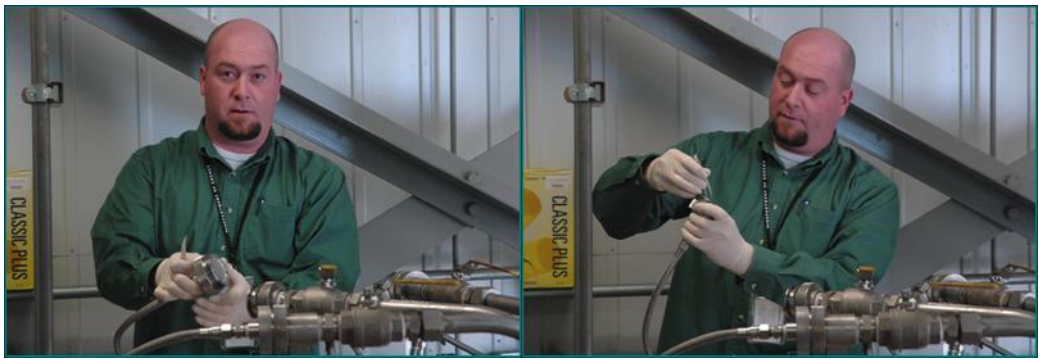
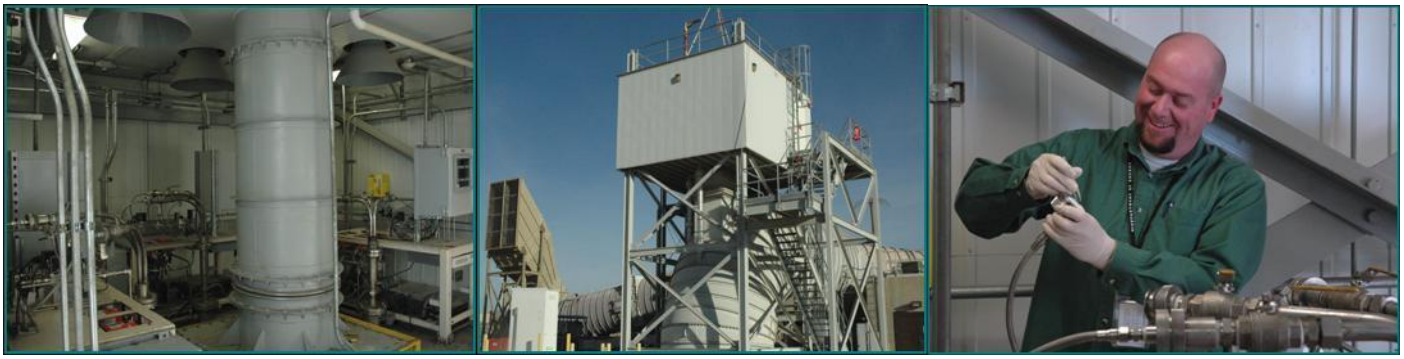
Carlsbad Environmental Monitoring & Research Center





2007

Report

2007 Report
Carlsbad Environmental Monitoring & Research Center

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College of Engineering
NM STATE
Institute for Energy
& the Environment

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Acronyms and Abbreviations

µBq	microBecquerel
µm	micrometer
AA, AAS	atomic absorption, atomic absorption spectrometry
Ag	silver
Al	aluminum
Am	americium
As	arsenic
ASTM	American Society for Testing and Materials
Ba	barium
Be	beryllium
Bq	Becquerel
C	centigrade
Ca	calcium
Cd	cadmium
Ce	cerium
CEMRC	Carlsbad Environmental Monitoring & Research Center
CEMRP	Carlsbad Environmental Monitoring & Research Program
CFR	Code of Federal Regulations
Ci	Curie
CLP	Contract Laboratory Program
cm	centimeter
Cm	curium
Co	cobalt
Cr	chromium
CRDL	Contract Required Detection Limit
CRM	certified reference materials
Cs	cesium
Cu	copper
DL	detection limit
DOE	U.S. Department of Energy
Dy	dysprosium
EM	Environmental Monitoring
EML	Environmental Monitoring Laboratory
EPA	U.S. Environmental Protection Agency
Er	erbium
ERA	Environmental Research Associates
Eu	europium
F	fluoride
FAS	fixed air samplers
Fe	iron
FY	fiscal year
g	gram
Gd	gadolinium
Ge	germanium
GPS	global positioning satellite
HCl	hydrochloric acid
$HClO_4$	perchloric acid

HF	hydrofluoric acid
Hg	mercury
HNO_3	nitric acid
H_2O_2	hydrogen peroxide
hr	hour
IC	ion chromatography
ICP-MS	inductively coupled plasma-mass spectrometry
K	potassium
km	kilometer
L	liter
La	lanthanum
LaF_3	lanthanum fluoride
lb	pound
LDBC	"Lie Down and Be Counted"
LFB	Laboratory Fortified Blank
LFM	Laboratory Fortified Matrix
Li	lithium
LRB	Laboratory Reagent Blanks
m	meter
mb	millibar
MBL	mobile bioassay laboratory
mBq	milliBecquerel
MDC	minimum detectable concentration
Mg	magnesium
min	minute
MJ	megajoule
mL	milliliter
mm	millimeter
Mn	manganese
Mo	molybdenum
Na	sodium
NaOH	sodium hydroxide
Nd	neodymium
Ni	nickel
NIST	National Institute of Standards and Technology
nm	nanometer
NMSU	New Mexico State University
Np	neptunium
ORNL	Oak Ridge National Laboratory
p	probability
Pa	protactinium
Pb	lead
pH	scale indicating acidity or alkalinity of a substance
PM_{10}	particulate matter smaller than 10 micrometers in aerodynamic diameter
$PM_{2.5}$	particulate matter smaller than 2.5 micrometers in aerodynamic diameter
Pr	praseodymium
PRB	Program Review Board
Pu	plutonium
QA	quality assurance
QAP	quality assurance program
QC	quality control
RIP	Radiochemistry Intercomparison Program

