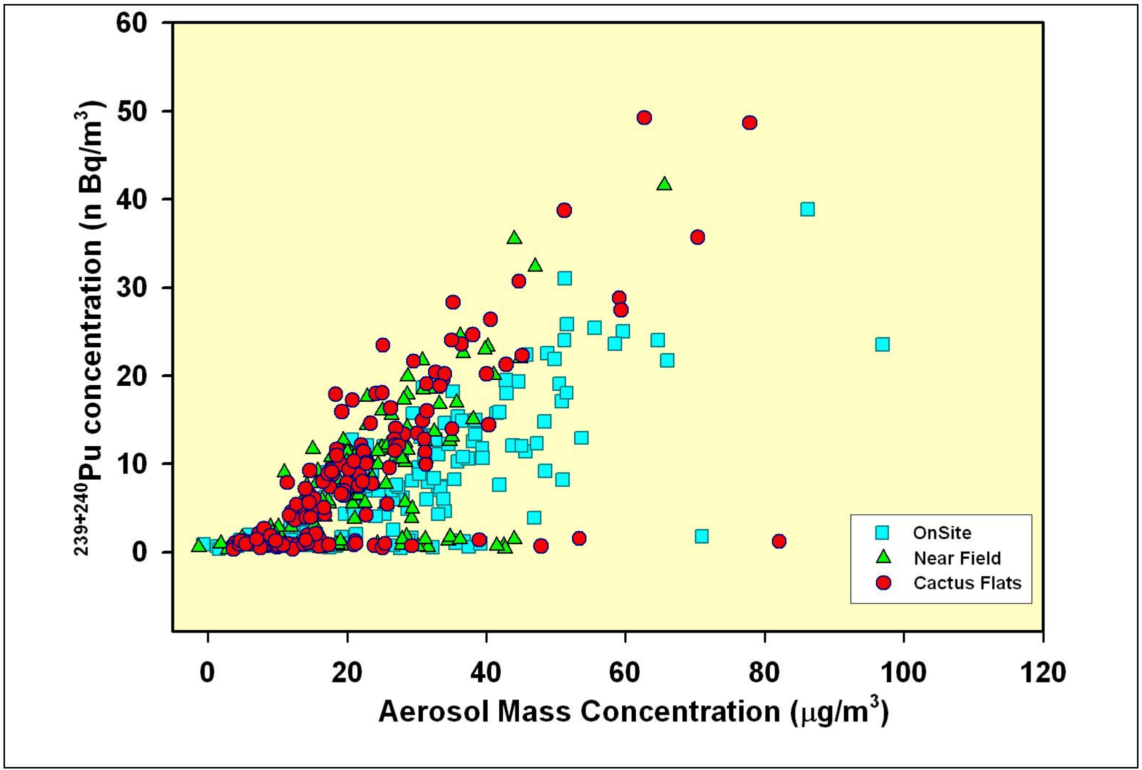


Figure 5.18 Aerosol mass vs. $^{239+240}$Pu activity concentrations in high volume aerosol samples at the three stations near the WIPP site.

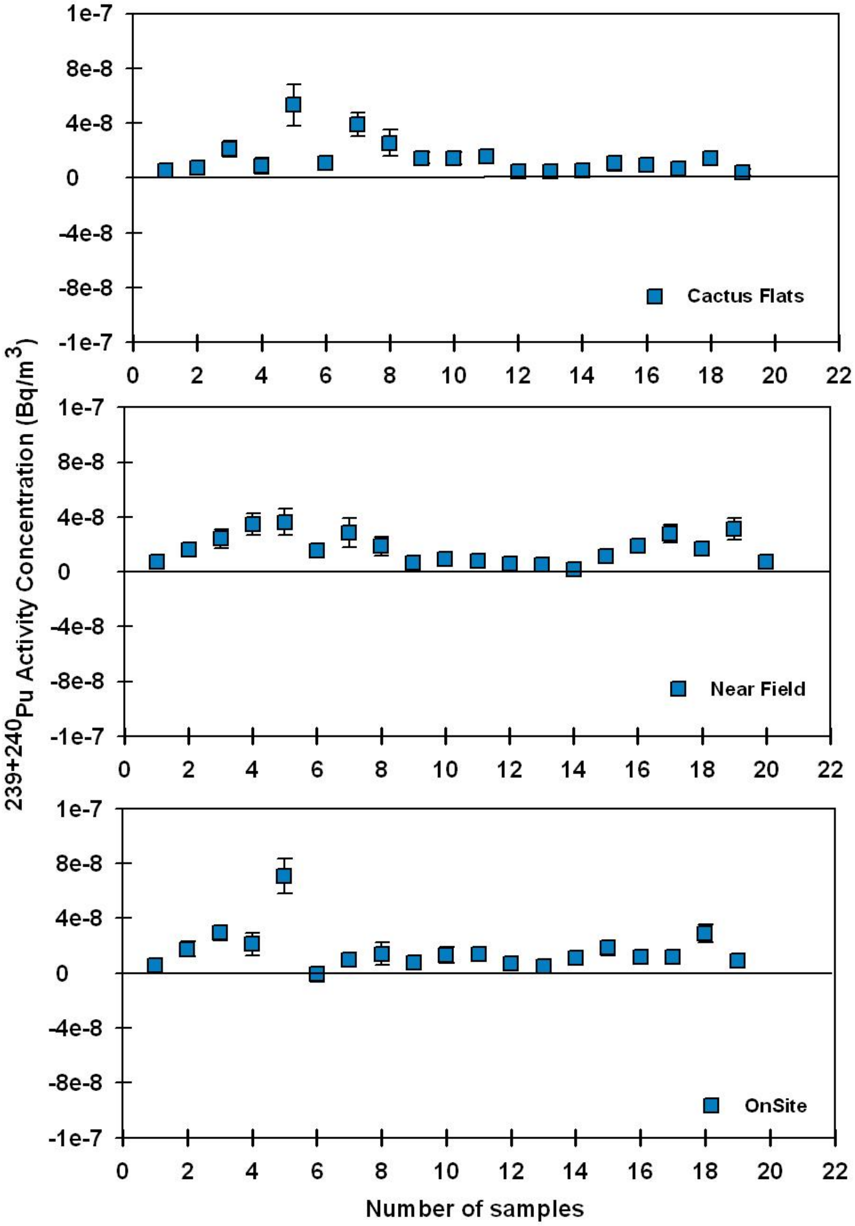


Figure 5.19 $^{239+240}$Pu Concentrations in Aerosol Filters Collected in 2012

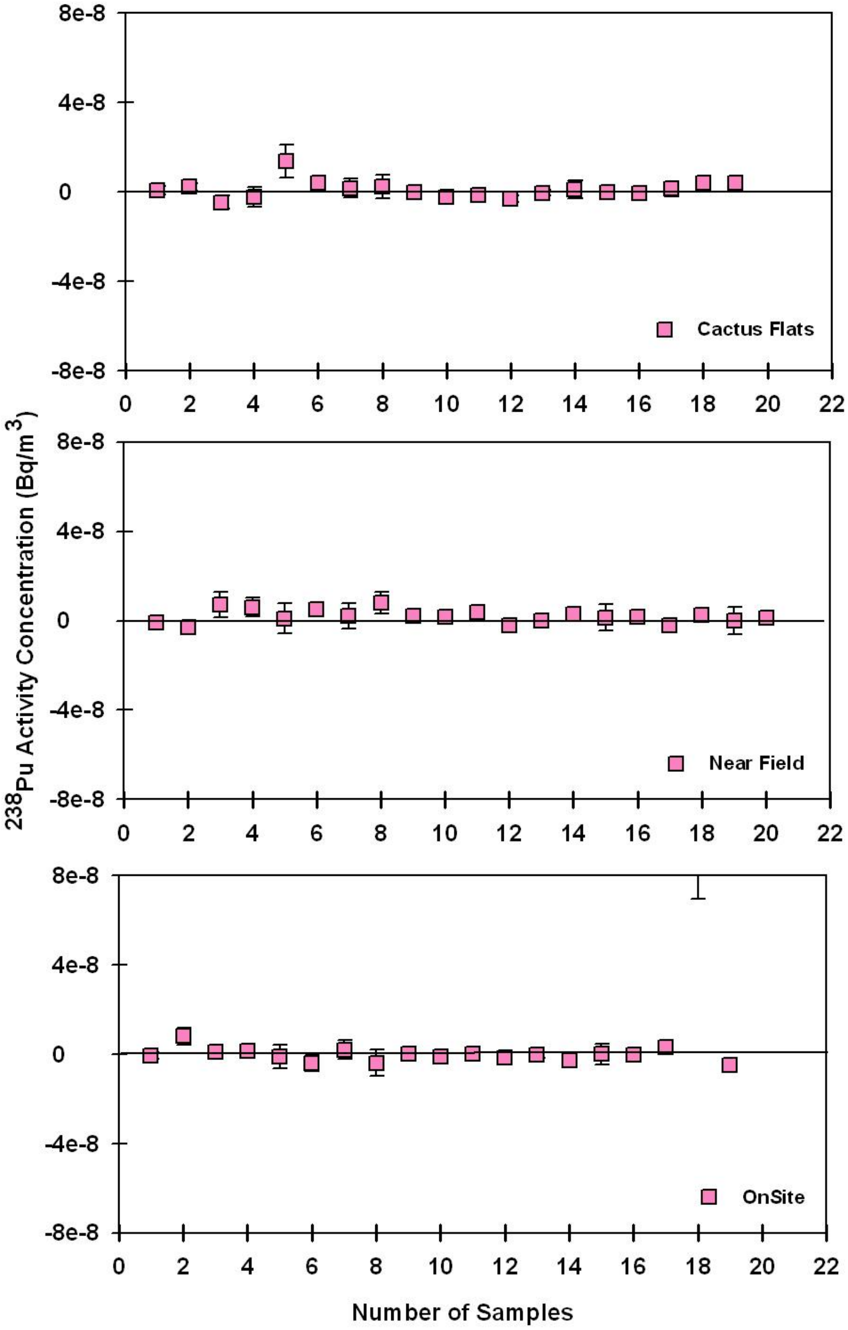


Figure 5.20 ^{238}Pu Concentrations in Aerosol Filters Collected in 2012

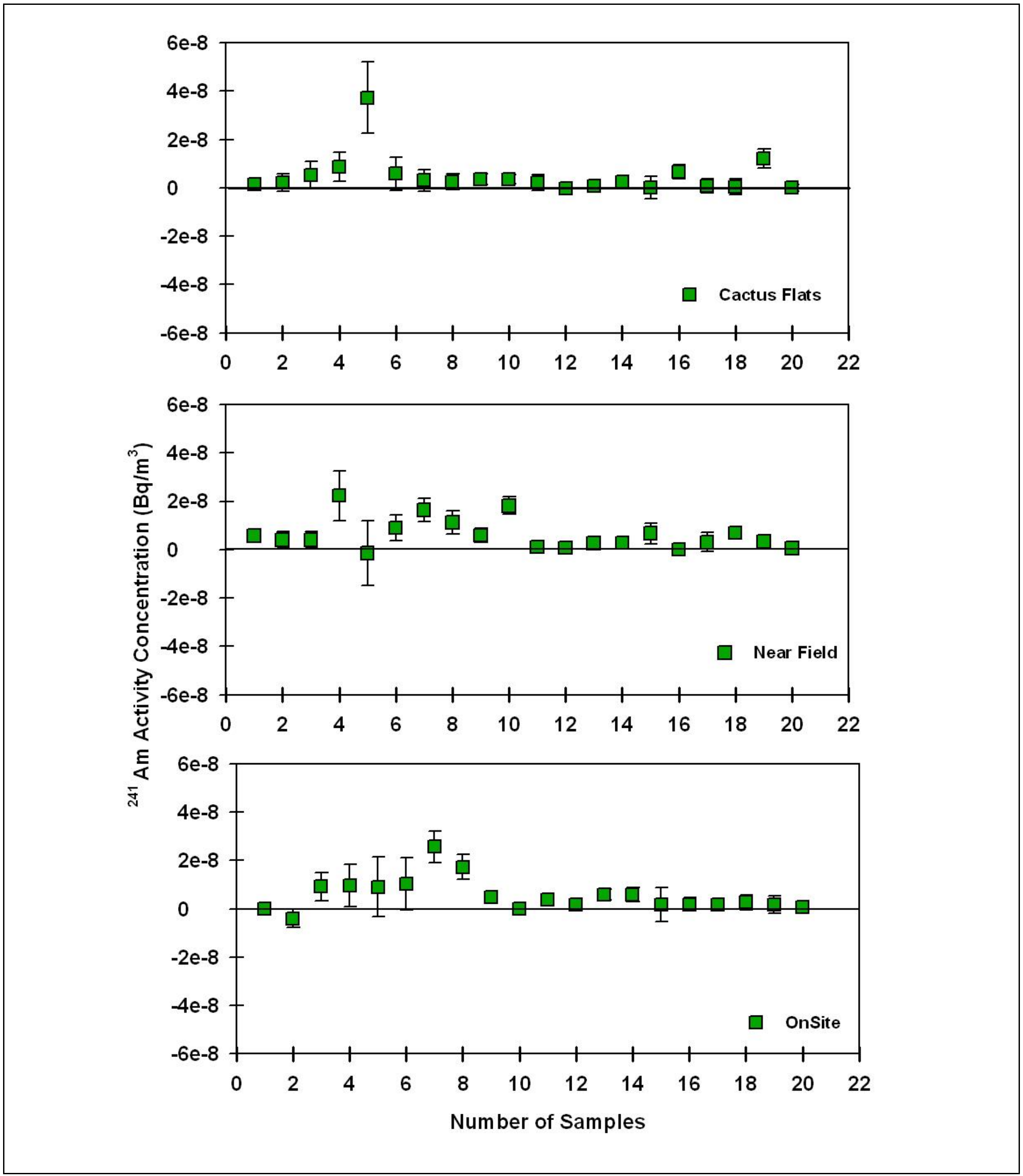


Figure 5.21 ^{241}Am Concentrations in Aerosol Filters Collected in 2012

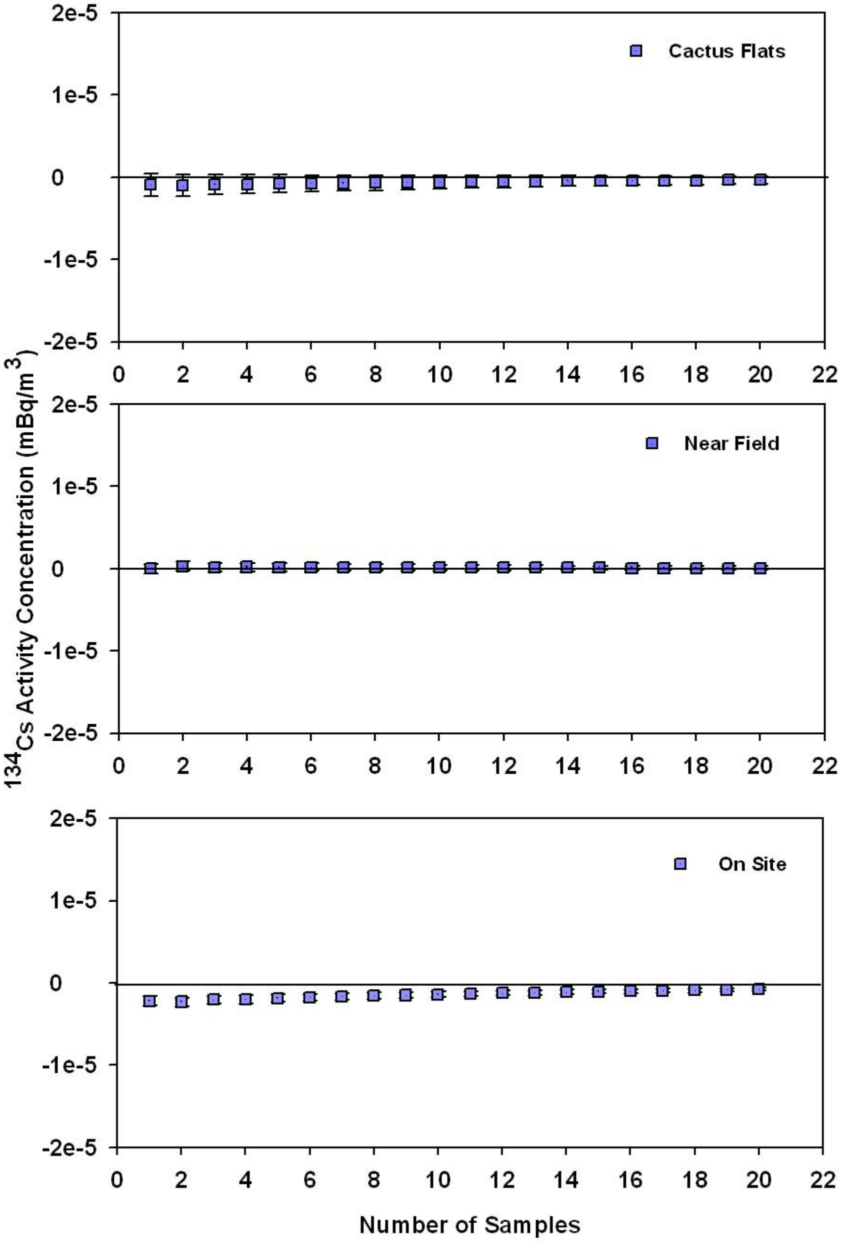


Figure 5.22 ^{134}Cs Concentrations in Aerosol Filters Collected in 2012

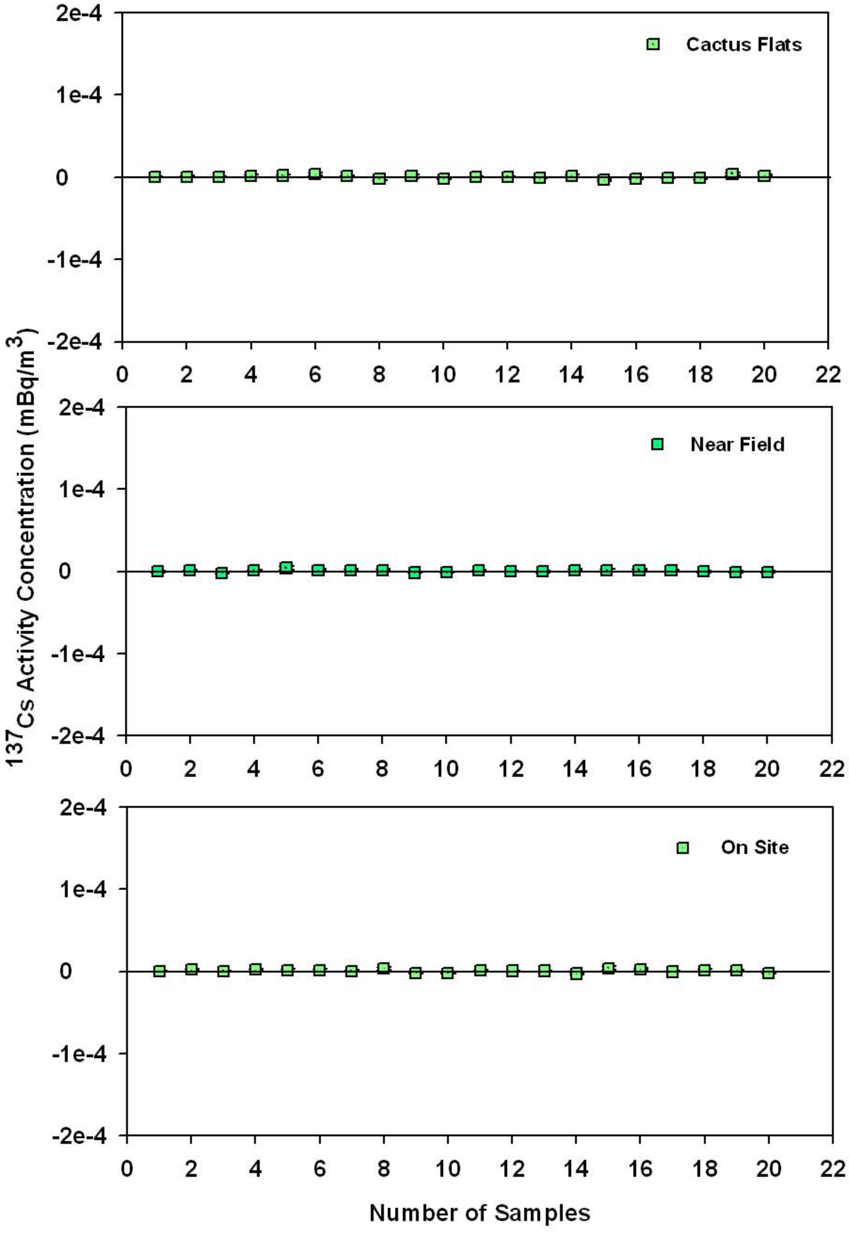


Figure 5.23 ^{137}Cs Concentrations in Aerosol Filters Collected in 2012

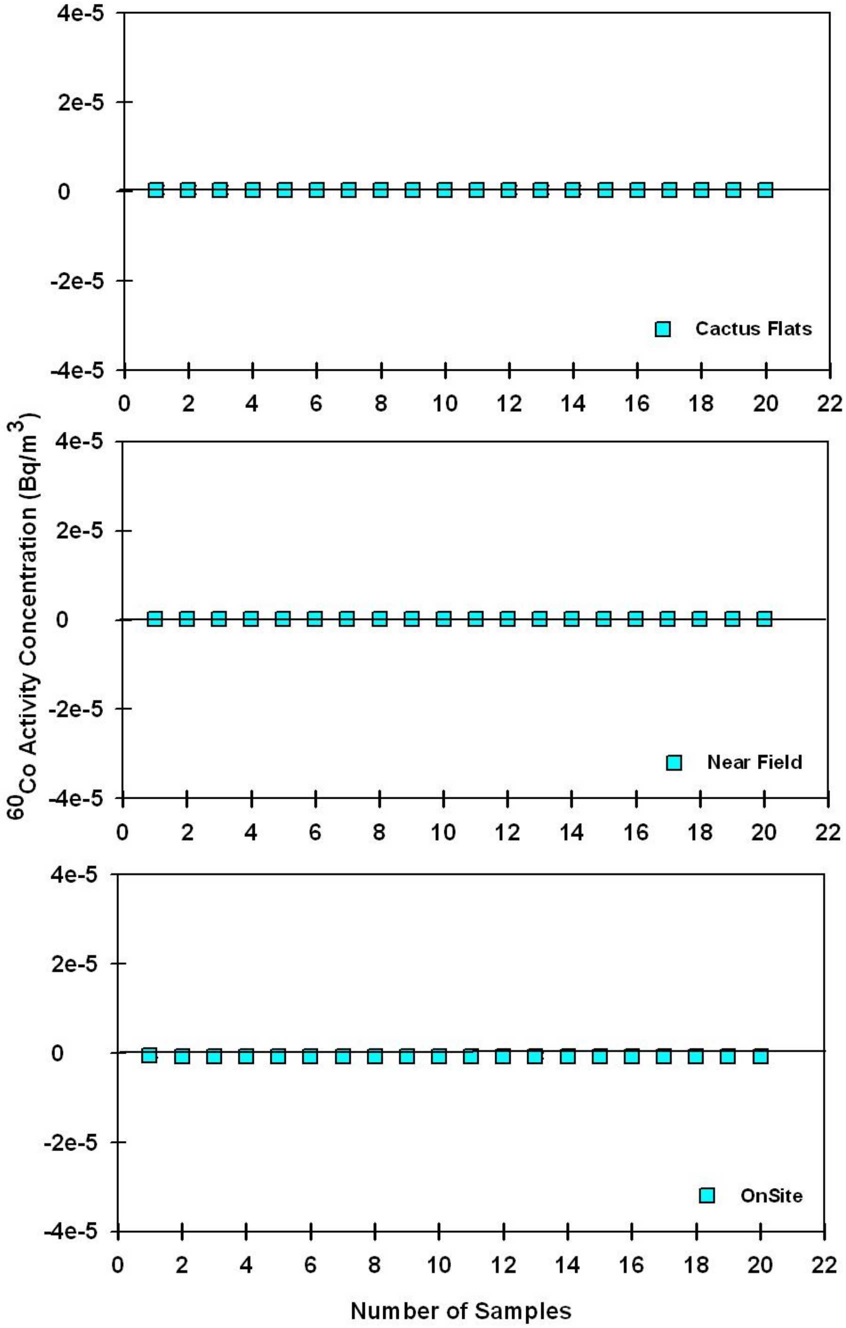


Figure 5.24 ^{60}Co Concentrations in Aerosol Filters Collected in 2012

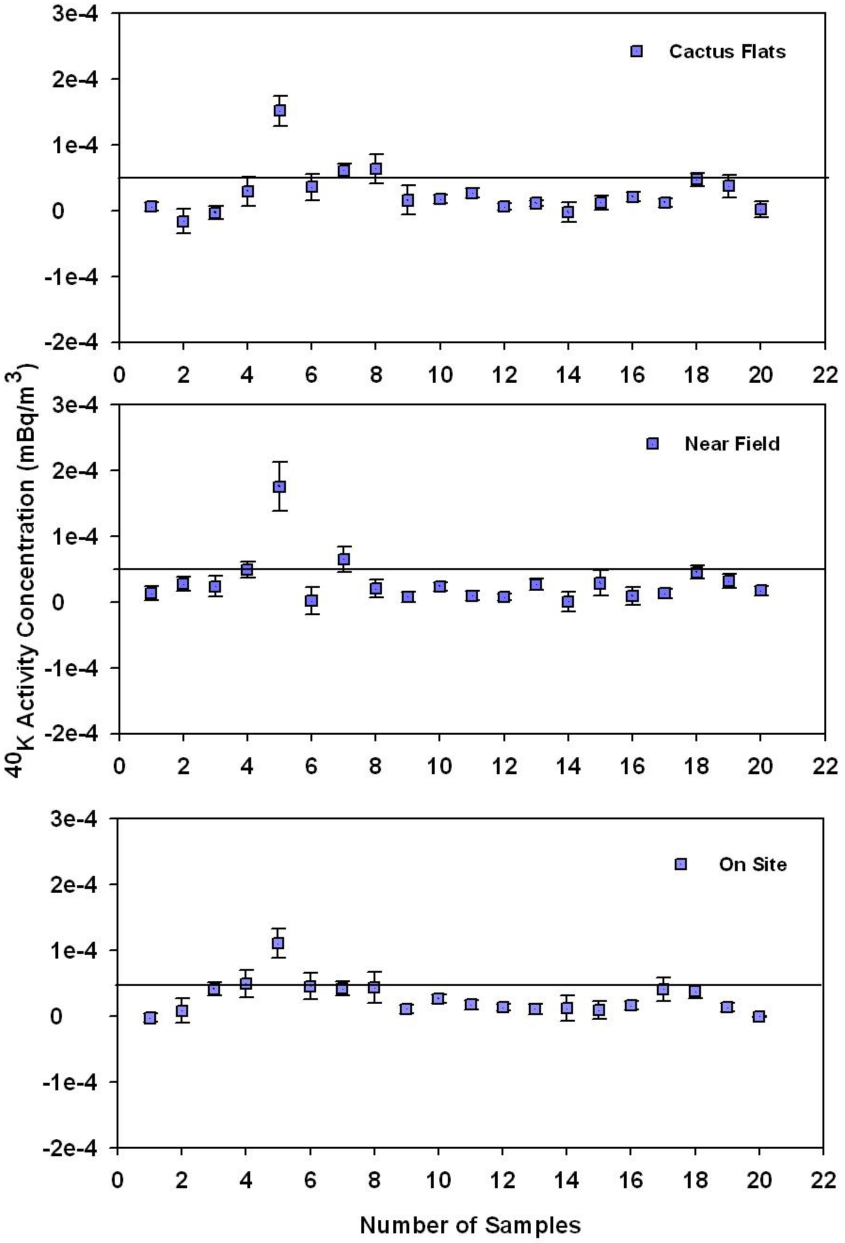


Figure 5.25 ^{40}K Concentrations in Aerosol Filters Collected in 2012

Table 5.3 Radioactivity Concentrations of Individual Sample at On-Site Location in 2012

Radionuclides	Activity (Bq/m^3)	SD (Bq/m^3)	MDC (Bq/m^3)
^{241}Am	-1.25E-10	1.75E-09	7.30E-09
	-3.93E-09	3.77E-09	2.02E-08
	9.12E-09	5.89E-09	1.75E-08
	9.65E-09	8.83E-09	2.94E-08
	9.08E-09	1.23E-08	4.26E-08
	1.04E-08	1.08E-08	3.86E-08
	2.56E-08	6.61E-09	1.02E-08
	1.73E-08	5.24E-09	3.41E-09
	4.77E-09	2.29E-09	5.66E-09
	-1.43E-10	1.63E-09	6.20E-09
	3.76E-09	2.51E-09	7.21E-09
	1.78E-09	1.65E-09	5.13E-09
	5.89E-09	2.08E-09	4.55E-09
	5.85E-09	2.78E-09	6.88E-09
	1.69E-09	6.93E-09	2.52E-08
	1.83E-09	2.75E-09	9.37E-09
	1.64E-09	1.92E-09	6.22E-09
	2.68E-09	3.13E-09	1.02E-08
	1.75E-09	3.52E-09	1.24E-08
	6.11E-10	1.84E-09	6.59E-09
^{238}Pu	-8.24E-10	1.37E-09	7.40E-09
	7.93E-09	3.68E-09	1.02E-08
	9.44E-10	2.50E-09	1.02E-08
	1.24E-09	2.79E-09	1.16E-08
	-1.17E-09	5.21E-09	2.34E-08
	-4.29E-09	3.66E-09	1.81E-08
	1.94E-09	4.33E-09	1.80E-08
	-4.03E-09	5.88E-09	2.70E-08
	0.00E+00	1.56E-09	6.84E-09
	-1.25E-09	3.10E-09	1.33E-08
	0.00E+00	2.50E-09	1.06E-08
	-1.61E-09	1.42E-09	7.04E-09
	-4.59E-10	1.22E-09	5.53E-09
	-2.73E-09	2.73E-09	1.47E-08
	-1.83E-14	4.57E-09	1.86E-08
	-2.66E-10	2.59E-09	1.14E-08
	3.07E-09	1.78E-09	5.41E-09
	8.01E-08	1.06E-08	2.19E-08
	-5.01E-09	3.23E-09	1.45E-08

Table 5.3 Radioactivity Concentrations of Individual Sample at On-Site Location in 2012 (continued)

Radionuclides	Activity (Bq/m^3)	SD (Bq/m^3)	MDC (Bq/m^3)
^{239}Pu	5.57E-09	2.87E-09	8.56E-09
	1.75E-08	5.39E-09	1.32E-08
	2.93E-08	5.77E-09	1.02E-08
	2.13E-08	8.30E-09	2.48E-08
	7.10E-08	1.27E-08	1.89E-08
	-6.39E-10	5.54E-09	2.21E-08
	9.57E-09	4.37E-09	7.50E-09
	1.41E-08	8.30E-09	2.64E-08
	7.61E-09	2.70E-09	6.84E-09
	1.33E-08	5.95E-09	1.82E-08
	1.42E-08	3.76E-09	6.50E-09
	7.00E-09	2.22E-09	4.97E-09
	4.63E-09	1.84E-09	4.94E-09
	1.12E-08	4.96E-09	1.48E-08
	1.85E-08	5.61E-09	1.23E-08
	1.21E-08	5.14E-09	1.51E-08
	1.20E-08	3.06E-09	6.46E-09
	2.88E-08	6.41E-09	1.46E-08
	9.16E-09	4.55E-09	1.43E-08
^{137}Cs	-4.11E-07	5.16E-07	1.72E-06
	2.17E-06	1.20E-06	3.95E-06
	3.64E-07	7.71E-07	2.55E-06
	1.85E-06	1.42E-06	4.69E-06
	7.31E-07	1.74E-06	5.75E-06
	8.99E-07	1.35E-06	4.49E-06
	4.11E-07	8.44E-07	2.79E-06
	3.67E-06	1.48E-06	4.81E-06
	-2.00E-06	5.28E-07	1.78E-06
	-1.87E-06	5.17E-07	1.74E-06
	8.86E-07	5.78E-07	1.90E-06
	5.20E-07	3.86E-07	1.27E-06
	5.42E-07	3.99E-07	1.31E-06
	-2.91E-06	6.77E-07	2.29E-06
	3.89E-06	1.99E-06	6.51E-06
	2.52E-06	1.30E-06	4.27E-06
	-5.21E-07	6.77E-07	2.25E-06
	1.17E-06	1.74E-06	5.74E-06
	1.27E-06	7.55E-07	2.48E-06
	-2.40E-06	5.53E-07	1.87E-06

Table 5.3 Radioactivity Concentrations of Individual Sample at On-Site Location in 2012 (continued)

Radionuclides	Activity (Bq/m^3)	SD (Bq/m^3)	MDC (Bq/m^3)
^{60}K	-2.89E-06	6.53E-06	2.18E-05
	8.13E-06	1.84E-05	6.11E-05
	4.13E-05	9.95E-06	3.21E-05
	4.94E-05	2.11E-05	6.90E-05
	1.11E-04	2.23E-05	7.15E-05
	4.55E-05	1.99E-05	6.51E-05
	4.20E-05	1.11E-05	3.58E-05
	4.35E-05	2.33E-05	7.65E-05
	1.09E-05	6.21E-06	2.04E-05
	2.67E-05	6.19E-06	1.99E-05
	1.73E-05	7.33E-06	2.40E-05
	1.30E-05	4.90E-06	1.60E-05
	1.09E-05	7.88E-06	2.60E-05
	1.19E-05	1.98E-05	6.57E-05
	9.09E-06	1.36E-05	4.51E-05
	1.60E-05	6.59E-06	2.15E-05
	4.10E-05	1.75E-05	5.69E-05
	3.73E-05	9.39E-06	3.04E-05
	1.31E-05	6.39E-06	2.10E-05
^{60}Co	-5.38E-07	6.20E-07	2.08E-06
	-8.54E-07	6.60E-07	2.21E-06
	-6.96E-07	6.40E-07	2.14E-06
	-7.75E-07	6.50E-07	2.18E-06
	-7.35E-07	6.45E-07	2.16E-06
	-7.55E-07	6.48E-07	2.17E-06
	-7.45E-07	6.47E-07	2.17E-06
	-7.50E-07	6.47E-07	2.17E-06
	-7.48E-07	6.47E-07	2.17E-06
	-7.49E-07	6.47E-07	2.17E-06
	-7.48E-07	6.47E-07	2.17E-06
	-7.48E-07	6.47E-07	2.17E-06
	-7.48E-07	6.47E-07	2.17E-06
	-7.48E-07	6.47E-07	2.17E-06
	-7.48E-07	6.47E-07	2.17E-06
	-7.48E-07	6.47E-07	2.17E-06
	-7.48E-07	6.47E-07	2.17E-06
	-7.48E-07	6.47E-07	2.17E-06
	-7.48E-07	6.47E-07	2.17E-06
	-7.48E-07	6.47E-07	2.17E-06

Table 5.4 Radioactivity Concentrations of Individual Sample at Near Field Location in 2012

Radionuclides	Activity (Bq/m^3)	SD (Bq/m^3)	MDC (Bq/m^3)
^{241}Am	5.83E-09	2.22E-09	4.50E-09
	4.17E-09	3.48E-09	1.05E-08
	4.04E-09	3.35E-09	9.83E-09
	2.24E-08	1.03E-08	2.66E-08
	-1.44E-09	1.34E-08	5.91E-08
	8.98E-09	5.27E-09	1.57E-08
	1.65E-08	4.78E-09	9.47E-09
	1.12E-08	4.87E-09	1.03E-08
	5.89E-09	3.00E-09	8.06E-09
	1.82E-08	3.67E-09	5.49E-09
	1.21E-09	2.22E-09	7.58E-09
	7.75E-10	1.74E-09	6.12E-09
	2.75E-09	1.40E-09	1.25E-09
	2.93E-09	2.38E-09	6.98E-09
	6.73E-09	4.37E-09	1.22E-08
	1.23E-10	2.55E-09	9.74E-09
	3.12E-09	3.94E-09	1.31E-08
	7.03E-09	2.30E-09	4.07E-09
	3.33E-09	2.88E-09	8.04E-09
	6.28E-10	1.87E-09	6.70E-09
^{238}Pu	-8.08E-10	1.81E-09	8.71E-09
	-2.96E-09	3.22E-09	1.51E-08
	7.23E-09	5.74E-09	1.95E-08
	6.04E-09	4.36E-09	1.45E-08
	8.52E-10	6.79E-09	2.79E-08
	4.82E-09	2.96E-09	8.87E-09
	2.13E-09	5.80E-09	2.37E-08
	7.83E-09	4.81E-09	1.45E-08
	2.16E-09	2.78E-09	1.03E-08
	1.48E-09	2.35E-09	8.91E-09
	3.79E-09	2.01E-09	5.58E-09
	-2.30E-09	1.22E-09	6.48E-09
	0.00E+00	2.56E-09	1.06E-08
	3.12E-09	3.12E-09	1.12E-08
	1.39E-09	5.76E-09	2.22E-08
	1.68E-09	2.03E-09	7.66E-09
	-1.91E-09	1.91E-09	1.03E-08
	2.65E-09	2.48E-09	8.69E-09

Table 5.4 Radioactivity Concentrations of Individual Sample at Near Field Location in 2012 (continued)

Radionuclides	Activity (Bq/m^3)	SD (Bq/m^3)	MDC (Bq/m^3)
	-5.02E-14	5.96E-09	2.40E-08
	1.23E-09	1.79E-09	6.81E-09
^{239}Pu	7.29E-09	4.64E-09	1.52E-08
	1.61E-08	4.47E-09	8.04E-09
	2.43E-08	6.93E-09	1.46E-08
	3.48E-08	7.73E-09	1.70E-08
	3.62E-08	9.69E-09	1.83E-08
	1.57E-08	4.98E-09	1.11E-08
	2.85E-08	1.05E-08	2.88E-08
	1.87E-08	6.67E-09	1.45E-08
	6.88E-09	2.90E-09	7.68E-09
	9.66E-09	3.71E-09	1.05E-08
	8.17E-09	2.91E-09	7.04E-09
	5.64E-09	1.86E-09	4.25E-09
	4.85E-09	3.24E-09	1.06E-08
	1.84E-09	3.32E-09	1.28E-08
	1.12E-08	5.23E-09	1.51E-08
	1.90E-08	4.31E-09	7.66E-09
	2.79E-08	6.55E-09	1.58E-08
	1.65E-08	3.81E-09	7.93E-09
	3.12E-08	7.89E-09	1.52E-08
	7.40E-09	3.20E-09	9.44E-09
^{137}Cs	-3.87E-07	7.64E-07	2.56E-06
	7.94E-07	8.57E-07	2.83E-06
	-1.72E-06	1.17E-06	3.95E-06
	1.08E-06	9.22E-07	3.04E-06
	4.05E-06	2.48E-06	8.16E-06
	1.37E-06	1.31E-06	4.31E-06
	1.51E-06	1.28E-06	4.22E-06
	1.33E-06	1.09E-06	3.58E-06
	-1.57E-06	6.23E-07	2.09E-06
	-1.37E-06	5.08E-07	1.71E-06
	7.27E-07	5.73E-07	1.89E-06
	2.53E-07	3.93E-07	1.30E-06
	-2.15E-07	9.20E-07	3.06E-06
	1.54E-06	1.53E-06	5.04E-06
	1.30E-06	1.96E-06	6.50E-06
	1.64E-06	1.36E-06	4.49E-06

Table 5.4 Radioactivity Concentrations of Individual Sample at Near Field Location in 2012 (continued)

Radionuclides	Activity (Bq/m^3)	SD (Bq/m^3)	MDC (Bq/m^3)
	1.04E-06	6.59E-07	2.17E-06
	-3.62E-07	1.12E-06	3.71E-06
	-8.83E-07	1.15E-06	3.81E-06
	-7.48E-07	7.57E-07	2.52E-06
^{40}K	1.26E-05	1.07E-05	3.55E-05
	2.74E-05	1.10E-05	3.58E-05
	2.36E-05	1.56E-05	5.12E-05
	4.91E-05	1.16E-05	3.75E-05
	1.75E-04	3.71E-05	1.18E-04
	1.32E-06	2.04E-05	6.82E-05
	6.47E-05	1.86E-05	6.00E-05
	2.02E-05	1.37E-05	4.50E-05
	7.79E-06	7.62E-06	2.52E-05
	2.36E-05	6.26E-06	2.03E-05
	9.29E-06	7.43E-06	2.45E-05
	7.37E-06	4.75E-06	1.56E-05
	2.64E-05	8.51E-06	2.74E-05
	3.83E-07	1.47E-05	4.92E-05
	2.83E-05	1.94E-05	6.40E-05
	9.32E-06	1.37E-05	4.55E-05
	1.25E-05	6.70E-06	2.19E-05
	4.52E-05	1.07E-05	3.40E-05
	3.17E-05	1.08E-05	3.50E-05
	1.72E-05	7.36E-06	2.40E-05
^{60}Co	1.94E-07	5.76E-07	1.92E-06
	2.19E-07	5.42E-07	1.80E-06
	2.07E-07	5.59E-07	1.86E-06
	2.13E-07	5.51E-07	1.83E-06
	2.10E-07	5.55E-07	1.85E-06
	2.11E-07	5.53E-07	1.84E-06
	2.11E-07	5.54E-07	1.84E-06
	2.11E-07	5.53E-07	1.84E-06
	2.11E-07	5.54E-07	1.84E-06
	2.11E-07	5.53E-07	1.84E-06
	2.11E-07	5.53E-07	1.84E-06
	2.11E-07	5.53E-07	1.84E-06
	2.11E-07	5.53E-07	1.84E-06

Table 5.4 Radioactivity Concentrations of Individual Sample at Near Field Location in 2012 (continued)

Radionuclides	Activity (Bq/m^3)	SD (Bq/m^3)	MDC (Bq/m^3)
	2.11E-07	5.53E-07	1.84E-06
	2.11E-07	5.53E-07	1.84E-06
	2.11E-07	5.53E-07	1.84E-06
	2.11E-07	5.53E-07	1.84E-06
	2.11E-07	5.53E-07	1.84E-06
	2.11E-07	5.53E-07	1.84E-06
	2.11E-07	5.53E-07	1.84E-06

Table 5.5 Radioactivity Concentrations of Individual Sample at Cactus Flats Location in 2012

Radionuclides	Activity (Bq/m^3)	SD (Bq/m^3)	MDC (Bq/m^3)
^{241}Am	1.68E-09	1.44E-09	1.74E-09
	2.21E-09	3.73E-09	1.34E-08
	5.35E-09	5.55E-09	1.85E-08
	8.76E-09	5.92E-09	1.64E-08
	3.73E-08	1.48E-08	4.33E-08
	5.89E-09	6.77E-09	2.43E-08
	3.18E-09	4.45E-09	1.52E-08
	2.64E-09	3.33E-09	1.00E-08
	3.64E-09	2.15E-09	5.71E-09
	3.47E-09	1.89E-09	4.39E-09
	2.17E-09	3.29E-09	1.13E-08
	-1.30E-10	2.31E-09	8.58E-09
	8.49E-10	1.39E-09	4.72E-09
	2.51E-09	2.42E-09	7.47E-09
	1.72E-10	4.58E-09	1.73E-08
	6.78E-09	2.93E-09	6.19E-09
	9.50E-10	2.90E-09	1.02E-08
	5.84E-10	3.32E-09	1.19E-08
	1.22E-08	3.93E-09	8.17E-09
	9.02E-11	1.34E-09	4.92E-09
^{238}Pu	6.79E-10	1.80E-09	7.31E-09
	2.16E-09	1.87E-09	2.92E-09
	-4.64E-09	2.78E-09	1.39E-08
	-2.28E-09	4.52E-09	1.94E-08
	1.37E-08	7.26E-09	2.02E-08
	4.02E-09	3.00E-09	9.89E-09