Ru	ruthenium
SAB	Science Advisory Board
Sb	antimony
Sc	scandium
SD	standard deviation
Se	selenium
SE	standard error
sec	second
Sm	samarium
Sn	tin
Sr	strontium
$T_{1/2}$	half-life
Th	thorium
Ti	titanium
TIMS	thermal ionization mass spectrometry
Tl	thallium
TSP	total suspended particulates
U	uranium
UVB	Ultra-Violet B
V	vanadium
W	watt
WERC	Waste-management Education & Research Consortium
WID	Waste Isolation Division
WIPP	Waste Isolation Pilot Plant
WTS	Westinghouse TRU Solutions

New VOC GC-MS Laboratory

Light Hall – Home of CEMRC

Plutonium-Glove Box in New Radiochemistry Laboratory

Inductively Coupled Plasma-Mass Spectrometer

Oxford/Canberra Oasis Alpha Spectrometer

GC-MS for Head Space Gas

Hivol air samplers near WIPP

FORWARD

This report was written, edited and produced collaboratively by the staff of the Carlsbad Environmental Monitoring & Research Center (CEMRC), who are hereby acknowledged for their contributions to the report and the project activities described herein. The first section is an overview of the current program activities, structure, resources and quality assurance. The second section consists of data summaries as specific chapters containing methods and descriptions of results of studies in the WIPP Environmental Monitoring project and other activities at CEMRC during 2007.

Production of this report is supported as part of the Carlsbad Environmental Monitoring and Research Center, a grant from the U.S. Department of Energy to New Mexico State University (DE-FG04-91-AL74167). The issuance of this report and other publications fulfills a CEMRC mission in making the results of CEMRC research available for public access.

This year's cover photograph is of the rear entrance to the CEMRC facility. The Forward shows various equipment and laboratories used by scientists at CEMRC.

OVERVIEW

Current Program Status

HISTORY

The Carlsbad Environmental Monitoring and Research Center (CEMRC) was established in 1991 with a grant from the U.S. Department of Energy (DOE). The primary goals of the CEMRC are to:

- Establish a permanent center of excellence to anticipate and respond to emerging health and environmental needs, and
- Develop and implement an independent health and environmental monitoring program in the vicinity of the DOE Waste Isolation Pilot Plant (WIPP), and make the results easily accessible to all interested parties.

CEMRC is a division of the College of Engineering at New Mexico State University (NMSU). Under the terms of the grant from DOE, the design and conduct of research for environmental monitoring at the WIPP are carried out independently of the DOE, and the production and release of resulting reports do not require DOE review or approval. A brief history of the CEMRC is presented in Appendix A.

The CEMRC is operated as a research institute within NMSU, supported through grants and service contracts. The CEMRC's primary objectives are to:

- Provide for objective, independent health and environmental monitoring;
- Conduct research on environmental phenomena, with particular emphasis on natural and anthropogenic radionuclide chemistry;
- Provide advanced training and educational opportunities;
- Develop improved measurement methods, procedures and sensors; and
- Establish a health and environmental database accessible to all sectors.

About half of CEMRC's funding comes from the monitoring mission and the other half is split among three direct contracts by providing facility and scientific support to entities such as Los Alamos National Laboratory (LANL), Washington TRU Solutions (WTS) and the LES National Enrichment Facility (NEF).

KEY ACTIVITIES

The key activities necessary to continue developing CEMRC and monitoring in the vicinity of the WIPP (WIPP Environmental Monitoring Project) are:

1. **Assemble a team of highly qualified research scientists and support staff capable of carrying out current and future projects.**

At the end of 2007, the CEMRC employed 24 personnel (Table 1). Two positions were in recruitment.

2. **Create state-of-the-art laboratory facilities capable of supporting advanced studies in areas of scientific specialization.**

In January 1996, the CEMRC was relocated to Light Hall, a new 26,000 ft^2 laboratory and office facility constructed adjacent to the NMSU-Carlsbad branch campus. In 2007, significant facility

upgrade included ventilation upgrades, installation of environmental outbuildings to provide controlled storage to free space for additional laboratory activities.

The CEMRC's scientific activities are organized into major areas of specialization, with corresponding assignment of staff roles and responsibilities. Although some of the CEMRC's projects involve only one or two of the program areas, all of the program areas collaborate in carrying out the WIPP Environmental Monitoring project. The five scientific program areas include (1) radiochemistry, (2) environmental chemistry, (3) informatics and modeling, (4) internal dosimetry, and (5) field programs. Administration, facility management and records management provide support to the programmatic areas. Detailed descriptions of each program area and associated facilities and instrumentation are on the CEMRC web site at http://www.cemrc.org.

3. Establish grants and contracts to replace the original grant.

The following is a list of grants and contracts generated during FY2007.

DOE CBFO

- $1.84 million for WIPP Environmental Monitoring

Washington TRU Solutions

- $205 thousand for Technical Support
- $393 thousand for VOC analyses
- $135 thousand for Whole Body Counting of WTS employees

Los Alamos National Laboratory

- $365 thousand for Actinide Chemistry scientific support

Sandia National Laboratory

- $175 thousand for Performance Assessment Scientific Support

Waste Control Specialists

- $52 thousand for Whole Body Counting of WCS employees

4. Establish effective liaisons with leading research groups and laboratories to facilitate shared services and collaborative research.

In response to the need for expanding the CEMRC research role, the Center has developed a partnership with LANL to conduct actinide chemistry research for WIPP recertification, and with WTS radiochemistry group to support compliance activities such as radiobioassay and WIPP permit-required environmental monitoring. A new collaboration was developed with the NEF to provide Whole Body Counting of NEF employees and for laboratory support for uranium analyses that resulted in a new contract.

5. Publish research results and create a database management system to provide access to information generated by the CEMRC.

CEMRC staff authored or co-authored many presentations at international, national and regional scientific meetings and several papers were published in peer-reviewed scientific journals and books during 2007 (Appendix B). A cumulative list of publications by CEMRC staff since 1996 can be obtained by request, as can previous CEMRC annual reports and other CEMRC information.

6. **Establish regional, national and international outreach and collaboration.**

During 2007, the CEMRC hosted various colloquia presented by visiting scientists, and participated in other outreach activities including presentations for local civic and professional groups and exhibits for various school, and community events some of which are listed in Appendix C. As described in a later section, over 800 volunteers from the local community have participated in the "Lie Down and Be Counted" program.

7. **Implement programs to offer visiting scientists training in specialized research techniques and methodologies and to involve CEMRC resources and personnel in providing educational opportunities for students nationwide.**

During 2007, undergraduate students worked in laboratory aide positions at CEMRC. These positions provided training and basic skills development relevant to the position assignments. Also, post-docs and visiting scientists worked in the CEMRC facility during 2007 (Appendix D).

Table 1: Listing of CEMRC Staff as of the end of 2007

Name	Position
Arimoto, Richard	Senior Scientist
Ballard, Sally	Environmental Scientist
Brown, Becky	Administrative Services Manager
Brown, Bill	Facilities Manager
Conca, James	Director
Ganaway, David	Environmental Scientist
Garrett, Fran	Secretary
Greene, Chris	Physicist Scientist
Hudston, Jonathan	Specialist
Hudston, Lisa	Environmental Scientist
Kirchner, Thomas	Computer & Information Systems Manager
Marple, Julia	Chemical Technician
McCauley, Sharyl	Quality Assurance Manager
Monk, James	Environmental Scientist
Najera, Angela	Secretary
Pennock, Karl	Environmental Scientist
Sage, Sondra	Physical Scientist
Schoep, David	Radiation Safety Training Specialist
Sneller, Michele	Chemical Technician
Sullivan, Tina	Network/Computer Systems Administrator
Ui Chearnaigh, Kim	Environmental Scientist
White, Corey	Environmental Scientist
White, Whitney	Environmental Scientist
York, Larry	Biological Technician

WIPP Environmental Monitoring Project

PROJECT CONCEPT

As defined in the original grant, the purpose of the WIPP EM project is to establish and maintain independent environmental research and monitoring in the vicinity of the WIPP and to make the results easily accessible to all interested parties. This project was implemented during the WIPP pre-disposal phase, and is now continuing during the operational (disposal) phase. The WIPP EM project is organized and carried out independent of direct oversight by DOE, and the project does not provide data to any regulatory body to meet the compliance demonstration requirements applicable to the WIPP. Analytical results and interpretations from the WIPP EM are published by CEMRC to inform the public and particularly the environmental science community.

A detailed description of the WIPP EM concepts, sampling design and baseline studies is presented on the CEMRC web page. The following is a summary of 2007 activities for the major environmental medium in the WIPP EM. It is important to note that nuclear waste first began being received at WIPP on March 26, 1999. Mixed waste was first received by the WIPP on September 9, 2000, and higher-activity waste (called remote handled or RH waste) was first received at the beginning of 2007. Results summarized in this report cover samples collected through December 2007.

Based on the radiological analyses of monitoring phase samples (collected since March 26, 1999) completed to date for area residents and for selected aerosols, soils, drinking water and surface water, there is no evidence of increased radiological contamination in the region of the WIPP that could be attributed to releases from the WIPP. Levels of radiological and non-radiological analytes measured in 2007 were within the range of levels measured previously by CEMRC for the targeted analytes, and are within the ranges measured by other entities at the State and local levels since before disposal phase operations began in 1999.

In 2003, CEMRC reported detection of a small quantity of Pu in a composite aerosol sample from the second calendar quarter. This discovery was corroborated by both EEG and WTS through the analyses of samples that were independently collected and analyzed. The activity was extremely low and well within historic background, but indicated the ability of the monitoring program to detect radionuclides of interest at any level

above the MDC. This year, CEMRC has again detected a small quantity of Pu in composite aerosol samples from the first and third calendar quarters of 2007 similar to the 2003 detection, and also corroborated by WTS. Such small occasional detections are to be expected and the 2003 and 2007 hits provide a baseline for future events.

In the summer of 2001, the Carlsbad Field Office (CBFO) of DOE requested CEMRC to investigate whether the Center's direction could become more closely aligned with scientific and analytical activities foreseen by the CBFO to support the safe and efficient operation of the WIPP. To further develop the CEMRC program, during 2007 the Center has been working with the CBFO management to define research and analytical tasks that will address such needs. This redirection permits CEMRC to pursue new research avenues aggressively in partnership with the DOE community.

ORGANIZATION OF THE MONITORING PROGRAM

The scheduling and management of sample analyses collected in the WIPP EM project are based on (1) priorities for providing information to the public, (2) relative risks of human exposure to contaminants among the various media sampled, (3) needs for data validation and verification prior to release, (4) time constraints resulting from sample preparation and analysis procedures, (5) personnel loss resulting from the difficulty in attracting and retaining qualified staff in Carlsbad (6) funding changes, and (7) time and resource coordination among the other programs in the facility.