Table 5.5 Radioactivity Concentrations of Individual Sample at Cactus Flats Location in 2012 (continued)

Radionuclides	Activity (Bq/m^3)	SD (Bq/m^3)	MDC (Bq/m^3)
	1.63E-09	4.30E-09	1.76E-08
	2.18E-09	5.22E-09	2.18E-08
	0.00E+00	2.08E-09	8.80E-09
	-2.25E-09	2.49E-09	1.13E-08
	-1.44E-09	2.93E-09	1.26E-08
	-2.98E-09	1.50E-09	7.54E-09
	-4.53E-10	1.36E-09	5.95E-09
	1.22E-09	4.05E-09	1.60E-08
	-3.57E-15	2.18E-09	1.13E-08
	-8.14E-10	2.69E-09	1.14E-08
	1.27E-09	3.41E-09	1.37E-08
	3.86E-09	1.83E-09	5.12E-09
	3.82E-09	2.13E-09	6.39E-09
^{239}Pu	5.44E-09	3.20E-09	1.02E-08
	7.56E-09	4.71E-09	1.52E-08
	2.13E-08	5.65E-09	1.39E-08
	9.04E-09	5.92E-09	1.94E-08
	5.34E-08	1.52E-08	3.76E-08
	1.08E-08	5.01E-09	1.44E-08
	3.90E-08	8.37E-09	1.19E-08
	2.55E-08	9.59E-09	2.49E-08
	1.44E-08	4.14E-09	1.03E-08
	1.43E-08	4.32E-09	1.13E-08
	1.55E-08	4.03E-09	7.97E-09
	4.53E-09	1.73E-09	4.33E-09
	4.72E-09	2.39E-09	7.45E-09
	5.49E-09	4.49E-09	1.53E-08
	1.08E-08	5.57E-09	1.66E-08
	9.73E-09	3.25E-09	7.55E-09
	7.03E-09	3.32E-09	8.65E-09
	1.41E-08	3.01E-09	5.12E-09
	4.14E-09	2.58E-09	8.27E-09
^{137}Cs	-3.30E-08	5.06E-07	1.68E-06
	4.29E-07	1.28E-06	4.24E-06
	4.45E-08	7.57E-07	2.51E-06
	1.40E-06	1.37E-06	4.54E-06
	1.91E-06	1.73E-06	5.72E-06

Table 5.5 Radioactivity Concentrations of Individual Sample at Cactus Flats Location in 2012 (continued)

Radionuclides	Activity (Bq/m^3)	SD (Bq/m^3)	MDC (Bq/m^3)
	3.61E-06	1.34E-06	4.35E-06
	1.57E-06	8.45E-07	2.78E-06
	-1.80E-06	1.67E-06	5.60E-06
	1.35E-06	2.40E-06	7.94E-06
	-1.73E-06	5.19E-07	1.75E-06
	5.15E-07	5.89E-07	1.95E-06
	7.63E-07	3.85E-07	1.26E-06
	-1.13E-06	3.91E-07	1.31E-06
	1.83E-06	1.49E-06	4.92E-06
	-3.50E-06	9.10E-07	3.07E-06
	-1.70E-06	6.09E-07	2.05E-06
	-4.19E-07	6.80E-07	2.26E-06
	-1.23E-06	1.10E-06	3.67E-06
	4.22E-06	1.72E-06	5.62E-06
	1.81E-06	1.22E-06	4.01E-06
^{40}K	5.54E-06	6.41E-06	2.12E-05
	-1.65E-05	1.84E-05	6.19E-05
	-3.31E-06	9.62E-06	3.21E-05
	2.95E-05	2.21E-05	7.29E-05
	1.51E-04	2.24E-05	7.06E-05
	3.60E-05	2.01E-05	6.59E-05
	6.06E-05	1.08E-05	3.46E-05
	6.35E-05	2.26E-05	7.34E-05
	1.54E-05	2.23E-05	7.40E-05
	1.72E-05	6.34E-06	2.07E-05
	2.65E-05	7.34E-06	2.38E-05
	5.83E-06	4.81E-06	1.59E-05
	1.10E-05	4.57E-06	1.49E-05
	-2.80E-06	1.48E-05	4.97E-05
	1.20E-05	1.05E-05	3.46E-05
	2.08E-05	6.96E-06	2.27E-05
	1.24E-05	6.44E-06	2.11E-05
	4.71E-05	1.04E-05	3.30E-05
	3.69E-05	1.73E-05	5.65E-05
	1.26E-06	1.22E-05	4.06E-05
^{60}Co	3.16E-07	1.04E-06	3.48E-06
	3.78E-07	9.40E-07	3.14E-06

Table 5.5 Radioactivity Concentrations of Individual Sample at Cactus Flats Location in 2012 (continued)

Radionuclides	Activity (Bq/m3)	SD (Bq/m3)	MDC (Bq/m3)
	3.47E-07	9.91E-07	3.31E-06
	3.62E-07	9.65E-07	3.22E-06
	3.55E-07	9.78E-07	3.26E-06
	3.58E-07	9.72E-07	3.24E-06
	3.57E-07	9.75E-07	3.25E-06
	3.57E-07	9.74E-07	3.25E-06
	3.57E-07	9.74E-07	3.25E-06
	3.57E-07	9.74E-07	3.25E-06
	3.57E-07	9.74E-07	3.25E-06
	3.57E-07	9.74E-07	3.25E-06
	3.57E-07	9.74E-07	3.25E-06
	3.57E-07	9.74E-07	3.25E-06
	3.57E-07	9.74E-07	3.25E-06
	3.57E-07	9.74E-07	3.25E-06
	3.57E-07	9.74E-07	3.25E-06
	3.57E-07	9.74E-07	3.25E-06
	3.57E-07	9.74E-07	3.25E-06
	3.57E-07	9.74E-07	3.25E-06

Table 5.6 Minimum, Maximum, and Average Radionuclide Concentrations (Bq/m^3) in Aerosol Filters at On Site Station

Radionuclide		Concentration	SD	MDC
	2010			
^{241}Am	Minimum	-2.83E-12	4.75E-10	4.16E-10
	Maximum	5.58E-09	1.93E-09	6.13E-09
	Average	1.87E-09	1.07E-09	2.81E-09
^{238}Pu	Minimum	-4.09E-09	7.34E-10	2.54E-09
	Maximum	2.42E-09	5.04E-09	2.27E-08
	Average	2.50E-10	2.01E-09	8.01E-09
$^{239+240}$Pu	Minimum	5.66E-10	7.81E-10	2.94E-09
	Maximum	1.20E-08	6.73E-09	2.12E-08
	Average	5.48E-09	2.57E-09	7.68E-09
^{234}U	Minimum	3.82E-07	1.24E-08	2.02E-09
	Maximum	1.46E-06	4.11E-08	1.36E-08
	Average	8.70E-07	2.71E-08	6.87E-09
^{235}U	Minimum	1.54E-08	1.95E-09	1.71E-09
	Maximum	5.39E-08	7.12E-09	9.07E-09
	Average	3.74E-08	4.97E-09	5.21E-09
^{238}U	Minimum	3.62E-07	1.19E-08	2.46E-09
	Maximum	1.27E-06	3.73E-08	9.64E-09
	Average	8.06E-07	2.57E-08	5.71E-09

Table 5.6 Minimum, Maximum, and Average Radionuclide Concentrations (Bq/m^3) in Aerosol Filters at On Site Station (continued)

Radionuclide		Concentration	SD	MDC
	2010			
^{137}Cs	Minimum	-1.11E-06	2.38E-07	7.82E-07
	Maximum	1.08E-06	1.27E-06	4.24E-06
	Average	6.17E-08	5.91E-07	1.97E-06
^{60}Co	Minimum	-3.32E-06	2.82E-07	9.26E-07
	Maximum	2.48E-06	1.28E-06	4.29E-06
	Average	1.62E-07	6.37E-07	2.13E-06
^{40}K	Minimum	1.06E-05	2.95E-06	9.47E-06
	Maximum	7.39E-05	1.22E-05	3.72E-05
	Average	2.63E-05	6.16E-06	1.95E-05
	2011			
^{241}Am	Minimum	-2.04E-09	1.75E-09	3.13E-09
	Maximum	1.36E-08	7.51E-09	2.63E-08
	Average	3.62E-09	3.81E-09	1.12E-08
^{238}Pu	Minimum	-1.19E-08	1.87E-09	5.99E-09
	Maximum	1.46E-08	1.41E-08	5.48E-08
	Average	1.44E-09	5.96E-09	2.40E-08
$^{239+240}$Pu	Minimum	1.37E-09	2.45E-09	5.38E-09
	Maximum	3.92E-08	1.44E-08	5.24E-08
	Average	1.83E-08	8.14E-09	2.26E-08
^{234}U	Minimum	1.99E-07	6.17E-10	-1.02E-07
	Maximum	4.73E-06	1.02E-07	-7.64E-09
	Average	1.53E-06	3.29E-08	-3.57E-08
^{235}U	Minimum	8.79E-10	-1.61E-09	-1.46E-08
	Maximum	2.62E-07	1.35E-08	3.31E-08
	Average	8.16E-08	4.60E-09	6.29E-09
^{238}U	Minimum	-9.01E-08	-1.03E-08	-1.33E-07
	Maximum	3.92E-06	7.91E-08	-1.81E-08
	Average	1.11E-06	1.91E-08	-4.86E-08
^{134}Cs	Minimum	-5.82E-06	3.32E-07	1.12E-06
	Maximum	2.26E-04	5.72E-06	1.62E-05
	Average	9.26E-06	1.76E-06	5.30E-06
^{137}Cs	Minimum	-5.82E-06	3.32E-07	1.12E-06
	Maximum	2.49E-04	5.72E-06	1.62E-05
	Average	2.08E-05	1.59E-06	4.62E-06
^{60}Co	Minimum	-2.49E-05	4.45E-07	1.49E-06
	Maximum	2.37E-05	4.70E-05	1.57E-04
	Average	1.48E-06	5.08E-06	1.69E-05
^{40}K	Minimum	-2.49E-05	5.27E-06	1.75E-05
	Maximum	2.37E-05	4.70E-05	1.57E-04
	Average	3.18E-06	1.74E-05	5.78E-05
	2012			
^{241}Am	Minimum	-3.93E-09	1.63E-09	3.41E-09
	Maximum	2.56E-08	1.23E-08	4.26E-08
	Average	5.46E-09	4.41E-09	1.37E-08
^{238}Pu	Minimum	-5.01E-09	1.22E-09	5.41E-09
	Maximum	8.01E-08	1.06E-08	2.70E-08
	Average	3.87E-09	3.41E-09	1.35E-08

Table 5.6 Minimum, Maximum, and Average Radionuclide Concentrations (Bq/m^3) in Aerosol Filters at On Site Station (continued)

Radionuclide		Concentration	SD	MDC
	2012			
$^{239+240}$Pu	Minimum	-6.39E-10	1.84E-09	4.94E-09
	Maximum	7.10E-08	1.27E-08	2.64E-08
	Average	1.61E-08	5.23E-09	1.32E-08
^{234}U	Minimum	7.40E-08	-2.48E-06	-2.69E-06
	Maximum	5.26E-06	-5.69E-07	-5.89E-07
	Average	1.12E-06	-1.07E-06	-1.13E-06
^{235}U	Minimum	4.34E-07	-8.20E-08	-7.96E-08
	Maximum	-3.89E-08	-1.54E-07	-1.53E-07
	Average	4.34E-07	-8.20E-08	-7.96E-08
^{238}U	Minimum	-2.21E-07	-3.28E-06	-3.46E-06
	Maximum	8.01E-06	-4.43E-08	-4.64E-08
	Average	9.19E-07	-1.36E-06	-1.41E-06
^{134}Cs	Minimum	-2.30E-06	1.85E-07	6.28E-07
	Maximum	-7.85E-07	5.46E-07	1.85E-06
	Average	-1.43E-06	3.38E-07	1.15E-06
^{137}Cs	Minimum	-2.91E-06	3.86E-07	1.27E-06
	Maximum	3.89E-06	1.99E-06	6.51E-06
	Average	5.40E-07	9.71E-07	3.21E-06
^{60}Co	Minimum	-8.54E-07	6.20E-07	2.08E-06
	Maximum	-5.38E-07	6.60E-07	2.21E-06
	Average	-7.41E-07	6.46E-07	2.16E-06
^{40}K	Minimum	-2.89E-06	4.90E-06	1.60E-05
	Maximum	1.11E-04	2.33E-05	7.65E-05
	Average	2.87E-05	1.25E-05	4.10E-05

Table 5.7 Minimum, Maximum, and Average Radionuclide Concentrations (Bq/m^3) in Aerosol Filters at Near Field Station

Radionuclide		Concentration	SD	MDC
	2010			
^{241}Am	Minimum	-1.03E-12	5.34E-10	8.73E-10
	Maximum	4.43E-09	1.57E-09	3.49E-09
	Average	1.39E-09	8.79E-10	2.17E-09
^{238}Pu	Minimum	-1.08E-09	7.94E-10	2.50E-09
	Maximum	1.23E-09	2.76E-09	1.28E-08
	Average	2.39E-10	1.35E-09	5.75E-09
$^{239+240}$Pu	Minimum	0.00E+00	1.28E-09	2.62E-09
	Maximum	7.31E-09	5.35E-09	1.81E-08
	Average	4.82E-09	2.39E-09	7.26E-09
^{234}U	Minimum	3.60E-07	1.13E-08	2.59E-09
	Maximum	1.32E-06	3.86E-08	9.63E-09
	Average	6.92E-07	2.21E-08	5.49E-09
^{235}U	Minimum	1.26E-08	2.02E-09	9.24E-10
	Maximum	8.44E-08	9.15E-09	1.15E-08
	Average	3.15E-08	4.34E-09	5.01E-09

Table 5.7 Minimum, Maximum, and Average Radionuclide Concentrations (Bq/m^3) in Aerosol Filters at Near Field Station (continued)

Radionuclide		Concentration	SD	MDC
	2010			
^{238}U	Minimum	3.47E-07	1.10E-08	2.31E-09
	Maximum	1.19E-06	3.59E-08	9.61E-09
	Average	6.50E-07	2.12E-08	5.72E-09
^{137}Cs	Minimum	-3.07E-07	2.34E-07	7.75E-07
	Maximum	9.05E-07	8.96E-07	2.97E-06
	Average	3.55E-07	4.93E-07	1.63E-06
^{60}Co	Minimum	-1.82E-06	2.74E-07	9.03E-07
	Maximum	1.52E-06	9.99E-07	3.42E-06
	Average	-1.11E-07	5.52E-07	1.85E-06
^{40}K	Minimum	5.35E-06	2.26E-06	6.59E-06
	Maximum	3.77E-05	8.94E-06	2.91E-05
	Average	1.99E-05	5.39E-06	1.73E-05
	2011			
^{241}Am	Minimum	-7.04E-10	1.10E-09	3.62E-09
	Maximum	2.11E-08	8.99E-09	2.64E-08
	Average	5.24E-09	4.63E-09	1.34E-08
^{238}Pu	Minimum	-2.21E-08	1.24E-09	6.17E-09
	Maximum	1.88E-08	1.92E-08	8.54E-08
	Average	1.28E-09	6.46E-09	2.56E-08
$^{239+240}$Pu	Minimum	-1.34E-09	2.58E-09	3.16E-09
	Maximum	4.40E-08	2.01E-08	5.62E-08
	Average	1.94E-08	8.69E-09	2.41E-08
^{234}U	Minimum	4.85E-07	7.46E-09	-8.68E-08
	Maximum	4.26E-06	7.43E-08	-9.78E-09
	Average	1.51E-06	3.34E-08	-3.57E-08
^{235}U	Minimum	-4.26E-09	-1.26E-09	-2.07E-08
	Maximum	7.55E-07	5.01E-08	8.34E-08
	Average	1.08E-07	7.09E-09	1.08E-08
^{238}U	Minimum	1.16E-07	-1.38E-08	-1.06E-07
	Maximum	3.44E-06	5.23E-08	-9.29E-09
	Average	1.00E-06	1.79E-08	-4.80E-08
^{134}Cs	Minimum	-9.81E-06	3.30E-07	1.10E-06
	Maximum	2.90E-04	7.22E-06	1.63E-05
	Average	1.12E-05	1.85E-06	5.45E-06
^{137}Cs	Minimum	-2.07E-06	4.20E-07	1.39E-06
	Maximum	3.23E-04	6.78E-06	1.06E-05
	Average	1.48E-05	1.52E-06	4.31E-06
^{60}Co	Minimum	-4.76E-06	4.50E-07	1.50E-06
	Maximum	2.36E-06	4.88E-06	1.64E-05
	Average	-4.37E-07	1.71E-06	5.69E-06
^{40}K	Minimum	-1.15E-05	5.16E-06	1.70E-05
	Maximum	4.23E-05	4.69E-05	1.56E-04
	Average	1.21E-05	1.74E-05	5.77E-05
	2012			
^{241}Am	Minimum	-1.44E-09	1.40E-09	1.25E-09
	Maximum	2.24E-08	1.34E-08	5.91E-08
	Average	6.22E-09	4.00E-09	1.18E-08

Table 5.7 Minimum, Maximum, and Average Radionuclide Concentrations (Bq/m^3) in Aerosol Filters at Near Field Station (continued)

Radionuclide		Concentration	SD	MDC
	2012			
^{238}Pu	Minimum	-2.96E-09	1.22E-09	5.58E-09
	Maximum	7.83E-09	6.79E-09	2.79E-08
	Average	1.92E-09	3.47E-09	1.33E-08
$^{239+240}$Pu	Minimum	1.84E-09	1.86E-09	4.25E-09
	Maximum	3.62E-08	1.05E-08	2.88E-08
	Average	1.66E-08	5.23E-09	1.26E-08
^{234}U	Minimum	1.73E-07	-2.52E-06	-2.66E-06
	Maximum	3.65E-06	-5.72E-07	-5.92E-07
	Average	8.80E-07	-1.10E-06	-1.15E-06
^{235}U	Minimum	-1.33E-07	-3.65E-07	-3.65E-07
	Maximum	1.61E-08	-8.28E-08	-8.38E-08
	Average	-6.93E-08	-1.60E-07	-1.60E-07
^{238}U	Minimum	-1.57E-07	-3.32E-06	-3.44E-06
	Maximum	2.04E-06	-7.42E-07	-7.65E-07
	Average	4.10E-07	-1.44E-06	-1.49E-06
^{134}Cs	Minimum	-9.60E-09	2.02E-07	6.68E-07
	Maximum	2.91E-07	5.81E-07	1.93E-06
	Average	1.13E-07	3.67E-07	1.22E-06
^{137}Cs	Minimum	-1.72E-06	3.93E-07	1.30E-06
	Maximum	4.05E-06	2.48E-06	8.16E-06
	Average	4.68E-07	1.07E-06	3.55E-06
^{60}Co	Minimum	1.94E-07	5.42E-07	1.80E-06
	Maximum	2.19E-07	5.76E-07	1.92E-06
	Average	2.10E-07	5.54E-07	1.84E-06
^{40}K	Minimum	3.83E-07	4.75E-06	1.56E-05
	Maximum	1.75E-04	3.71E-05	1.18E-04
	Average	2.97E-05	1.28E-05	4.19E-05

Table 5.8 Minimum, Maximum, and Average Radionuclide Concentrations (Bq/m^3) in Aerosol Filters at Cactus Flats Station

Radionuclide		Concentration	SD	MDC
	2010			
^{241}Am	Minimum	-3.46E-10	5.88E-10	1.54E-09
	Maximum	3.50E-09	1.56E-09	5.31E-09
	Average	1.72E-09	1.14E-09	3.30E-09
^{238}Pu	Minimum	-2.68E-09	8.27E-10	3.43E-09
	Maximum	1.24E-09	1.97E-09	9.54E-09
	Average	-8.79E-10	1.29E-09	6.08E-09
$^{239+240}$Pu	Minimum	3.79E-10	1.11E-09	3.78E-09
	Maximum	5.44E-09	3.41E-09	1.11E-08
	Average	2.89E-09	1.88E-09	6.11E-09
^{234}U	Minimum	2.67E-07	9.57E-09	2.37E-09
	Maximum	1.13E-06	3.40E-08	8.27E-09
	Average	6.13E-07	1.99E-08	5.21E-09

Table 5.8 Minimum, Maximum, and Average Radionuclide Concentrations (Bq/m^3) in Aerosol Filters at Cactus Flats Station (continued)

Radionuclide		Concentration	SD	MDC
	2010			
^{235}U	Minimum	7.85E-09	1.59E-09	2.36E-09
	Maximum	5.41E-08	6.50E-09	1.05E-08
	Average	2.73E-08	3.99E-09	5.59E-09
^{238}U	Minimum	2.52E-07	9.24E-09	2.36E-09
	Maximum	1.02E-06	3.15E-08	7.92E-09
	Average	5.69E-07	1.89E-08	5.21E-09
^{137}Cs	Minimum	-2.83E-07	2.35E-07	7.80E-07
	Maximum	4.59E-07	7.16E-07	2.38E-06
	Average	1.18E-07	3.84E-07	1.27E-06
^{60}Co	Minimum	-7.00E-07	2.74E-07	9.05E-07
	Maximum	1.07E-06	8.54E-07	2.83E-06
	Average	1.87E-07	4.43E-07	1.47E-06
^{40}K	Minimum	-4.60E-07	2.39E-06	6.77E-06
	Maximum	3.32E-05	8.82E-06	2.91E-05
	Average	1.01E-05	4.46E-06	1.45E-05
	2011			
^{241}Am	Minimum	-6.76E-09	1.78E-09	4.41E-09
	Maximum	2.06E-08	8.57E-09	3.44E-08
	Average	4.61E-09	4.77E-09	1.51E-08
^{238}Pu	Minimum	-4.15E-08	1.65E-09	2.98E-09
	Maximum	3.12E-08	2.21E-08	1.18E-07
	Average	-3.18E-09	7.12E-09	3.14E-08
$^{239+240}$Pu	Minimum	3.70E-09	2.33E-09	4.56E-09
	Maximum	8.21E-08	2.77E-08	1.06E-07
	Average	1.71E-08	9.26E-09	2.91E-08
^{234}U	Minimum	4.44E-07	6.75E-09	-8.42E-08
	Maximum	3.30E-06	1.06E-07	-1.48E-08
	Average	1.42E-06	3.28E-08	-3.72E-08
^{235}U	Minimum	-7.74E-09	-3.02E-09	-6.94E-09
	Maximum	2.60E-07	1.67E-08	4.41E-08
	Average	7.41E-08	4.31E-09	6.58E-09
^{238}U	Minimum	-1.43E-07	-1.18E-08	-1.17E-07
	Maximum	2.97E-06	7.98E-08	-4.72E-09
	Average	9.35E-07	1.76E-08	-4.62E-08
^{134}Cs	Minimum	-1.18E-05	3.69E-07	1.26E-06
	Maximum	2.30E-04	5.79E-06	1.33E-05
	Average	8.73E-06	1.81E-06	5.46E-06
^{137}Cs	Minimum	-9.00E-07	4.27E-07	1.41E-06
	Maximum	2.55E-04	5.42E-06	8.91E-06
	Average	1.28E-05	1.50E-06	4.36E-06
^{60}Co	Minimum	-3.67E-06	4.54E-07	1.52E-06
	Maximum	6.90E-06	3.82E-06	1.27E-05
	Average	-2.30E-07	1.73E-06	5.77E-06
^{40}K	Minimum	-3.83E-05	5.52E-06	1.84E-05
	Maximum	4.66E-05	3.87E-05	1.30E-04
	Average	-4.48E-07	1.80E-05	6.01E-05

Table 5.8 Minimum, Maximum, and Average Radionuclide Concentrations (Bq/m^3) in Aerosol Filters at Cactus Flats Station (continued)

Radionuclide		Concentration	SD	MDC
	2012			
^{241}Am	Minimum	-1.30E-10	1.34E-09	1.74E-09
	Maximum	3.73E-08	1.48E-08	4.33E-08
	Average	5.01E-09	3.92E-09	1.22E-08
^{238}Pu	Minimum	-4.64E-09	1.36E-09	2.92E-09
	Maximum	1.37E-08	7.26E-09	2.18E-08
	Average	1.04E-09	3.02E-09	1.17E-08
$^{239+240}$Pu	Minimum	4.14E-09	1.73E-09	4.33E-09
	Maximum	5.34E-08	1.52E-08	3.76E-08
	Average	1.46E-08	5.08E-09	1.32E-08
^{234}U	Minimum	5.60E-08	-2.58E-06	-2.74E-06
	Maximum	4.36E-06	-5.45E-07	-5.72E-07
	Average	8.71E-07	-1.08E-06	-1.13E-06
^{235}U	Minimum	-1.42E-07	-3.78E-07	-3.82E-07
	Maximum	1.29E-07	-7.06E-08	-7.53E-08
	Average	-6.59E-08	-1.57E-07	-1.55E-07
^{238}U	Minimum	-2.01E-07	-3.40E-06	-3.53E-06
	Maximum	3.07E-06	-7.14E-07	-7.41E-07
	Average	4.27E-07	-1.42E-06	-1.46E-06
^{134}Cs	Minimum	-1.00E-06	4.52E-07	1.51E-06
	Maximum	-3.37E-07	1.35E-06	4.49E-06
	Average	-6.12E-07	8.26E-07	2.75E-06
^{137}Cs	Minimum	-3.50E-06	3.85E-07	1.26E-06
	Maximum	4.22E-06	2.40E-06	7.94E-06
	Average	3.94E-07	1.08E-06	3.56E-06
^{60}Co	Minimum	3.16E-07	9.40E-07	3.14E-06
	Maximum	3.78E-07	1.04E-06	3.48E-06
	Average	3.56E-07	9.76E-07	3.26E-06
^{40}K	Minimum	-1.65E-05	4.57E-06	1.49E-05
	Maximum	1.51E-04	2.26E-05	7.40E-05
	Average	2.65E-05	1.28E-05	4.20E-05

CHAPTER 6

Surface Soil Monitoring

A soil monitoring program offers the most direct means of determining the concentrations (activities), distribution, and long-term trends of radionuclides and chemicals present around nuclear facilities (DOE 1991). Soil is an integrating medium that may receive substances released to the atmosphere, particles resuspended and transported by wind, and substances in water used for irrigation. Consequently, soil contaminant data may provide information about potential pathways (e.g., soil ingestion, food ingestion, resuspension into the air, and groundwater contamination) that could deliver radioactive materials or chemicals to humans and biota. Environmental soil monitoring was conducted in 2012 in the Vicinity of the WIPP site with the primary objective of measuring radionuclides.

Introduction

Soils are of high interest to the WIPP-EM because aerosol releases of contaminants would eventually be deposited in surface soils, which then can serve as a source for continuing contaminant exposure and uptake via direct contact, food chain pathways, and re-suspension. From these prospectives, soils are an integrating medium of primary concern in predictive ecosystem and contaminant transport modeling that requires good information about the dispersion of analytes of concern across the landscape. The source of transuranic radionuclides in soils is mainly due to integrated global fallout from the testing of above-ground nuclear devices. The plutonium isotope ^{238}Pu has been injected into the stratosphere by the burn-up of a failed radioactive thermal generator in 1964, release at the Gnome Site, and regional fallout from above-ground testing at the Nevada Test Site(NTS). Each of these sources has characteristic radionuclide signatures and /or abundances that can, in principle, be used to identify their presence in the soils and to estimate their concentrations. The WIPP soils are primarily characterized as sand, with some areas of gravelly loams, sandy loams and loamy sands. The topography is generally monotonous with some areas having dune formations. Hummocks are frequently associated with the shrubs that occur throughout the region. A brief comparison of the radiochemical procedures used for the determination of transuranic nuclides in soil samples is also included to show major trends.

Results reported herein are from soil samples collected during 2012 from a grid of 16 locations surrounding the WIPP site (Near Field and Cactus Flats as shown in Figure 6.1). Also reported are summary statistics for the 2012 data for the Near Field and Cactus Flats soil samples (Table 6.1. and 6.2.).

METHODS AND ANALYSIS

Sample collection

Soil samples were collected from the two locations where the high-volume air samplers are stationed around the WIPP site: Site 107 (Near Field) and Site 109 (Cactus Flats).
In both 1998 and 1999 at each of the 32 locations (grid nodes), soil was collected from three randomly selected sites within a 50-m radius of the selected reference point. In 2000, one

sample was collected at each of the 32 grid nodes. In 2001, two samples were collected at each of the 32 grid nodes. One of each pair of the 2001 samples was analyzed and the other was archived. In 2005 one sample was collected at each of the 16 grid nodes, but these samples were collected in an annulus between 20 and 40 meters from the grid node in order to reduce the chance of re-sampling an area. As in 2005 and 2009, one sample was collected at each of the 16 grid nodes in 2010. In 2012, a total of 16 soil samples (8 from Near Field, Grid B_1-B_8 and 8 from Cactus Flats, grid D_1-D_8) were collected. Two field duplicates were collected at randomly selected reference points each year within each grid sampled. Individual sampling sites were selected on the basis of relatively flat topography, minimum surface erosion and minimum surface disturbance by human or livestock activity. Approximately 4L of soil samples were collected from within a 50×50 cm area, to a depth of approximately 2-cm for radionuclide analyses. Soil samples were excavated using a trowel and placed in plastic bags for transport and storage. Sampling equipment was cleaned between samples.

Sample Preparation

Initial preparation of the samples for radiological analyses consisted of passing the soil through a 2-mm sieve to remove rocks, roots and other materials. Samples were then dried at 105˚C for 12 hours and ground using a jar mill. Approximately 300-mL (500g) aliquots were used for gamma spectroscopy analysis. The samples for gamma analysis were sealed in a ~ 300-mL can and stored for at least 21 days to allow radon progeny to reach equilibrium with parent radionuclides.

Gamma analysis was conducted using a high purity germanium (HPGe) detector for 48 hours. A set of soil matrix standards procured from Eckert and Ziegler Analytics (GA) was used to establish matrix-specific calibration and counting efficiencies. Reported concentrations are blank-corrected.

Dissolution of Soil Samples

Soil samples were dried at 110°C and blended prior to sampling. For actinides analyses, 5-10g of sample were heated in a muffle furnace at 500°C for at least 6 hours or more to combust organic material. Each sample was then spiked with a radioactive trace and digested in a Teflon beaker with 30 ml of HCl, 10 ml of HNO_3 and 40 ml of HF. Sea sand was used as a matrix for Laboratory Control Standard (LCS) and reagent blank. The samples were heated at 250°C for at least 2 hours; longer heating does no harm. After digestion is complete, the samples were evaporated to dryness and 40 ml of $HClO_4$ was added and evaporated to complete dryness. This step was repeated once more with 30 ml of $HClO_4$. Then 20 ml of HF were added and evaporated to dryness. To each beaker 80 ml of 8M HNO_3, 1.5 g of H_3BO_3 and 0.5 ml of 30% H_2O_2 were added, covered with a watch glass and heated to boiling for 30 minutes. After cooling, samples were transferred to a 50 ml centrifuge tube and centrifuged at 3600 rpm for 10 minutes. The leachate was filtered through a 0.45 micron filter and transferred to a 250 ml beaker.

Actinides Separation

The oxidation state of Pu was adjusted by adding 1 ml of 1.0M NH_4I with a 10 min wait step, followed by 2 ml of $NaNO_2$. The sample solutions were then ready for the purification procedure with anion exchange and by extraction chromatography. Next Pu was separated from Am and U using an anion exchange column. U was separated from Am on UTEVA and the Am subsequently purified from lanthanides with TEVA. Uranium fraction from UTEVA may be purified further (if needed) with anion exchange columns. Finally, Pu, Am and U were micro-coprecipitated on stainless steel discs and counted on the alpha spectrometer for five days.

RESULTS AND DISCUSSION

The $^{239+240}$Pu, ^{238}Pu, ^{241}Am, isotopes of uranium (^{238}U, ^{235}U and ^{234}U) and gamma radionuclides ^{40}K, ^{137}Cs, ^{134}Cs and ^{60}Co were analyzed for all the soil samples. The mean concentrations of these radionuclides measured in 2012 soil samples are summarized in Tables 6.1 and 6.2. Individual concentrations of these radionuclides collected from the Near Field and Cactus Flats grid are also presented in Table 6.3 and 6.4. The ^{241}Am concentration slightly greater than MDC was detected in seven samples, whereas ^{238}Pu was not detected in any soil samples in Near Field soil for 2012. The $^{239+240}$Pu was detected in every soil sample with one exception. For Cactus Flats, the ^{241}Am and $^{239+240}$Pu concentrations slightly greater than MDC were detected in every soil sample, whereas ^{238}Pu was detected in only three samples. All detected concentrations of ^{238}Pu, $^{239+240}$Pu and ^{241}Am were extremely low and were relatively close to the respective MDCs.

Activity concentrations of ^{241}Am ranged in the surface soil from 0.0035- 0.050 Bq/kg, while that of ^{238}Pu varied from -0.035-0.050 Bq/kg. The range of $^{239+240}$Pu concentrations (0.011-0.38 Bq/kg) fell within the range reported by Kenney (1995) at the WIPP site (0-0.74 Bq/kg). These values are lower than those measured at Hueston Woods and Urbana, Ohio (0.7-1.0 Bq/kg; Alberts et al., 1980) and between Ft. Collins and Colorado Springs, Colorado (0.6-1.7 Bq/kg; Hodge et al., 1996). The concentrations of $^{239+240}$Pu, ^{238}Pu, and ^{241}Am in Gnome soil were in the range 0.007-1550 Bq/kg, 0.016-219 Bq/kg and 0.004-346 Bq/kg, respectively with an overall mean of 149 Bq/kg, 28.8 Bq/kg and 36.1 Bq/kg (CEMRC Report, 2005/2006). The deposition of radioactive fallout from weapons testing is known to vary with latitude, being greatest in the middle latitudes of the northern hemisphere (UNSCEAR, 1969). Fallout levels have also been shown to be correlated with precipitation (Hardy and Alexander, 1962). The lower levels of $^{239+240}$Pu at the semi-arid WIPP site may likely be due to the lower precipitation levels in this region as compared to the Ohio and Colorado sites, although some effect due to latitude cannot be ruled out. In addition, surface soil may show differences due to spatial variability in site-specific rates of vertical transport, bulk density and disturbances of surface soil after deposition.

The mean concentration of $^{239+240}$Pu in 1998 soil samples collected from the Near Field grid (B_1-B_8) were 0.12 Bq/kg, which is consistent with the mean value of 0.17 Bq/kg measured in 2012 soil samples collected from the same grid. The corresponding values for ^{238}Pu and ^{241}Am were slightly higher in 2012 than in 1998. For Cactus Flats grid (D1-D8), the mean concentration of $^{239+240}$Pu in 1998 soil samples was 0.26 Bq/kg, which is not very different from the mean value (0.037 Bq/kg) measured in 2012. The mean values measured in 1998 were 0.054 for ^{241}Am and 0.011 Bq/kg for ^{238}Pu, which is slightly higher than the corresponding values measured in 2012. The activity concentrations of ^{238}Pu, $^{239+240}$Pu and ^{241}Am in 2012 soil samples from the Near Field and Cactus Flats are shown in Figures 6.2-6.13.

The ^{137}Cs was detected in all soil samples collected from the Cactus Flats sampling site and all but one from the Near Field sampling site (Tables 6.5 and 6.6). Variability among the ^{137}Cs concentrations was not very significant. Although ^{137}Cs is a fission product, it is ubiquitous in soil because of global fallout from atmospheric weapons testing (UNSCEAR, 2000). The activity concentrations of ^{137}Cs ranged from 0.015-8.86 Bq/kg. The Gnome soil samples show elevated concentrations of ^{137}Cs as compared to WIPP soil. The maximum observed concentration of ^{137}Cs for the Gnome soil, 2980 Bq/kg (CEMRC Report, 2005/2006), is about 1000 times larger than the largest concentration seen in the WIPP surface soil. Hodge et al. (1996) suggests that the ratio of ^{137}Cs/$^{239+240}$Pu from global fallout remains relatively constant through time. However, perturbations in this ratio could result if the soil chemistry favored the downward migration of one these radionuclides or if there were a local source of one of the nuclides or both with a very different ratio. The average value of ^{137}Cs/$^{239+240}$Pu for northern-hemisphere fallout is 36±4 (as of July 1995, ^{137}Cs data in literature has been corrected to the sampling date of current study). Additionally, values of 33 and 30 (as of 1 July 1995) are reported from studies of fallout radionuclides in glaciers in Greenland and Antarctica (Koida et al., 1982), while "NTS-only" fallout values of 21 and 6 are reported for sediments taken from two reservoirs in Utah (Krey et al., 1981). The mean ratio of ^{137}Cs/$^{239+240}$Pu for the WIPP soil, 24±2 is lower than the northern hemisphere value of 36±4. The lower ratio at the WIPP site suggests contamination from sources other than fallout. The mean ratio of ^{137}Cs/$^{239+240}$Pu for Gnome soil, 3591±1635, was significantly greater than the WIPP soil.

The mean ratio of ^{238}Pu/$^{239+240}$Pu from the WIPP samples (0.16) are not significantly different than the mean ratio for the Gnome samples (0.14±0.02). In either case the ^{238}Pu/$^{239+240}$Pu ratios for both WIPP and Gnome exceed the global fallout ratio of ~0.061 (Mitchell, 1997). This ratio suggests that the fallout in the vicinity of the WIPP is a mixture of global fallout from thermonuclear devices and the local fallout from the above-ground testing at the Nevada Test Site (NTS).

The ^{40}K was detected in every sample (Tables 6.5 and 6.6). This naturally occurring gamma-emitting radionuclide is ubiquitous in soils. 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 soil. The ^{60}Co was not detected at any sampling location (Tables 6.5 and 6.6). The average concentrations of $^{239+240}$Pu, ^{238}Pu, ^{241}Am, ^{137}Cs, ^{60}Co and ^{40}K around the WIPP site across the years are shown in Figures 6.14-6.25. The concentrations of radionuclides have not changed after WIPP became operational. In fact, the concentrations of ^{137}Cs, $^{239+240}$Pu and ^{241}Am fell within the range of values previously measured for the WIPP soil samples.

CONCLUSION

The soil monitoring in the vicinity of the WIPP site suggests that the Pu and Cs in the WIPP environment originated mainly from global fallout from thermonuclear devices and local fallout from above-ground testing at the Nevada Test Site, although contamination of WIPP soil from the Gnome test remains a possibility. The monitoring results indicate that there is no evidence of increased radiological contamination in the region of the WIPP that could be attributed to release from the WIPP.