During 2003/2004, the elements of the monitoring project were reviewed and evaluated as part of the strategic planning for CEMRC activities over the next few years. A redefinition of the scope of the monitoring program has been driven by three factors - (1) the diminishing resources available for the monitoring work, (2) loss of qualified personnel, and (3) the increased emphasis at CEMRC on direct research and technical support of WIPP operations. The challenge that has faced CEMRC during 2007 has been to restructure and optimize the WIPP EM in order to maintain a long-term environmental monitoring program that will contribute to the public's confidence in the safe operation of the WIPP, and identify missing elements in our understanding of the WIPP environment that are not addressed by the ongoing and proposed long-term monitoring studies.

A major reduction in the resources devoted to the WIPP EM was proposed by CEMRC through a cut back in the frequency of sampling of the various media and by reducing the number of target analytes. The justification for this reduction is based on the fact that, to date, there has been no evidence for any perturbation to drinking water, soils, surface water or sediments caused by the WIPP operations. Studies of airborne particulate matter (aerosols) will continue to be the major focus of the CEMRC's monitoring efforts because, in the event that radioactive or chemical contaminants are released from WIPP, these materials could be rapidly dispersed through the atmosphere and spread throughout the environment. In addition, monitoring of the public through the Lie Down and Be Counted program is of the

utmost importance as humans are the most important target regardless of the transmission vector for contaminants.

Past public surveys indicated that air monitoring and direct monitoring of people (whole body counting), followed by monitoring of drinking water, were the areas of greatest public interest. While it is highly unlikely that any chemical impacts of the WIPP will be detected through analyses of media other than air and people, CEMRC considers there is value in continued monitoring of soils, water and sediments, and vegetation and biota in some form and frequency. Thus, a program has been recommended, and will be revised yearly with input from various stakeholders, in which one of the media other than air and people are sampled each year on a rotating basis.

The continuation of the WIPP EM and new WIPP-related projects reflect the Center's commitment to ensuring that the public, workers, and the environment are protected from exposure to contaminants. It is likely that additional adjustments to the WIPP EM will be needed as the Center's capabilities continue to evolve and the other programs supporting the WIPP also move in new directions.

AEROSOLS

Aerosol particle sampling is conducted at four locations, with samplers operating continuously at each location. The locations include a port inside the WIPP exhaust shaft [Station A, samples form fixed air samplers (FAS)], a site approximately 0.1 km northwest (downwind) of the WIPP exhaust shaft (on site station), a site approximately 1 km northwest (downwind) of the WIPP (Near Field station), and a site approximately 19 km southeast (upwind) of the WIPP (Cactus Flats station). In November 2006, CEMRC began collecting samples at a point inside the WIPP exhaust but after the filtration system (Station B). The schedule for analysis of these samples will be decided based upon discussions with stakeholders.

Continuous sampling of aerosol particles was conducted through December 2007, and analyses has been completed through June of 2006 for radiological analytes and are reported herein. Samples from this point to the present will be analyzed as soon as possible, as well inorganic analysis for all aerosol samples from 2006 and 2007. All FAS samples from 2007 have been analyzed with respect to gross alpha, gross beta, U and Pu, and inorganics and are reported herein, while 2007 samples from the other aerosol sites along with gamma spectroscopy on the 2007 FAS samples are still being analyzed.

SOILS

During 2007, no soil samples were collected or analyzed.

SURFACE WATER AND SEDIMENTS

During 2007, no surface water and sediment samples were collected or analyzed.

DRINKING WATER

The WIPP EM studies of ground water focus on the major drinking water supplies used by communities in the WIPP region because these are often perceived by the public as a potential route for contaminants to reach humans. Five community supplies of drinking water (representing three major regional aquifers) are included in routine sampling, including Carlsbad, Loving/Malaga, Otis, Hobbs and a secondary source for Carlsbad. One private water well (representing a fourth aquifer) that is located within 16 km of the WIPP is also sampled. During 2007, drinking water samples were collected in the spring at five of the six drinking water supplies (the sixth was dry), and results of radiological and non-radiological analyses are reported herein for 2007.

HUMAN POPULATION

The *Lie Down and Be Counted* (LDBC) project serves as a component of the WIPP EM that directly addresses the general concern about personal exposure to contaminants shared by residents who live near DOE sites. As in other aspects of the WIPP EM, *in vivo* bioassay testing was used to establish a baseline profile of internally-deposited radionuclides in a sample of local residents before disposal phase operations began, and has continued into the disposal phase to the present. The sampling design includes solicitation of volunteers from all segments of the community, with sample sizes sufficient to meet or exceed a 15% range in margin of error for comparisons between major population ethnicity and gender categories as identified in the 1990 census. Radiobioassays of the original volunteer cohort have been ongoing since July 1999. New volunteers will continue to be recruited each year to establish new study cohorts and replace volunteer attrition. It has been difficult to attract new volunteers and to bring back previous volunteers for recounts. Previous fear or concern appears to have waned in the region as WIPP operations continue to proceed with no serious incidents. Results of the LDBC project through December 2007 are reported herein.

RADIOCHEMICAL AND ACTIVITY UNITS

The primary unit of activity, or radioactivity, used in this report is the becquerel (Bq) which is equal to one disintegration of a nucleus per second. This disintegration gives rise to ejection of a particle or ray of ionizing radiation, either an alpha, beta, neutron, or gamma. Sometimes the unit Curie (Ci) is used and is equal to 3.7×10^{10} Bq.

Quality Assurance

The CEMRC is subject to the policies, procedures and guidelines adopted by NMSU, as well as state and federal laws and regulations that govern the operation of the University and radiological facilities. The management of CEMRC is committed to conducting a well-defined quality assurance program, incorporating good professional practice and focusing on the quality of its testing and calibration in research and service to sponsors. CEMRC technical programmatic areas in 2007 included: Environmental Chemistry, Organic Chemistry, Radiochemistry, Field

Programs, Informatics and Modeling and Internal Dosimetry. The development and implementation of an independent health and environmental monitoring program has been CEMRC's primary activity since establishment.

PROJECT REPORTING REQUIREMENTS

Since its inception, CEMRC's WIPP Environmental Monitoring Program (WIPP-EM) has been conducted as a scientific investigation, that is, without any compliance, regulatory, or oversight responsibilities. As such, there are no specific requirements for reporting data other than good scientific practices. An example of reporting decisions made by CEMRC for this program is whether to correct or not correct data for blanks. The decision to subtract blanks from the monitoring data was made by the senior staff in the mid-1990s because the consensus opinion was that this procedure provided the best means for determining the analytes' true concentrations, i.e. bias-free estimates of the values. The practice of correcting environmental data for blanks is well established, as described by the International Union of Pure and Applied Chemistry (IUPAC) and the International Organization for Standardization (ISO). See also http://epa.gov/waterscience/methods/det/faca/mtg20051208/blank.html

QUALITY ASSURANCE PROGRAM

Beginning in early 2002, a significant effort was devoted to refining CEMRC's quality system to meet applicable requirements of the U.S. DOE Carlsbad Field Office (CBFO) Quality Assurance Program Document (QAPD, CAO-94-1012). This effort was in response to the CBFO's request for a change in CEMRC's direction to allow it to become more closely aligned with scientific and analytical activities seen by CBFO to support the safe and efficient operation of WIPP. As a result, CEMRC produced a center-wide Quality Assurance Plan (QAP) CP-QAP-004, which was subsequently submitted to and approved by DOE.

Internal audits were performed during 2007 on the following programmatic areas: Environmental Chemistry, Field Programs, Informatics and Modeling, Internal Dosimetry Organic Chemistry, Administrative Services, and Document Control. In addition, an internal surveillance was performed on the Radiochemistry program. A summary of 2007 audits is reported in Appendix E.

QUALITY ASSURANCE/ QUALITY CONTROL FOR ORGANIC CHEMISTRY

The following audits were conducted on the Organic Chemistry group:

- A VOCs Confirmatory Monitoring Audit, conducted by WTS QA as part of their

routine yearly program audits in compliance with contract require-ments, was passed in March 2007.
- A CEMRC internal audit was conducted on the OC group in October 2007 in compliance with the Center's QAP, and the group passed.

QUALITY ASSURANCE/QUALITY CONTROL FOR RADIOANALYSES

Routine quality assurance/quality control activities conducted for radioanalyses include tracking and verification of analytical instrument performance, use of American Chemical Society certified reagents, use of National Institute of Standards and Technology (NIST) traceable radionuclide solutions and verification testing of radionuclide concentrations for tracers not purchased directly from NIST or Eckert and Ziegler Analytics. When making laboratory solutions, volumes and lot numbers of stock chemicals are recorded. Prior to weighing radionuclide tracers and samples, the balance being used is checked using NIST traceable weights.

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

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

For the Oxford Oasis alpha spectrometer, efficiency, resolution and centroid control charting was performed using ^{148}Gd check sources on a regular basis. Before each sample count, pulser checks were performed to ensure acceptable detector resolution and centroid. Blanks counted for 5 days were used as a background history for calculating results.

During 2007, CEMRC participated in the the Mixed-Analyte Performance Evaluation Program (MAPEP) for air filter and water analysis. For MAPEP, the matrices selected were air filters, soils, and water and the isotopes were $^{233/234}$U, ^{238}U, ^{238}Pu, $^{239/240}$Pu, and ^{241}Am. The analyses were carried out using CEMRC's actinide and separation procedures, and were treated as a regular sample set to test regular performance. CEMRC's results were consistently close to the known value. Results for MAPEP are given in Appendix E.

QUALITY ASSURANCE/QUALITY CONTROL FOR ENVIRONMENTAL CHEMISTRY INORGANIC ANALYSES

The analytical methods employed for inorganic analyses in the environmental

chemistry program at CEMRC are based, when applicable, on various standard procedures (EPA/600/4-79-020, 1983; EPA/SW-846, 1997; American Public Health Association, 1981). For some matrix/analyte combinations, appropriate external standard procedures do not exist, and for those cases, specialized procedures have been developed to meet the needs of the WIPP EM and other research projects.

INSTRUMENTATION

Inorganic analyses were performed using Perkin-Elmer Elan 6000 and 6100 inductively-coupled plasma mass spectrometers (ICP-MS). Regular QC verifications and batch QC provide records of sample performance data. For all environmental chemistry analyses, QC samples are analyzed with each sample batch as an indicator of the reliability of the data produced. The types, frequencies of analysis, and limits for these QC samples have been established in a set of standard operating procedures. Extraction QC samples include Laboratory Reagent Blanks, or LRBs (for aerosol and FAS samples, unused cellulose ester filters were used as LRB samples), Laboratory Fortified Blanks, or LFBs (a cellulose ester CRM, "Trace Metals on Filter Media" from High Purity Standards in Charleston, South Carolina, was used for QC of aerosol sample metals analyses), duplicates and Laboratory Fortified Matrix (LFM) samples. In cases where duplicate aliquots from the original sample were not feasible (such as aerosol filters), separate aliquots of the sample extract were analyzed for the duplicate and LFM analyses. The digestion QC parameters used for the evaluation of constituents in water, soils, and sediments were based on concepts in EPA Contract Laboratory Program (EPA 540/R-94013, 1994); and SW-846 methods (EPA/SW-846, 1997). No comparable control parameters presently exist for aerosol samples. All constituents values were reported relative to the method detection limit as determined by the method outlined in 40 CFR 136, Appendix B.