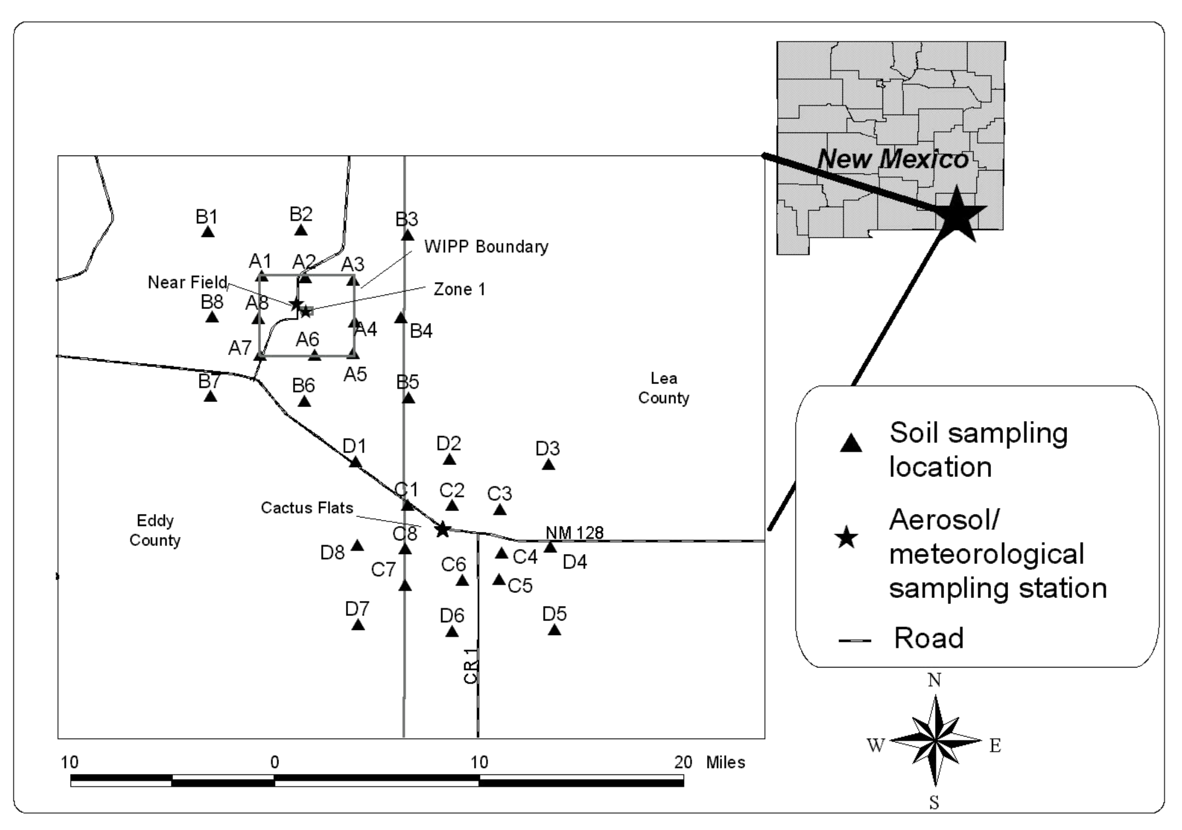


Figure 6.1 Soil Sampling Locations in the Vicinity of the WIPP Site

Table 6.1 Summary Statistics for Radionuclides in Soil Samples Collected in Near Field 2012

Radionuclides	Unit	Near Field			
		[a]N	[b]Mean	SD	Range
^{241}Am	Bq/ kg	7	3.66E-02	1.07E-02	3.54E-03 - 6.80E-02
^{137}Cs	Bq/ kg	8	2.33E+00	1.23E-01	1.51E-01 - 3.66E+00
^{40}K	Bq/ kg	9	1.76E+02	1.10E+01	1.41E+02 - 2.04E+02
^{60}Co	Bq/ kg	0	-3.15E-02	9.41E-02	-1.84E-01 - 6.23E-02
^{238}Pu	Bq/ kg	0	4.53E-03	1.11E-02	-3.46E-02 - 1.96E-02
$^{239+240}$Pu	Bq/ kg	8	1.13E-01	2.16E-02	1.40E-02 - 1.73E-01
^{238}U	Bq/ kg	9	6.45E+00	1.75E-01	4.91E+00 - 7.63E+00
^{234}U	Bq/ kg	9	6.17E+00	1.69E-01	4.66E+00 - 7.11E+00
^{235}U	Bq/ kg	9	3.60E-01	3.34E-02	3.10E-01 - 4.67E-01

[a] N = number of samples > MDC
[b] Mean = arithmetic mean

Table 6.2 Summary Statistics for Radionuclides in Soil Samples Collected in Cactus Flats 2012

Radionuclides	Unit	Cactus Flats			
		[a]N	[b]Mean	SD	Range
^{241}Am	Bq/ kg	9	7.11E-02	1.35E-02	3.90E-02 - 1.60E-01
^{137}Cs	Bq/ kg	9	4.08E+00	1.56E-01	1.53E+00 - 8.86E+00
^{40}K	Bq/ kg	9	1.76E+02	1.10E+01	1.44E+02 - 2.03E+02
^{60}Co	Bq/ kg	0	-7.77E-02	9.59E-02	-2.41E-01 - 9.23E-02
^{238}Pu	Bq/ kg	1	1.56E-02	1.03E-02	5.45E-03 - 5.01E-02
$^{239+240}$Pu	Bq/ kg	9	2.01E-01	2.76E-02	1.15E-01 - 3.78E-01
^{238}U	Bq/ kg	9	6.76E+00	1.66E-01	5.54E+00 - 8.02E+00
^{234}U	Bq/ kg	9	6.34E+00	1.70E-01	4.91E+00 - 7.63E+00
^{235}U	Bq/ kg	9	3.50E-01	3.18E-02	2.57E-01 - 4.33E-01

[a] N = number of samples > MDC
[b] Mean = arithmetic mean

Table 6.3 Americium, Plutonium, and Uranium Concentrations (Bq/kg) in the Soils Collected from Near Field in 2012

	Grid Node	Activity (Bq/kg)	SD (Bq/kg)	MDC (Bq/kg)
^{241}Am	B-1	6.80E-02	1.43E-02	1.91E-02
	B-2	3.54E-03	7.11E-03	2.55E-02
	B-3	3.65E-02	1.14E-02	2.55E-02
	B-4	4.44E-02	1.01E-02	1.45E-02
	B-5	2.81E-02	8.83E-03	6.16E-03
	B-6	3.42E-02	1.03E-02	1.78E-02
	B-7	4.95E-02	1.14E-02	2.28E-02
	B-7(Dup)	3.10E-02	1.31E-02	3.43E-02
	B-8	3.41E-02	9.74E-03	1.64E-02
^{238}Pu	B-1	1.96E-02	1.52E-02	5.14E-02
	B-2	1.80E-02	1.04E-02	3.17E-02
	B-3	-3.46E-02	1.54E-02	6.93E-02
	B-4	5.52E-03	6.76E-03	2.56E-02
	B-5	9.80E-04	8.89E-03	3.73E-02
	B-6	9.04E-03	1.11E-02	4.20E-02
	B-7	4.93E-03	1.48E-02	5.92E-02
	B-7(Dup)	1.07E-02	9.46E-03	3.32E-02
	B-8	6.59E-03	7.96E-03	3.01E-02
$^{239+240}$Pu	B-1	1.73E-01	2.84E-02	4.71E-02
	B-2	1.40E-02	1.11E-02	3.76E-02
	B-3	8.88E-02	2.01E-02	4.60E-02
	B-4	1.43E-01	2.31E-02	4.55E-02
	B-5	1.51E-01	2.26E-02	2.36E-02
	B-6	1.24E-01	2.12E-02	3.01E-02
	B-7	9.18E-02	2.24E-02	5.30E-02
	B-7(Dup)	1.08E-01	2.48E-02	5.89E-02
	B-8	1.20E-01	2.09E-02	3.01E-02
^{234}U	B-1	6.71E+00	1.74E-01	2.46E-02
	B-2	4.66E+00	1.37E-01	3.51E-02
	B-3	7.11E+00	1.85E-01	3.21E-02
	B-4	6.32E+00	1.63E-01	2.17E-02
	B-5	5.86E+00	1.73E-01	2.94E-02
	B-6	5.53E+00	1.64E-01	4.52E-02
	B-7	6.55E+00	1.80E-01	2.98E-02
	B-7(Dup)	6.53E+00	1.77E-01	2.82E-02
	B-8	6.23E+00	1.67E-01	4.11E-02
^{235}U	B-1	3.10E-01	2.91E-02	2.36E-02
	B-2	3.13E-01	3.10E-02	2.13E-02

Table 6.3 Americium, Plutonium, and Uranium Concentrations (Bq/kg) in the Soils Collected from Near Field in 2012 (continued)

	Grid Node	Activity (Bq/kg)	SD (Bq/kg)	MDC (Bq/kg)
	B-3	3.12E-01	3.06E-02	2.12E-02
	B-4	3.54E-01	3.12E-02	2.83E-02
	B-5	3.28E-01	3.21E-02	3.38E-02
	B-6	3.99E-01	3.83E-02	3.49E-02
	B-7	4.67E-01	4.02E-02	4.12E-02
	B-7(Dup)	3.63E-01	3.28E-02	3.20E-02
	B-8	3.92E-01	3.50E-02	3.62E-02
^{238}U	B-1	7.33E+00	1.87E-01	1.89E-02
	B-2	4.91E+00	1.43E-01	3.70E-02
	B-3	7.63E+00	1.95E-01	2.73E-02
	B-4	6.75E+00	1.72E-01	2.17E-02
	B-5	5.87E+00	1.74E-01	2.41E-02
	B-6	5.33E+00	1.59E-01	4.36E-02
	B-7	6.67E+00	1.82E-01	2.67E-02
	B-7(Dup)	6.92E+00	1.85E-01	3.57E-02
	B-8	6.60E+00	1.74E-01	3.18E-02

Table 6.4 Americium, Plutonium, and Uranium Concentrations (Bq/kg) in the Soils Collected from Cactus Flats in 2012

Radionuclides	Grid Node	Activity (Bq/kg)	SD (Bq/kg)	MDC (Bq/kg)
^{241}Am	D-1	5.19E-02	1.27E-02	1.90E-02
	D-2	5.52E-02	1.22E-02	2.03E-02
	D-3	3.90E-02	8.89E-03	1.50E-02
	D-4	1.60E-01	2.02E-02	2.61E-02
	D-4 (Dup)	6.57E-02	1.26E-02	2.08E-02
	D-5	4.94E-02	1.18E-02	1.72E-02
	D-6	8.71E-02	1.67E-02	7.95E-03
	D-7	5.45E-02	1.18E-02	1.60E-02
	D-8	7.67E-02	1.44E-02	2.35E-02
^{238}Pu	D-1	7.25E-03	1.03E-02	1.96E-02
	D-2	1.01E-02	1.01E-02	3.72E-02
	D-3	6.06E-03	6.06E-03	2.23E-02
	D-4	2.54E-02	1.24E-02	1.37E-02
	D-4 (Dup)	7.85E-03	9.61E-03	3.64E-02
	D-5	1.60E-02	1.07E-02	1.45E-02
	D-6	5.01E-02	1.39E-02	9.68E-03
	D-7	5.45E-03	1.02E-02	3.85E-02
	D-8	1.25E-02	9.29E-03	3.06E-02
$^{239+240}$Pu	D-1	2.23E-01	3.73E-02	6.24E-02
	D-2	1.89E-01	2.78E-02	3.90E-02
	D-3	1.15E-01	1.93E-02	2.23E-02
	D-4	3.78E-01	3.83E-02	3.38E-02
D-4 (Dup)	D-4 (Dup)	2.65E-01	2.87E-02	3.38E-02
	D-5	1.46E-01	2.55E-02	4.13E-02
	D-6	2.17E-01	2.97E-02	4.14E-02
	D-7	1.57E-01	2.16E-02	2.53E-02
	D-8	1.19E-01	2.03E-02	3.20E-02
^{234}U	D-1	6.59E+00	1.70E-01	2.56E-02
	D-2	5.41E+00	1.38E-01	3.73E-02
	D-3	5.31E+00	1.28E-01	2.17E-02
	D-4	7.90E+00	1.66E-01	2.92E-02
	D-4(Dup)	7.26E+00	1.68E-01	1.60E-02
	D-5	7.41E+00	1.87E-01	1.67E-02
	D-6	6.26E+00	1.56E-01	3.44E-02
	D-7	5.87E+00	1.57E-01	2.79E-02
	D-8	7.86E+00	2.02E-01	3.09E-02
^{235}U	D-1	4.33E-01	4.09E-02	4.83E-02
	D-2	4.31E-01	3.49E-02	7.32E-03
	D-3	2.57E-01	2.41E-02	2.46E-02
	D-4	3.70E-01	3.02E-02	2.74E-02

Table 6.4 Americium, Plutonium, and Uranium Concentrations (Bq/kg) in the Soils Collected from Cactus Flats in 2012 (continued)

Radionuclides	Grid Node	Activity (Bq/kg)	SD (Bq/kg)	MDC (Bq/kg)
	D-4 (Dup)	2.88E-01	2.87E-02	2.50E-02
	D-5	4.09E-01	3.59E-02	3.69E-02
	D-6	2.81E-01	2.83E-02	2.10E-02
	D-7	2.82E-01	2.80E-02	3.22E-02
	D-8	4.00E-01	3.50E-02	3.57E-02
^{238}U	D-1	7.12E+00	1.80E-01	3.31E-02
	D-2	5.77E+00	1.44E-01	3.45E-02
	D-3	5.54E+00	1.32E-01	1.78E-02
	D-4	7.69E+00	1.63E-01	2.91E-02
	D-4 (Dup)	7.22E+00	1.68E-01	4.08E-02
	D-5	7.44E+00	1.88E-01	2.59E-02
	D-6	6.16E+00	1.54E-01	2.86E-02
	D-7	5.84E+00	1.56E-01	2.13E-02
	D-8	8.02E+00	2.06E-01	2.35E-02

Table 6.5 Selected Gamma Radionuclide Activity Concentrations (Bq/kg) in the Soils Collected from Near Field in 2012

	Grid Node	Activity (Bq/kg)	SD (Bq/kg)	MDC (Bq/kg)
^{137}Cs	B-1	3.50E+00	1.41E-01	3.37E-01
	B-2	1.51E-01	9.64E-02	3.17E-01
	B-3	2.05E+00	1.20E-01	3.38E-01
	B-4	3.66E+00	1.46E-01	3.46E-01
	B-5	2.47E+00	1.20E-01	3.18E-01
	B-6	2.52E+00	1.23E-01	3.24E-01
	B-7	2.41E+00	1.25E-01	3.38E-01
	B-7(Dup)	2.01E+00	1.20E-01	3.39E-01
	B-8	2.15E+00	1.17E-01	3.23E-01
^{40}K	B-1	2.04E+02	1.27E+01	2.57E+00
	B-2	1.41E+02	8.82E+00	2.46E+00
	B-3	1.99E+02	1.24E+01	2.56E+00
	B-4	1.99E+02	1.24E+01	2.68E+00
	B-5	1.48E+02	9.26E+00	2.50E+00
	B-6	1.47E+02	9.18E+00	2.46E+00
	B-7	1.97E+02	1.23E+01	2.62E+00
	B-7 (Dup)	1.86E+02	1.16E+01	2.57E+00
	B-8	1.67E+02	1.05E+01	2.45E+00
^{60}Co	B-1	-1.29E-01	9.68E-02	3.23E-01
	B-2	-1.84E-01	9.06E-02	3.03E-01
	B-3	5.77E-02	9.56E-02	3.16E-01
	B-4	6.23E-02	9.86E-02	3.26E-01
	B-5	2.05E-02	8.85E-02	2.93E-01
	B-6	3.03E-02	9.22E-02	3.06E-01
	B-7	-3.17E-02	9.58E-02	3.18E-01
	B-7(Dup)	-1.10E-02	9.56E-02	3.17E-01
	B-8	-9.83E-02	9.30E-02	3.10E-01

Table 6.6 Selected Gamma Radionuclide Activity Concentrations (Bq/kg) in the Soils Collected from Cactus Flats in 2012

	Grid Node	Activity (Bq/kg)	SD (Bq/kg)	MDC (Bq/kg)
^{137}Cs	D-1	4.19E+00	1.56E-01	3.47E-01
	D-2	3.68E+00	1.42E-01	3.26E-01
	D-3	2.22E+00	1.18E-01	3.21E-01
	D-4	8.86E+00	2.49E-01	3.35E-01
	D-4	6.23E+00	1.94E-01	3.37E-01
	D-5	3.03E+00	1.39E-01	3.57E-01
	D-6	3.95E+00	1.50E-01	3.37E-01
	D-7	3.04E+00	1.34E-01	3.37E-01
	D-8	1.53E+00	1.19E-01	3.56E-01
^{40}K	D-1	1.88E+02	1.17E+01	2.61E+00
	D-2	1.44E+02	8.99E+00	2.49E+00
	D-3	1.53E+02	9.57E+00	2.46E+00
	D-4	1.55E+02	9.72E+00	2.58E+00
	D-4	1.67E+02	1.04E+01	2.57E+00
	D-5	1.97E+02	1.23E+01	2.64E+00
	D-6	1.77E+02	1.10E+01	2.64E+00
	D-7	2.03E+02	1.27E+01	2.56E+00
	D-8	1.99E+02	1.24E+01	2.77E+00
^{60}Co	D-1	-7.78E-02	9.81E-02	3.27E-01
	D-2	-2.41E-01	9.32E-02	3.13E-01
	D-3	-1.92E-01	9.28E-02	3.11E-01
	D-4	9.23E-02	9.06E-02	2.99E-01
	D-4	1.58E-02	9.61E-02	3.18E-01
	D-5	-1.06E-01	1.00E-01	3.35E-01
	D-6	1.70E-02	9.34E-02	3.10E-01
	D-7	-7.91E-02	9.78E-02	3.26E-01
	D-8	-1.28E-01	1.01E-01	3.36E-01

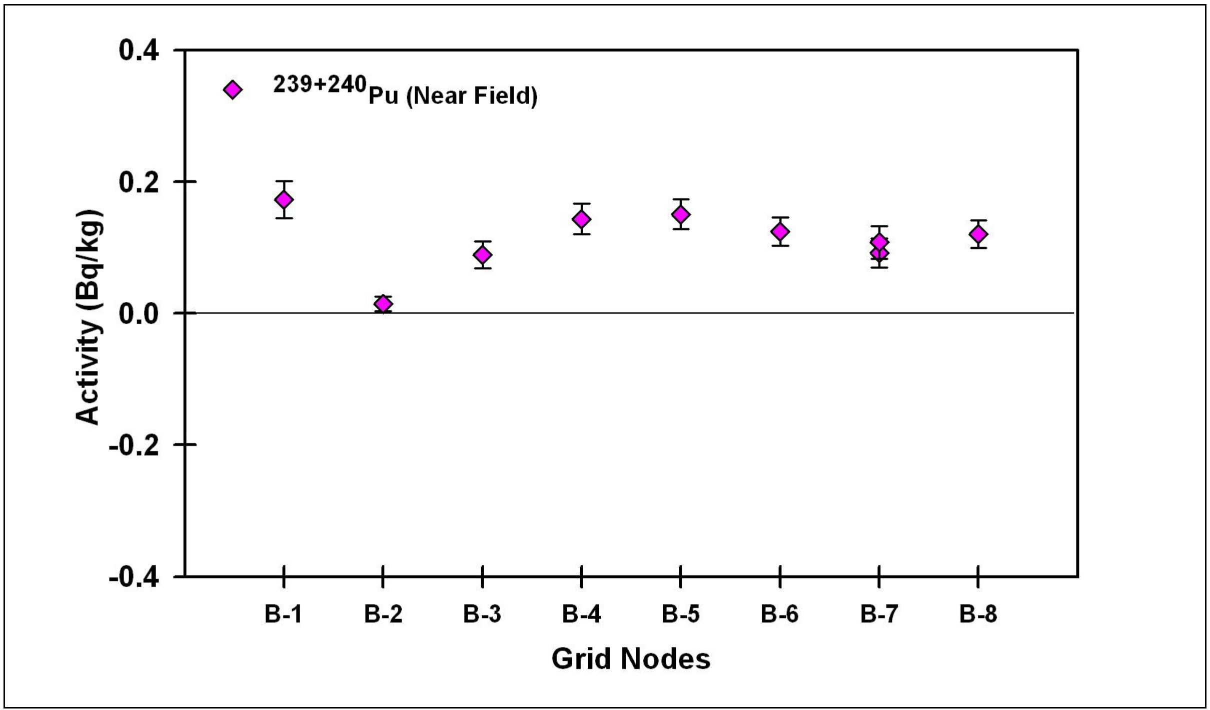


Figure 6.2 Activity Concentrations of $^{239+240}$Pu in Soil Samples Collected from Near Field in 2012

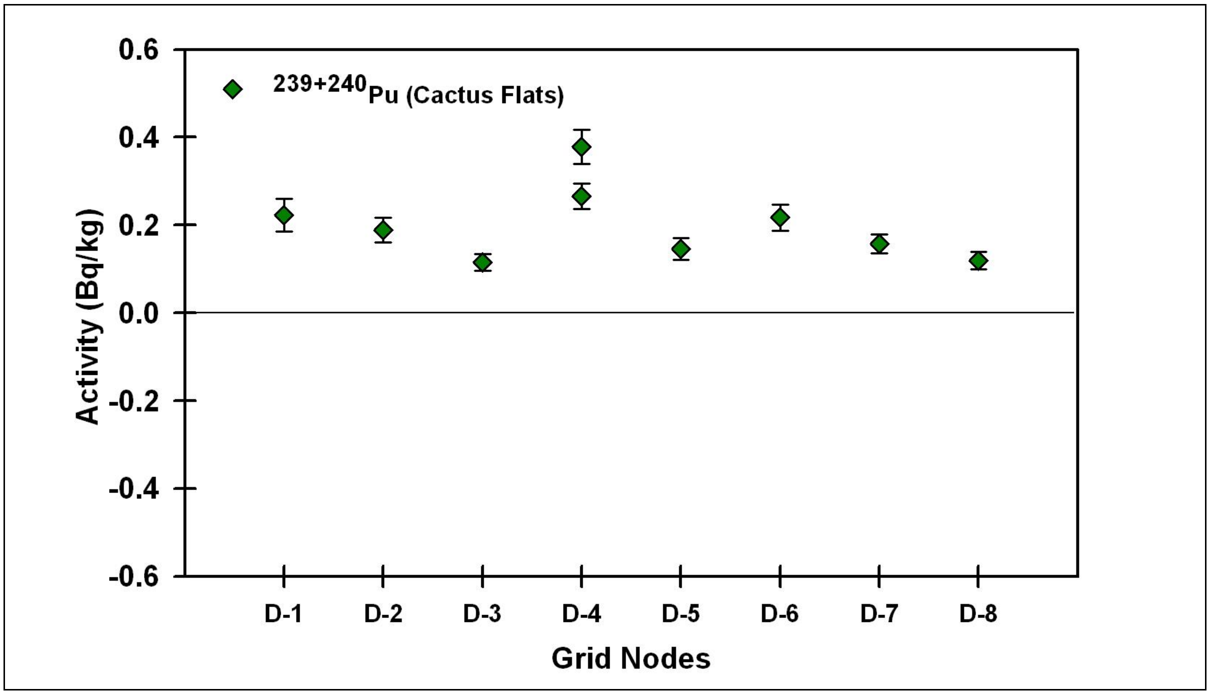


Figure 6.3 Activity Concentrations of $^{239+240}$Pu in Soil Samples Collected from Cactus Flats in 2012

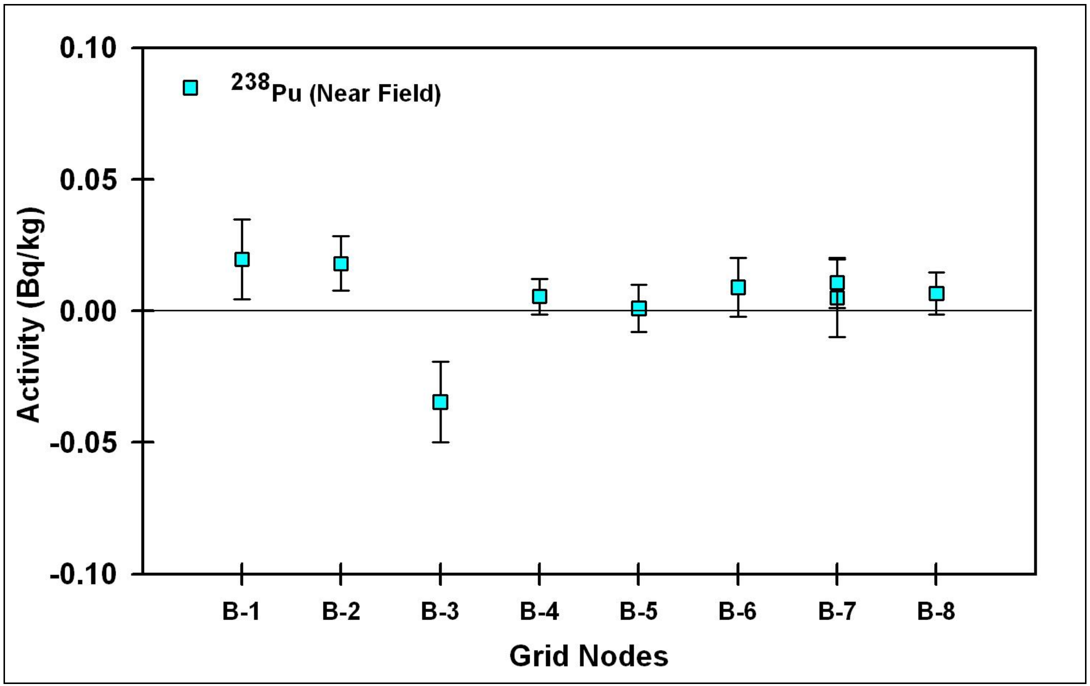


Figure 6.4 Activity Concentrations of ^{238}Pu in Soil Samples Collected from Near Field in 2012

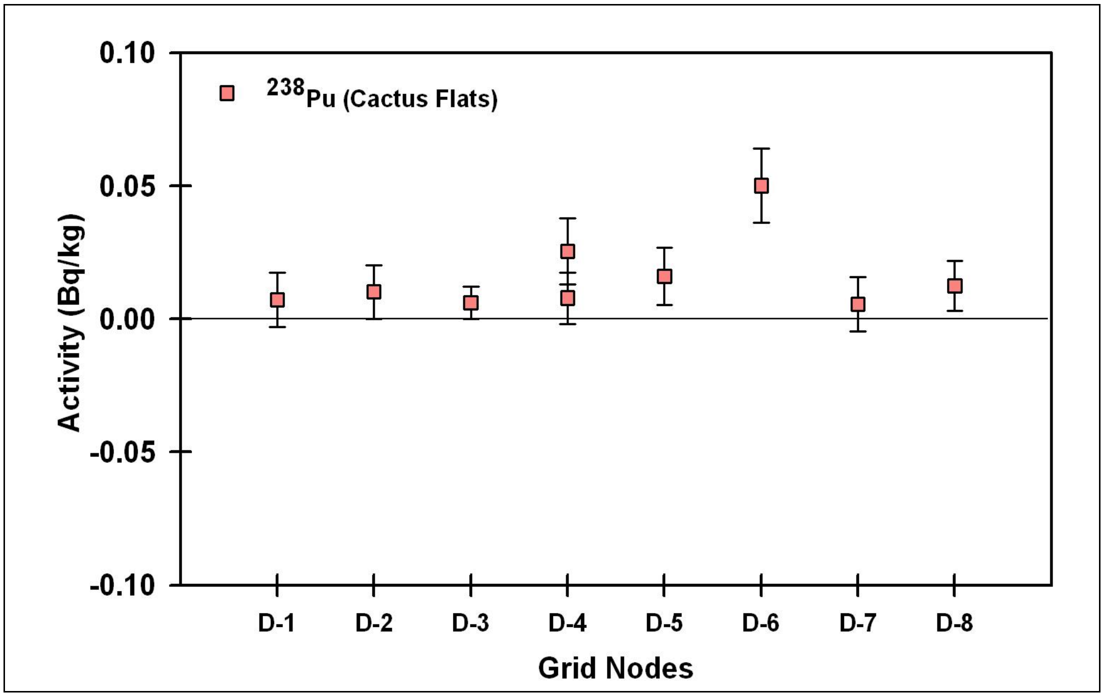


Figure 6.5 Activity Concentrations of ^{238}Pu in Soil Samples Collected from Cactus Flats in 2012

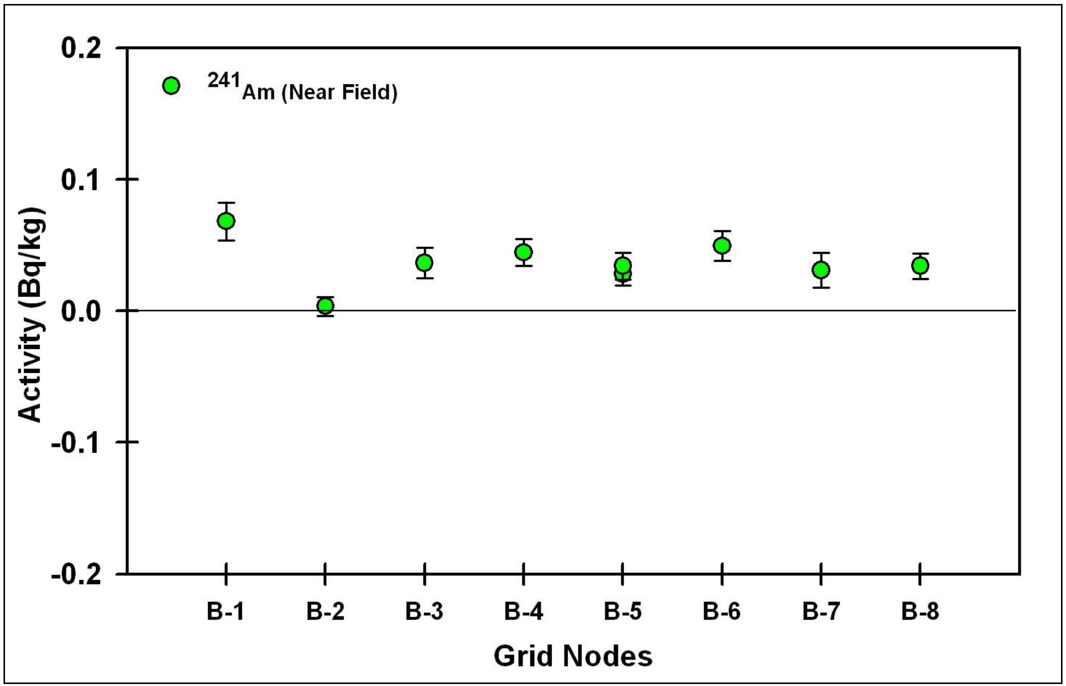


Figure 6.6 Activity Concentrations of ^{241}Am in Soil Samples Collected from Near Field Grid in 2012

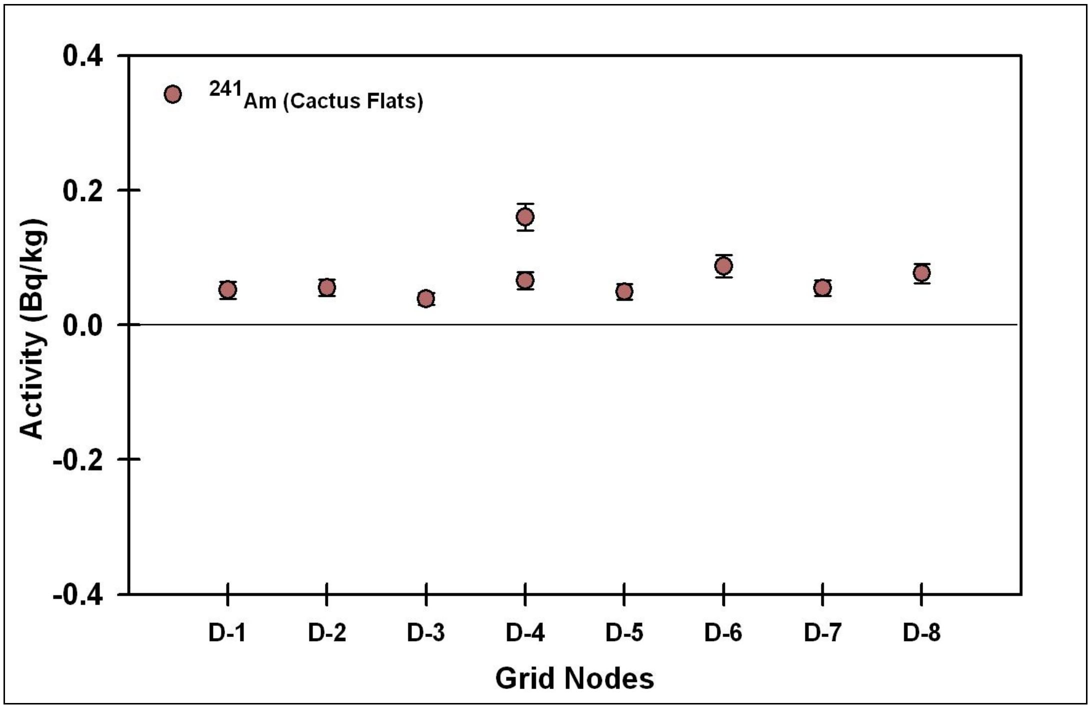


Figure 6.7 Activity Concentrations of ^{241}Am in Soil Samples Collected from Cactus Flats in 2012

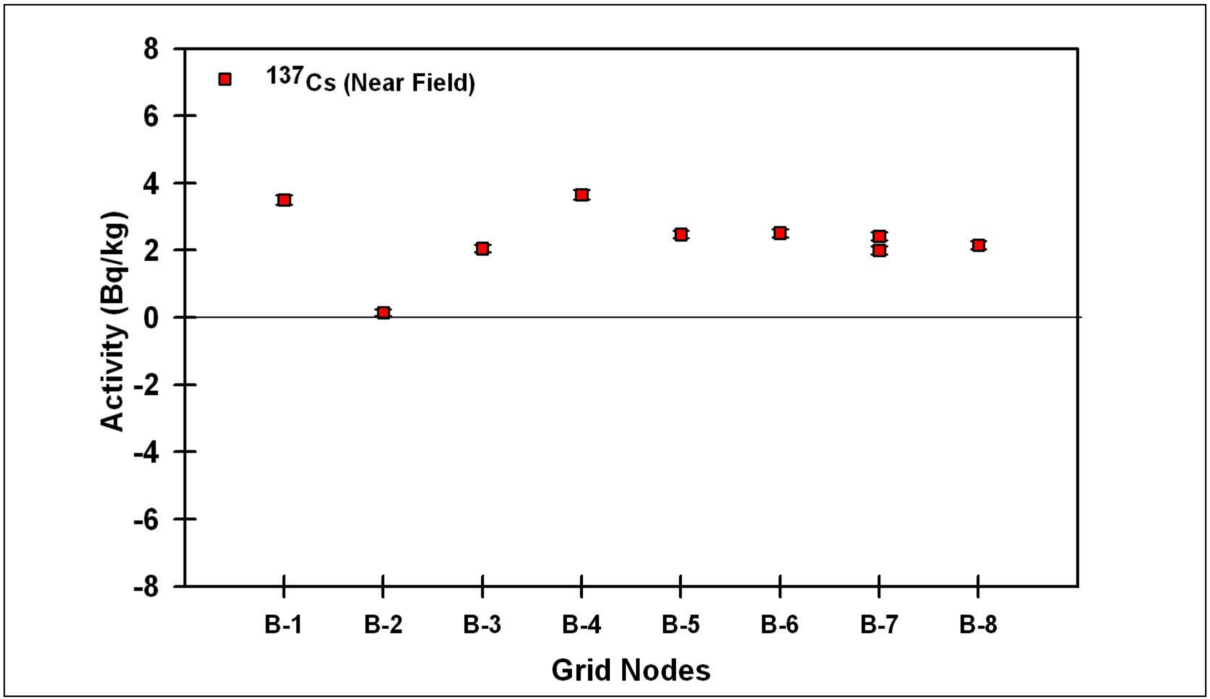


Figure 6.8 Activity Concentrations of ^{137}Cs in Soil Samples Collected from Near Field in 2012

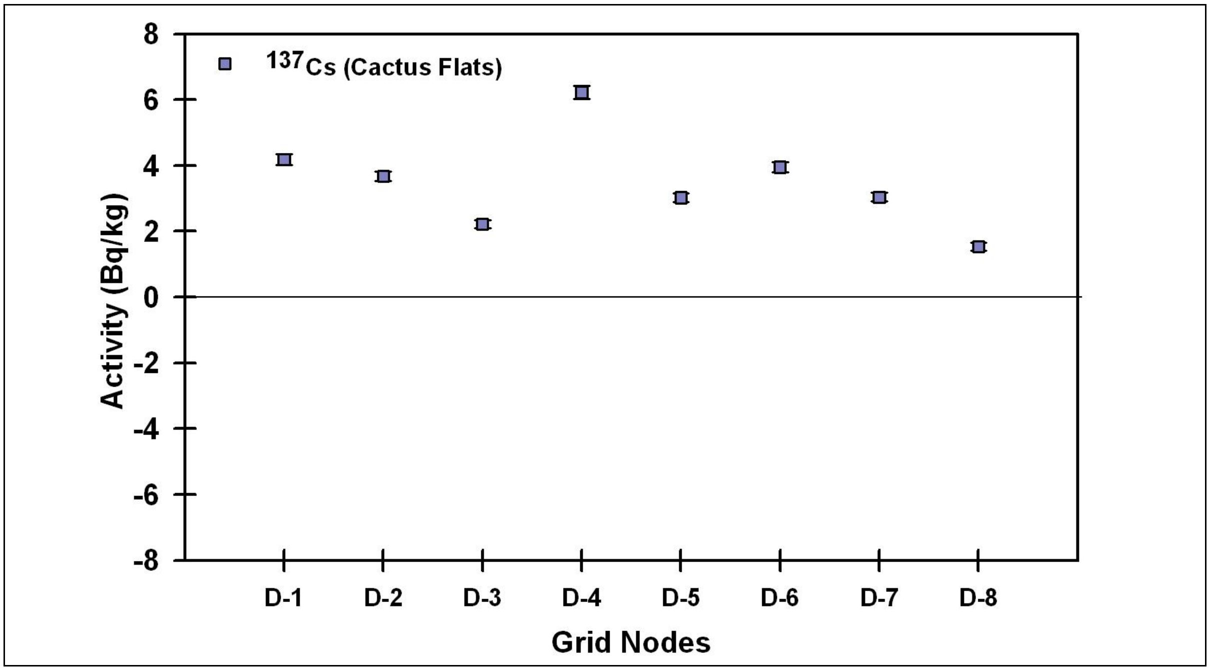


Figure 6.9 Activity Concentrations of ^{137}Cs in Soil Samples Collected from Cactus Flats in 2012

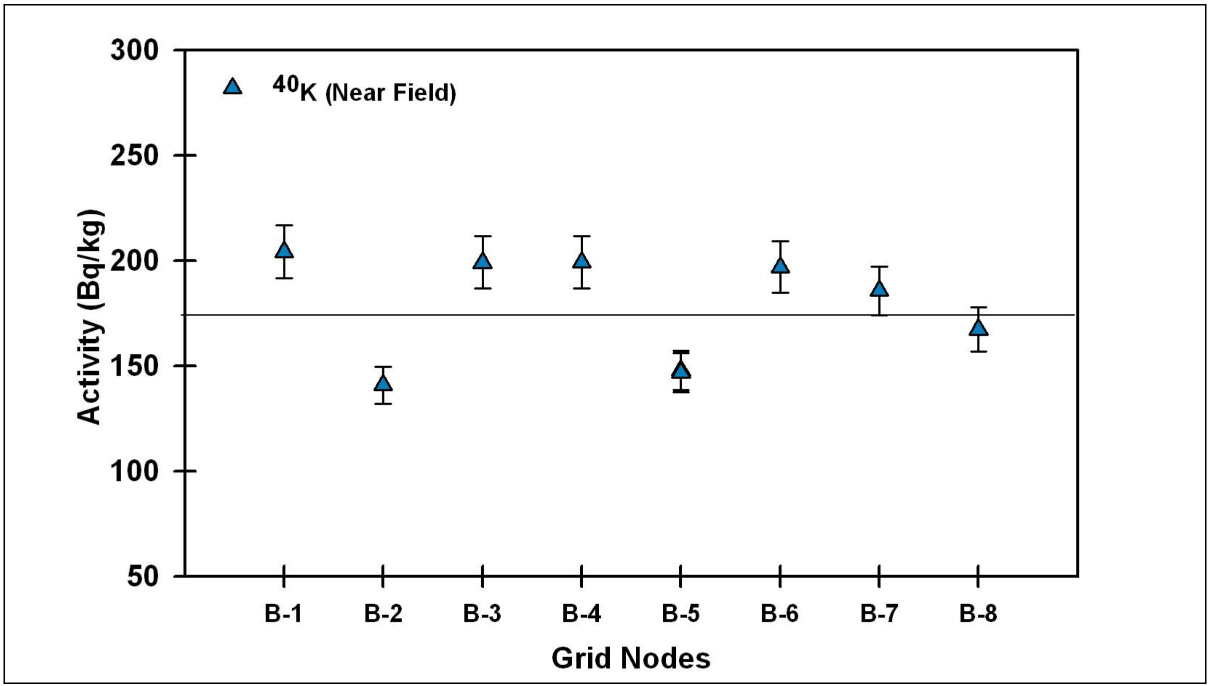


Figure 6.10 Activity Concentrations of ^{40}K in Soil Samples Collected from Near Field in 2012

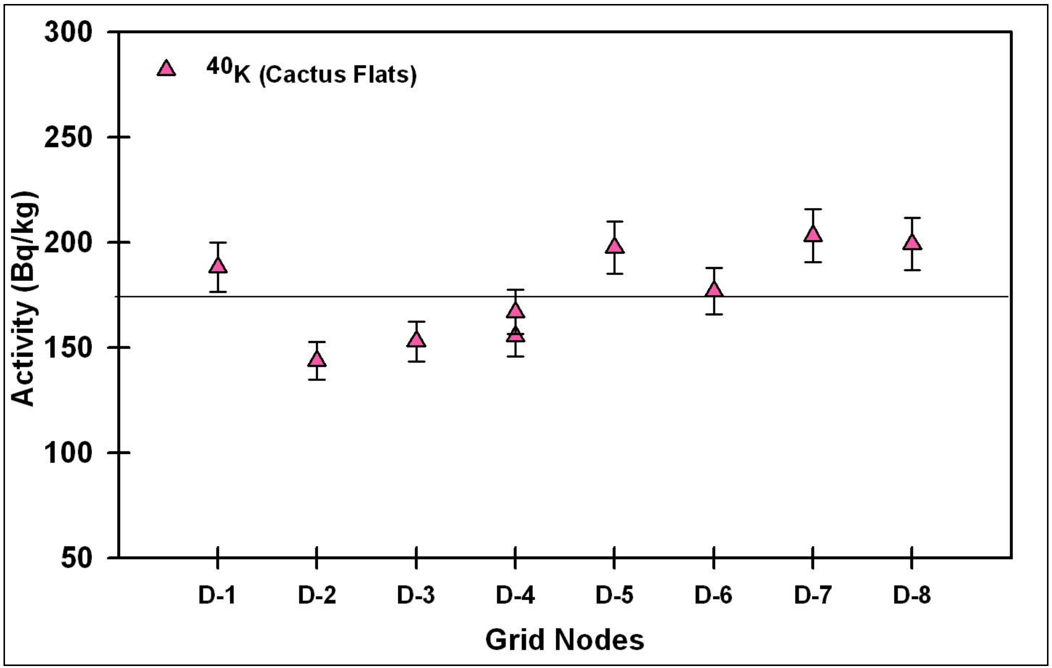


Figure 6.11 Activity Concentrations of ^{40}K in Soil Samples Collected from Cactus Flats in 2012

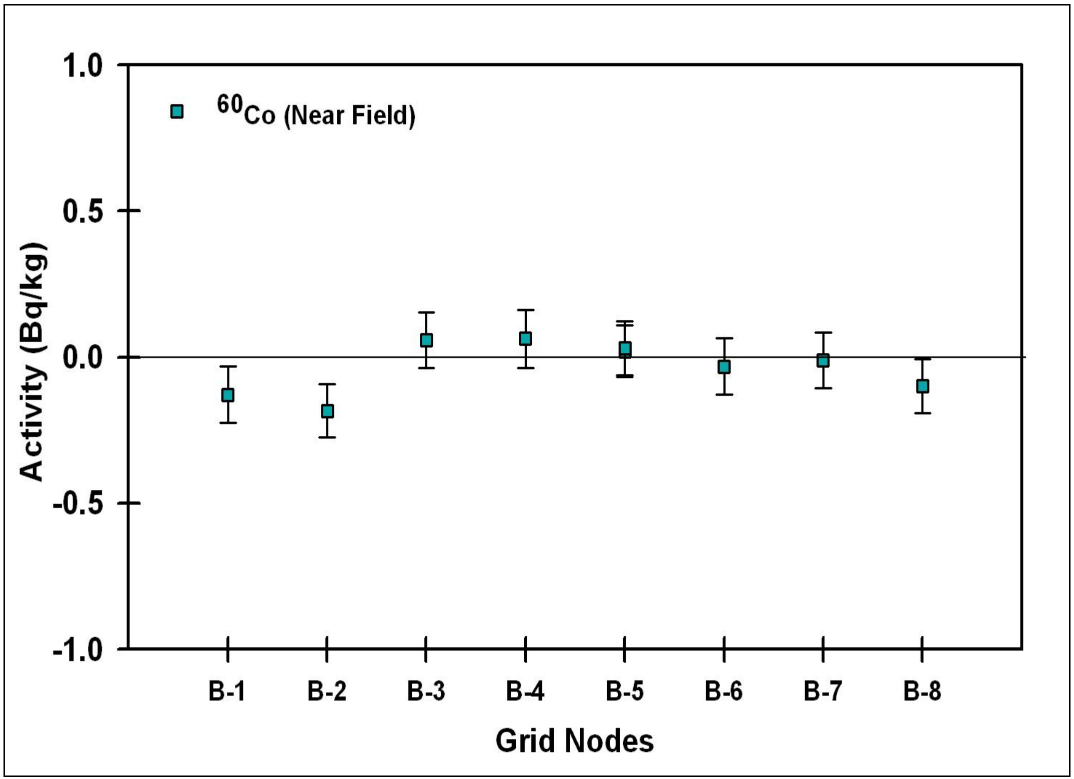


Figure 6.12 Activity Concentrations of ^{60}Co in Soil Samples Collected from Near Field in 2012