For each ICP-MS analysis, the QC requirements are as follows: 1) A spiked blank (LFB, or laboratory fortified blank) is prepared identically to a sample for every batch (ten samples) and its percent recovery must be within 15% of the fortified value. 2) A batch blank (LRB, or laboratory reagent blank) is prepared and analyzed for every ten samples, and its value must be lower than the method detection limit (MDL). If the value is higher than the MDL, the entire batch is reanalyzed up to 3 times. If the value consistently exceeds the MDL, blank subtraction may be performed on the samples in that batch, or the data for the analyte(s) in question are flagged or not reported, at the discretion of the lead scientist. 3) One duplicate sample for every ten samples is either collected in the field or two aliquots from a single field sample are prepared and analyzed identically. The percent difference between duplicates must be within 20%. 4) One laboratory fortified sample matrix (LFSM) is prepared for each batch of 10 samples by spiking a sample with a known amount of standard. The percent recovery for the spike must fall within 15% of the expected value. 5) After calibration, an initial calibration verification (ICV) standard from a different lot number and/or manufacturer of the calibration standards is analyzed, and the value must fall within 10% of the expected value. If one or more analytes falls outside of the expected range, recalibration is performed or the analyte(s) in question are either flagged as having a greater uncertainty or are not reported. 6) A mid-range

calibration standard is reanalyzed every ten samples and the percent recovery must be within 15% of the true value. 7) The calibration blank is reanalyzed immediately after calibration and then every ten samples thereafter (including batch blanks and batch spiked blanks) and must be less than 3 times the instrument detection limit. 8) The relative percent difference between the 3 replicate sweeps of the instrument for each analyte must be less than 20%. 9) The correlation coefficient for the linear regression of the calibration curve must be greater than 0.995. 10) All samples and standards are spiked with an internal standard (usually indium), and the percent recovery of the internal standard must lie between 60% and 125% of the value measured in the calibration blank.

Independent quality assurance samples are obtained and analyzed to verify the performance of the instrumentation and the proficiency of the analyst. Reference samples (obtained from an outside source or prepared internally, with true values known at the time of analysis) are the primary method used to perform this function at CEMRC. Occasionally, blind samples (obtained from an outside source, with true values not known at the time of analysis) are used. However, since blind samples are usually diluted many times, the instrument is not optimized for any one or group of elements, and the instrument measures such a large number of analytes at one time at near their MDCs, several analytes often exceed the acceptable range by several percent, in particular aluminum, beryllium, cobalt, iron, chlorine and fluorine. This increases the overall uncertainty of the analyses. Examples of results from a reference sample and a blind sample (from the Environmental Resource Associates [ERA] WatR^{TM} Supply Proficiency Testing Study) for 2008 (the time period in which the 2007 samples were analyzed) are given in Appendix E. Table E-6 gives an example of the daily performance tests for ICP-MS.

QUALITY ASSURANCE/QUALITY CONTROL FOR FIELD SAMPLING

For the collection of most WIPP EM samples, no external standard procedures are considered completely appropriate for the objectives of the studies. In these cases, customized plans are developed and documented. After the activity is completed, the plan is revised to reflect any departures from the original plan, and documented to file. For most environmental media, the sampling plans combine selected standard procedures with specific adaptations to address scientific objectives of interest. For example, procedures for collection and preservation of samples for compliance with Safe Drinking Water Act requirements are applied to the collection of drinking water and surface water samples, but the locations of sample collection are selected on the basis of other criteria. Likewise, high-volume air samplers are operated to meet an EPA standard of 1.13 $m^3 min^{-1}$, but the frequency of filter replacement is based on optimal loading for radioanalysis.

Logbooks are maintained by technical staff in field operations to record locations and other specifics of sample collection, and data on instrument identification, performance, calibration and maintenance. Data generated from field sampling equipment are error-checked by using routine cross checks, control charts and graphical summaries. Most data collected in written form are also entered in electronic files, and electronic copies are

crosschecked against the original data forms. All electronic files are backed up daily.

Calibration and maintenance of equipment and analytical instruments are carried out on predetermined schedules coinciding with manufacturer's specifications or modified to special project needs. Calibrations are either carried out by equipment vendors or by CEMRC personnel using certified calibration standards.

QUALITY ASSURANCE/QUALITY CONTROL FOR INTERNAL DOSIMETRY

The *in vivo* bioassay program at CEMRC participates in the Department of Energy's *In Vivo* Laboratory Accreditation Program (DOELAP) via WIPP, and is currently accredited as a service laboratory to perform the following direct bioassays:

- Transuranrium elements via L x-ray in lungs
- 241Am in lungs
- 234Th in lungs
- 235U in lungs
- Fission and activation products in lungs including 54Mn, 58Co, 60Co and 144Ce
- Fission and activation products in total body including 134Cs and 137Cs

Under DOELAP, the *in vivo* bioassay program is subject to the performance and quality assurance requirements specified in *Department of Energy Laboratory Accreditation Program for Radiobioassay* (DOE-STD-1112-98) and *Performance Criteria for Radiobioassay* (ANSI-N13.30). A DOELAP testing cycle was completed in 2005-2006 that included counting phantoms representative of each of the categories listed above. The next testing cycle is 2009/2010.

To evaluate system performance, quality control data were routinely collected throughout the year in order to verify that the lung and whole body counting system was operating as it was at the time the system was calibrated. Quality control parameters that track both overall system performance and individual detector performance were measured. Quality control parameters tracked to evaluate individual detector performance, included:

- Net peak area, peak centroid and peak resolution (FWHM) across the energy range of the spectrum,
- Detector background

Quality control parameters tracked to assess overall system performance included:

- Mean weighted activity of a standard source
- Summed detector background

In addition, calibration verification counts were routinely performed using NIST-traceable standards and phantoms.