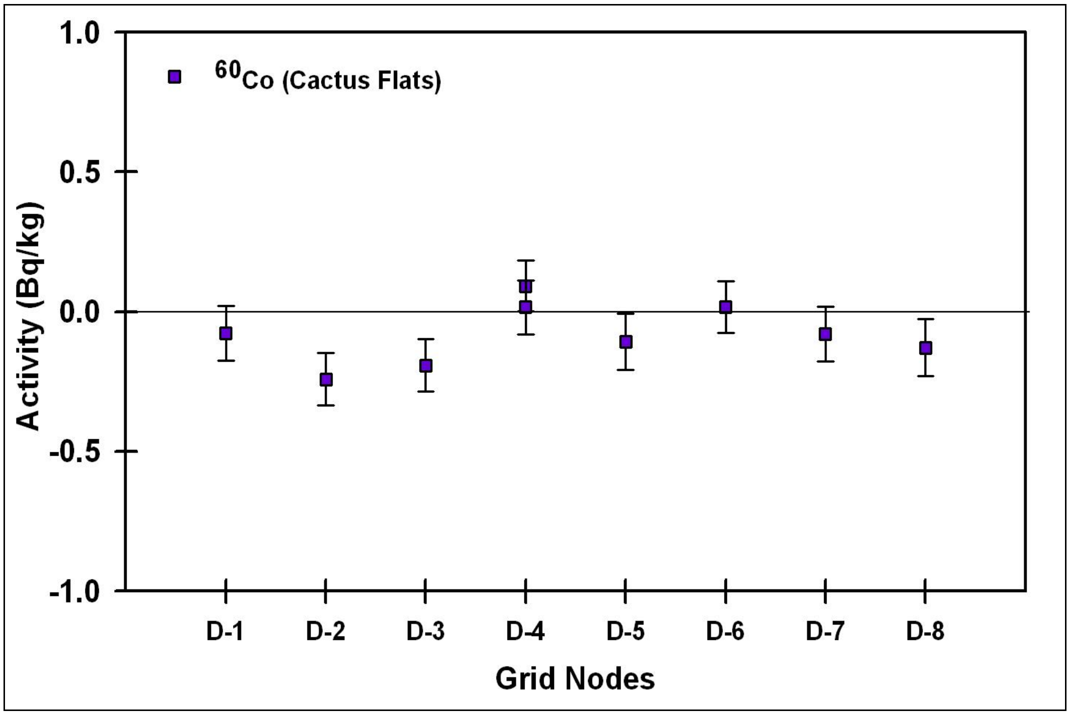


Figure 6.13 Activity Concentrations of ^{60}Co in Soil Samples Collected from Cactus Flats in 2012

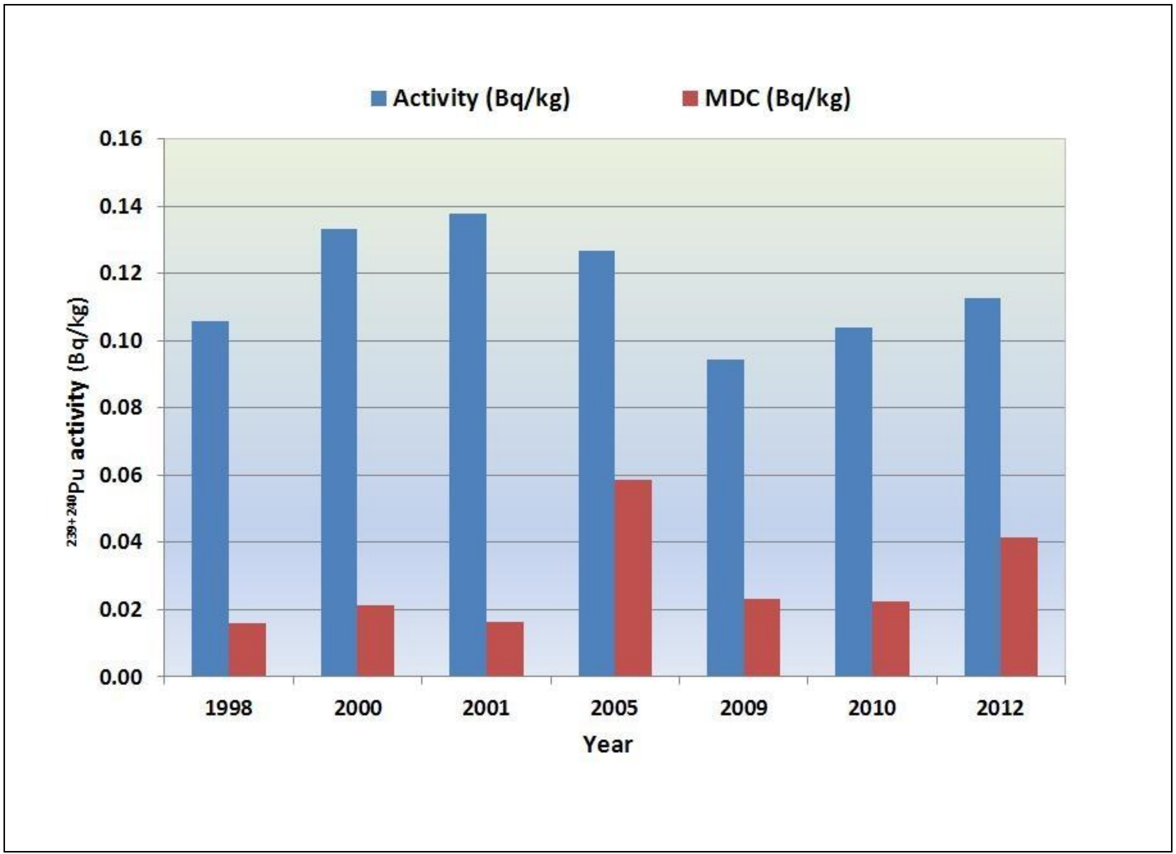


Figure 6.14 Average Activity Concentrations of $^{239+240}$Pu in Near Field Soil (1998-2012)

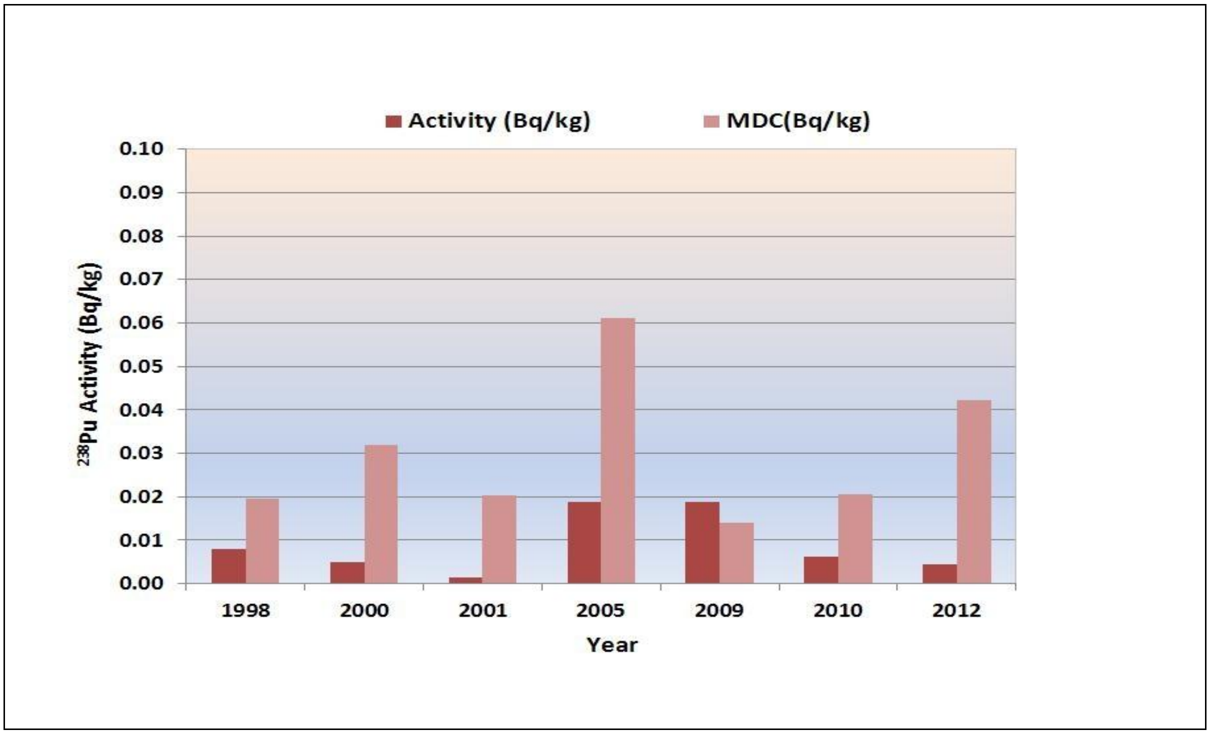


Figure 6.15 Average Activity Concentrations of ^{238}Pu in Near Field Soil (1998-2012)

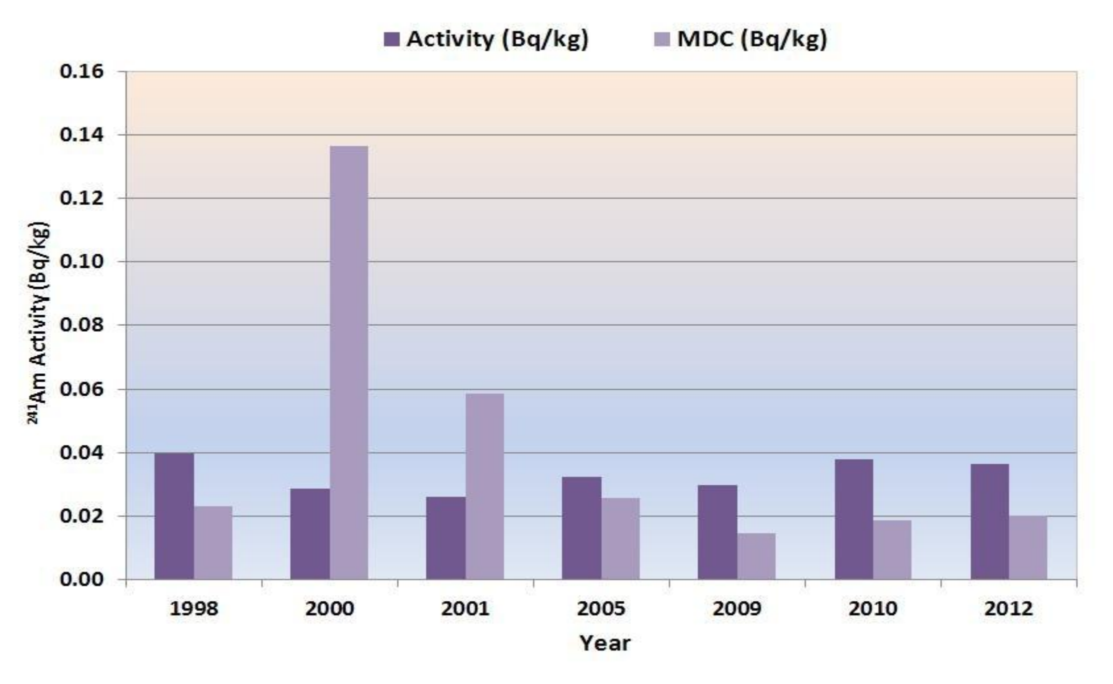


Figure 6.16 Average Activity Concentrations of ^{241}Am in Near Field Soil (1998-2012)

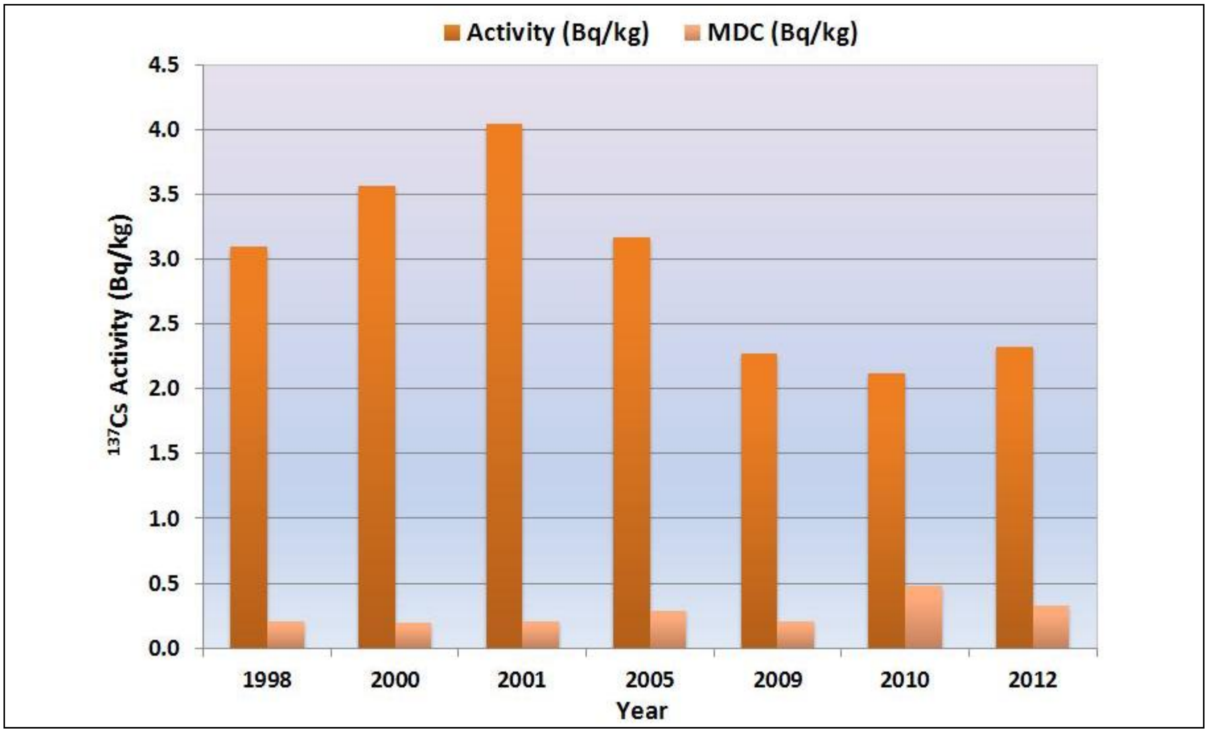


Figure 6.17 Average Activity Concentrations of ^{137}Cs in Near Field Soil (1998-2012)

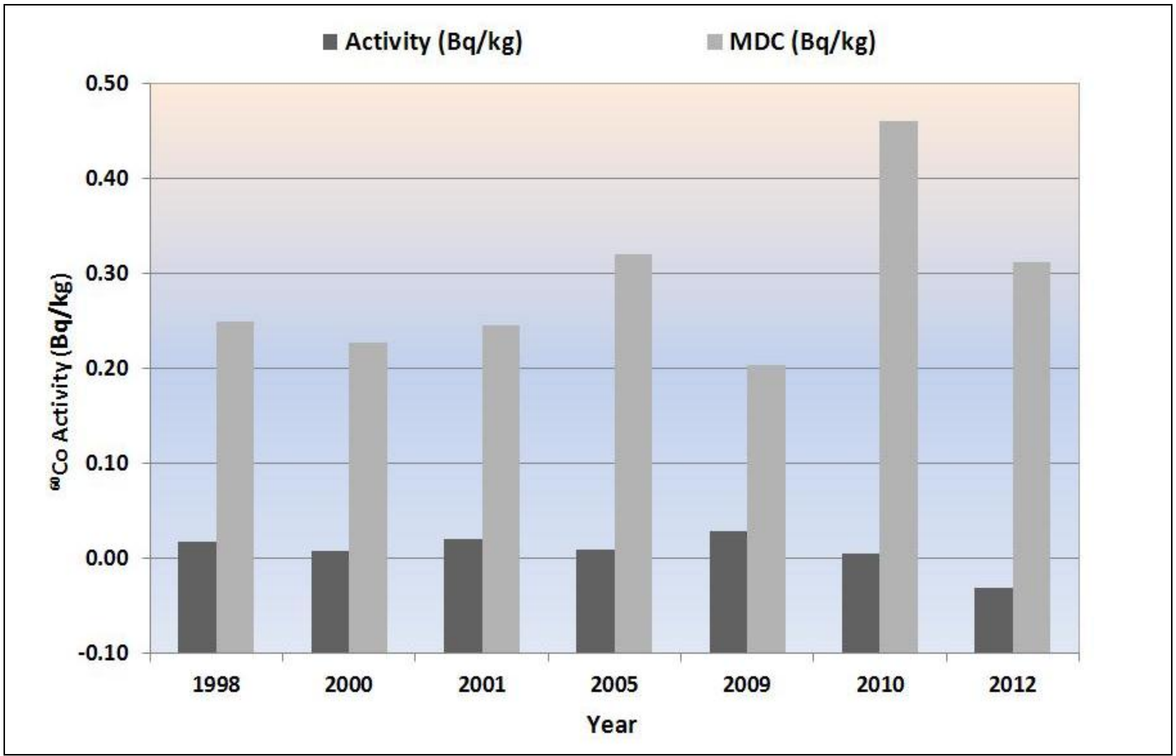


Figure 6.18 Average Activity Concentrations of ^{60}Co in Near Field Soil (1998-2012)

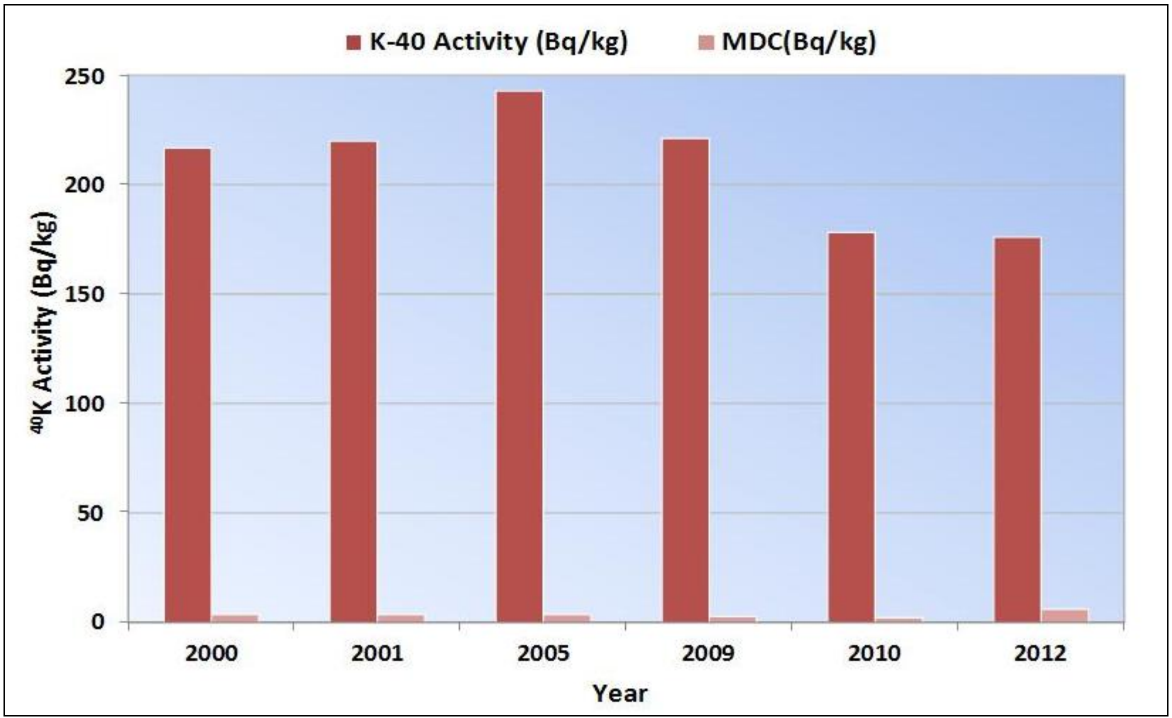


Figure 6.19 Average Activity Concentrations of ^{40}K in Near Field Soil (1998-2012)

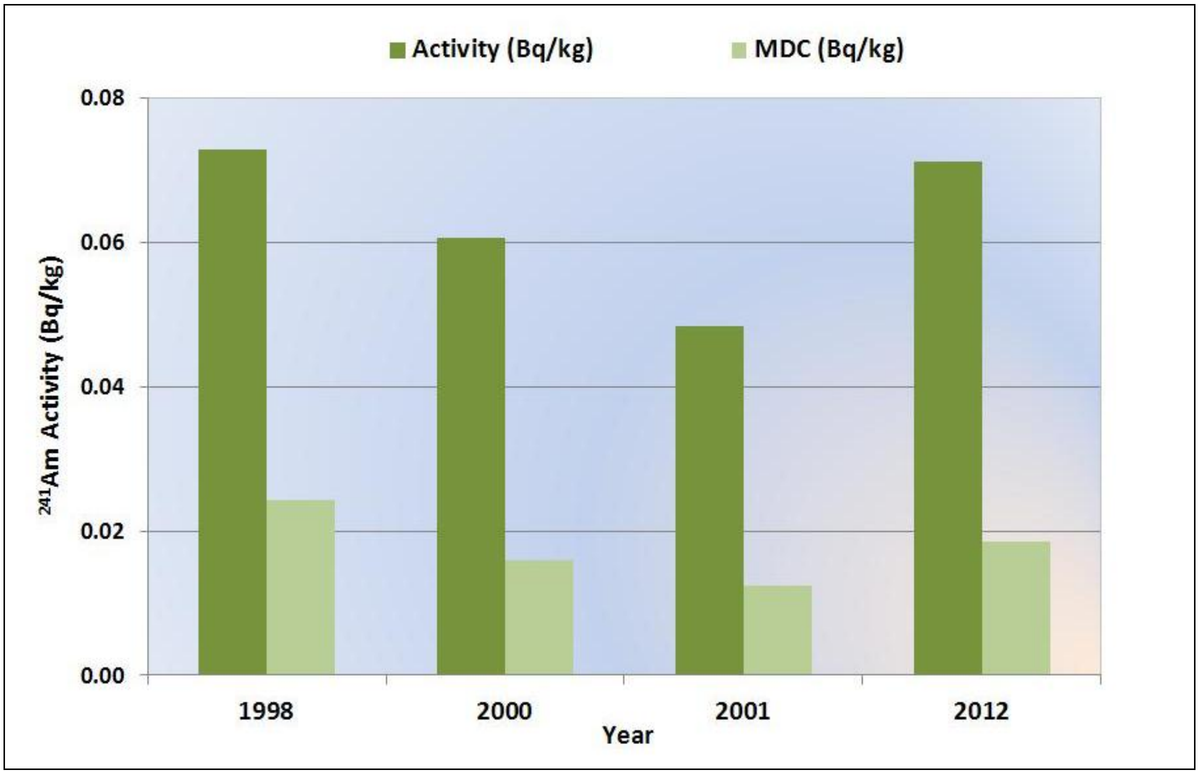


Figure 6.20 Average Activity Concentrations of ^{241}Am in Cactus Flats (1998-2012)

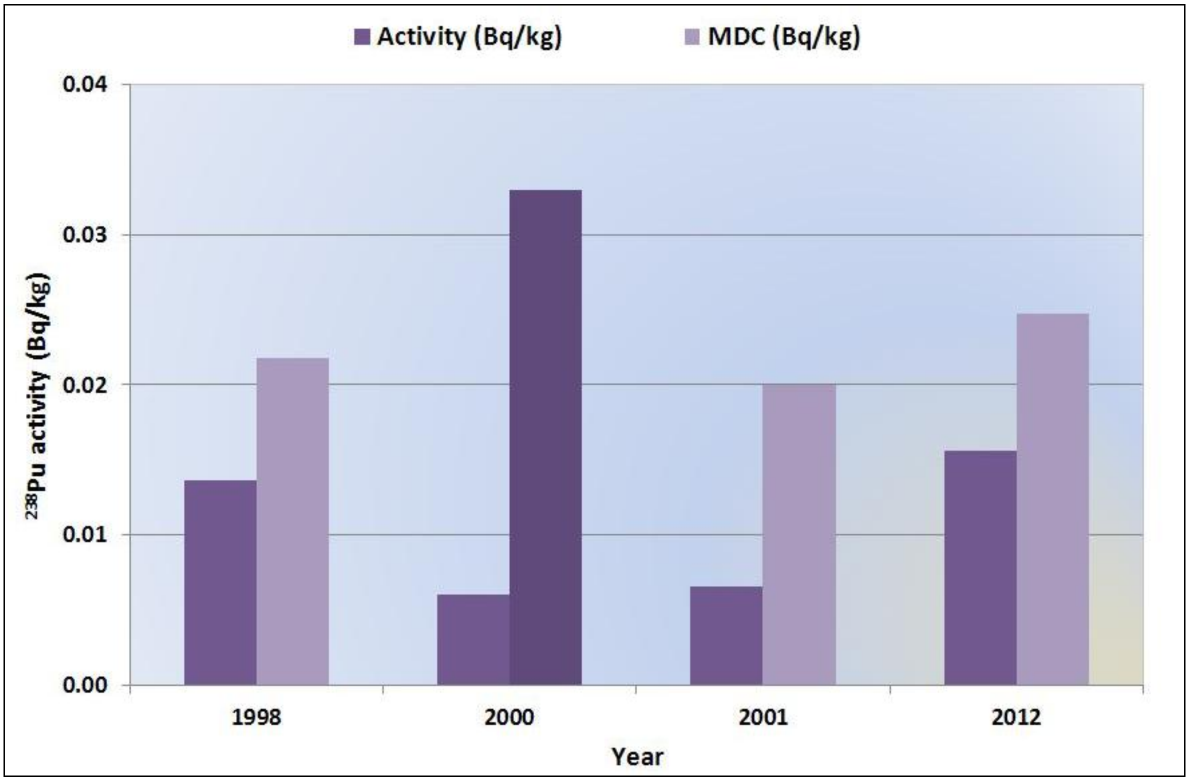


Figure 6.21 Average Activity Concentrations of ^{238}Pu in Cactus Flats (1998-2012)

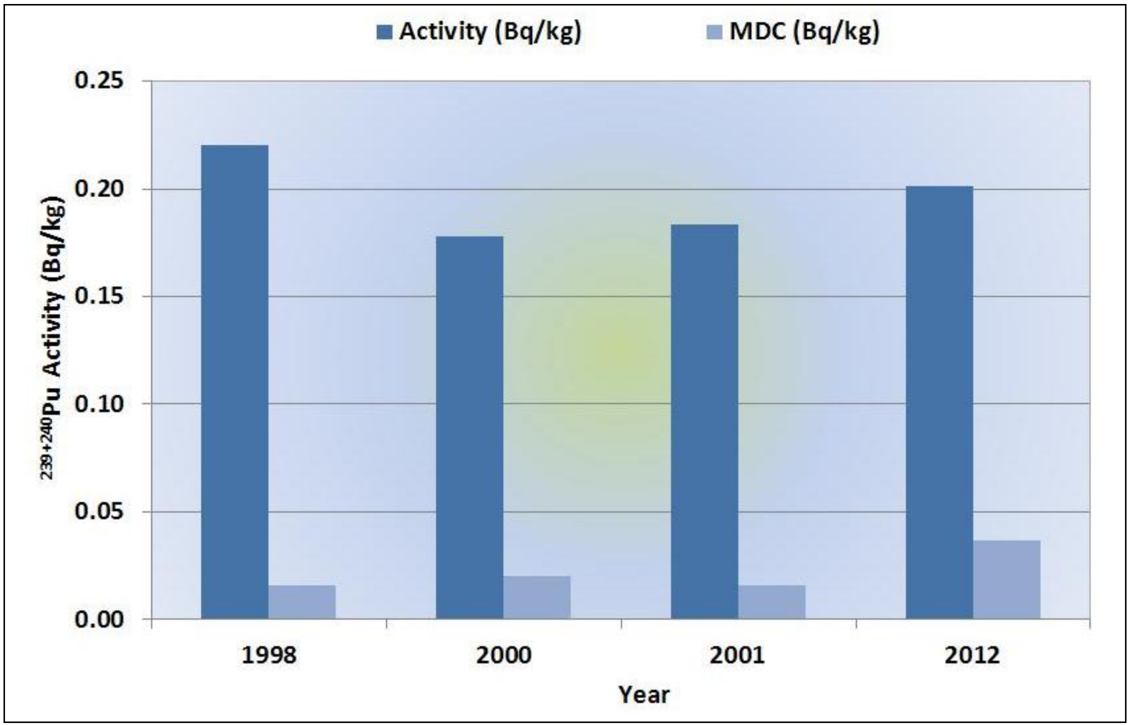


Figure 6.22 Average Activity Concentrations of $^{239+240}$Pu in Cactus Flats (1998-2012)

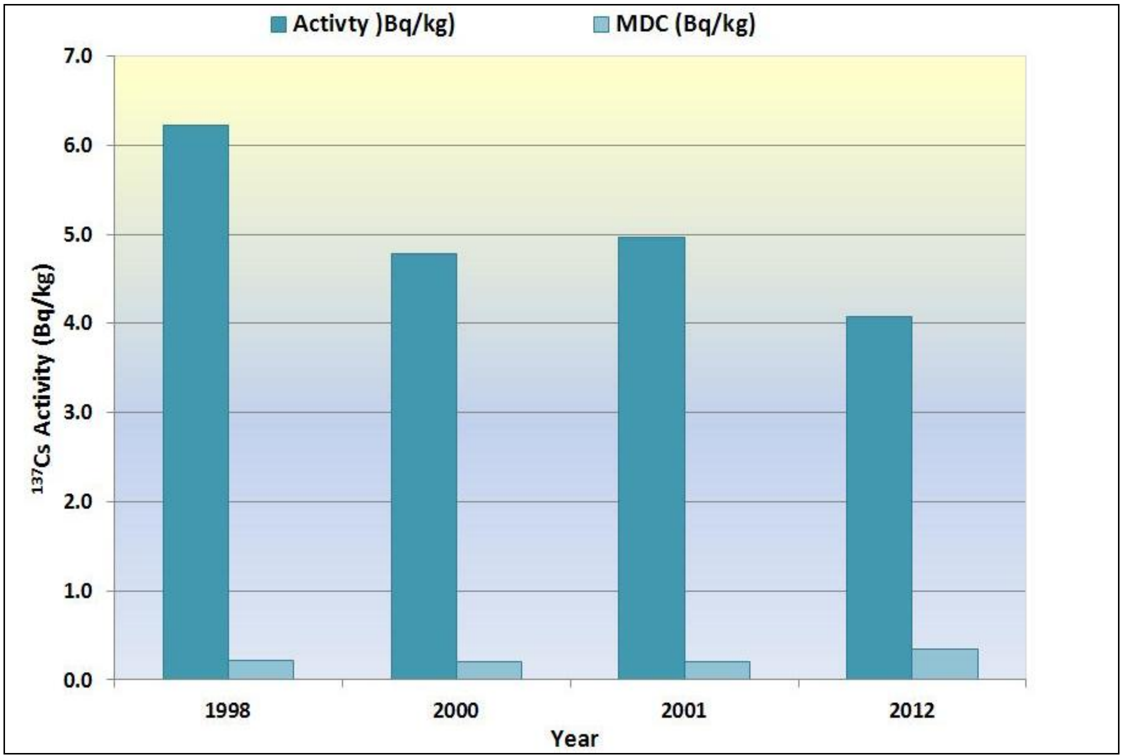


Figure 6.23 Average Activity Concentrations of ^{137}Cs in Cactus Flats (1998-2012)

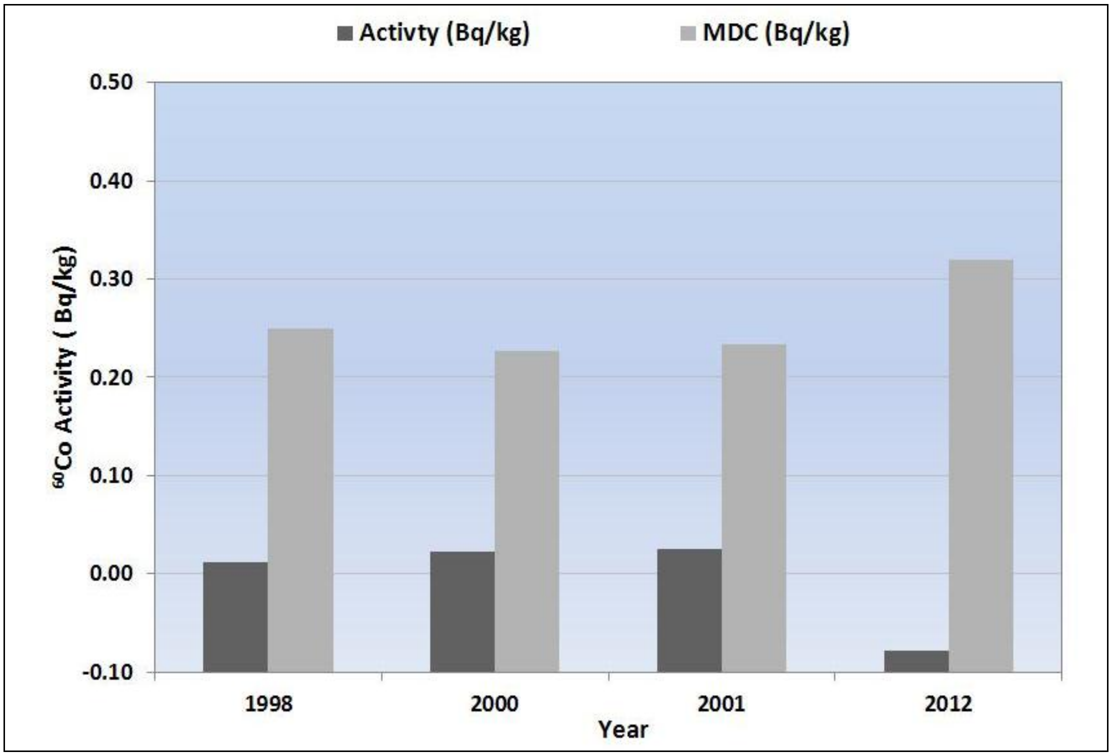


Figure 6.24 Average Activity Concentrations of ^{60}Co in Cactus Flats (1998-2012)

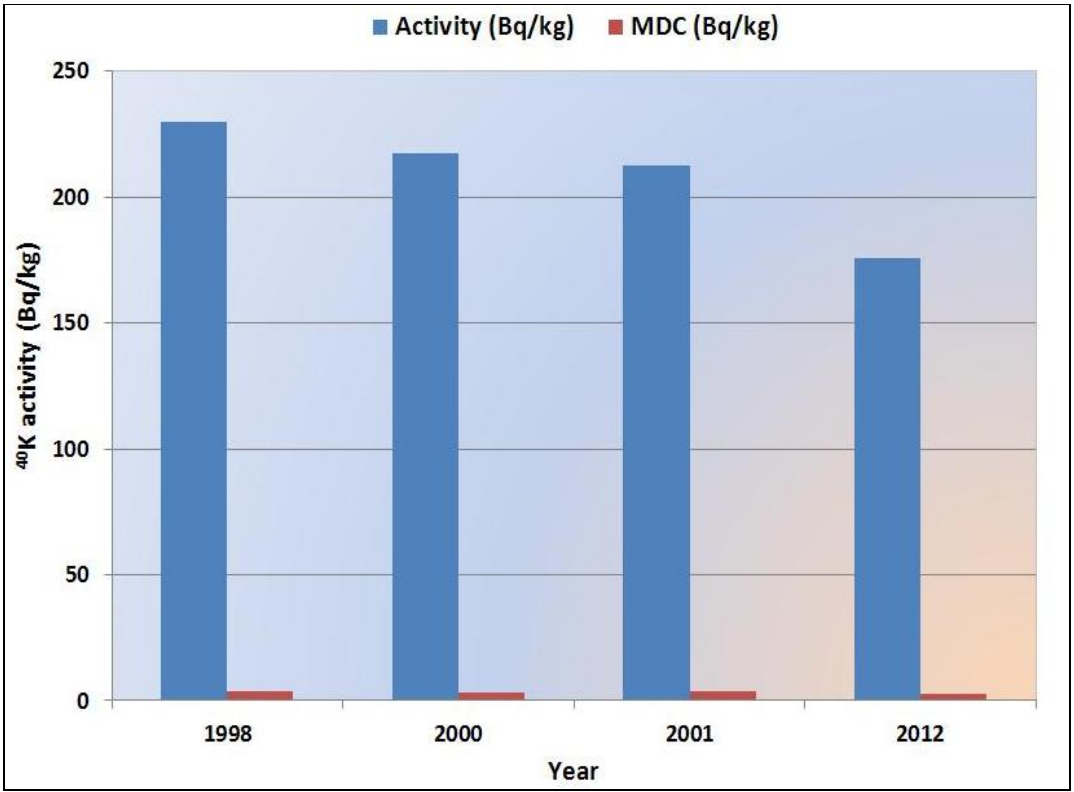


Figure 6.25 Average Activity Concentrations of ^{40}K in Cactus Flats (1998-2012)

CHAPTER 7

Surface Water and Sediments Monitoring

Samples of surface water and sediment in the vicinity of the WIPP site were collected and analyzed to determine the concentrations of radiological contaminants attributable to the site. Surface water bodies measured included Brantley Lake, Lake Carlsbad and Red Bluff Reservoir. In addition to surface water samples, aquatic sediment was collected from these three locations as well. Radiological constituents of interest included the following gamma-emitting radionuclides: uranium-234, uranium-235, uranium-238, plutonium-238, and plutonium-239+240. Non-radiological analyses, consisting of elemental analyses, anion analyses, and analysis for mercury, were performed separately from the radiochemical analyses conducted for regional surface water samples. All radiological and non-radiological contaminant concentrations measured in the vicinity of the WIPP site during 2012 were close to the baseline levels, indicating no impact of WIPP related activities to the local environment.

Introduction

Lake Carlsbad

As part of the WIPP EM project, surface water and sediments are collected from three regional reservoirs situated along the Pecos River. Brantley Lake and Red Bluff Reservoir were selected for sampling because they are impoundments located "upstream" and "downstream", respectively, relative to surface and ground water flows from the area immediately surrounding the WIPP site (Figure 7.1). Both reservoirs support a warm water fishery and are used for irrigation, livestock watering, wildlife habitat and recreation. Lake Carlsbad is an impounded section of the Pecos River within the city of Carlsbad that is used extensively by the local population for recreational warm water fishing, boating and swimming. In 1997, a pilot study of the surface water and sediments in Brantley Lake was conducted, in which 15 sediment and three surface water samples were collected during March and April and three additional water samples in September. A summary of the sample analyses was included in the 1997 CEMRC Report. In 1998, 24 sediment and 17 surface water samples were collected from Brantley Lake, Lake Carlsbad, and Red Bluff Reservoir. These included 12 sediment samples and 11 surface water samples collected during the January-April timeframe and the remaining samples (12 sediment and 6 surface water) collected during the August-October timeframe. The results of actinide, elemental, inorganic and selected organic analyses of the first set of samples collected in 1998 were reported in the 1998 CEMRC Report. In 1999, six surface water and 12 sediment samples were collected from the three reservoirs during June-July and again in May -June of 2000 and 2001. No radiological analyses for sediment and surface water samples were performed during the years 2002-2011; however, non-radiological analyses of surface water samples were performed and reported in 2005.

The sediments accumulate soluble radionuclides by sorption on suspended sediment and insoluble radionuclides by settling. Any inferences from measurements are qualitative because distribution of radionuclides between water and sediments depends on the combined characteristics of the sediment, the water, and the radionuclides. Moreover, contaminated materials may move downstream or be covered by other materials.
Further, radionuclides can expose persons to external radiation when little or no water covers the sediment, e.g. at the banks. Radionuclides in sediment also are not direct sources of internal exposure to persons but may be indirect sources if taken up by fish or released to waters that are then ingested by humans.

Many of the sediment samples were found to contain fission-produced ^{137}Cs; while a few contained fission-produced ^{90}Sr and ^{134}Cs; activation-produced ^{60}Co, ^{58}Co, ^{54}Mn, and ^{65}Zn; and the transuranium (TRU) isotopes ^{239}Pu and ^{241}Am. Some ^{137}Cs, ^{90}Sr, and ^{239}Pu are fallout from nuclear tests in the atmosphere, which peaked in 1962-1963, and to a minor extent from the nuclear accidents at the Chernobyl and Fukushima nuclear power plants. However, naturally occurring radionuclides including uranium, thorium and ^{40}K also were detected. Many of the measured values are very low and near the limits of detection.

Analyses reported herein are for 2012 sediments and surface water samples. These samples were analyzed for radionuclides including alpha and gamma emitting radionuclides of interest to the WIPP while surface water samples were further analyzed for non-radiological analyses including elemental, anion, and mercury. ***The 2012 monitoring results show no increase in the levels of radionuclides or non-radiological constituents that could be attributed to WIPP-related activities***.

Sample collection

As mentioned previously, sediment samples were collected from the 3 reservoirs located in the vicinity of the WIPP site including Brantley Lake, Lake Carlsbad, and Red Bluff Reservior, with one duplicate sample collected from one reservoir chosen at random. Sediment and surface water samples were collected during June 2012 from previously selected sites within each reservoir. Four site 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. The thickness of the sediment collected ranged from 5 to 10 cm. Prior to collection, excess water was decanted from the sediment. Approximately 5 L of sediment was sealed in a pre-cleaned plastic bucket in the field and transported to CEMRC for preparation prior to analyses.

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

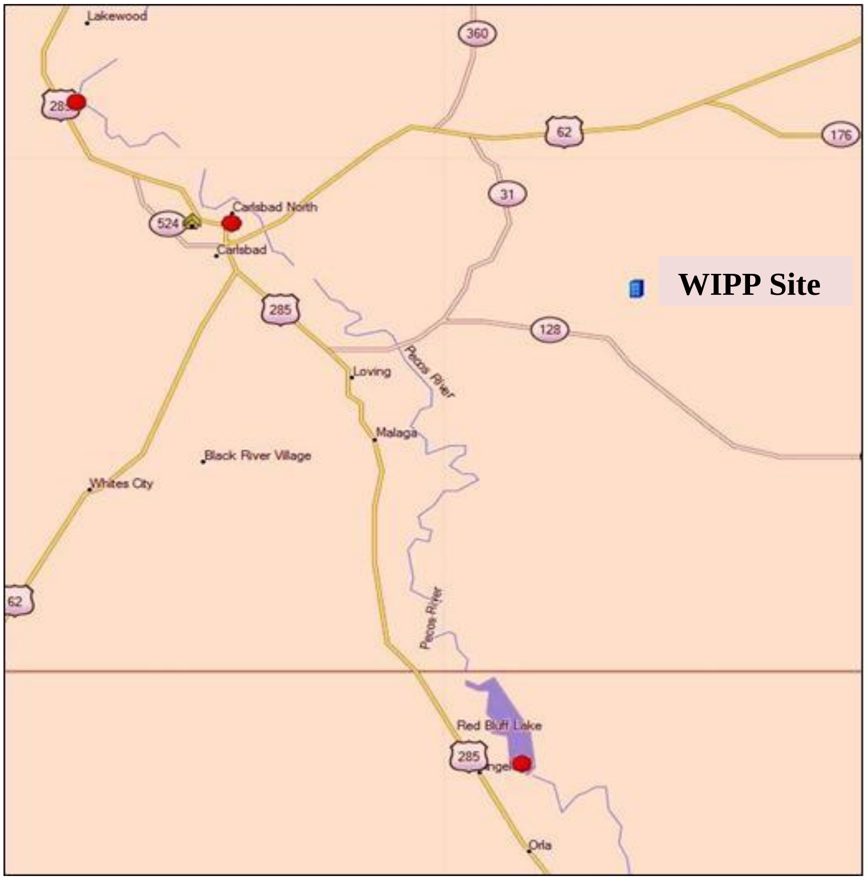


Figure 7.1 Sampling location for sediment and surface water samples

Sample Preparation

Sediment samples

In the laboratory, the sediment samples were air-dried, pulverized to pass a 2-mm sieve, and homogenized for radiochemical analyses. Samples were further dried at 105°C for 24 hours and pulverized in a jar mill prior to analysis. Approximately 300-mL (500g) aliquots were used for gamma spectroscopy analysis. The samples for gamma analysis were sealed in a ~ 300-mL can and stored for at least 21 days to allow radon progeny to reach equilibrium with parent radionuclides. Gamma analysis was conducted using a high purity germanium (HPGe) detector for 48 hours. A set of soil matrix standards procured from Eckert and Ziegler Analytics (GA) was used to establish matrix-specific calibration and counting efficiencies. Reported concentrations are blank-corrected.

Dissolution of sediment Samples

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

Actinides Separation

The oxidation state of Pu was adjusted by adding 1 ml of 1.0M NH_4I with a 10 min wait step, followed by 2 ml of $NaNO_2$. The sample solutions were then ready for the purification procedure with anion exchange and by extraction chromatography. Next Pu was separated from Am and U using an anion exchange column. U was separated from Am on UTEVA and the Am subsequently purified from lanthanides with TEVA. Uranium fraction from UTEVA may be purified further (if needed) with anion exchange columns. Finally, Pu, Am and U were micro-coprecipitated on stainless steel discs and counted on the alpha spectrometer for five days.

Surface water

In the laboratory, surface water samples collected for radiological analyses were acidified with HNO_3 to a $pH < 2$ and the sample containers were shaken to distribute suspended material evenly. One 2-L portion was used for gamma spectroscopy and another 1L portion was used for sequential analysis of the uranium/transuranic isotopes. The first aliquot was transferred to 2L Marinelli beakers for the measurement of the gamma-emitting radionuclides potassium (^{40}K), cobalt (^{60}Co), and cesium (^{137}Cs, ^{134}Cs), by gamma spectroscopy using a high purity germanium (HPGe) detector. Before collecting the measurements, the gamma system was calibrated for energy and efficiency to enable both qualitative and quantitative analysis of the water samples. The energy and efficiency calibrations were carried out using a mixed standards material from Eckert and Ziegler, Analytics (GA) in the energy range between 60 to 2000 keV for a 2L Marinelli geometry. The counting time for each sample was 48 hours.

The second, 1L aliquot, was used for actinides analyses. Tracers consisting of uranium, americium, and plutonium (^{232}U, ^{243}Am, and ^{242}Pu) were added and the samples were digested using concentrated nitric 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.

Finally, the separated radionuclides were micro-precipitated using lanthanum fluoride (LaF_3) and deposited onto planchets for counting by alpha spectroscopy.

Results and Discussion

Sediment samples

The $^{239+240}$Pu, ^{238}Pu, ^{241}Am, isotopes of uranium (^{238}U, ^{235}U and ^{234}U) and gamma radionuclides ^{40}K, ^{137}Cs, ^{134}Cs and ^{60}Co were analyzed for all the sediment samples. The individual concentrations of these radionuclides collected are listed in Tables 7.1 and 7.2. The ^{241}Am and $^{239+240}$Pu concentrations slightly greater than MDC were detected in all sediment samples, whereas ^{238}Pu was not detected in any sediment samples. The activity concentrations of ^{241}Am in the sediments ranged from 0.025-0.092 Bq/kg, while that of $^{239+240}$Pu varied from 0.11-0.21 mBq/g. The $^{239+240}$Pu activities were highest in the sediment collected from Lake Carlsbad Reservoir. The concentrations of ^{241}Am, ^{238}Pu and $^{239+240}$Pu in the sediment samples collected from three regional reservoirs are shown in Figure 7.2. The baseline concentrations of $^{239+240}$Pu ranged from 0.07 to 0.41mBq/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 Report, 1999). The ^{241}Am activities in sediment samples from the three reservoirs are lower than $^{239+240}$Pu activities. The maximum activity of ^{241}Am (0.092 mBq/g) was measured in Lake Carlsbad. However, the maximum concentrations of $^{239+240}$Pu and ^{241}Am measured in 2012 sediments samples were within the range of the baseline phase data for the sediment samples collected in 1998. The range of activity concentrations of some selected radionuclides in the sediment samples collected from the three regional reservoirs in1998-1999 are summarized in Table 7.3. Comparison of baseline to monitoring phase levels of radionuclides in sediment samples collected within the Pecos River valley revealed no detectable increases above those typical of natural variation.

Uranium isotopes (^{234}U, ^{235}U and ^{238}U) were detected in all the sediment samples collected in 2012. Maximum activity concentrations for ^{234}U, ^{235}U and ^{238}U (Table 7.1 and Figure 7.3) increased slightly in the monitoring phase relative to the baseline phase for samples collected from all three reservoirs. The concentrations of ^{238}U and ^{234}U were lowest in Lake Carlsbad, and highest in Red Bluff reservoir. 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 1.5 to 1.6 (Figure 7.4)

The ^{137}Cs was detected in all sediment samples collected in 2012 (Table 7.2 and Figure 7.5), although variability among the ^{137}Cs concentrations was not very significant. Maximum activity concentrations for ^{137}Cs (Table 7.2) decreased slightly in the monitoring phase relative to the baseline phase for samples collected from all three reservoirs. The ^{40}K was detected in every sample (Table 7.2 and Figure 7.8), which was expected as this naturally occurring gamma-emitting radionuclide is ubiquitous in sediments. However, 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 7.2 and Figures 7.6 and 7.7, the ^{60}Co and ^{134}Cs were not detected at any sampling location in 2012. Comparison of activity concentrations of gamma-emitting radionuclides determined during the monitoring phase (1999-2001 and 2012) and baseline phase (1998) reflected no increase in radionuclide concentrations.

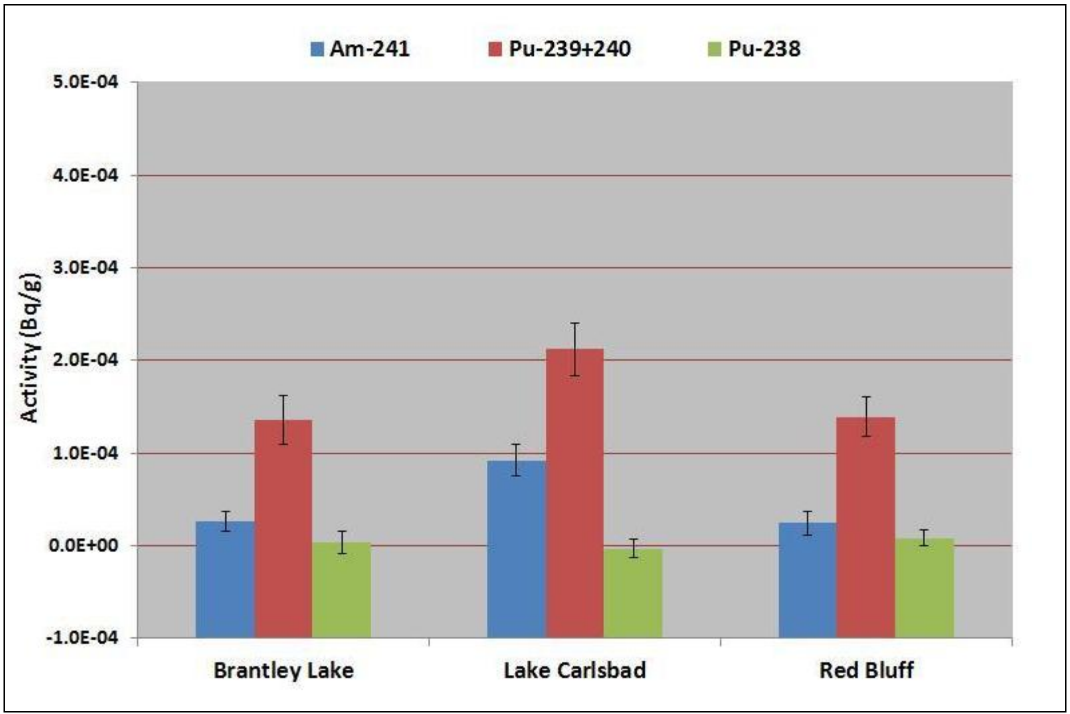


Figure 7.2 ^{241}Am, ^{238}Pu and $^{239+240}$Pu activity concentrations in sediment samples in three regional reservoirs

Table 7.1 Plutonium Americium and Uranium Concentrations (Bq/g) in Sediment Samples collected in the vicinity of the WIPP site

Radionuclides	Location	Activity (Bq/g)	SD (Bq/g)	MDC (Bq/g)	Qualifier
^{241}Am	Brantley Lake	2.61E-05	1.10E-05	2.23E-05	+
	Lake Carlsbad	9.23E-05	1.70E-05	2.34E-05	+
	Red Bluff	2.47E-05	1.27E-05	3.42E-05	+
	Red Bluff (DUP)	3.77E-05	1.18E-05	2.36E-05	+
$^{239+240}$Pu	Brantley Lake	1.36E-04	2.63E-05	5.33E-05	+
	Lake Carlsbad	2.12E-04	2.81E-05	3.60E-05	+
	Red Bluff	1.39E-04	2.13E-05	3.54E-05	+
	Red Bluff (DUP)	1.09E-04	2.10E-05	4.45E-05	+

Table 7.1 Plutonium Americium and Uranium Concentrations (Bq/g) in Sediment Samples collected in the vicinity of the WIPP site (continued)

Radionuclides	Location	Activity (Bq/g)	SD (Bq/g)	MDC (Bq/g)	Qualifier
^{238}Pu	Brantley Lake	3.78E-06	1.25E-05	4.95E-05	U
	Lake Carlsbad	-3.35E-06	1.00E-05	4.39E-05	U
	Red Bluff (DUP)	8.59E-06	8.59E-06	3.08E-05	U
^{238}U	Brantley Lake	3.51E-02	8.13E-04	4.04E-05	+
	Lake Carlsbad	3.31E-02	8.94E-04	3.45E-05	+
	Red Bluff	3.52E-02	7.47E-04	2.70E-05	+
	Red Bluff (DUP)	3.35E-02	7.52E-04	4.90E-05	+
^{235}U	Brantley Lake	1.62E-03	8.19E-05	4.02E-05	+
	Lake Carlsbad	1.65E-03	8.51E-05	3.94E-05	+
	Red Bluff	2.36E-03	9.37E-05	2.06E-05	+
	Red Bluff (DUP)	1.77E-03	8.13E-05	2.75E-05	+
^{234}U	Brantley Lake	5.26E-02	1.19E-03	4.70E-05	+
	Lake Carlsbad	4.99E-02	1.32E-03	4.12E-05	+
	Red Bluff	5.67E-02	1.17E-03	3.17E-05	+
	Red Bluff (DUP)	5.46E-02	1.19E-03	4.20E-05	+

Qualifier: Indicated whether radionuclide was detected. Plus (+) equals detected. U equals undetected.

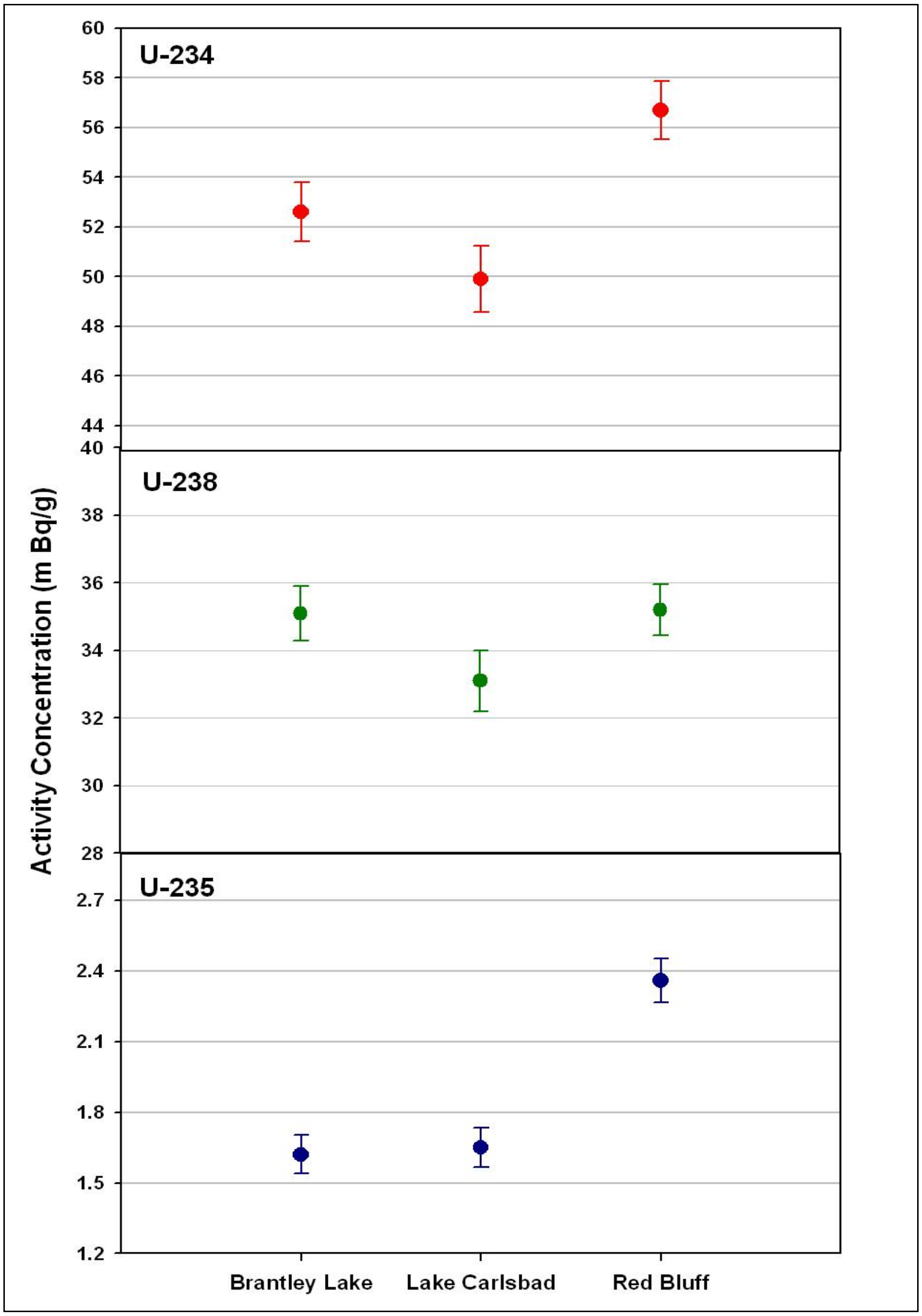


Figure 7.3 Activity concentrations of three uranium isotopes in sediment samples from three regional reservoirs in 2012

Table 7.2 Gamma Radionuclides Concentrations (Bq/g) in Sediment Samples collected in the vicinity of the WIPP site

Radionuclides	Location	Activity (Bq/g)	SD (Bq/g)	MDC (Bq/g)	Qualifier
^{40}K	Brantley Lake	4.00E-01	3.96E-02	1.29E-02	+
	Lake Carlsbad	2.81E-01	2.80E-02	1.21E-02	+
	Red Bluff	3.18E-01	3.16E-02	1.11E-02	+
	Red Bluff (DUP)	2.98E-01	2.97E-02	1.10E-02	+
^{60}Co	Brantley Lake	-3.15E-04	3.06E-04	1.02E-03	U
	Lake Carlsbad	-1.25E-05	2.89E-04	9.61E-04	U
	Red Bluff	-1.84E-04	2.54E-04	8.48E-04	U
	Red Bluff (DUP)	-3.18E-05	2.45E-04	8.17E-04	U
^{134}Cs	Brantley Lake	-4.87E-04	1.94E-04	6.24E-04	U
	Lake Carlsbad	-8.24E-05	2.00E-04	6.67E-04	U
	Red Bluff	-6.08E-05	1.63E-04	5.37E-04	U
	Red Bluff (DUP)	2.09E-05	1.66E-04	5.48E-04	U
^{137}Cs	Brantley Lake	2.90E-03	3.21E-04	9.63E-04	+
	Lake Carlsbad	3.60E-03	3.17E-04	8.98E-04	+
	Red Bluff	1.62E-03	2.50E-04	7.79E-04	+
	Red Bluff (DUP)	1.96E-03	2.42E-04	7.34E-04	+

Qualifier: Indicated whether radionuclide was detected. Plus (+) equals detected. U equals undetected.

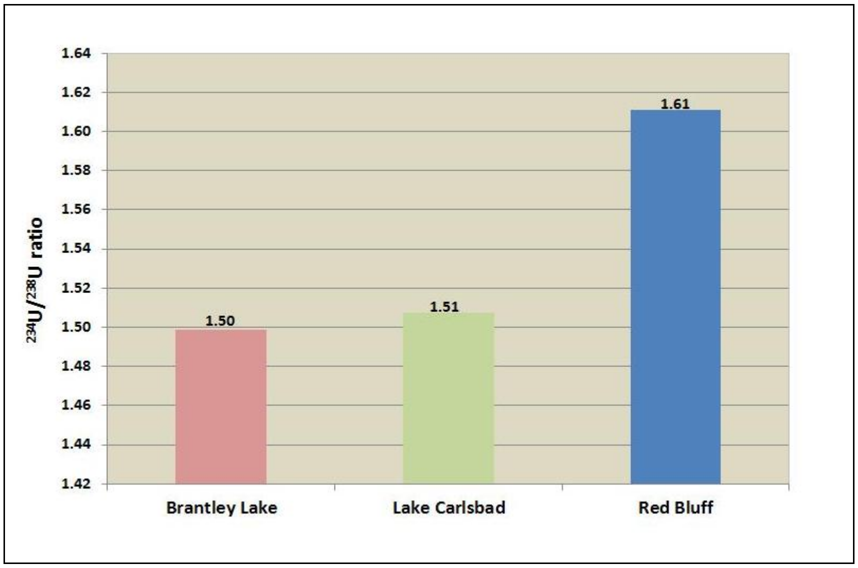


Figure 7.4 The ^{234}U/^{238}U Activity Ratio in sediment samples of three reservoirs in the vicinity of the WIPP site

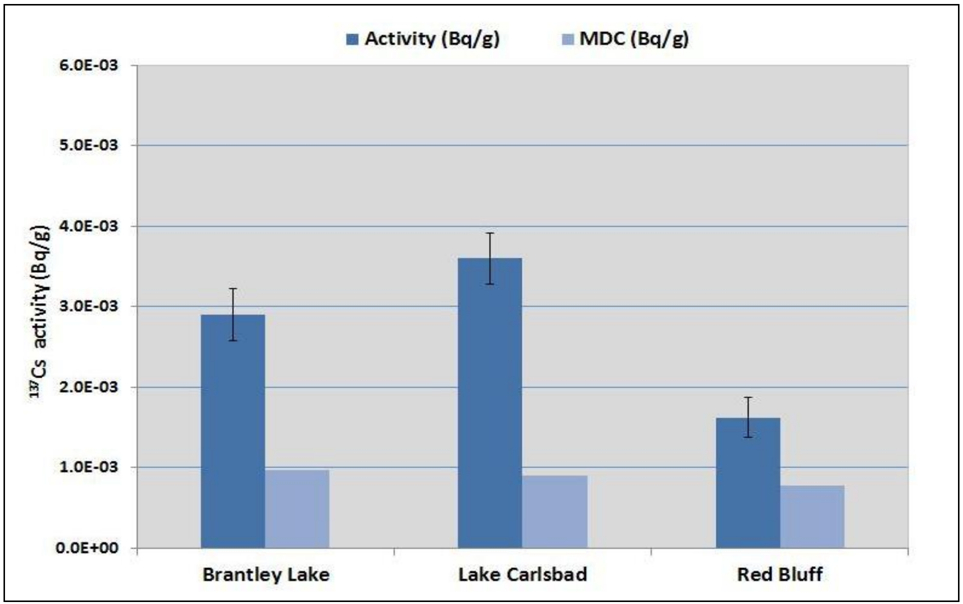


Figure 7.5 ^{137}Cs activity concentrations in sediment samples in three regional reservoirs

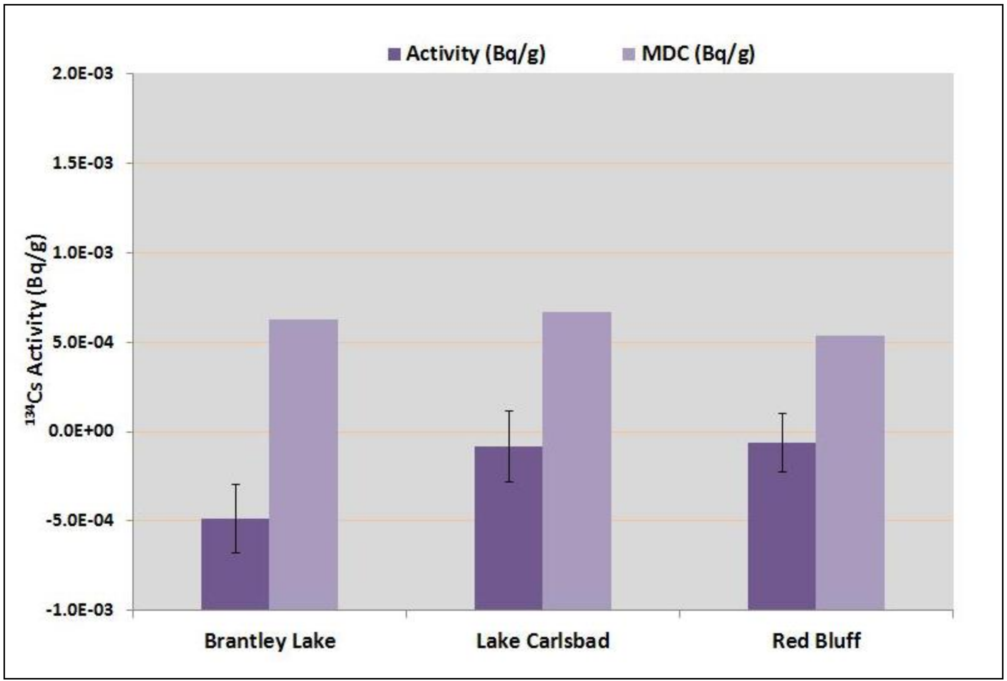


Figure 7.6 ^{134}Cs activity concentrations in sediment samples in three regional reservoirs

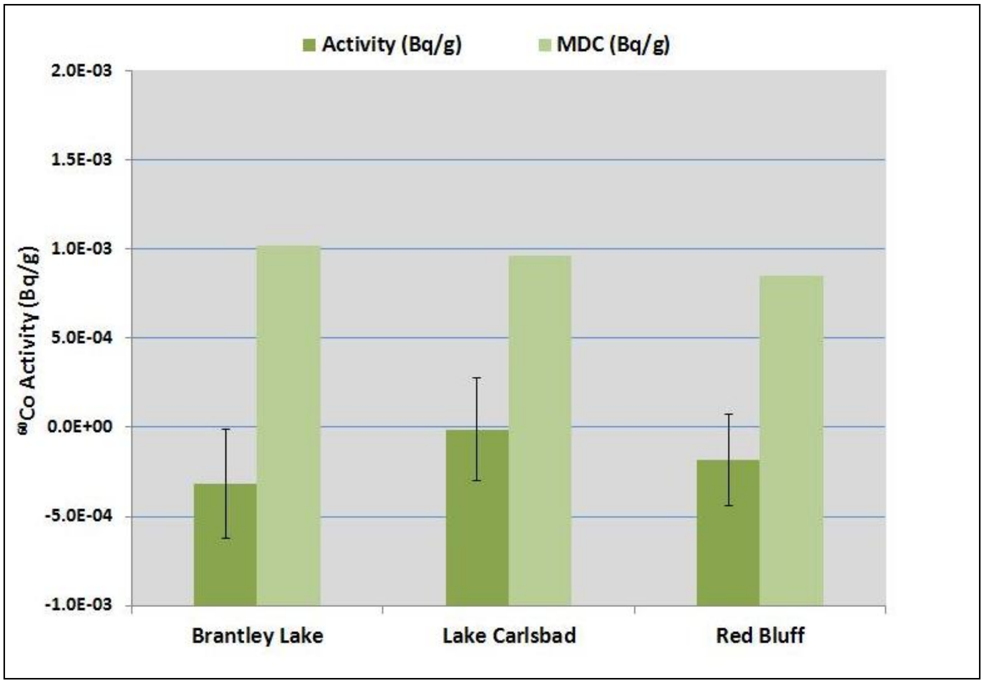


Figure 7.7 ^{60}Co activity concentrations in sediment samples in three regional reservoirs

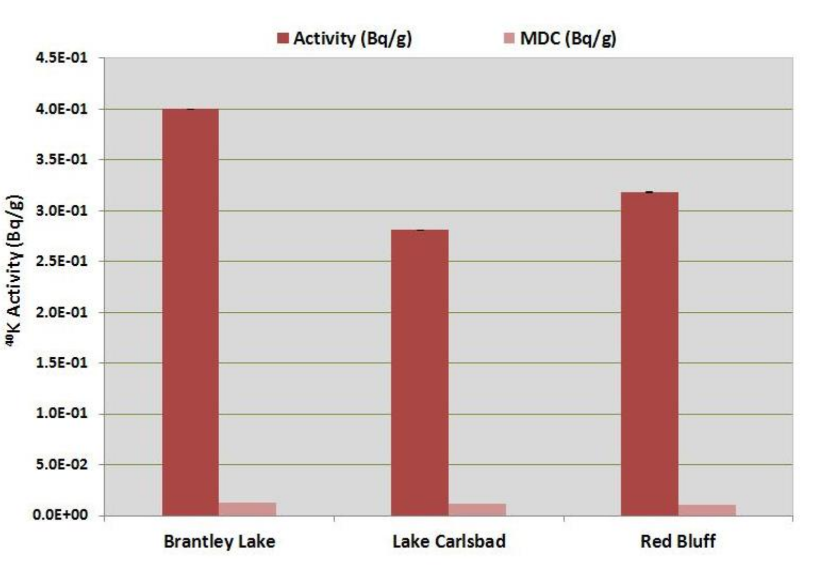


Figure 7.8 ^{40}K activity concentrations in sediment samples in three regional reservoirs

Table 7.3 Range of activity concentration for selected radionuclides in sediment samples collected from three regional reservoirs during 1998-1999

Radionuclides	Baseline N	Baseline Minimum (Bq/g)	Baseline Maximum (Bq/g)
		Brantley Lake	
^{241}Am	9	6.93E-05	1.00E-04
^{137}Cs	8	7.33E-03	9.00E-03
^{40}K	8	4.72E-01	6.21E-01
$^{239+240}$Pu	9	2.06E-04	2.87E-04
^{234}U	9	4.34E-02	6.82E-02
^{235}U	9	2.20E-03	3.16E-03
^{238}U	9	3.64E-02	4.55E-02
		Lake Carlsbad	
^{241}Am	8	3.17E-05	5.47E-05
^{137}Cs	8	2.48E-03	5.19E-03
^{40}K	8	2.75E-01	4.51E-01
$^{239+240}$Pu	8	8.97E-05	1.63E-04
^{234}U	8	3.51E-02	5.23E-02
^{235}U	8	1.40E-03	2.44E-03
^{238}U	8	2.56E-02	3.76E-02
		Red Bluff reservoir	
^{241}Am	8	5.28E-05	1.81E-04
^{137}Cs	8	4.88E-03	1.11E-02
^{40}K	8	4.08E-01	4.55E-01
$^{239+240}$Pu	8	1.49E-04	4.35E-04
^{234}U	8	4.35E-02	1.02E-01
^{235}U	11	1.97E-03	4.44E-03
^{238}U	8	2.99E-02	6.15E-02

N = number of samples >MDC

Surface water

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 2012. The concentrations of ^{241}Am, ^{238}Pu, and $^{239+240}$Pu measured in the three surface water reservoirs in the vicinity of the WIPP site are listed in Table 7.4 and shown in Figures 7.9-7.11. The ^{241}Am, ^{238}Pu, and $^{239+240}$Pu were not detected in any of the surface water samples collected during 1999, 2000 and 2001 from all three reservoirs. In comparison, a detectable quantity of ^{241}Am (2.56 mBq/ L) was reported by NWP predecessor Laboratory Westinghouse Waste Isolation Division (WID) in a surface water sample having a high level of suspended sediment that was collected from the Pecos River near Artesia in 1997 (approximately 65 km northwest of WIPP) (1998, *Waste Isolation Pilot Plant Annual Site Environmental Report Calendar Year 1997,* DOE/WIPP 98-2225). In addition, a higher ^{241}Am value of 3.05 mBq/L was reported for a sample collected from the Pecos River near Carlsbad during 1993-1995 by the Environmental Evaluation Group (EEG; Kenny et al., 1998, *Preoperational Radiation Surveillance of the WIPP Project by EEG during 1993 through 1995*, EEG-67). As a result, the inclusion of suspended sediment could possibly be a source of the ^{241}Am occasionally detected in the surface water samples.

Uranium isotopes (^{234}U, ^{235}U and ^{238}U) were detected in all the surface water samples collected in 2012. The highest activity concentrations for ^{234}U, ^{235}U and ^{238}U (Table 7.4 and Figure 7.12) were measured in the Red Bluff reservoir. The concentration ranges for these isotopes, showed no significant difference between baseline and monitoring phases. The isotopic ratios were very similar for Brantley and Red Bluff reservoirs, but was lower for Lake Carlsbad. The reservoirs appeared to be slightly enriched in ^{234}U compared to ^{238}U, with the activity ratios ranging from 1.52 to 2.21 (Figure 7.13) Maximum activity concentrations for ^{234}U, ^{235}U and ^{238}U (Table 7.4) 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 7.5.

The ^{40}K was the only gamma-emitting radionuclide determined at activity concentrations above MDC, and it was only detected in samples from Red Bluff Reservoir (2.47-2.72 Bq/L). These levels were not significantly different from those determined in samples collected in 1998. The gamma emitting radionuclides measured in 2012 surface water samples are summarized in Table 7.6. The individual concentration measured were shown in Figures 7.14-7.17.

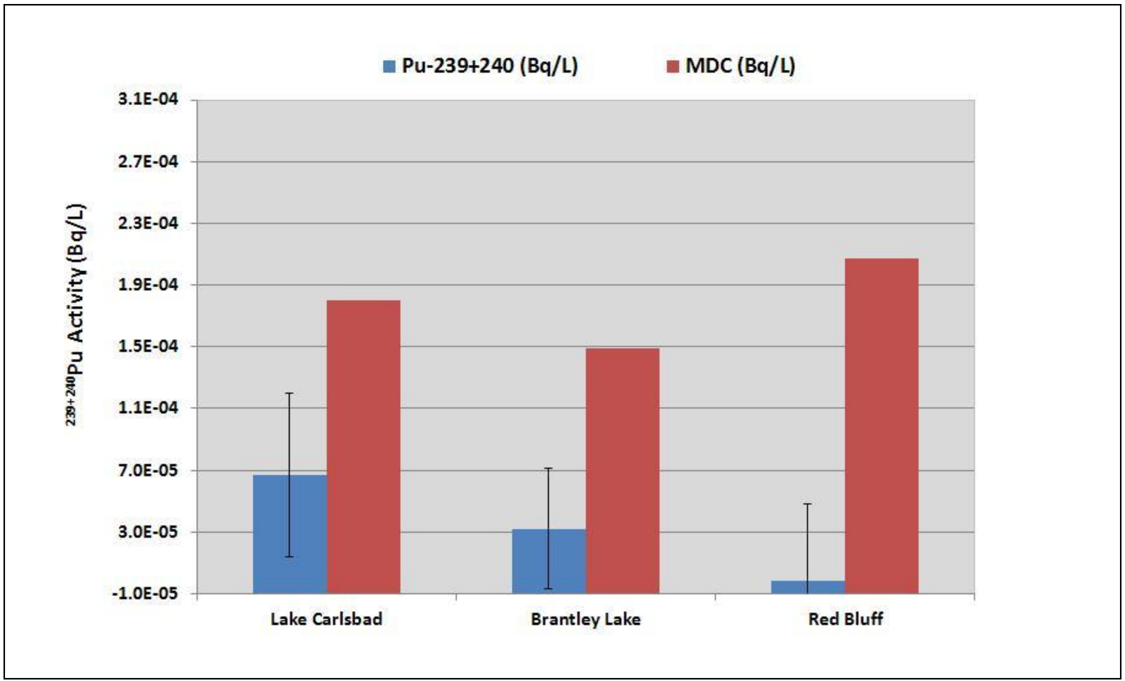


Figure 7.9 $^{239+240}$Pu activity concentrations in surface water samples in three regional reservoirs

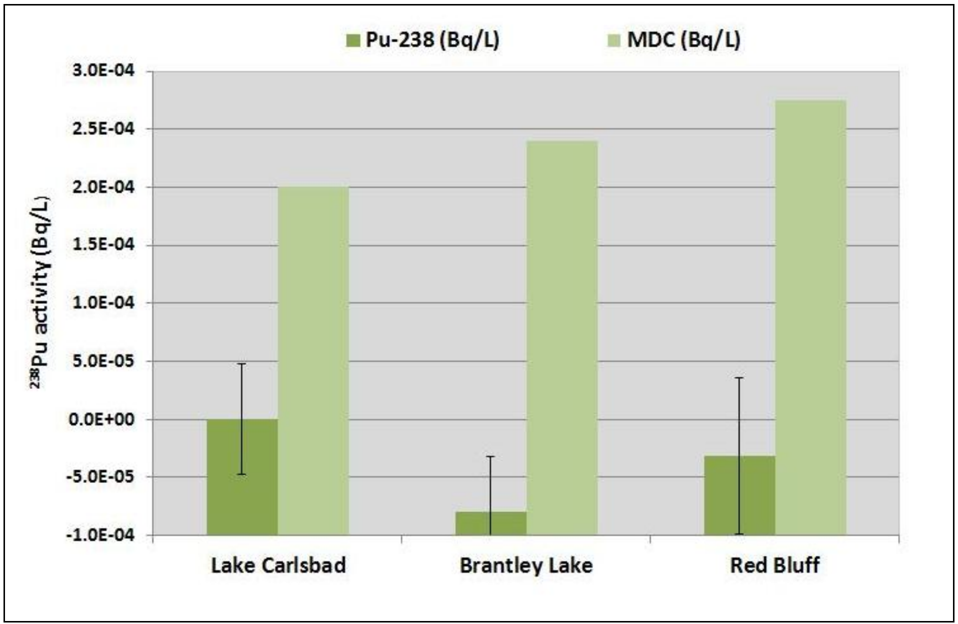


Figure 7.10 ^{238}Pu activity concentrations in surface water samples in three regional reservoirs

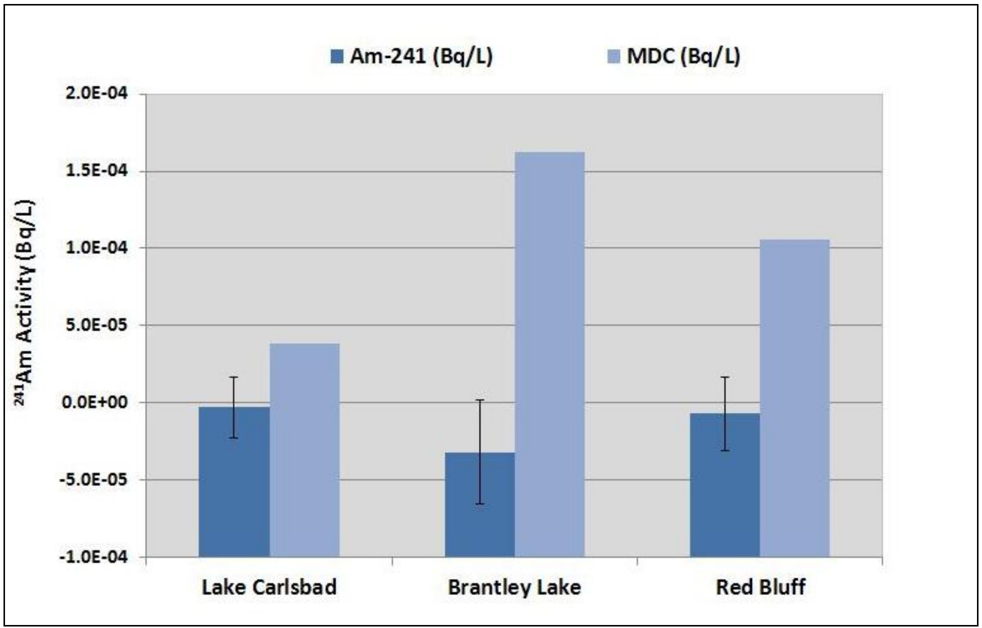


Figure 7.11 ^{241}Am activity concentrations in surface water samples in three regional reservoirs

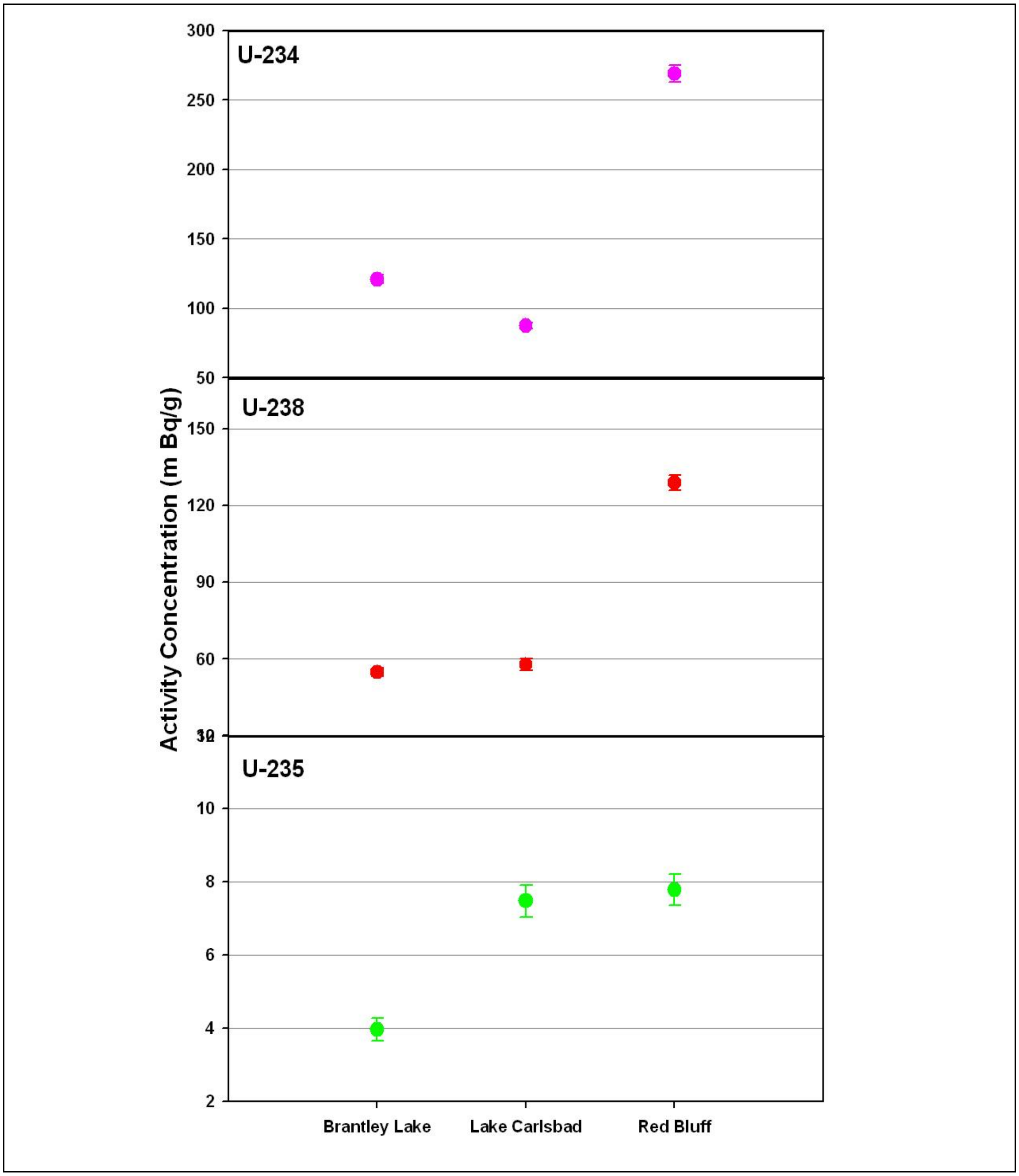


Figure 7.12 Activity concentrations of three uranium isotopes in surface water samples from three regional reservoirs in 2012

Table 7.4 Radionuclide Concentrations (Bq/L) in Surface water Samples collected in the vicinity of the WIPP site

Radionuclide	Depth (m)	Activity (Bq/L)	SD (Bq/L)	MDC (Bq/L)	Qualifier
Lake Carlsbad					
^{241}Am	0.5	-3.09E-06	2.00E-05	3.83E-05	U
	2.35	4.57E-05	6.94E-05	2.51E-04	U
^{238}Pu	0.5	0.00E+00	4.73E-05	2.01E-04	U
	2.35	4.72E-05	4.72E-05	1.69E-04	U
$^{239+240}$Pu	0.5	6.69E-05	5.29E-05	1.80E-04	U
	2.35	1.03E-04	5.67E-05	1.74E-04	U
^{234}U	0.5	8.76E-02	2.00E-03	1.71E-04	+
	2.35	8.57E-02	2.19E-03	2.11E-04	+
^{235}U	0.5	7.48E-03	4.41E-04	2.23E-04	+
	2.35	2.21E-03	2.27E-04	1.61E-04	+
^{238}U	0.5	5.78E-02	2.15E-03	2.77E-04	+
	2.35	3.85E-02	1.06E-03	1.76E-04	+
Brantley Lake					
^{241}Am	0.5	-3.22E-05	3.36E-05	1.62E-04	U
	9.6	4.86E-05	3.57E-05	9.20E-05	U
^{238}Pu	0.5	-8.00E-05	4.80E-05	2.40E-04	U
	9.6	1.22E-04	8.62E-05	2.83E-04	U
$^{239+240}$Pu	0.5	3.20E-05	3.92E-05	1.49E-04	U
	9.6	2.07E-04	9.05E-05	2.24E-04	U
^{234}U	0.5	1.21E-01	3.09E-03	2.69E-04	+
	9.6	1.20E-01	2.90E-03	3.28E-04	+
^{235}U	0.5	3.96E-03	3.13E-04	2.06E-04	+
	9.6	7.48E-03	4.41E-04	2.23E-04	+
^{238}U	0.5	5.48E-02	1.58E-03	2.15E-04	+
	9.6	5.51E-02	1.52E-03	3.14E-04	+
Red Bluff					
^{241}Am	0.5	-7.11E-06	2.36E-05	1.06E-04	U
	3.26	1.20E-05	2.77E-05	4.33E-05	U
^{238}Pu	0.5	-3.16E-05	6.69E-05	2.75E-04	U
	3.26	-3.88E-06	1.86E-05	8.12E-05	U
$^{239+240}$Pu	0.5	-1.83E-10	4.99E-05	2.07E-04	U
	3.26	4.69E-05	2.57E-05	7.32E-05	U
^{234}U	0.5	2.69E-01	5.76E-03	1.81E-04	+
	3.26	2.79E-01	5.79E-03	2.38E-04	+
^{235}U	0.5	7.78E-03	4.34E-04	2.24E-04	+
	3.26	7.11E-03	4.03E-04	2.37E-04	+
^{238}U	0.5	1.29E-01	2.96E-03	2.79E-04	+
	3.26	1.37E-01	3.04E-03	3.19E-04	+

Qualifier: Indicated whether radionuclide was detected. Plus (+) equals detected. U equals undetected.