The Internal Dosimetry program also participated in an intercomparison study program for whole body counting administered by Oak Ridge National Laboratory (ORNL). Under this program bottle phantoms containing unknown amounts of ^{137}Cs, ^{60}Co, ^{57}Co, ^{88}Y and ^{133}Ba were sent to CEMRC quarterly. The phantoms were counted on the lung and whole body counting system and the measured activities were reported back to ORNL and compared against the known activities. Appendix E shows an example of results for one quarter. For all years since CEMRC has participated in the

ORNL program, CEMRC has consistently out performed all other laboratories in this area.

CHAPTER 1

Ambient Aerosol Studies for the WIPP-EM

INTRODUCTION

The CEMRC ambient aerosol monitoring studies focus on both man-made and naturally-occurring radionuclides, but special emphasis is given to the members of the actinide series that are major components of the wastes emplaced at the WIPP. The main objective for the aerosol studies presented, 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. The aerosol program also has included investigations of several non-radioactive, inorganic chemical species because the data for those substances have been found to be useful for interpreting the results of the actinide studies. Summaries of the WIPP-EM aerosol studies have been included in prior Annual Reports from the Center starting in 1997, and papers specifically based on the WIPP-EM aerosol research have been published in peer-reviewed journals (Arimoto et al. 2002, 2005, and 2006).

One element of particular interest for the WIPP-EM is plutonium (Pu, element 94), which has been dispersed throughout the global environment mainly by nuclear weapons tests. When quantified by alpha spectrometry ^{239}Pu typically is determined together with ^{240}Pu, because isotopes are difficult to separate chemically, and they are represented as ^{239,240}Pu (^{239}Pu half-life, $t_{1/2}$ = 24,110 yr and ^{240}Pu $t_{1/2}$ = 6563 yr). ^{239}Pu and ^{240}Pu also have similar alpha particle energies, about 5.25 MeV. Another actinide of interest is ^{241}Am ($t_{1/2}$ = 432 yr), which is not directly produced in significant quantities during the detonation of thermonuclear weapons but rather is a daughter of bomb-produced ^{241}Pu ($t_{1/2}$ = 14.3 yr).

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 ^{241}Am and Al. Related studies of soils collected on and near the WIPP site have shown that correlations exist among Al and both naturally-occurring and bomb-derived radionuclides including ^{239,240}Pu (Kirchner et al. 2002).

Here we briefly review the methods used for the ambient aerosol studies and then summarize some recent results, highlighting the continuing efforts to evaluate potential releases from the WIPP. 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 the following chapter.

METHODS

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 prior CEMRC reports starting in 1998. Samples for the aerosol/radionuclide studies have been collected using high-volume samplers ("hivols," flow rate ~1.13 m^3 min^{-1}) since the WIPP-EM program began in 1996. Three long-term aerosol sampling stations have been established; these are On Site, Near Field and Cactus Flats, and each supports a hivol sampler for collecting total suspended particulate (TSP) matter. The Near Field and Cactus Flats stations also supported a second hivol sampler for a time, and those were used for studies of PM_{10}, particulate matter less than 10 μm aerodynamic equivalent diameter. A fourth set of samples was collected at Hobbs over a period of approximately a year and a half, but the sampling there was discontinued in April 2002.

Until the end of March 2002, both low-volume samplers ("lovols," 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. The WIPP-EM underwent major restructuring in FY 2002, and afterwards sampling for the non-radiological aerosol analytes was done using dichots exclusively. In November 2004, the collection of aerosols by dichots was discontinued.

In brief, the sampling strategy for the aerosol/radionuclide studies has been to collect as much particulate material as reasonably practical so as to maximize the chances of detecting the radionuclides of interest. Individual samples typically have been collected over periods of 3 to 5 weeks depending on the rate at which the sample filters become loaded. For these studies, high-volume samples were collected on 20 x 25 cm Gelman A/E™ glass fiber filters. Gravimetric measurements of the glass fiber filters were made to determine the mass of aerosol material that accumulated over the sampling interval.

The high-volume samples were analyzed for selected radionuclides, including ^{238}Pu, $^{239,240}Pu$ and ^{241}Am following 4 hr of heating in a muffle furnace at 500° C, which drives off organics; dissolution of the material on the filters using strong acids (HF, HCl and $HClO_4$,); and multiple precipitation, co-precipitation, and ion-exchange and/or extraction chromatography steps. The nuclides of interest were precipitated with LaF_3, deposited onto filters, mounted on planchettes, and counted using an Oxford Oasis alpha spectroscopy system.

The radionuclide data are reported in the following two ways. First, the *activity concentration* is calculated as the nuclide's activity per unit volume of air sampled (Bq m^{-3}). Second, *activity density* is calculated as the nuclide's activity per unit aerosol mass collected (Bq g^{-1}).

RESULTS AND DISCUSSION

Summary Statistics

Summary data reported for high volume aerosol samples (hi-vols) are presented in Table 1-1. ^{238}Pu was infrequently detected, with activity concentrations slightly above minimum detectable levels in only fifteen of the 227 samples. $^{239,240}Pu$ was above detection limits in 223 of the 227 samples. As in prior years, the $^{239,240}Pu$ activity concentrations showed a strong annual

cycle with activities greatest in the spring (Figure 1.1).

During most years studied, the peak ^{239,240}Pu activities generally occur in the March to June timeframe, which is when strong and gusty winds in the area frequently give rise to blowing dust. Some samples taken at Cactus Flats in 1999 and 2000, and at On Site in 2004, exhibited slightly higher ^{239,240}Pu activity concentrations (Figure 1.1) than surrounding data points. The points correspond with higher activity densities as well (Figure 1.2). However, insufficient auxiliary data is available for attributing a cause to this result.