Table 7.5 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			
^{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

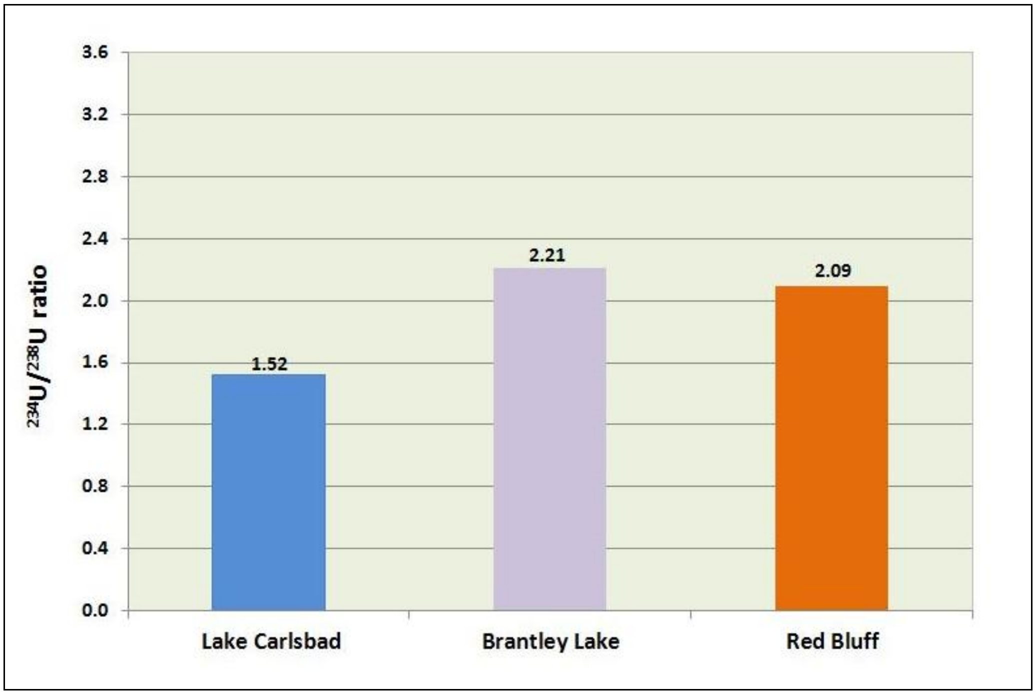


Figure 7.13 The ^{234}U/^{238}U Activity Ratio in surface water samples of three reservoirs in the vicinity of the WIPP site

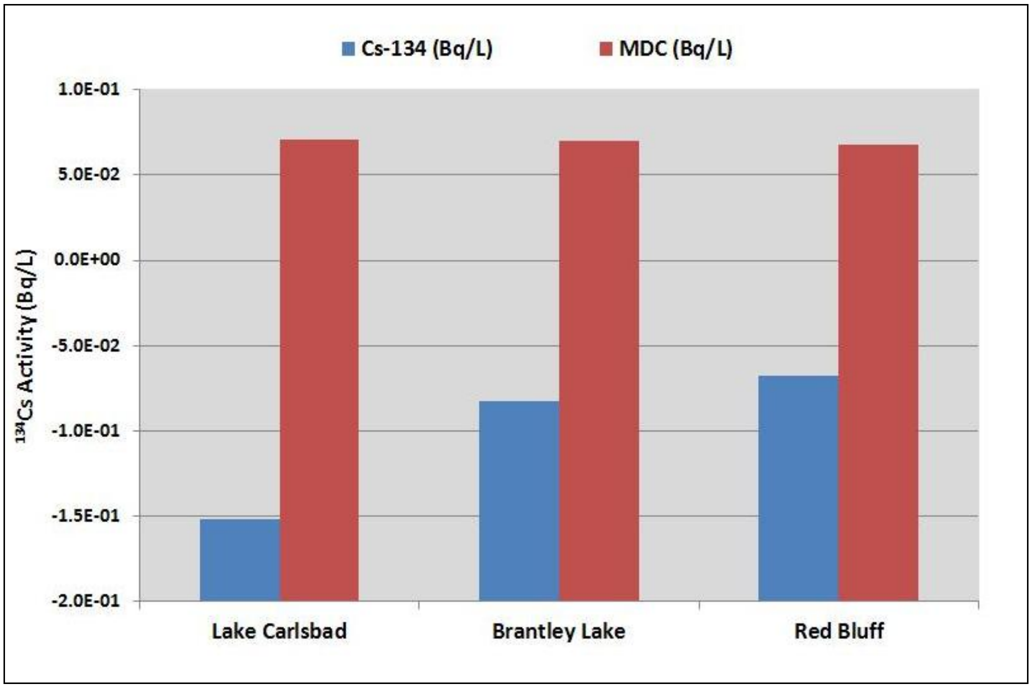


Figure 7.14 ^{134}Cs activity concentrations in surface water samples in three regional reservoirs

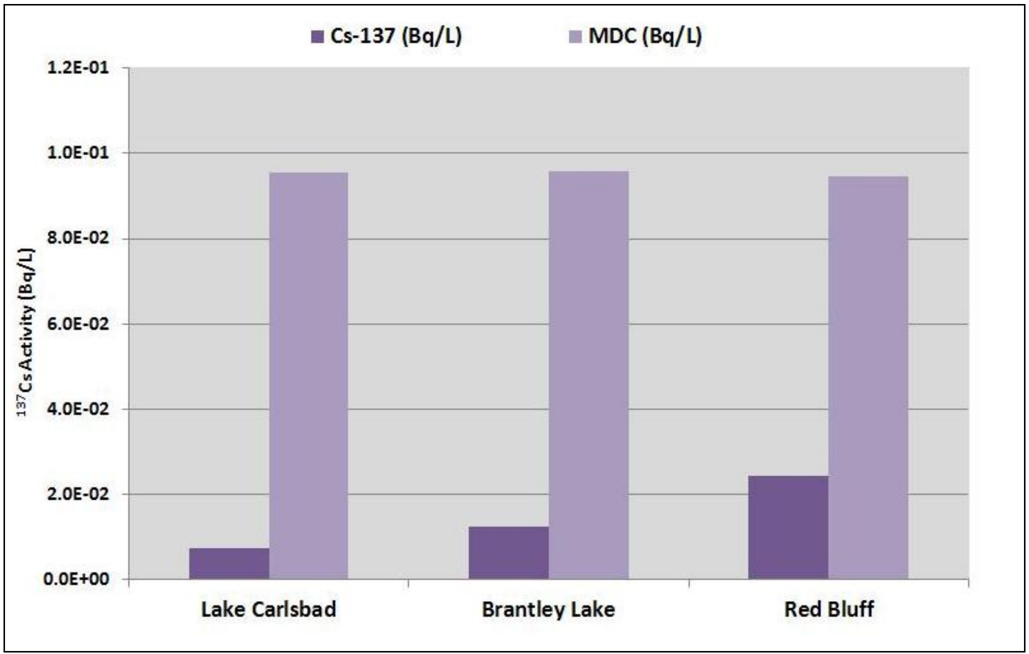


Figure 7.15 ^{137}Cs activity concentrations in surface water samples in three regional reservoirs

Table 7.6 Gamma Radionuclides Concentrations (Bq/L) in Surface water Samples collected in the vicinity of the WIPP site

Radionuclide	Depth (m)	Activity (Bq/L)	SD (Bq/L)	MDC (Bq/L)	Qualifier
Lake Carlsbad					
^{134}Cs	0.5	-1.52E-01	2.10E-02	7.08E-02	U
	2.35	-1.32E-01	2.12E-02	7.14E-02	U
^{137}Cs	0.5	7.26E-03	2.88E-02	9.54E-02	U
	2.35	1.83E-02	2.87E-02	9.48E-02	U
^{40}K	0.5	1.77E-01	3.35E-01	1.11E+00	U
	2.35	3.89E-01	3.42E-01	1.13E+00	U
^{60}Co	0.5	2.15E-02	2.65E-02	8.78E-02	U
	2.35	1.14E-02	2.63E-02	8.71E-02	U
Brantley Lake					
^{134}Cs	0.5	-8.23E-02	2.07E-02	6.98E-02	U
	9.6	-5.17E-02	1.94E-02	6.52E-02	U
^{137}Cs	0.5	1.25E-02	2.90E-02	9.59E-02	U
	9.6	2.23E-02	2.87E-02	9.48E-02	U
^{40}K	0.5	3.73E-01	3.40E-01	1.12E+00	U
	9.6	7.03E-01	3.34E-01	1.09E+00	U
^{60}Co	0.5	2.07E-02	2.70E-02	8.94E-02	U
	9.6	1.72E-02	2.62E-02	8.69E-02	U
Red Bluff					
^{134}Cs	0.5	-6.75E-02	2.02E-02	6.82E-02	U
	3.26	-8.91E-02	1.97E-02	6.68E-02	U
^{137}Cs	0.5	2.44E-02	2.87E-02	9.46E-02	U
	3.26	2.08E-02	2.88E-02	9.53E-02	U
^{40}K	0.5	2.47E+00	3.64E-01	1.13E+00	+
	3.26	2.72E+00	3.56E-01	1.09E+00	+
^{60}Co	0.5	4.90E-02	2.66E-02	8.73E-02	U
	3.26	2.53E-02	2.65E-02	8.76E-02	U

Qualifier: Indicated whether radionuclide was detected. Plus (+) equals detected. U equals undetected.

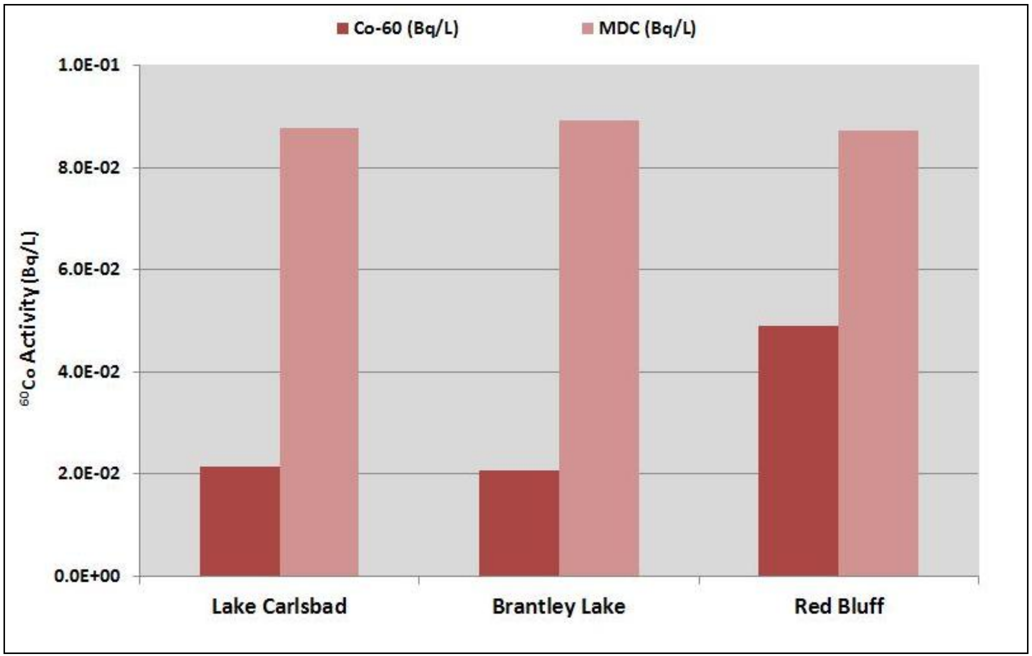


Figure 7.16 ^{60}Co activity concentrations in surface water samples in three regional reservoirs

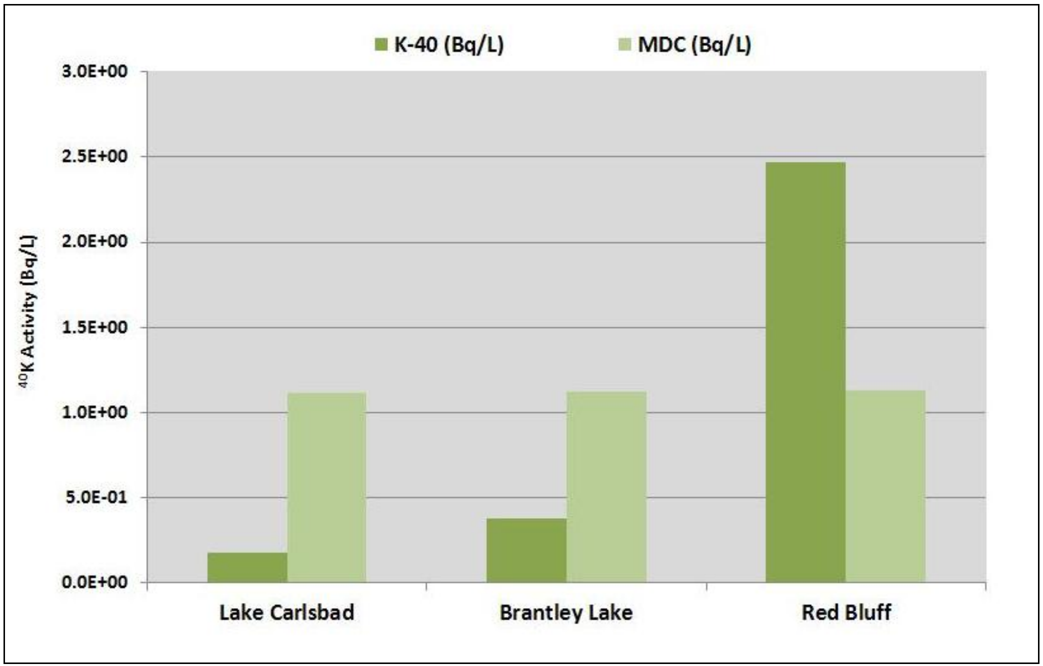


Figure 7.17 ^{40}K activity concentrations in surface water samples in three regional reservoirs

Non-Radiological Sample Collection (Surface Water)

For non-radiological analyses, all surface water samples were processed according to the CEMRC protocols for the collection, handling, and preservation of routine water samples. The following samples were taken from each sampling location: (1) 1L for elemental analyses, (2) 1L for anion analyses, and (3) 500ml for mercury analysis. The 1L samples collected for elemental analysis were preserved with distilled nitric acid during the sample collection phase

Non-Radiological Sample Preparation (Surface Water)

Each 1L sample collected for anion analysis was refrigerated immediately upon arrival at the CEMRC laboratory and analyzed within 48 hours of collection. All samples were filtered prior to analysis. Due to the high anion content, all samples were diluted with ultrapure water prior to analysis. Sample results were blank-corrected if applicable.

For mercury analysis, the samples collected in 500mL containers were preserved with a bromomonochloride solution upon receipt by the CEMRC laboratory. All samples were filtered prior to direct analysis (no sample dilution was necessary). For inorganic analysis, all samples were diluted using a similar nitric acid matrix and then filtered prior to analysis by ICP-MS. For both mercury and inorganic analyses, aliquots were blank-corrected after the application of dilution factors. As per the CEMRC procedure, only concentrations above laboratory MDC values are reported.

Non-Radiological Results and Discussion (Surface Water)

The 2012 inorganic results and how they compare to past data are summarized in Tables 7.7 – 7.9 for the three regional water sources. The results exhibited in these Tables are not used in assessing regulatory compliance. Tables presenting the surface water data summarized herein (and also previous years) are available on the CEMRC web site at http://www.cemrc.org.

Table 7.7 Range of Concentrations for Inorganic Constituents in Lake Carlsbad Surface Water Samples Collected (1999–2012)

Lake Carlsbad								
1999 - 2005					2012			
EL[1]	N[2]	N_{DET}[2]	Min[3]	Max[3]	MDC[4] (µg/L)	Blank Conc. (µg/L)	Shallow[5] Sample Conc. (µg/L)[6]	Deep[5] Sample Conc. (µg/L)[6]
Ag	8	0	N/A	N/A	4.00E-01	<MDC	4.00E-01	<MDC
Al	8	8	5.70E+01	5.03E+02	8.25E+00	7.23E-01	8.25E+00	3.63E+02
As	8	4	1.23E+00	2.37E+00	5.75E+00	<MDC	5.75E+00	1.11E+01
Ba	8	8	1.86E+01	3.30E+01	4.25E-01	2.22E-02	4.25E-01	3.67E+01
Be	8	4	1.51E-02	1.47E-01	1.82E+00	<MDC	1.82E+00	<MDC
Bi	2	0	N/A	N/A	N/A	N/A	N/A	N/A
Ca	6	6	3.04E+05	4.19E+05	3.90E+03	3.02E+01	3.90E+03	6.53E+05
Cd	8	1	9.00E-02	9.00E-02	N/A	N/A	N/A	N/A
Ce	8	8	8.08E-02	4.87E-01	5.00E-01	<MDC	5.00E-01	<MDC
Co	8	6	9.28E-01	5.22E+00	3.50E-01	<MDC	3.50E-01	1.29E+00
Cr	8	4	3.02E-01	2.19E+00	N/A	N/A	N/A	N/A
Cu	8	6	3.46E+00	1.13E+01	N/A	N/A	N/A	N/A
Dy	8	4	6.67E-03	3.51E-02	6.50E-02	<MDC	6.50E-02	<MDC
Er	8	4	1.17E-03	1.51E-02	7.50E-02	<MDC	7.50E-02	<MDC
Eu	8	4	6.54E-03	1.81E-02	1.67E-01	<MDC	1.67E-01	<MDC
Fe	8	8	7.60E+01	3.96E+03	2.95E+02	<MDC	2.95E+02	2.14E+03
Gd	8	4	9.10E-03	4.84E-02	7.50E-02	<MDC	7.50E-02	<MDC
Hg	4	1	2.82E-02	2.82E-02	2.50E-02	<MDC	2.50E-02	<MDC
K	8	8	4.96E+03	1.24E+04	4.55E+02	<MDC	4.55E+02	6.02E+03
La	8	4	4.29E-02	2.21E-01	3.00E-02	<MDC	3.00E-02	2.11E-01
Li	6	6	4.33E+01	7.75E+01	N/A	N/A	N/A	N/A
Mg	8	8	1.04E+05	1.51E+05	5.00E+00	1.13E+00	5.00E+00	1.54E+05
Mn	8	7	8.47E+00	6.65E+01	N/A	N/A	N/A	N/A
Mo	8	8	2.65E+00	3.64E+00	3.50E+00	<MDC	3.50E+00	4.84E+00
Na	6	6	3.38E+05	5.06E+05	2.10E+03	<MDC	2.10E+03	5.80E+05
Nd	8	6	3.79E-02	2.31E-01	1.25E-01	<MDC	1.25E-01	2.43E-01
Ni	8	8	2.33E+00	2.29E+01	2.37E-01	<MDC	2.37E-01	2.18E+01
P	2	2	8.35E+01	9.29E+01	1.03E+02	<MDC	1.03E+02	1.56E+03
Pb	8	6	6.38E-01	2.65E+00	1.50E-01	<MDC	1.50E-01	1.00E+00
Pr	8	4	1.11E-02	5.66E-02	N/A	N/A	N/A	N/A
Sb	8	1	1.17E-01	1.17E-01	5.00E-01	<MDC	5.00E-01	<MDC
Sc	2	2	4.42E+00	4.72E+00	3.00E+00	<MDC	3.00E+00	<MDC
Se	6	1	5.54E-01	5.54E-01	N/A	N/A	N/A	N/A
Si	2	2	7.15E+03	7.68E+03	N/A	N/A	N/A	N/A
Sn	4	0	N/A	N/A	N/A	N/A	N/A	N/A
Sr	8	8	4.16E+03	6.15E+03	1.20E+00	1.83E-02	1.20E+00	9.22E+03
Th	8	7	9.10E-03	5.79E-02	8.00E-02	4.95E-03	8.00E-02	4.07E-01
Ti	2	1	1.40E+01	1.40E+01	N/A	N/A	N/A	N/A
Tl	8	4	1.20E-01	1.65E-01	3.25E-01	<MDC	3.25E-01	<MDC
U	8	8	3.78E+00	9.17E+00	1.27E-01	<MDC	1.27E-01	4.89E+00
V	8	8	6.13E+00	9.31E+00	N/A	N/A	N/A	N/A
Zn	6	4	5.93E+00	2.08E+01	1.65E+02	1.33E+01	1.65E+02	3.06E+02

[1] El = Element analyzed;

[2] N = Total number of samples analyzed; N_{det} = number of samples with detectable (above MDC) values;

[3] Min = the lowest value measured above MDC; Max = the highest value measured;

[4] MDC = Minimum detectable concentration;

[5] For Lake Carlsbad, "Shallow" measurements were taken at 0.5m from the surface while "Deep" measurements were taken at 2.35m from the sediment bed;

[6] Concentrations below the MDC are reported as <MDC; N/A = Not Applicable

Table 7.8 Range of Concentrations for Inorganic Constituents in Brantley Lake Surface Water Samples Collected (1999–2012)

Brantley Lake								
1999 - 2005					2012			
EL[1]	N[2]	N_{DET}[2]	Min[3]	Max[3]	MDC[4] (µg/L)	Blank Conc. (µg/L)	Shallow[5] Sample Conc. (µg/L)[6]	Deep[5] Sample Conc. (µg/L)[6]
Ag	8	1	1.03E-02	1.03E-02	3.20E-01	<MDC	<MDC	<MDC
Al	8	7	4.25E+01	4.90E+02	6.60E+00	7.23E-01	8.63E+01	8.29E+01
As	8	6	1.21E+00	5.21E+00	4.60E+00	<MDC	5.08E+00	6.81E+00
Ba	8	8	4.41E+01	7.45E+01	3.40E-01	2.22E-02	2.34E+01	2.24E+01
Be	8	3	1.92E-02	1.43E-01	1.46E+00	<MDC	<MDC	<MDC
Bi	2	0	N/A	N/A	N/A	N/A	N/A	N/A
Ca	6	6	3.47E+05	6.22E+05	3.90E+03	3.02E+01	3.22E+05	3.28E+05
Cd	8	0	N/A	N/A	N/A	N/A	N/A	N/A
Ce	8	8	5.71E-02	4.64E-01	4.00E-01	<MDC	<MDC	<MDC
Co	8	6	1.51E+00	6.76E+00	2.80E-01	<MDC	6.91E-01	7.94E-01
Cr	8	4	3.17E-01	2.08E+00	N/A	N/A	N/A	N/A
Cu	8	6	3.10E+00	8.07E+00	N/A	N/A	N/A	N/A
Dy	8	5	5.79E-03	2.97E-02	5.20E-02	<MDC	1.00E-01	<MDC
Er	8	3	3.52E-03	2.16E-02	6.00E-02	<MDC	1.16E-01	<MDC
Eu	8	5	1.55E-02	3.35E-02	1.34E-01	<MDC	<MDC	<MDC
Fe	8	8	5.30E+01	6.71E+02	2.36E+02	<MDC	9.42E+02	1.11E+03
Gd	8	4	7.34E-03	5.26E-02	6.00E-02	<MDC	1.03E-01	<MDC
Hg	4	1	1.77E-01	1.77E-01	2.50E-02	<MDC	4.24E-01	2.20E-01
K	8	8	4.67E+03	1.51E+04	3.64E+02	<MDC	4.41E+03	4.41E+03
La	8	5	3.38E-02	1.68E-01	2.40E-02	<MDC	1.66E-01	4.32E-02
Li	6	6	3.89E+01	7.77E+01	N/A	N/A	N/A	N/A
Mg	8	8	9.31E+04	2.01E+05	4.00E+00	1.13E+00	9.05E+04	9.59E+04
Mn	8	7	8.98E+00	7.53E+02	N/A	N/A	N/A	N/A
Mo	8	8	2.41E+00	3.86E+00	2.80E+00	<MDC	5.17E+00	3.12E+00
Na	6	6	3.50E+05	1.07E+06	2.10E+03	<MDC	3.22E+05	3.17E+05
Nd	8	6	3.34E-02	2.18E-01	1.00E-01	<MDC	1.56E-01	<MDC
Ni	8	8	3.65E+00	2.91E+01	1.90E-01	<MDC	9.94E+00	1.09E+01
P	2	2	1.27E+02	1.48E+02	8.20E+01	<MDC	7.88E+02	8.01E+02
Pb	8	4	2.88E-01	9.71E-01	1.20E-01	<MDC	8.39E-01	4.97E-01
Pr	8	4	1.08E-02	5.87E-02	N/A	N/A	N/A	N/A
Sb	8	4	2.54E-01	3.01E-01	4.00E-01	<MDC	<MDC	<MDC
Sc	2	2	9.33E-01	1.56E+00	2.40E+00	<MDC	2.81E+00	2.81E+00
Se	5	0	N/A	N/A	N/A	N/A	N/A	N/A
Si	2	1	3.01E+03	3.01E+03	N/A	N/A	N/A	N/A
Sn	4	0	N/A	N/A	N/A	N/A	N/A	N/A
Sr	8	8	5.00E+03	1.02E+04	1.20E+00	1.83E-02	4.20E+03	4.18E+03
Th	8	5	1.67E-02	8.70E-02	6.40E-02	4.95E-03	1.85E-01	<MDC
Ti	2	0	N/A	N/A	N/A	N/A	N/A	N/A
Tl	8	1	4.81E-02	4.81E-02	2.60E-01	<MDC	<MDC	<MDC
U	8	8	3.42E+00	7.94E+00	1.02E-01	<MDC	3.56E+00	3.65E+00
V	8	8	3.47E+00	5.90E+00	N/A	N/A	N/A	N/A
Zn	6	4	1.07E+01	1.71E+01	1.32E+02	1.33E+01	2.78E+02	2.22E+02

[1] El = Element analyzed;

[2] N = Total number of samples analyzed; N_{det} = number of samples with detectable (above MDC) values;

[3] Min = the lowest value measured above MDC; Max = the highest value measured;

[4] MDC = Minimum detectable concentration;

[5] For Brantley Lake, "Shallow" measurements were taken at 0.5m from the surface while "Deep" measurements were taken at 9.36m from the sediment bed;

[6] Concentrations below the MDC are reported as <MDC; N/A = Not Applicable

Table 7.9 Range of Concentrations for Inorganic Constituents in Red Bluff Surface Water Samples Collected (1999–2012)

Red Bluff								
1999 - 2005					2012			
EL[1]	N[2]	N_{DET}[2]	Min[3]	Max[3]	MDC[4] (µg/L)	Blank Conc. (µg/L)	Shallow[5] Sample Conc. (µg/L)[6]	Deep[5] Sample Conc. (µg/L)[6]
Ag	7	0	N/A	N/A	1.60E+00	<MDC	<MDC	<MDC
Al	7	6	1.65E+01	3.96E+02	3.30E+01	7.23E-01	8.27E+01	1.02E+02
As	8	6	1.96E+00	5.00E+00	2.30E+01	<MDC	5.12E+01	3.34E+01
Ba	7	7	6.83E+01	9.82E+01	1.70E+00	2.22E-02	8.50E+01	7.89E+01
Be	7	4	3.28E-02	2.68E-01	7.30E+00	<MDC	<MDC	<MDC
Bi	2	0	N/A	N/A	N/A	N/A	N/A	N/A
Ca	6	6	4.19E+05	6.64E+05	1.95E+03	3.02E+01	8.94E+05	8.70E+05
Cd	7	2	4.11E-01	1.04E+00	N/A	N/A	N/A	N/A
Ce	7	7	3.93E-02	5.71E-01	2.00E+00	<MDC	<MDC	<MDC
Co	7	7	8.16E-01	6.01E+00	1.40E+00	<MDC	1.93E+00	2.70E+00
Cr	7	2	1.86E+00	2.24E+00	N/A	N/A	N/A	N/A
Cu	7	5	6.73E+00	8.87E+00	N/A	N/A	N/A	N/A
Dy	7	3	2.99E-03	4.24E-02	2.60E-01	<MDC	<MDC	<MDC
Er	7	2	2.08E-03	8.34E-03	3.00E-01	<MDC	<MDC	<MDC
Eu	7	6	2.36E-02	6.86E-02	6.70E-01	<MDC	<MDC	<MDC
Fe	7	7	3.38E+01	1.40E+03	1.18E+03	<MDC	3.29E+03	3.04E+03
Gd	7	4	1.44E-02	8.33E-02	3.00E-01	<MDC	<MDC	<MDC
Hg	4	0	N/A	N/A	2.50E-02	<MDC	2.14E-01	6.12E-02
K	8	8	1.92E+04	3.63E+04	1.82E+03	<MDC	7.47E+04	7.36E+04
La	7	4	3.51E-02	4.47E-01	1.20E-01	<MDC	1.47E-01	1.82E-01
Li	4	4	9.32E+01	1.23E+02	N/A	N/A	N/A	N/A
Mg	8	8	1.24E+05	2.49E+05	2.00E+01	1.13E+00	3.52E+05	3.45E+05
Mn	8	8	3.85E+01	2.97E+02	N/A	N/A	N/A	N/A
Mo	7	7	3.44E+00	5.82E+00	1.40E+01	<MDC	<MDC	<MDC
Na	6	6	7.21E+05	1.36E+06	5.25E+03	<MDC	2.55E+06	2.61E+06
Nd	7	3	2.06E-02	6.47E-02	5.00E-01	<MDC	<MDC	<MDC
Ni	7	7	1.24E+01	2.84E+01	9.50E-01	<MDC	2.99E+01	3.15E+01
P	2	2	1.33E+02	1.40E+02	4.10E+02	<MDC	3.15E+03	3.15E+03
Pb	7	4	2.62E-01	9.75E-01	6.00E-01	<MDC	3.24E+00	1.49E+00
Pr	7	3	7.11E-03	7.55E-02	N/A	N/A	N/A	N/A
Sb	7	7	2.47E-01	4.83E-01	2.00E+00	<MDC	<MDC	<MDC
Sc	2	1	5.93E-01	5.93E-01	1.20E+01	<MDC	<MDC	<MDC
Se	6	0	N/A	N/A	N/A	N/A	N/A	N/A
Si	2	0	N/A	N/A	N/A	N/A	N/A	N/A
Sn	3	0	N/A	N/A	N/A	N/A	N/A	N/A
Sr	8	8	5.76E+03	9.83E+03	3.00E+00	1.83E-02	1.50E+04	1.50E+04
Th	7	5	4.68E-03	3.31E-02	3.20E-01	4.95E-03	<MDC	4.77E-01
Ti	2	1	1.30E+01	1.30E+01	N/A	N/A	N/A	N/A
Tl	7	0	N/A	N/A	1.30E+00	<MDC	<MDC	<MDC
U	7	7	4.70E+00	9.51E+00	5.10E-01	<MDC	1.23E+01	1.20E+01
V	7	7	3.37E+00	5.27E+00	N/A	N/A	N/A	N/A
Zn	5	3	6.21E+00	1.09E+01	6.60E+02	1.33E+01	1.30E+03	1.21E+03

[1] El = Element analyzed;
[2] N = Total number of samples analyzed; N_{det} = number of samples with detectable (above MDC) values;
[3] Min = the lowest value measured above MDC; Max = the highest value measured;
[4] MDC = Minimum detectable concentration;
[5] For Red Bluff, “Shallow” measurements were taken at 0.5m from the surface while “Deep” measurements were taken at 3.26m from the sediment bed;
[6] Concentrations below the MDC are reported as <MDC; N/A = Not Applicable

CONCLUSION

Comparison of baseline to monitoring phase levels of radionuclides in surface water and sediment samples collected within the Pecos River valley revealed no detectable increases above those typical of natural variation. The saline nature of Red Bluff Reservoir relative to Brantley Lake and Lake Carlsbad is apparent from the elevated concentrations of inorganic constituents as well as radionuclides. While the elevated activities of naturally occurring radionuclides and the increased salt load could be explained by intersection of the salt-bed outcrops of the Salado formation by the Pecos River upstream from Red Bluff Reservoir and downstream from Brantley Lake and Lake Carlsbad, the elevated levels of man-made radionuclides cannot.

In addition to radiological studies conducted, no noticeable increase in the inorganic levels was observed in the regional surface water after the WIPP site started accepting mixed waste in August of 2000.

APPENDICES

Helpful Information

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

Scientific Notation

Scientific notation is commonly used as a shortcut 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. For example, 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 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 and Types of Radiation

Much of this annual report provides data on levels of radioactivity present in various types of environmental media and is typically presented in units of **curies (Ci)**, with conversions to **becquerels (Bq)** which is the International System of Units measure (Table A.1). The curie is the basic unit used to describe the amount of activity present with activities usually 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 as a quantity of any radionuclide that decays at the rate of 37 billion disintegrations per second. One becquerel, on the other hand, is equivalent to one disintegration per second.

Nuclear disintegrations produce spontaneous emissions of various types of radiation including alpha or beta particles, gamma radiation, or combinations of these. Although all forms of radiation are invisible to the naked eye, alpha radiation is the largest in terms of particle size. Because of its relatively large mass, alpha is considered to be a slow moving form of radiation that travels very short distances (1 to 2 inches) and can easily be shielded from entering the body by the thickness of one's skin or by layers of clothing. Once inside the body however, alpha radiation presents a hazard to internal organs and can be introduced into the body through inhalation, ingestion, or through an open wound.

Beta radiation has a smaller mass and as such travels much farther and faster than alpha. Beta can travel up to 20 feet in distance and can be shielded through the use of thin sheets of metal, plastic, or glass. Because of its ability to penetrate skin layers, beta radiation presents a hazard to internal organs as well as to outer layers of skin and the lenses of the eyes.

Gamma radiation, similar to x-ray radiation, consists of an electromagnetic wave that can travel several hundred feet in distance and at very fast speeds. Gamma radiation can only be shielded by thick layers of concrete, lead, or water and therefore, is very difficult to contain. Gamma radiation presents a hazard to the whole body as well as internal organs and external skin surfaces.

Table A.1: Names and symbols for Units of Radioactivity

Symbol	Name	Symbol	Name
Ci	curie	Bq	becquerel (2.7 x 10^{-11} Ci)
mCi	millicurie (1 x 10^{-3} Ci)	kBq	kilobecquerel (1 x 10^{3} Bq)
ìCi	microcurie (1 x 10^{-6} Ci)	MBq	megabecquerel (1 x 10^{6} Bq)
nCi	nanocurie (1 x 10^{-9} Ci)	mBq	millibecquerel (1 x 10^{-3} Bq)
pCi	picocurie (1 x 10^{-12} Ci)	GBq	gigabecquerel (1 x 10^{9} Bq)
fCi	femtocurie (1 x 10^{-15} Ci)	TBq	terabecquerel (1 x 10^{12} Bq)
aCi	attocurie (1 x 10^{-18} Ci)		

Understanding the Data Tables

Some degree of variability, or uncertainty, is associated with all types of 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, or as the result of 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.

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.

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 bellshape (i.e., normal) distribution. Figure.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.

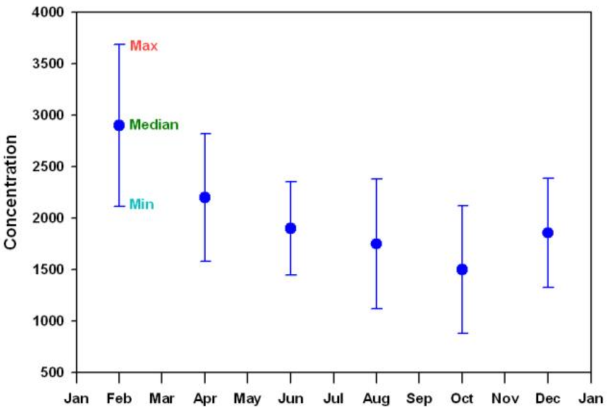


Figure A.1 A graphical representation of maximum, median and minimum

Negative Concentrations

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

Understanding Graphs

Graphs are useful when comparing numbers collected at several locations or at one location over time. Graphs often make it easy to visualize differences in data where they exist. However, careful consideration should be given to the scale (linear or logarithmic) and units. Some of the data graphed in this report may be plotted using logarithmic, or compressed, scales. Logarithmic scales are useful when plotting two or more numbers that differ greatly in size or are very close together. For example, a sample with a concentration of 5 grams per liter would get lost at the bottom of the graph if plotted on a linear scale with a sample having a concentration of 1,000 grams per liter (see Figure 2). A logarithmic plot of these same two numbers allows the reader to see both data points clearly (see Figure 3).

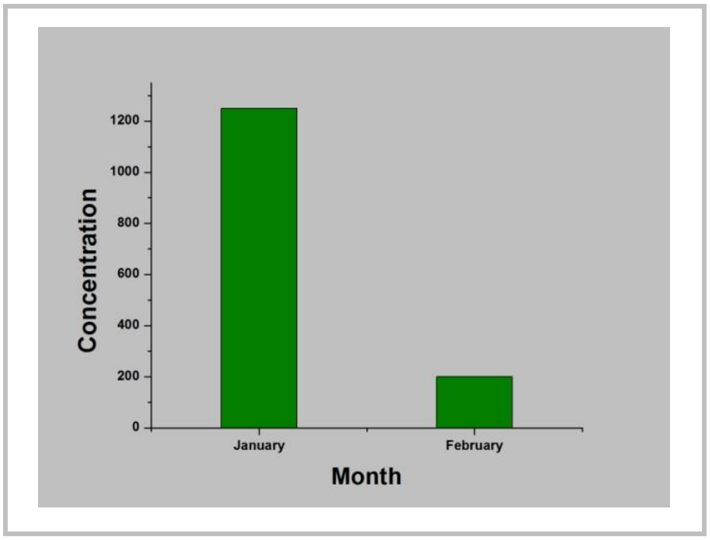


Figure A.2 Data plotted using a linear scale

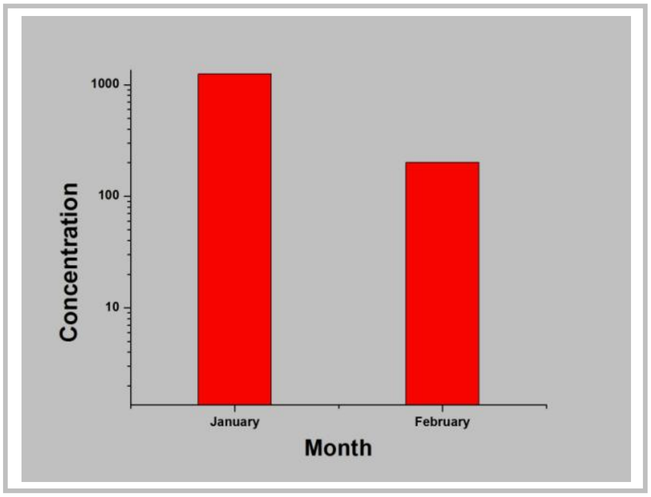


Figure A.3 Data plotted using a logarithmic scale

The mean (average) and median (defined earlier) values seen in graphics in this report have vertical lines extending above and below the data point. When used with a value, these lines (called error bars) indicate the amount of uncertainty (standard deviation, total propagated analytical uncertainty, or two standard error of the mean) in the reported value.

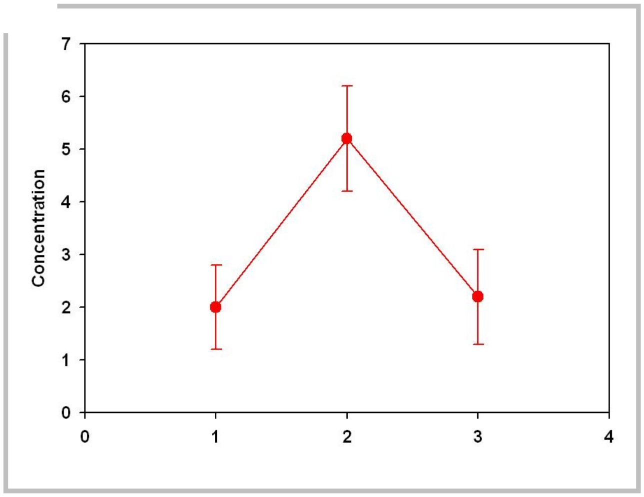


Figure A.4 Data with error bars plotted using a linear scale

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 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 3, the values may be statistically similar. If the error bars do not overlap (values 1 and 2 or values 2 and 3), the values may be statistically different. Additionally, 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 1).

Greater Than (>) or Less Than (<) Symbols

Greater than (>) or less than (<) symbols are used to indicate that the actual value may either be larger than the number given or smaller than the number given. For example, >0.09 would indicate that the actual value is greater than 0.09, whereas a symbol pointed in the opposite direction (<0.09) would indicate that the number is less than the value presented. A symbol used with an underscore (≤ or ≥) indicates that the actual value is less than or equal to or greater than or equal to the number given, respectively.

APPENDIX A: BRIEF HISTORY OF CARLSBAD ENVIRONMENTAL MONITORING AND RESEARCH PROGRAM

The Carlsbad Environmental Monitoring & Research Center (CEMRC) was created in 1991 as a division of the Waste-management Education & Research Consortium (WERC), in the College of Engineering at New Mexico State University (NMSU). The CEMRC was conceived as a result of inquiries to WERC by concerned citizens of the Carlsbad region, acting as a grassroots coalition who recognized the need for high-quality, independent, health and environmental assessment data. Many individuals and organizations supported the CEMRC's formation including the residents of Carlsbad, NM, and the surrounding region; NMSU; the Carlsbad Department of Development; the New Mexico Congressional Delegation; the New Mexico Radioactive and Hazardous Materials Committee; Westinghouse Electric Corporation; and the U.S. Department of Energy (DOE). The CEMRC was established with a financial assistance grant entitled "Carlsbad Environmental Monitoring and Research Program" (CEMRP) from the DOE to NMSU. The CEMRP was initially funded for $27 million over a seven-year period (1991–1998). Subsequently, the grant was increased to almost $33 million to support operations of the program until 2008.

Dr. Rohinton (Ron) K. Bhada served as Project Director for the CEMRP during 1991-1999. Dr. Donald J. Fingleton served as Director of the CEMRC during 1991-1996. In 1996, Dr. Marsha Conley became Director of Operations and in 1997, Director. Dr. Conley was named CEMRP Project Director in 1999. In July 2001, Dr. Conley retired and Dr. George Hidy acted as an interim director until February 2002, when Mr. Joel Webb was appointed Director of CEMRC. In September 2003, Dr. Deborah Moir became acting interim director during the search for a new permanent director. At the same time, the CEMRP grant ended, the environmental monitoring program stopped, and Washington TRU Solutions (WTS) and Los Alamos National Labs (LANL) provided operating funds to CEMRC in exchange for radiochemistry collaborations under contract at CEMRC which included residence of their staff in office and laboratory space at CEMRC. In September 2004, Dr. James Conca was appointed Director of CEMRC. In FY2005 the CEMRP grant was reinstated at about half the annual funding level ($1.2M). The grant funding was increased in 2007 to $1.84M and WTS funding was increased to accommodate new VOC analyses. In 2008, the Louisiana Energy Service's (LES) Nuclear Enrichment Facility (NEF) in Eunice began developing a program with CEMRC. Dr. James Conca served as Director of the CEMRC until August 2010. In September 2010, Dr. George Mulholland became interim director of CEMRC until January 2012. In January 2012, Dr. Russell Hardy was named as the Director or CEMRC and still holds the Director position as of December 2013.

Temporary office accommodations for the CEMRC initially were provided at the NMSU-Carlsbad campus beginning in 1991. In 1992, the CEMRC moved to a leased facility at 800 West Pierce in Carlsbad, which served as a basis for operations through December 1996. Flatow Moore Bryan Shaffer McCabe Architects (Albuquerque, New Mexico) and Research Facilities Design (San Diego, California) were selected in 1991 to design the CEMRC's permanent facility. In December of 1993, DOE Secretary Hazel O'Leary made a commitment to provide approximately $7 million in additional funding to support debt service for construction of the new facility. In 1994, the NMSU Board of Regents approved the sale of New Mexico State University Research Corporation Lease Revenue bonds to secure construction money. Construction of the Phase I facility began in August 1995 and was completed in December 1996. The facility is located adjacent to the NMSU-Carlsbad campus, on 22 acres of land donated to NMSU by then New Mexico State Representative Robert S. Light (D-55th District). On March 23, 1997, the Phase I facility was named the Joanna and Robert Light Hall.

In addition to work associated with the design and construction of buildings for the CEMRC, a variety of other developmental projects were undertaken to support the CEMRC's scientific activities. In 1993, design began for the Mobile Bioassay Laboratory (MBL) that would complement the facilities planned for the new CEMRC building. Construction of the MBL began in 1994, and the unit was completed and delivered to Carlsbad in 1996. A Radioactive Material License was submitted to the New Mexico Environment Department, and the license was issued in 1996. The MBL was loaned to the DOE Rocky Flats site in Colorado during 2003-2005 to assist in decommissioning of that site which was successfully completed in 2005 with the unit returning to CEMRC. In 2005, funding was obtained by CEMRC from the City of Carlsbad, partially matched by CEMRC, to undertake a major redesign of the radiochemistry laboratory space and to build an actinide chemistry laboratory for use by LANL and CEMRC staff to carry out experiments with Pu, U and Np, primarily with the focus of confirming previous WIPP-related performance assessments with respect to actinide elements in brine under repository conditions. The renovation was completed in 2006. Subsequently, other laboratory improvements occurred in 2006 such as the building of a new volatile organic compound (VOC) laboratory and the replacement of most of the ventilation system. These improvements were jointly funded by DOE, WTS and CEMRC. Additionally, a new sector-field mass spectrometry laboratory for uranium analysis was completed at CEMRC in 2008. Lastly, replacement of major portions of the facility began in 2008 and will continue to 2012, including replacement of the roof, major detectors, the phone system, upgrade of the electrical system and ventilation system, and upgrade of the Radioactive Materials License to accommodate higher activity levels.

In 1999, CEMRC was separated from WERC and became a division reporting directly to the Dean of Engineering at NMSU. In July 2006, the College of Engineering at NMSU combined the units CEMRC, WERC and SWTDI under the new Institute for Energy and the Environment (IEE), managed by Dr. Abbas Ghassemi. In 2011, CEMRC, WERC, and SWTDI were reorganized within the College of Engineering and now each report to the Associate Dean for Engineering Research, Dr. Martha Mitchell.

APPENDIX B: RECENT PUBLICATIONS

Author	Title	Publisher/Conference
P. Thakur; S. Ballard; R. Nelson.	Radioactive Fallout in the United States Due to the Fukushima Nuclear Plant Accident.	**Journal of Environmental Monitoring**, vol. 14, p. 1317 - 1324, 2012
P. Thakur; S. Ballard; R. Nelson.	Plutonium in the WIPP Environment: Its Detection, Distribution and Behavior.	**Journal of Environmental Monitoring**, vol. 14, p. 1604–1615, 2012.
P. Thakur; J.L. Conca; G.R. Choppin.	Mixed-ligand complexes of Am3+, Cm3+ and Eu3+ with HEDTA and HEDTA+NTA- complexation thermodynamics and structural aspects.	**Journal of Solution Chemistry,** vol. 4, p. 599 - 615, 2012.
P. Thakur and G. Mulholland.	Determination of Np in the Environmental and Nuclear Samples: A Review of the Analytical Method.	**Applied Radiation and Isotopes,** vol. 70, p. 1747 - 1778, 2012.
P. Thakur, Y. Xiong, M. Borkowski, G. R. Choppin	Thermodynamic Modeling of Trivalent Am, Cm and Eu-Citrate Complexation in Concentrated $NaClO_4$ Media	**Radiochim Acta** vol. 100, p. 165-172, 2012
P. Thakur; S. Ballard; and R. Nelson.	An overview of Fukushima radionuclides measured in the northern hemisphere.	**58th Annual Radiobioassay and Radiochemical Measurements Conference**, Ft. Collins Oct 29-Nov 2. 2012.
Breshears, D., Kirchner, T., Whicker, J., Field, J., & Allen, C.	Modeling aeolian transport in response to succession, disturbance and future climate: Dynamic long-term risk assessment for contaminant redistribution	**Aeolian Research,** Volume 3, Issue 4, January 2012, Pages 445-457.
I. Pillalamarri; P. Jagam; and G. I. Lykken.	Internal Dosimetry of ^{210}Pb In The Human Cranium: Preliminary Results From Instrumentation Needs For In Vivo Counting In A Low-Background Underground Counting Facility.	*Radiat Prot Dosimetry, Dec. 2012.*

APPENDIX C: RADIOACTIVE AND NON-RADIOACTIVE NUCLIDES MONITORED AT WIPP

Radionuclide	Radiation	Detection Method	Reason for Monitoring
^{234}U	Alpha	Alpha spectroscopy	Naturally occurring
^{235}U	Alpha	Alpha spectroscopy	Naturally occurring
^{238}U	Alpha	Alpha spectroscopy	Naturally occurring
^{40}K	Gamma	Gamma spectroscopy	Ubiquitous in nature
^{238}Pu	Alpha	Alpha spectroscopy	Component of waste
$^{239+240}Pu$	Alpha	Alpha spectroscopy	Component of waste
^{241}Am	Alpha	Alpha spectroscopy	Component of waste
^{137}Cs	Gamma	Gamma spectroscopy	Fission product/potential component of waste
^{60}Co	Gamma	Gamma spectroscopy	Fission product/potential component of waste
Non-Radioactive Nuclides			
Elemental Analysis Total number of elements 36	-	ICP-MS	Some of the elements are present in mixed waste
SO_4^{2-}	-	Ion chromatography	Present in drinking water
CO_3^-,	-	Ion chromatography	Present in drinking water
CO_2^-,	-	Ion chromatography	Present in drinking water
Cl^-	-	Ion chromatography	Present in drinking water
Br^-	-	Ion chromatography	Present in drinking water
PO_4^{3-}	-	Ion chromatography	Present in drinking water
NH^{4+}	-	Ion chromatography	Present in drinking water
K^+	-	Ion chromatography	Present in drinking water
Li^+	-	Ion chromatography	Present in drinking water
Na^+	-	Ion chromatography	Present in drinking water
Mg^{2+}	-	Ion chromatography	Present in drinking water
Ca^{2+}	-	Ion chromatography	Present in drinking water

The radionuclides ^{243}Am, ^{242}Pu, and ^{232}U are used as tracers in the CEMRC, Radiochemistry Laboratory. Radionuclides are considered "detected" in a sample if the measured concentration or activity is greater than the total propagated uncertainty (SD) at the 2 sigma (2 × SD) level, and greater than the minimum detectable concentration (MDC). The MDC is determined by the analytical laboratories based on the natural background radiation, the analytical technique, and inherent characteristics of the analytical equipment. The MDC represents the minimum concentration of a radionuclide detectable in a given sample using the given equipment and techniques with a specific statistical confidence (usually 95 percent). The SD is an estimate of the uncertainty in the measurement due to all sources, including counting error, measurement error, chemical recovery error, detector efficiency, randomness of radioactive decay, and any other sources of uncertainty. Measurements of radioactivity are actually probabilities due to the random nature of the disintegration process. A sample is decaying as it is being measured, so no finite value can be assigned. Instead, the ranges of possible activities are reported by incorporating the SDs of the method.

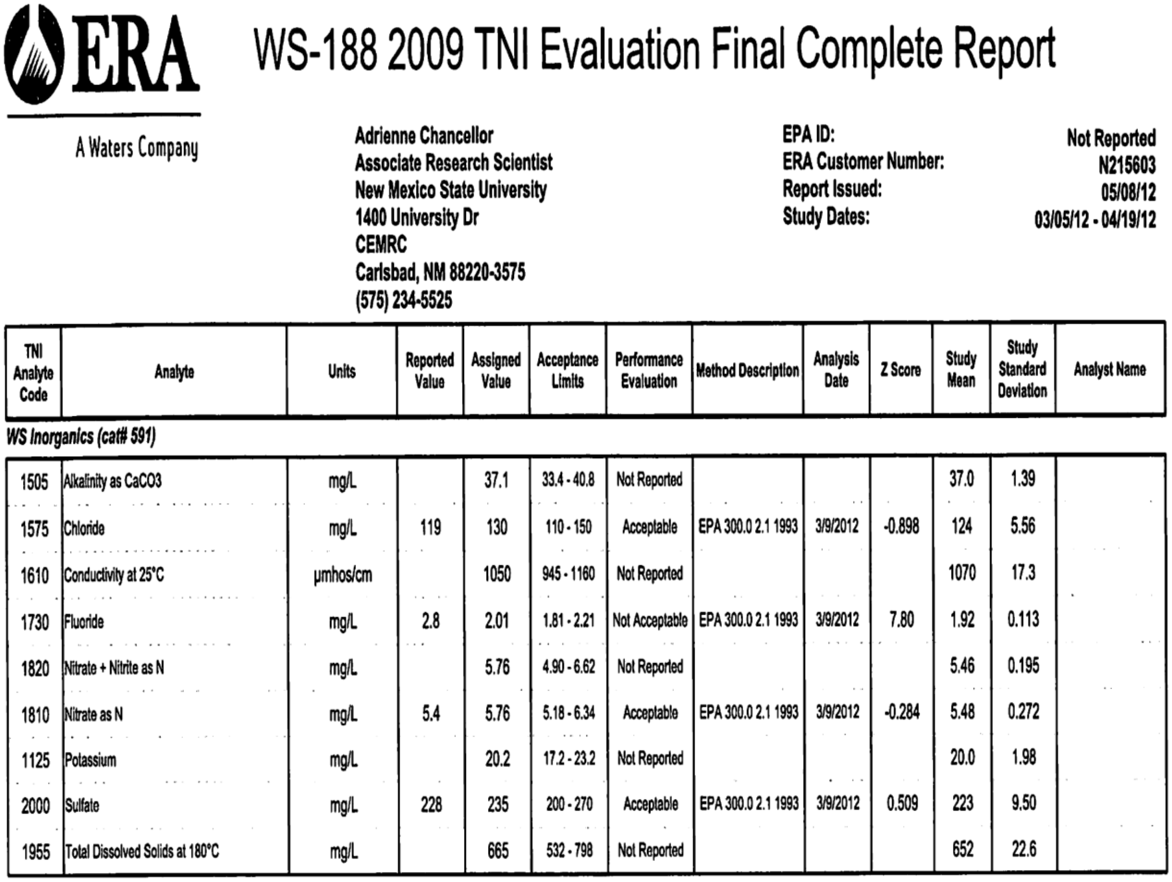
APPENDIX D: PERFORMANCE TESTS AND AUDITS

Below are summaries of external and internal audits, and results for three performance tests; one for Environmental Chemistry Inorganic analysis (Figures D.1 – D.3), and two for radiochemical analyses (Figures D.4 - D.11).

Figures D.4 – D.8 shows MAPEP results for three matrices; soil, water, and air filters. Specific selected analytes are tested each year and may be different for each matrix and between years. A value in the Result column means that analyte was tested Ref Values are the nominally correct answer and the Acceptance Range gives the range of values that are acceptable. Only one analysis result (^{241}Am in the filter matrix) did not meet the acceptance criteria for 2012, see Figure D.6.

Figures D.9 – D.11 shows NIST results for filters, water and soil. Only three analysis results (^{234}U, ^{235}U, and ^{238}Pu in soil) did not meet the acceptance criteria for 2012, see Figure D10. With the exception of these three, all other NIST bias results met the acceptance criteria for all radionuclides of interest at the WIPP site for 2012. Overall, the difference from the NIST values observed for the test nuclides are $\leq$ 10%.

Figure D.1 Blind Check 2012, Environmental Chemistry Analysis



ERA
A Waters Company

WS-188 2009 TNI Evaluation Final Complete Report

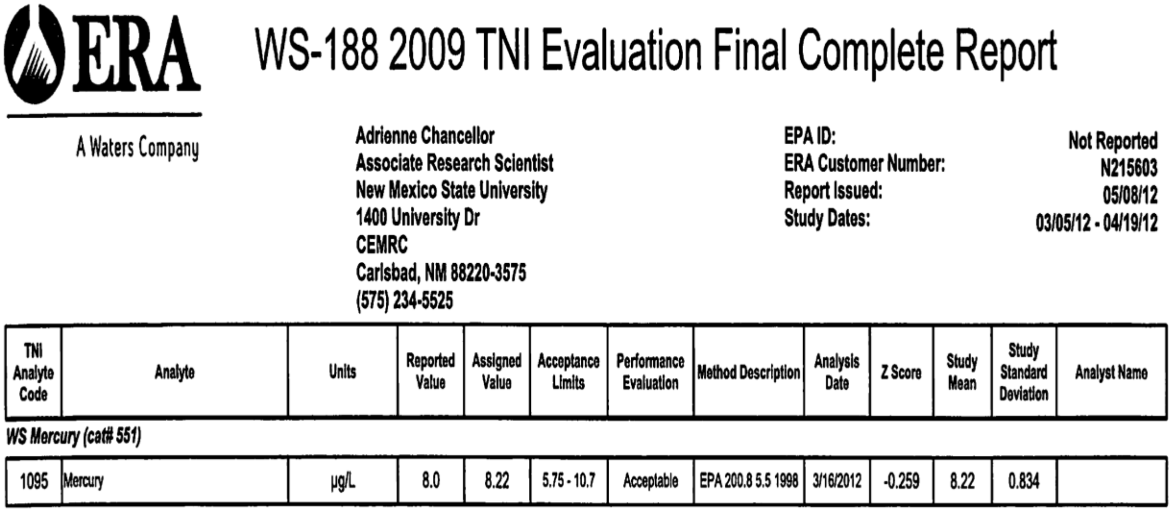
Adrienne Chancellor
Associate Research Scientist
New Mexico State University
1400 University Dr
CEMRC
Carlsbad, NM 88220-3575
(575) 234-5525

EPA ID:	Not Reported
ERA Customer Number:	N215603
Report Issued:	05/08/12
Study Dates:	03/05/12 - 04/19/12

WS Inorganics (cat# 591)

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
1505	Alkalinity as CaCO3	mg/L		37.1	33.4 - 40.8	Not Reported				37.0	1.39	
1575	Chloride	mg/L	119	130	110 - 150	Acceptable	EPA 300.0 2.1 1993	3/9/2012	-0.898	124	5.56	
1610	Conductivity at 25°C	µmhos/cm		1050	945 - 1160	Not Reported				1070	17.3	
1730	Fluoride	mg/L	2.8	2.01	1.81 - 2.21	Not Acceptable	EPA 300.0 2.1 1993	3/9/2012	7.80	1.92	0.113	
1820	Nitrate + Nitrite as N	mg/L		5.76	4.90 - 6.62	Not Reported				5.46	0.195	
1810	Nitrate as N	mg/L	5.4	5.76	5.18 - 6.34	Acceptable	EPA 300.0 2.1 1993	3/9/2012	-0.284	5.48	0.272	
1125	Potassium	mg/L		20.2	17.2 - 23.2	Not Reported				20.0	1.98	
2000	Sulfate	mg/L	228	235	200 - 270	Acceptable	EPA 300.0 2.1 1993	3/9/2012	0.509	223	9.50	
1955	Total Dissolved Solids at 180°C	mg/L		665	532 - 798	Not Reported				652	22.6	

Figure D.2. Blind Check 2012, Environmental Chemistry Analysis



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WS-188 2009 TNI Evaluation Final Complete Report

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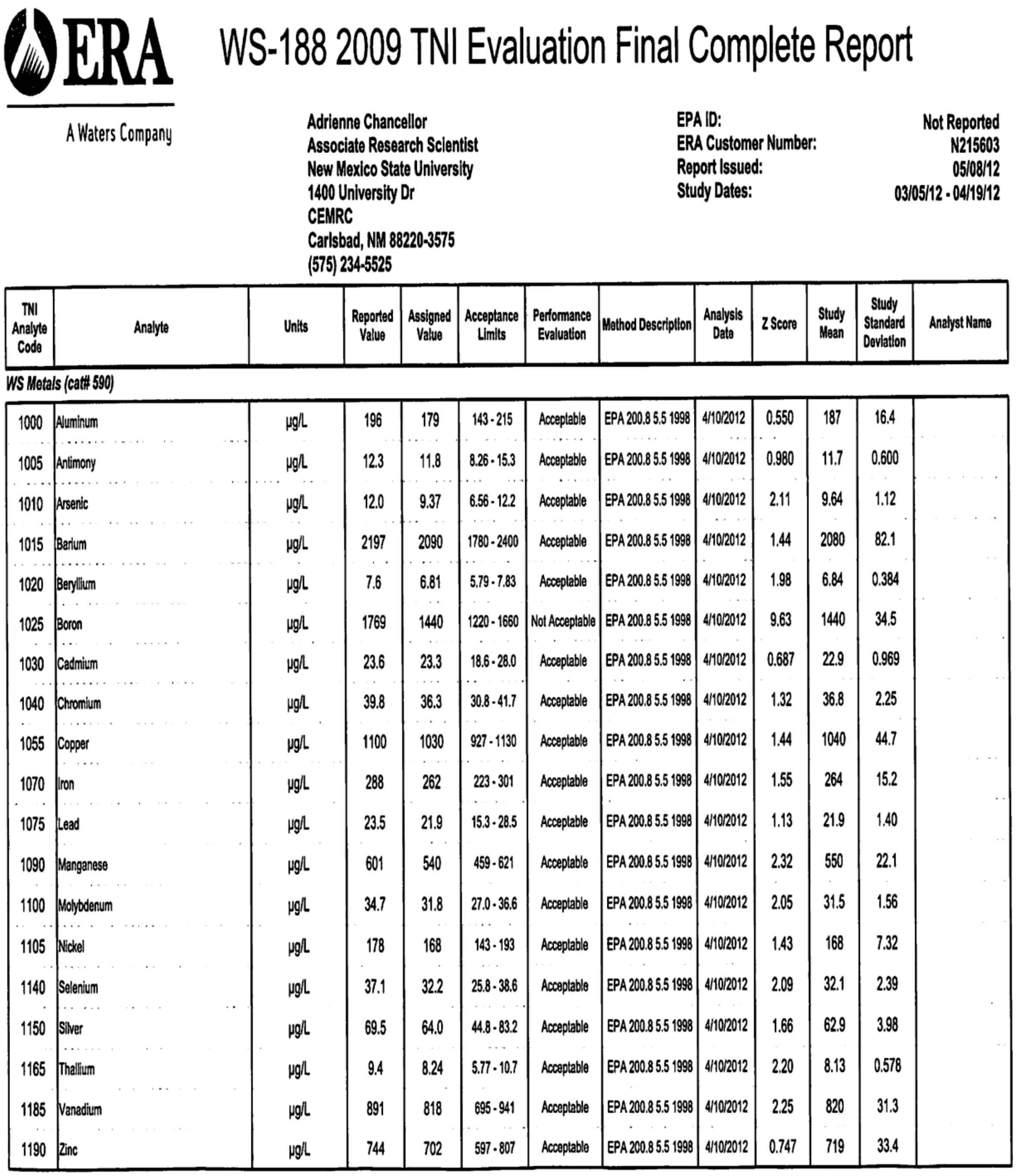
(575) 234-5525

EPA ID:	Not Reported
ERA Customer Number:	N215603
Report Issued:	05/08/12
Study Dates:	03/05/12 - 04/19/12

WS Mercury (cat# 551)

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
1095	Mercury	µg/L	8.0	8.22	5.75 - 10.7	Acceptable	EPA 200.8 5.5 1998	3/16/2012	-0.259	8.22	0.834	

Figure D.3 Blind Check 2012 Environmental Chemistry Inorganic Analyses



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WS-188 2009 TNI Evaluation Final Complete Report

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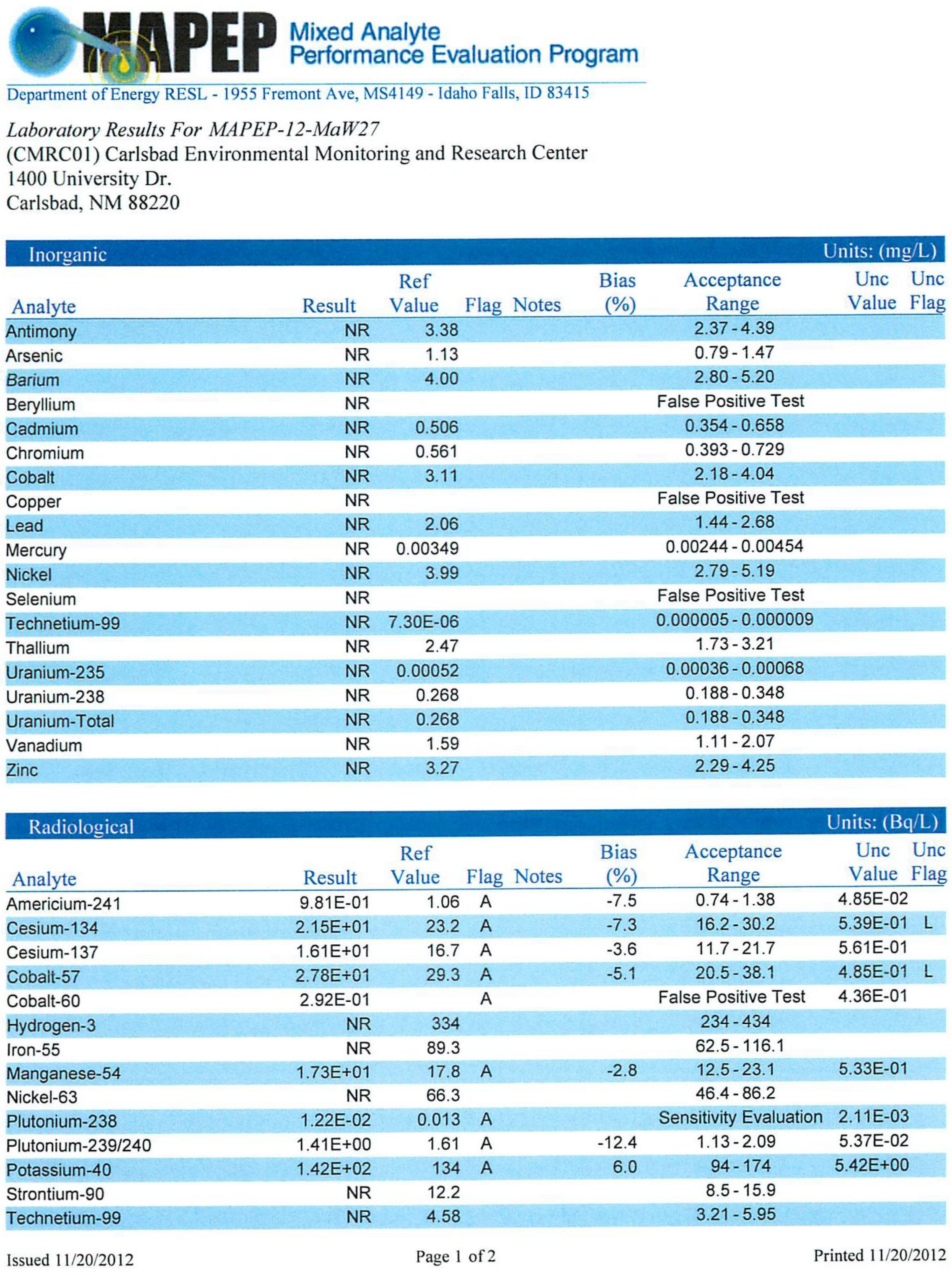
EPA ID:	**Not Reported**
ERA Customer Number:	**N215603**
Report Issued:	**05/08/12**
Study Dates:	**03/05/12 - 04/19/12**

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)												
1000	Aluminum	µg/L	196	179	143 - 215	Acceptable	EPA 200.8 5.5 1998	4/10/2012	0.550	187	16.4	
1005	Antimony	µg/L	12.3	11.8	8.26 - 15.3	Acceptable	EPA 200.8 5.5 1998	4/10/2012	0.980	11.7	0.600	
1010	Arsenic	µg/L	12.0	9.37	6.56 - 12.2	Acceptable	EPA 200.8 5.5 1998	4/10/2012	2.11	9.64	1.12	
1015	Barium	µg/L	2197	2090	1780 - 2400	Acceptable	EPA 200.8 5.5 1998	4/10/2012	1.44	2080	82.1	
1020	Beryllium	µg/L	7.6	6.81	5.79 - 7.83	Acceptable	EPA 200.8 5.5 1998	4/10/2012	1.98	6.84	0.384	
1025	Boron	µg/L	1769	1440	1220 - 1660	Not Acceptable	EPA 200.8 5.5 1998	4/10/2012	9.63	1440	34.5	
1030	Cadmium	µg/L	23.6	23.3	18.6 - 28.0	Acceptable	EPA 200.8 5.5 1998	4/10/2012	0.687	22.9	0.969	
1040	Chromium	µg/L	39.8	36.3	30.8 - 41.7	Acceptable	EPA 200.8 5.5 1998	4/10/2012	1.32	36.8	2.25	
1055	Copper	µg/L	1100	1030	927 - 1130	Acceptable	EPA 200.8 5.5 1998	4/10/2012	1.44	1040	44.7	
1070	Iron	µg/L	288	262	223 - 301	Acceptable	EPA 200.8 5.5 1998	4/10/2012	1.55	264	15.2	
1075	Lead	µg/L	23.5	21.9	15.3 - 28.5	Acceptable	EPA 200.8 5.5 1998	4/10/2012	1.13	21.9	1.40	
1090	Manganese	µg/L	601	540	459 - 621	Acceptable	EPA 200.8 5.5 1998	4/10/2012	2.32	550	22.1	
1100	Molybdenum	µg/L	34.7	31.8	27.0 - 36.6	Acceptable	EPA 200.8 5.5 1998	4/10/2012	2.05	31.5	1.56	
1105	Nickel	µg/L	178	168	143 - 193	Acceptable	EPA 200.8 5.5 1998	4/10/2012	1.43	168	7.32	
1140	Selenium	µg/L	37.1	32.2	25.8 - 38.6	Acceptable	EPA 200.8 5.5 1998	4/10/2012	2.09	32.1	2.39	
1150	Silver	µg/L	69.5	64.0	44.8 - 83.2	Acceptable	EPA 200.8 5.5 1998	4/10/2012	1.66	62.9	3.98	
1165	Thallium	µg/L	9.4	8.24	5.77 - 10.7	Acceptable	EPA 200.8 5.5 1998	4/10/2012	2.20	8.13	0.578	
1185	Vanadium	µg/L	891	818	695 - 941	Acceptable	EPA 200.8 5.5 1998	4/10/2012	2.25	820	31.3	
1190	Zinc	µg/L	744	702	597 - 807	Acceptable	EPA 200.8 5.5 1998	4/10/2012	0.747	719	33.4	

Figure D.4 Radiochemistry MAPEP 2012 Intercomparison Results

The full MAPEP reports are available at http://www.inl.gov/resl/mapep/



MAPEP Mixed Analyte Performance Evaluation Program

Department of Energy RESL - 1955 Fremont Ave, MS4149 - Idaho Falls, ID 83415

Laboratory Results For MAPEP-12-MaW27
(CMRC01) Carlsbad Environmental Monitoring and Research Center
1400 University Dr.
Carlsbad, NM 88220

Inorganic — Units: (mg/L)

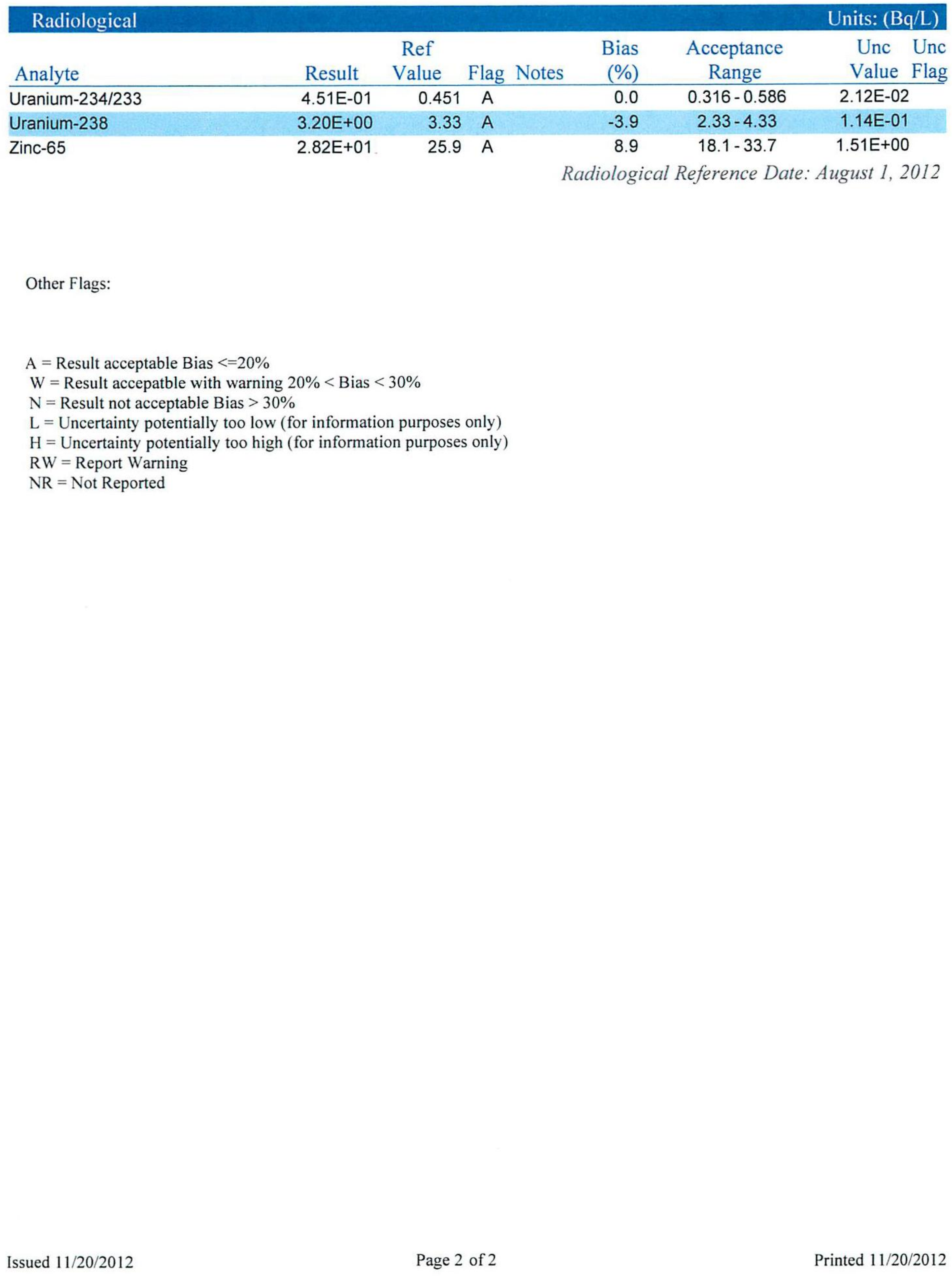
Analyte	Result	Ref Value	Flag	Notes	Bias (%)	Acceptance Range	Unc Value	Unc Flag
Antimony	NR	3.38				2.37 - 4.39		
Arsenic	NR	1.13				0.79 - 1.47		
Barium	NR	4.00				2.80 - 5.20		
Beryllium	NR					False Positive Test		
Cadmium	NR	0.506				0.354 - 0.658		
Chromium	NR	0.561				0.393 - 0.729		
Cobalt	NR	3.11				2.18 - 4.04		
Copper	NR					False Positive Test		
Lead	NR	2.06				1.44 - 2.68		
Mercury	NR	0.00349				0.00244 - 0.00454		
Nickel	NR	3.99				2.79 - 5.19		
Selenium	NR					False Positive Test		
Technetium-99	NR	7.30E-06				0.000005 - 0.000009		
Thallium	NR	2.47				1.73 - 3.21		
Uranium-235	NR	0.00052				0.00036 - 0.00068		
Uranium-238	NR	0.268				0.188 - 0.348		
Uranium-Total	NR	0.268				0.188 - 0.348		
Vanadium	NR	1.59				1.11 - 2.07		
Zinc	NR	3.27				2.29 - 4.25		

Radiological — Units: (Bq/L)

Analyte	Result	Ref Value	Flag	Notes	Bias (%)	Acceptance Range	Unc Value	Unc Flag
Americium-241	9.81E-01	1.06	A		-7.5	0.74 - 1.38	4.85E-02	
Cesium-134	2.15E+01	23.2	A		-7.3	16.2 - 30.2	5.39E-01	L
Cesium-137	1.61E+01	16.7	A		-3.6	11.7 - 21.7	5.61E-01	
Cobalt-57	2.78E+01	29.3	A		-5.1	20.5 - 38.1	4.85E-01	L
Cobalt-60	2.92E-01		A			False Positive Test	4.36E-01	
Hydrogen-3	NR	334				234 - 434		
Iron-55	NR	89.3				62.5 - 116.1		
Manganese-54	1.73E+01	17.8	A		-2.8	12.5 - 23.1	5.33E-01	
Nickel-63	NR	66.3				46.4 - 86.2		
Plutonium-238	1.22E-02	0.013	A			Sensitivity Evaluation	2.11E-03	
Plutonium-239/240	1.41E+00	1.61	A		-12.4	1.13 - 2.09	5.37E-02	
Potassium-40	1.42E+02	134	A		6.0	94 - 174	5.42E+00	
Strontium-90	NR	12.2				8.5 - 15.9		
Technetium-99	NR	4.58				3.21 - 5.95		

Issued 11/20/2012 Page 1 of 2 Printed 11/20/2012

Figure D.4 Radiochemistry MAPEP 2012 Intercomparison Results (continued)



Radiological — Units: (Bq/L)

Analyte	Result	Ref Value	Flag	Notes	Bias (%)	Acceptance Range	Unc Value	Unc Flag
Uranium-234/233	4.51E-01	0.451	A		0.0	0.316 - 0.586	2.12E-02	
Uranium-238	3.20E+00	3.33	A		-3.9	2.33 - 4.33	1.14E-01	
Zinc-65	2.82E+01	25.9	A		8.9	18.1 - 33.7	1.51E+00	

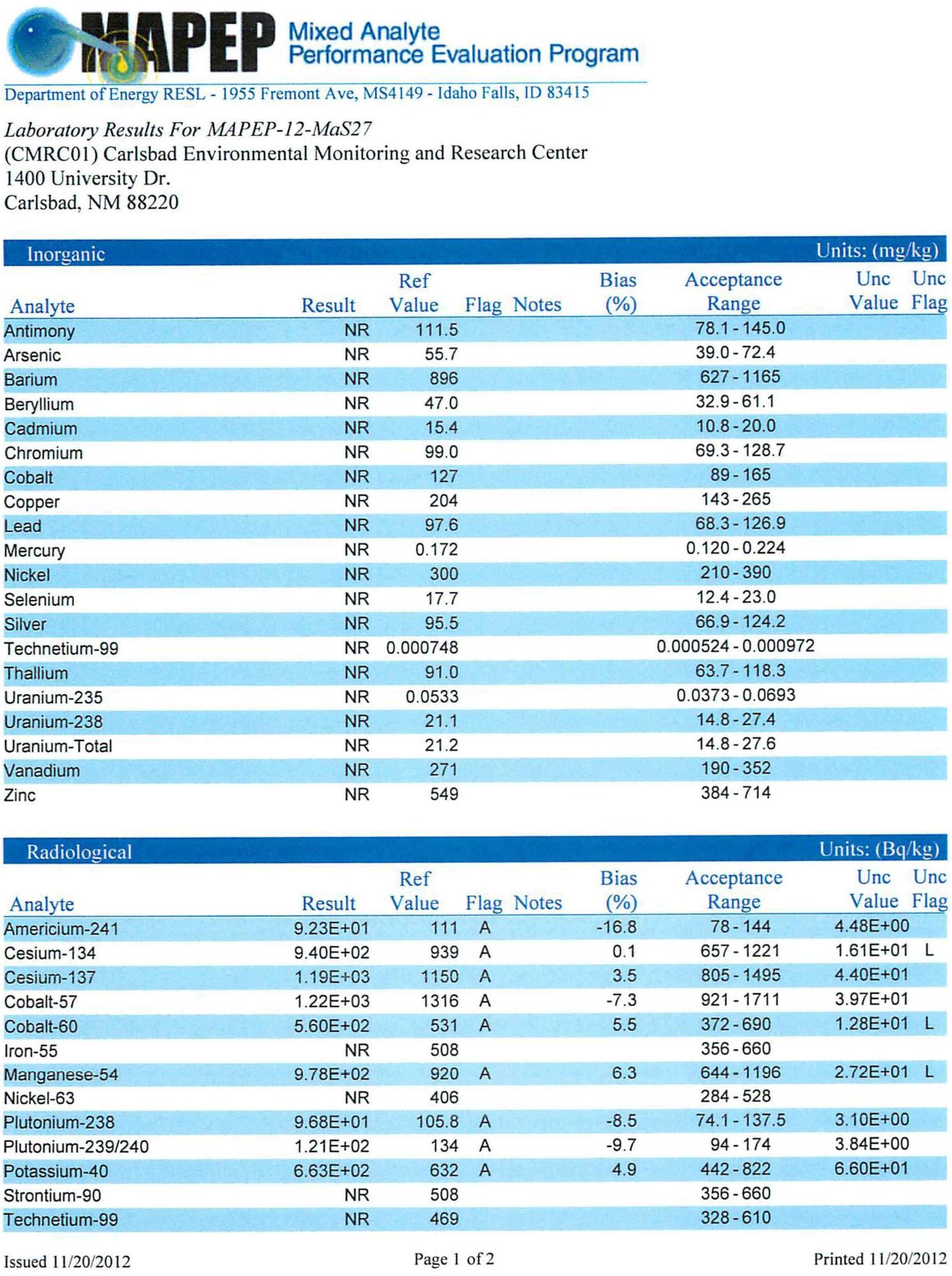
Radiological Reference Date: August 1, 2012

Other Flags:

A = Result acceptable Bias <=20%
W = Result accepatble with warning 20% < Bias < 30%
N = Result not acceptable Bias > 30%
L = Uncertainty potentially too low (for information purposes only)
H = Uncertainty potentially too high (for information purposes only)
RW = Report Warning
NR = Not Reported

Issued 11/20/2012 Page 2 of 2 Printed 11/20/2012

Figure D.5 Radiochemistry MAPEP 2012 Intercomparison Results



MAPEP Mixed Analyte Performance Evaluation Program

Department of Energy RESL - 1955 Fremont Ave, MS4149 - Idaho Falls, ID 83415

Laboratory Results For MAPEP-12-MaS27

(CMRC01) Carlsbad Environmental Monitoring and Research Center
1400 University Dr.
Carlsbad, NM 88220

Inorganic Units: (mg/kg)

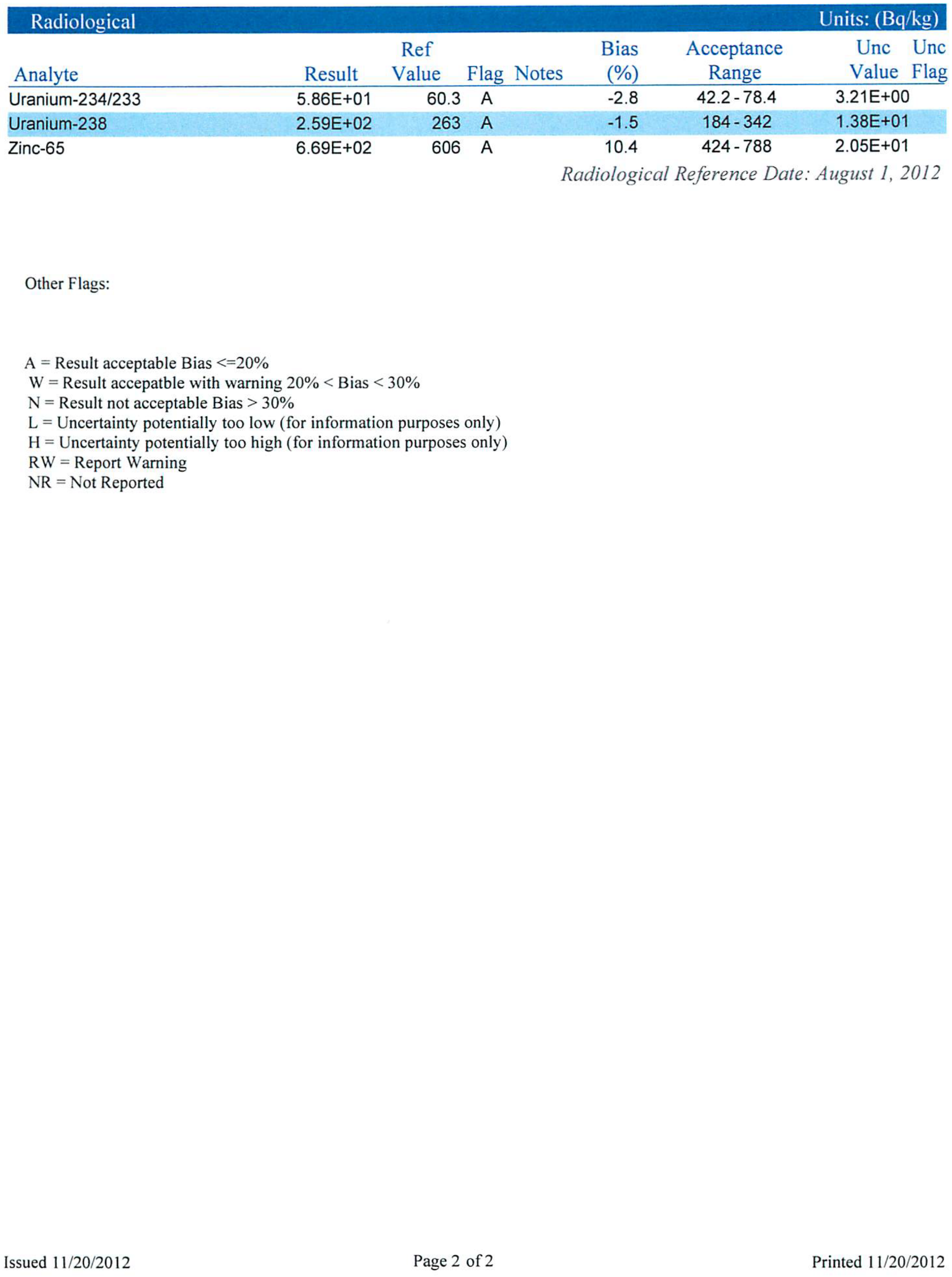
Analyte	Result	Ref Value	Flag	Notes	Bias (%)	Acceptance Range	Unc Value	Unc Flag
Antimony	NR	111.5				78.1 - 145.0		
Arsenic	NR	55.7				39.0 - 72.4		
Barium	NR	896				627 - 1165		
Beryllium	NR	47.0				32.9 - 61.1		
Cadmium	NR	15.4				10.8 - 20.0		
Chromium	NR	99.0				69.3 - 128.7		
Cobalt	NR	127				89 - 165		
Copper	NR	204				143 - 265		
Lead	NR	97.6				68.3 - 126.9		
Mercury	NR	0.172				0.120 - 0.224		
Nickel	NR	300				210 - 390		
Selenium	NR	17.7				12.4 - 23.0		
Silver	NR	95.5				66.9 - 124.2		
Technetium-99	NR	0.000748				0.000524 - 0.000972		
Thallium	NR	91.0				63.7 - 118.3		
Uranium-235	NR	0.0533				0.0373 - 0.0693		
Uranium-238	NR	21.1				14.8 - 27.4		
Uranium-Total	NR	21.2				14.8 - 27.6		
Vanadium	NR	271				190 - 352		
Zinc	NR	549				384 - 714		

Radiological Units: (Bq/kg)

Analyte	Result	Ref Value	Flag	Notes	Bias (%)	Acceptance Range	Unc Value	Unc Flag
Americium-241	9.23E+01	111	A		-16.8	78 - 144	4.48E+00	
Cesium-134	9.40E+02	939	A		0.1	657 - 1221	1.61E+01	L
Cesium-137	1.19E+03	1150	A		3.5	805 - 1495	4.40E+01	
Cobalt-57	1.22E+03	1316	A		-7.3	921 - 1711	3.97E+01	
Cobalt-60	5.60E+02	531	A		5.5	372 - 690	1.28E+01	L
Iron-55	NR	508				356 - 660		
Manganese-54	9.78E+02	920	A		6.3	644 - 1196	2.72E+01	L
Nickel-63	NR	406				284 - 528		
Plutonium-238	9.68E+01	105.8	A		-8.5	74.1 - 137.5	3.10E+00	
Plutonium-239/240	1.21E+02	134	A		-9.7	94 - 174	3.84E+00	
Potassium-40	6.63E+02	632	A		4.9	442 - 822	6.60E+01	
Strontium-90	NR	508				356 - 660		
Technetium-99	NR	469				328 - 610		

Issued 11/20/2012 Page 1 of 2 Printed 11/20/2012

Figure D.5 Radiochemistry MAPEP 2012 Intercomparison Results (continued)



Radiological | Units: (Bq/kg)

Analyte	Result	Ref Value	Flag	Notes	Bias (%)	Acceptance Range	Unc Value	Unc Flag
Uranium-234/233	5.86E+01	60.3	A		-2.8	42.2 - 78.4	3.21E+00	
Uranium-238	2.59E+02	263	A		-1.5	184 - 342	1.38E+01	
Zinc-65	6.69E+02	606	A		10.4	424 - 788	2.05E+01	

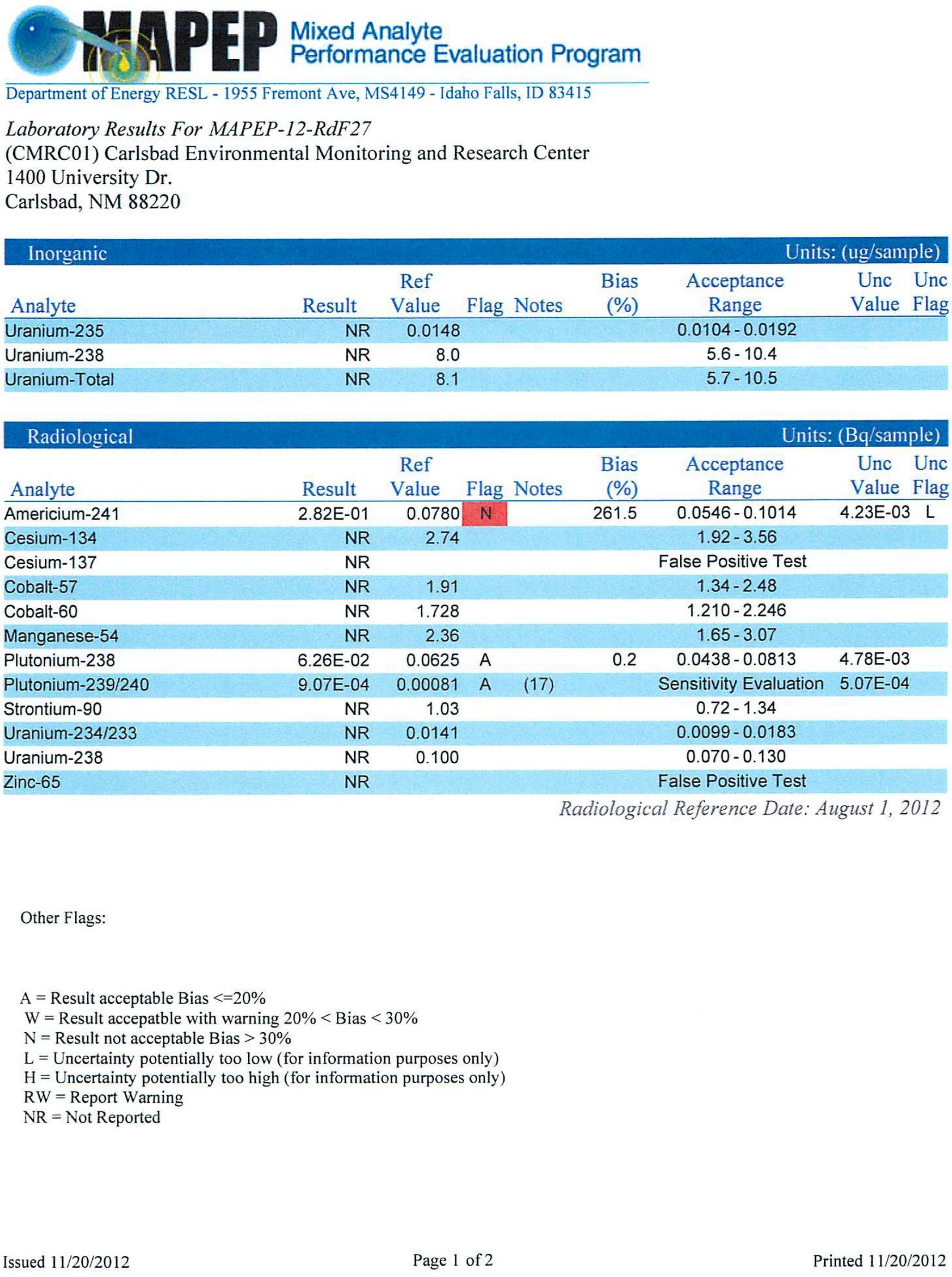
Radiological Reference Date: August 1, 2012

Other Flags:

A = Result acceptable Bias <=20%
W = Result accepatble with warning 20% < Bias < 30%
N = Result not acceptable Bias > 30%
L = Uncertainty potentially too low (for information purposes only)
H = Uncertainty potentially too high (for information purposes only)
RW = Report Warning
NR = Not Reported

Issued 11/20/2012 Page 2 of 2 Printed 11/20/2012

Figure D.6 Radiochemistry MAPEP 2012 Intercomparison Results



MAPEP Mixed Analyte Performance Evaluation Program

Department of Energy RESL - 1955 Fremont Ave, MS4149 - Idaho Falls, ID 83415

Laboratory Results For MAPEP-12-RdF27
(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	0.0148				0.0104 - 0.0192		
Uranium-238	NR	8.0				5.6 - 10.4		
Uranium-Total	NR	8.1				5.7 - 10.5		

Radiological							Units: (Bq/sample)	
Analyte	Result	Ref Value	Flag	Notes	Bias (%)	Acceptance Range	Unc Value	Unc Flag
Americium-241	2.82E-01	0.0780	N		261.5	0.0546 - 0.1014	4.23E-03	L
Cesium-134	NR	2.74				1.92 - 3.56		
Cesium-137	NR					False Positive Test		
Cobalt-57	NR	1.91				1.34 - 2.48		
Cobalt-60	NR	1.728				1.210 - 2.246		
Manganese-54	NR	2.36				1.65 - 3.07		
Plutonium-238	6.26E-02	0.0625	A		0.2	0.0438 - 0.0813	4.78E-03	
Plutonium-239/240	9.07E-04	0.00081	A	(17)		Sensitivity Evaluation	5.07E-04	
Strontium-90	NR	1.03				0.72 - 1.34		
Uranium-234/233	NR	0.0141				0.0099 - 0.0183		
Uranium-238	NR	0.100				0.070 - 0.130		
Zinc-65	NR					False Positive Test		

Radiological Reference Date: August 1, 2012

Other Flags:

A = Result acceptable Bias <=20%
W = Result accepatble with warning 20% < Bias < 30%
N = Result not acceptable Bias > 30%
L = Uncertainty potentially too low (for information purposes only)
H = Uncertainty potentially too high (for information purposes only)
RW = Report Warning
NR = Not Reported

Issued 11/20/2012 Page 1 of 2 Printed 11/20/2012

Figure D.6 Radiochemistry MAPEP 2012 Intercomparison Results (continued)

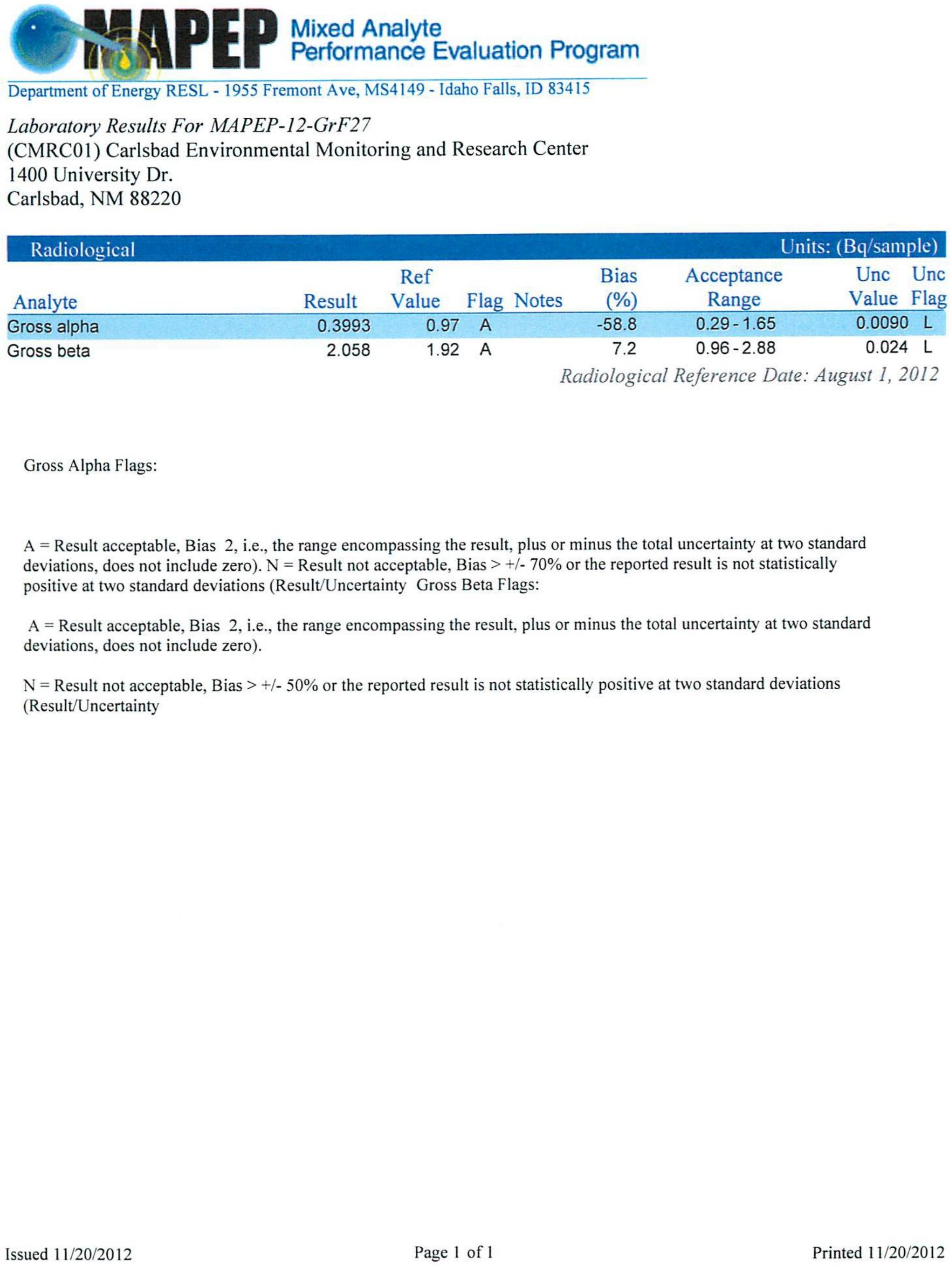
Radiological Units: (Bq/sample)

Analyte	Result	Ref Value	Flag	Notes	Bias (%)	Acceptance Range	Unc Value	Unc Flag

Notes:

(17) = NOT DETECTED - reported a statistically zero result

Figure D.7 Radiochemistry MAPEP 2012 Intercomparison Results



MAPEP Mixed Analyte Performance Evaluation Program

Department of Energy RESL - 1955 Fremont Ave, MS4149 - Idaho Falls, ID 83415

Laboratory Results For MAPEP-12-GrF27
(CMRC01) Carlsbad Environmental Monitoring and Research Center
1400 University Dr.
Carlsbad, NM 88220

Radiological — Units: (Bq/sample)

Analyte	Result	Ref Value	Flag	Notes	Bias (%)	Acceptance Range	Unc Value	Unc Flag
Gross alpha	0.3993	0.97	A		-58.8	0.29 - 1.65	0.0090	L
Gross beta	2.058	1.92	A		7.2	0.96 - 2.88	0.024	L

Radiological Reference Date: August 1, 2012

Gross Alpha Flags:

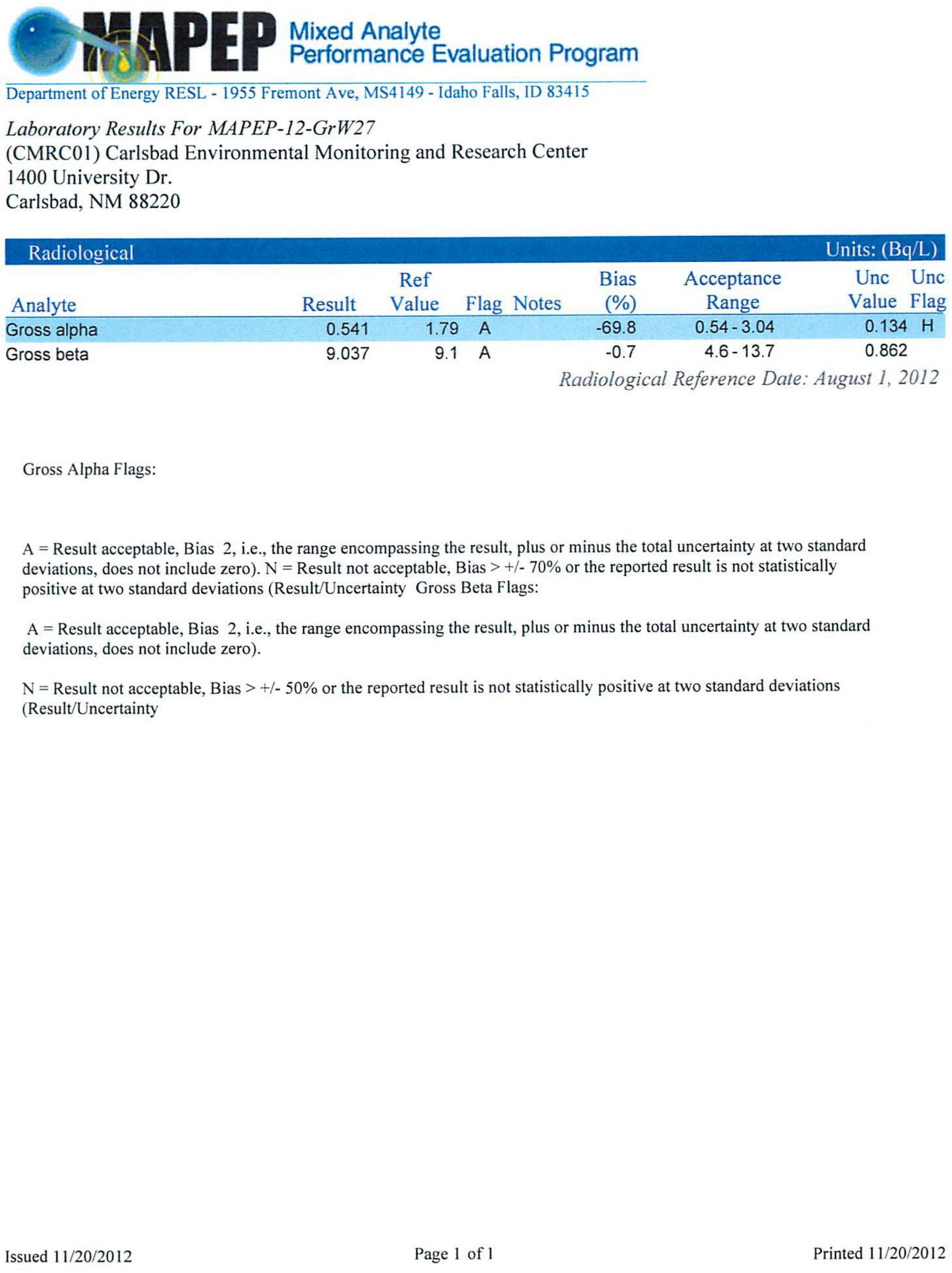
A = Result acceptable, Bias 2, i.e., the range encompassing the result, plus or minus the total uncertainty at two standard deviations, does not include zero). N = Result not acceptable, Bias > +/- 70% or the reported result is not statistically positive at two standard deviations (Result/Uncertainty Gross Beta Flags:

A = Result acceptable, Bias 2, i.e., the range encompassing the result, plus or minus the total uncertainty at two standard deviations, does not include zero).

N = Result not acceptable, Bias > +/- 50% or the reported result is not statistically positive at two standard deviations (Result/Uncertainty

Issued 11/20/2012 — Page 1 of 1 — Printed 11/20/2012

Figure D.8 Radiochemistry MAPEP 2012 Intercomparison Results



MAPEP Mixed Analyte Performance Evaluation Program

Department of Energy RESL - 1955 Fremont Ave, MS4149 - Idaho Falls, ID 83415

Laboratory Results For MAPEP-12-GrW27
(CMRC01) Carlsbad Environmental Monitoring and Research Center
1400 University Dr.
Carlsbad, NM 88220

Radiological — Units: (Bq/L)

Analyte	Result	Ref Value	Flag	Notes	Bias (%)	Acceptance Range	Unc Value	Unc Flag
Gross alpha	0.541	1.79	A		-69.8	0.54 - 3.04	0.134	H
Gross beta	9.037	9.1	A		-0.7	4.6 - 13.7	0.862	

Radiological Reference Date: August 1, 2012

Gross Alpha Flags:

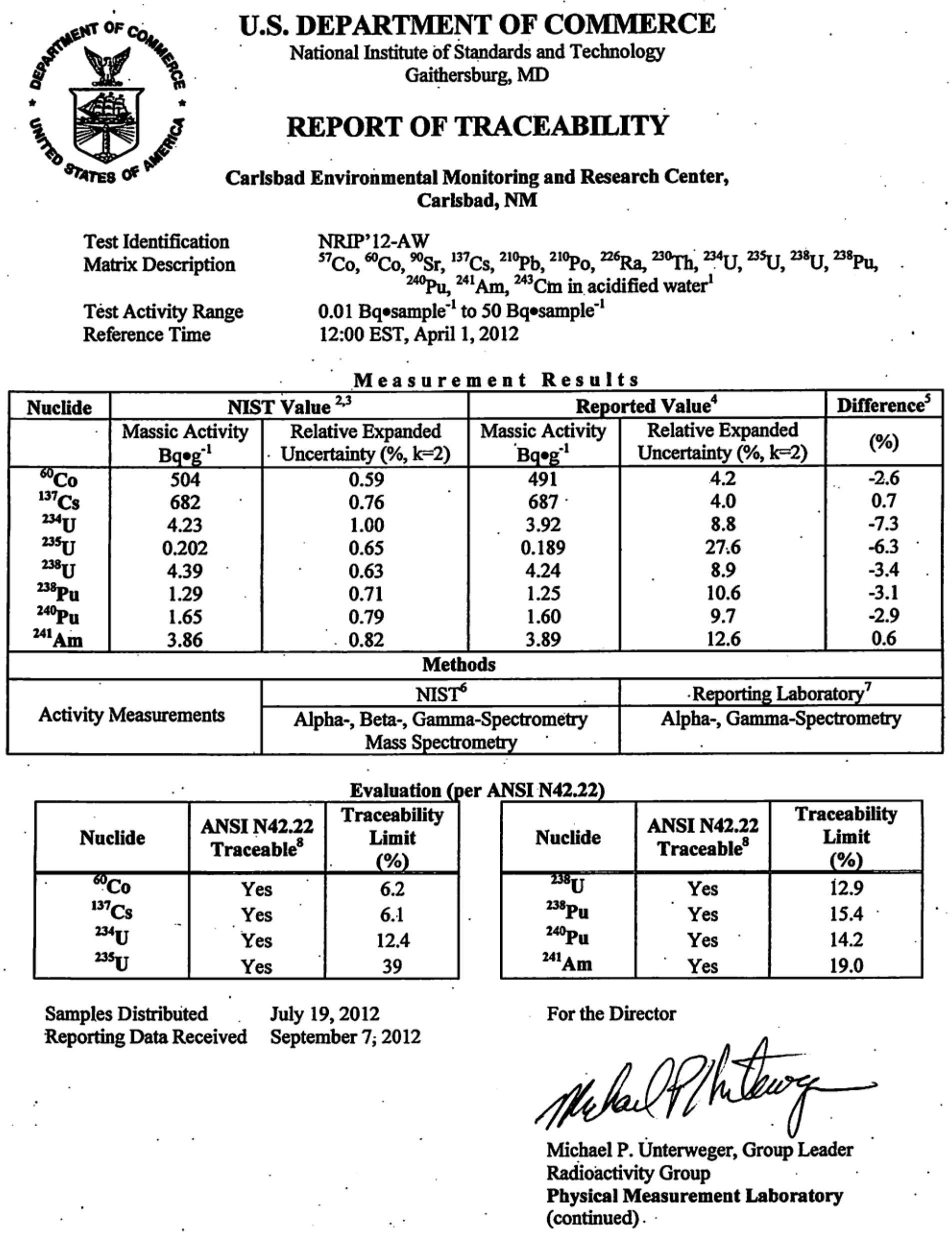
A = Result acceptable, Bias 2, i.e., the range encompassing the result, plus or minus the total uncertainty at two standard deviations, does not include zero). N = Result not acceptable, Bias > +/- 70% or the reported result is not statistically positive at two standard deviations (Result/Uncertainty Gross Beta Flags:

A = Result acceptable, Bias 2, i.e., the range encompassing the result, plus or minus the total uncertainty at two standard deviations, does not include zero).

N = Result not acceptable, Bias > +/- 50% or the reported result is not statistically positive at two standard deviations (Result/Uncertainty

Issued 11/20/2012 Page 1 of 1 Printed 11/20/2012

Figure D.9 Participation in 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'12-AW
Matrix Description	^{57}Co, ^{60}Co, ^{90}Sr, ^{137}Cs, ^{210}Pb, ^{210}Po, ^{226}Ra, ^{230}Th, ^{234}U, ^{235}U, ^{238}U, ^{238}Pu, ^{240}Pu, ^{241}Am, ^{243}Cm in acidified water[1]
Test Activity Range	0.01 Bq•sample^{-1} to 50 Bq•sample^{-1}
Reference Time	12:00 EST, April 1, 2012

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	504	0.59	491	4.2	-2.6
^{137}Cs	682	0.76	687	4.0	0.7
^{234}U	4.23	1.00	3.92	8.8	-7.3
^{235}U	0.202	0.65	0.189	27.6	-6.3
^{238}U	4.39	0.63	4.24	8.9	-3.4
^{238}Pu	1.29	0.71	1.25	10.6	-3.1
^{240}Pu	1.65	0.79	1.60	9.7	-2.9
^{241}Am	3.86	0.82	3.89	12.6	0.6

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	6.2
^{137}Cs	Yes	6.1
^{234}U	Yes	12.4
^{235}U	Yes	39

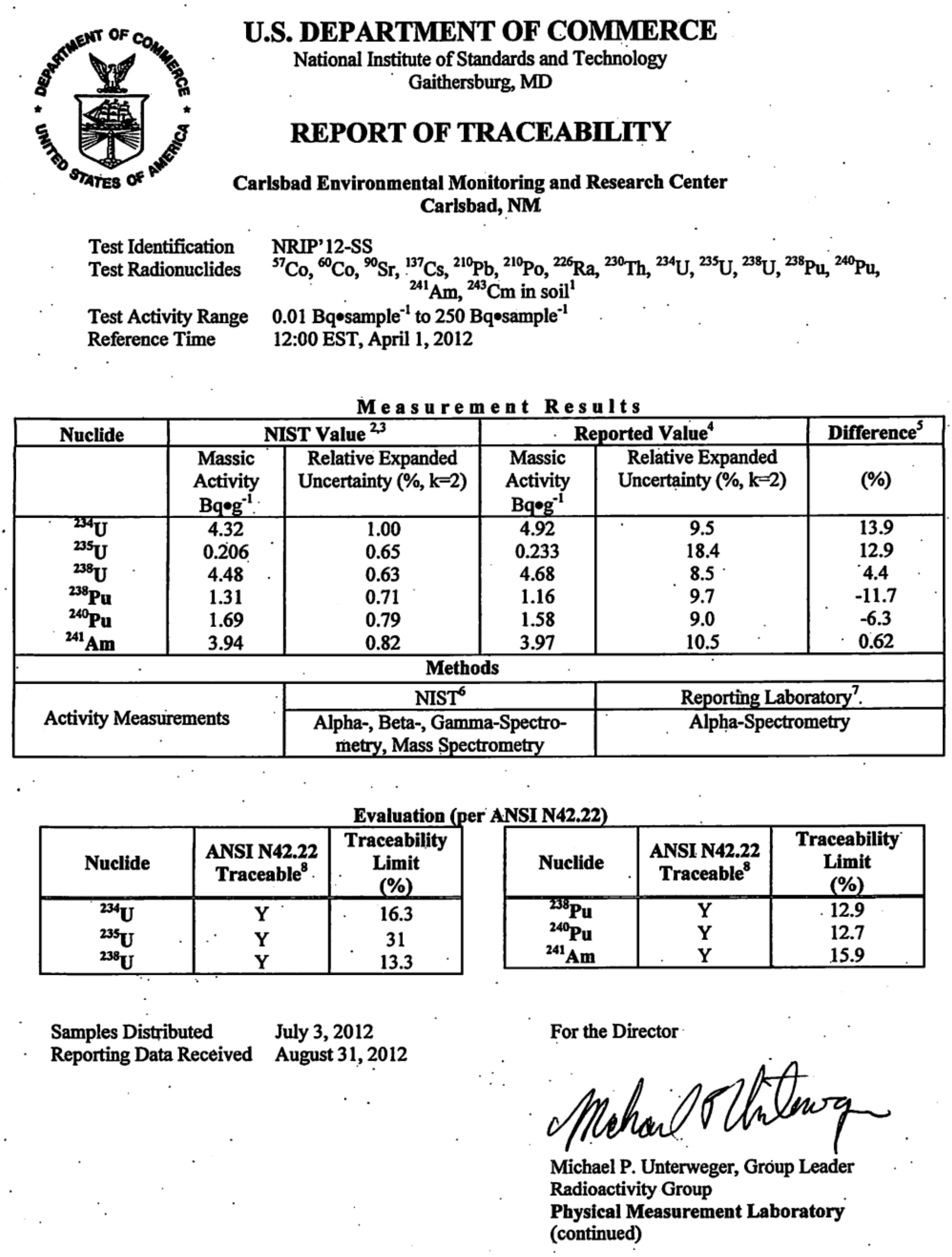
Nuclide	ANSI N42.22 Traceable[8]	Traceability Limit (%)
^{238}U	Yes	12.9
^{238}Pu	Yes	15.4
^{240}Pu	Yes	14.2
^{241}Am	Yes	19.0

Samples Distributed	July 19, 2012
Reporting Data Received	September 7, 2012

For the Director

Michael P. Unterweger, Group Leader
Radioactivity Group
Physical Measurement Laboratory
(continued)

Figure D.10 Participation in 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'12-SS
Test Radionuclides	^{57}Co, ^{60}Co, ^{90}Sr, ^{137}Cs, ^{210}Pb, ^{210}Po, ^{226}Ra, ^{230}Th, ^{234}U, ^{235}U, ^{238}U, ^{238}Pu, ^{240}Pu, ^{241}Am, ^{243}Cm in soil[1]
Test Activity Range	0.01 Bq•sample^{-1} to 250 Bq•sample^{-1}
Reference Time	12:00 EST, April 1, 2012

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)	(%)
^{234}U	4.32	1.00	4.92	9.5	13.9
^{235}U	0.206	0.65	0.233	18.4	12.9
^{238}U	4.48	0.63	4.68	8.5	4.4
^{238}Pu	1.31	0.71	1.16	9.7	-11.7
^{240}Pu	1.69	0.79	1.58	9.0	-6.3
^{241}Am	3.94	0.82	3.97	10.5	0.62

Methods

	NIST[6]	Reporting Laboratory[7].
Activity Measurements	Alpha-, Beta-, Gamma-Spectrometry, Mass Spectrometry	Alpha-Spectrometry

Evaluation (per ANSI N42.22)

Nuclide	ANSI N42.22 Traceable[8]	Traceability Limit (%)
^{234}U	Y	16.3
^{235}U	Y	31
^{238}U	Y	13.3

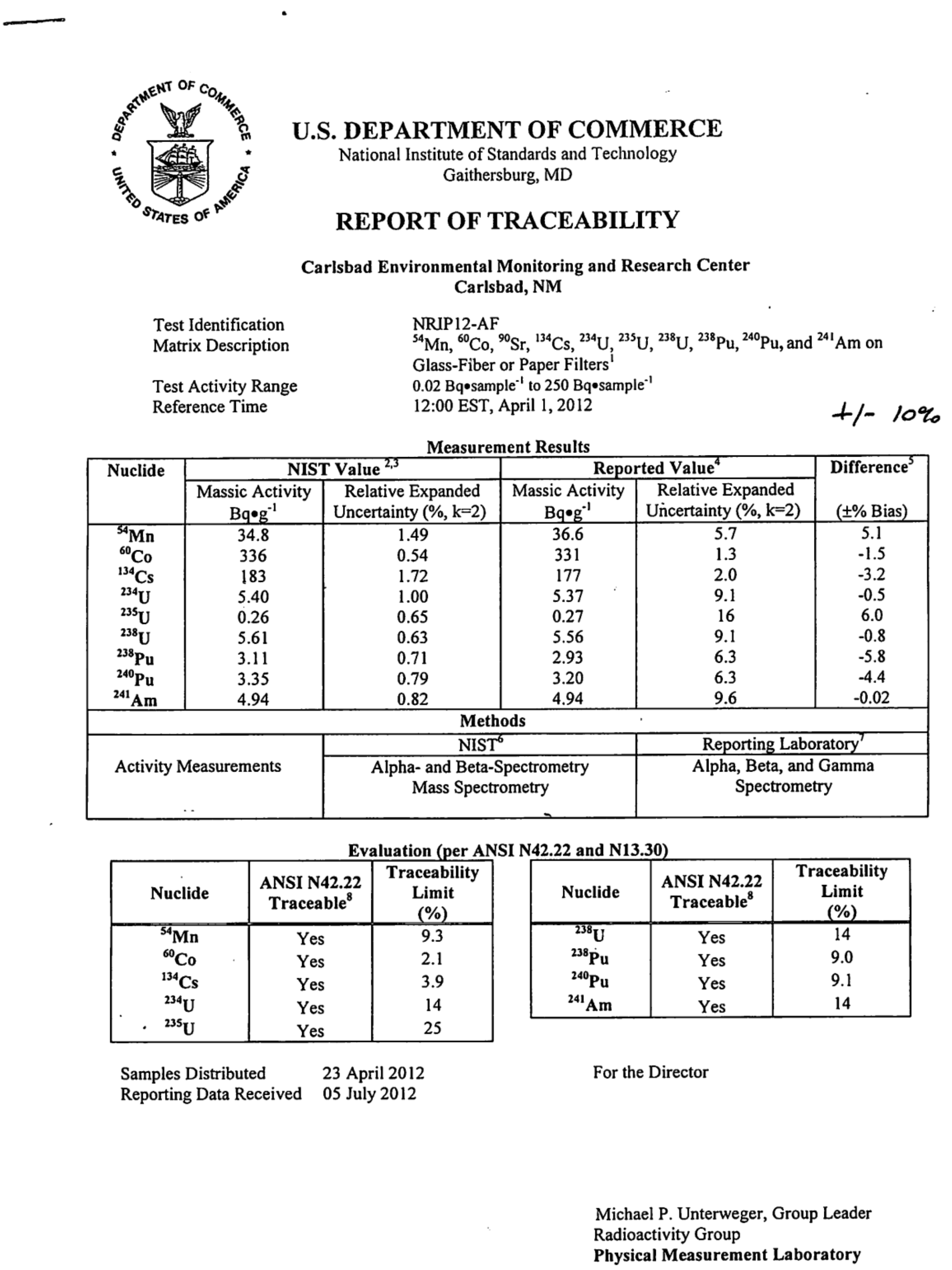
Nuclide	ANSI N42.22 Traceable[8]	Traceability Limit (%)
^{238}Pu	Y	12.9
^{240}Pu	Y	12.7
^{241}Am	Y	15.9

Samples Distributed	July 3, 2012
Reporting Data Received	August 31, 2012

For the Director

Michael P. Unterweger, Group Leader
Radioactivity Group
Physical Measurement Laboratory
(continued)

Figure D.11 Participation in 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	NRIP12-AF
Matrix Description	^{54}Mn, ^{60}Co, ^{90}Sr, ^{134}Cs, ^{234}U, ^{235}U, ^{238}U, ^{238}Pu, ^{240}Pu, and ^{241}Am on Glass-Fiber or Paper Filters[1]
Test Activity Range	0.02 Bq•sample^{-1} to 250 Bq•sample^{-1}
Reference Time	12:00 EST, April 1, 2012

+/- 10%

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)
^{54}Mn	34.8	1.49	36.6	5.7	5.1
^{60}Co	336	0.54	331	1.3	-1.5
^{134}Cs	183	1.72	177	2.0	-3.2
^{234}U	5.40	1.00	5.37	9.1	-0.5
^{235}U	0.26	0.65	0.27	16	6.0
^{238}U	5.61	0.63	5.56	9.1	-0.8
^{238}Pu	3.11	0.71	2.93	6.3	-5.8
^{240}Pu	3.35	0.79	3.20	6.3	-4.4
^{241}Am	4.94	0.82	4.94	9.6	-0.02

Methods

	NIST[6]	Reporting Laboratory[7]
Activity Measurements	Alpha- and Beta-Spectrometry Mass Spectrometry	Alpha, Beta, and Gamma Spectrometry

Evaluation (per ANSI N42.22 and N13.30)

Nuclide	ANSI N42.22 Traceable[8]	Traceability Limit (%)
^{54}Mn	Yes	9.3
^{60}Co	Yes	2.1
^{134}Cs	Yes	3.9
^{234}U	Yes	14
^{235}U	Yes	25

Nuclide	ANSI N42.22 Traceable[8]	Traceability Limit (%)
^{238}U	Yes	14
^{238}Pu	Yes	9.0
^{240}Pu	Yes	9.1
^{241}Am	Yes	14

Samples Distributed	23 April 2012
Reporting Data Received	05 July 2012

For the Director

Michael P. Unterweger, Group Leader
Radioactivity Group
Physical Measurement Laboratory

CEMRC MANAGEMENT ASSESSMENT
QUALITY ASSURANCE REPORT

January 1, 2012 – December 31, 2012

This report serves as a periodic review of the Quality Assurance Program at the Carlsbad Environmental Monitoring & Research Center (CEMRC). The purpose of this report is to meet the requirement of the CEMRC Quality Assurance Plan (QAP) for an annual management assessment. This report summarizes procedural development, vendor qualification, external audits, internal assessments and nonconformance/non-routine events for January 1, 2012 through December 31, 2012.

Currently, there are 68 active procedures under the CEMRC Controlled Document Program. These procedures are scheduled for review every two years. Thirty-four vendors are currently qualified.

An external audit was conducted during the past year on two CEMRC programmatic areas: Organic Chemistry and Internal Dosimetry. In May 2012, URS Washington TRU Solutions (WTS) audited the Volatile Organic Compound Monitoring Program (Organic Chemistry) and the In-Vivo Radiobioassay Program (Internal Dosimetry). The audit led to recertification of each program with no findings, six conditions corrected during the audit and seven observations. From this quality assurance perspective both programs continue to demonstrate sound performance.

In addition to the URSWTS audits cited above, internal audits or surveillances were conducted on two CEMRC programmatic areas in 2012. Eight non-routine events (NREs) and one nonconformance (NCR) were recorded for most recent assessment. All NREs have been closed with the exception of one (NRE 113011RB43), which is to be closed when the WBC detector 10 is repaired properly and returned from Canberra. The NCR has also been closed. As with the previous annual assessment, none of the incidents involved implementation of a center-wide procedure. It should also be noted that NREs and NCRs, per se, do not necessarily indicate a weakness in any particular programmatic area, but rather may reflect a more robust corrective action program, which benefits Center activities.

In conclusion, the Quality Assurance Program at CEMRC continues to be effectively implemented as demonstrated by the recertification of Center programs and the absence of any serious conditions encountered during internal audits. CEMRC continues to be challenged by limited resources and turnover in personnel, which emphasizes the need for effective planning and execution of QA duties.

APPENDIX E: RADIOCHEMICAL EQUATIONS

Detection

All radionuclides with the exception of the gamma spectroscopy targets (^{137}Cs, ^{60}Co, and ^{40}K) are considered "detected" if the radionuclide activity or concentration is greater than the minimum detectable concentration and greater than the total propagated uncertainty at the 2 sigma level. The gamma radionuclides are considered detected when the above criteria are met and the gamma spectroscopy software used to identify the peak generates an associated identification confidence of 90 percent or greater (ID Confidence >0.90).

Minimum Detectable Concentration (MDC)

The MDC is the smallest amount (activity or mass) of a radionuclide in a sample that will be detected with a 5 percent probability of non-detection while accepting a 5 percent probability of erroneously deciding that a positive quantity of a radionuclide is present in an appropriate blank sample. This method assures that any claimed MDC has at least a 95 percent chance of being detected. It is possible to achieve a very low level of detection by analyzing a large sample size and counting for a very long time. CEMRC uses the following equation for calculating the MDCs for each radionuclide in various sample matrices:

$$\mathbf{MDC} = \frac{4.65\sqrt{\sigma^2\mathbf{bkg}\dfrac{\mathbf{T_{blank}}}{\mathbf{T_{bkg}}}}}{\mathbf{KT_{bkg}}} + \frac{2.71}{\mathbf{KT_{bkg}}}$$

Where:

K = A correction factor that includes items such as unit conversions, sample volume/weight, decay correction, detector efficiency, chemical recovery and abundance correction, etc.

T_{blank} = Blank count time

T_{bkg} = Background count time. For further evaluation of the MDC, refer to ANSI N13.30, *Performance Criteria for Radiobioassay*.

Standard Deviation (SD)

The SD is an estimate of the uncertainty in the measurement due to all sources, including counting error, measurement error, chemical recovery error, detector efficiency, randomness of radioactive decay, and any other sources of uncertainty. The SD for each data point is reported at the 1σ level. SD is found by using the following equation:

$$\mathbf{SD} = \frac{\sqrt{\dfrac{\mathbf{C_s}}{\mathbf{t_s^2}} + \dfrac{\mathbf{C_{BK}}}{\mathbf{t^2_{BK}}}.\mathbf{S_{Tr}}}}{\mathbf{N_{Tr}.U}}$$

Where:

SD = Standard deviation

Cs = Total sample counts for analyte of interest

C_{BK} = Total background counts for the analyte of interest

t_s = sample count time

t_{BK} = background count time

S_{Tr} = Initial activity of the tracer added to the sample

N_{Tr} = Net count rate of the tracer

U = Conversion factor taking into account branching ration, radioactive decay during counting, etc.

Percent Bias (% Bias)

The percent bias is a measure of the accuracy of radiochemical separation methods and counting instruments; that is, a measure of how reliable the results of analyses are when compared to the actual values.

$$\%\mathbf{BIAS} = \frac{[\mathbf{A_m} - \mathbf{A_k}]}{\mathbf{A_k}} * 100\,\%$$

Where:

% BIAS = Percent Bias

A_m = Measured Sample Activity

A_k = Known Sample Activity

Table E.1. % Chemical Recovery of Tracers in FAS Samples

Radionuclide	*Minimum*	*Maximum*	*Average*	*SD*
^{243}Am	41.00	100.65	91.00	13.8
^{242}Pu	52.42	100.85	81.18	14.1
^{232}U	34.89	99.56	67.56	19.3

Table E.2. % Chemical Recovery of Tracers in Drinking Water Samples

Radionuclide	*Minimum*	*Maximum*	*Average*	*SD*
^{243}Am	89.07	96.25	92.43	3.2
^{242}Pu	84.38	89.60	86.66	2.0
^{232}U	23.05	79.24	54.66	19.4

Table E.3. % Chemical Recovery of Tracers in Ambient Aerosol Samples

Radionuclide	*Minimum*	*Maximum*	*Average*	*SD*
^{243}Am	27.79	84.32	103.04	16.4
^{242}Pu	25.53	99.55	60.78	21.9
^{232}U	35.07	95.74	69.37	13.8

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