Methods for determining the activity of ^{241}Am were developed by the CEMRC radiochemistry group over a period of years, and the available ambient aerosol data for this nuclide are presented here. The activity concentrations of ^{241}Am (Figure 1.3) in the high-volume samples closely tracked those of ^{239,240}Pu as shown in Figure 1.1. Most notably, strong springtime peaks in ^{241}Am activity concentrations were evident in the samples from 2001 through 2002, and 2004 through 2005. Data from 2003 and 2006 do not exhibit these springtime peaks. A time series plot for ^{241}Am activity density is presented in Figure 1.4.

In contrast to the actinide data, the aerosol mass loadings at On Site were generally the highest of the three stations with comparable data sets (Table 1-1). A time-series plot (Figure 1.5) shows that the aerosol mass loadings at all stations tend to track one another remarkably well, but that during several extended periods, most noticeably January 1999 to July 2000, July 2001 to January 2002, and January 2004 to January 2006 the mass loadings at On Site were consistently higher than at the other sites.

As a consequence of the similar ^{239,240}Pu activity concentrations at all stations and the higher mass loadings at On Site, the activity densities at On Site tended to be lower than at Cactus Flats or Near Field (Table 1-1 and Figure 1.2). The combination of ^{239,240}Pu and gravimetrics data thus suggest that activities at the WIPP may in fact generate detectable levels of aerosol particles, but those particles actually contain less ^{239,240}Pu than typical ambient aerosols. These are most probably particles from construction dusts or salt from the underground operations.

A summary of the latest ambient aerosol sampling program is given in Table 1-2.

SUMMARY STATEMENTS

The results presented here demonstrate that actinide concentrations have not changed significantly since the WIPP began receiving waste. Ambient aerosol samples continue to be collected on a regular basis and will be analyzed and the data reported as time permits.

Table 1-1: Summary Statistics for Aerosol Mass Loadings and Actinide Activities in High-Volume Aerosol Samples

Station		Cactus Flats	Near Field	On Site
Type of Sample		TSP	TSP	TSP
Number of Samples		76	75	76
Aerosol Mass, micrograms per cubic meter	[a]N	75	73	73
	Mean	28.4	25.6	34.8
	StdDev	14.2	10.3	14.9
^{241}Am Activity Concentration, Bq m^{-3}	N	38	35	41
	Mean	5.0E-09	4.0E-09	4.0E-09
	StdDev	3.2E-09	2.0E-09	2.2E-09
^{241}Am Activity Density, Bq g^{-1}	N	37	34	41
	Mean	1.8E-04	1.5E-04	1.3E-04
	StdDev	5.7 E-05	6.2E-05	5.7E-05
^{238}Pu Activity Concentration, Bq m^{-3}	N	6	2	7
	Mean	8.2E-09	1.2E-09	2.8E-09
	StdDev	1.4E-09	4.6E-10	1.7E-09
^{238}Pu Activity Density, Bq g^{-1}	N	6	2	7
	Mean	3.5E-04	3.8E-05	7.1E-05
	StdDev	6.7E-04	5.1E-06	3.8E-05
^{239,240}Pu Activity Concentration, Bq m^{-3}	N	76	72	74
	Mean	1.6E-08	1.2E-08	1.3E-08
	StdDev	1.2E-08	7.5E-09	7.9E-09
^{239,240}Pu Activity	N	75	72	75

Density,	Mean	5.3E-04	4.5E-04	3.6E-04
Bq g^{-1}	StdDev	2.0E-04	1.4E-04	2.1E-04

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

Table 1-2: Aerosol Sampling Status for WIPP EM (January 2007)

Site	[a]Sampler	Analyses	Frequency	Comments
Station A (Exhaust Shaft)	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 41 Filter	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.

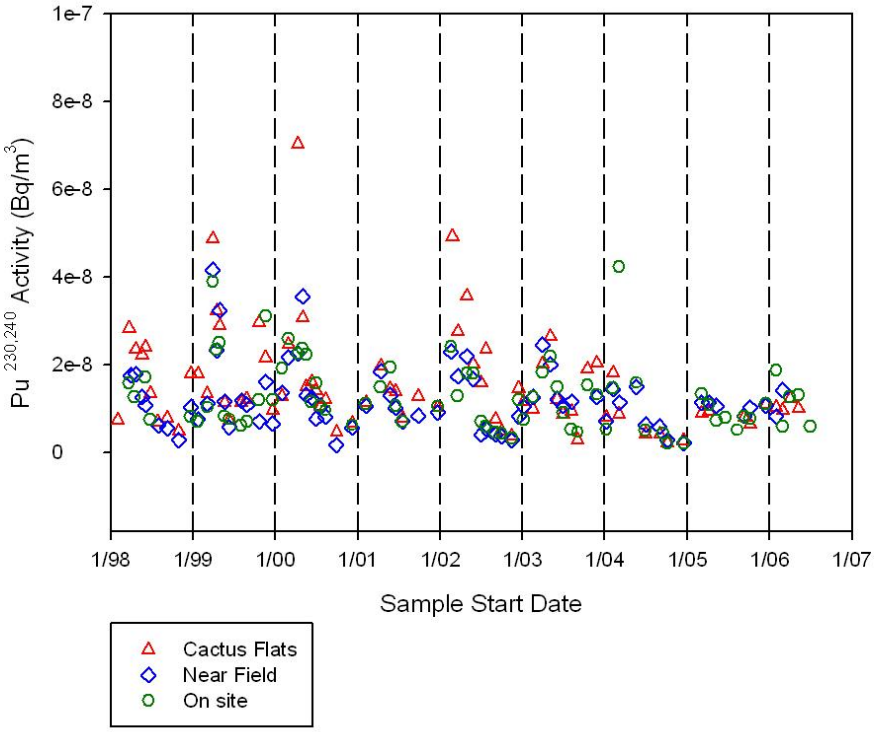

Figure 1.1: High Volume Ambient Aerosol ^{239,240}Pu Activity Concentration

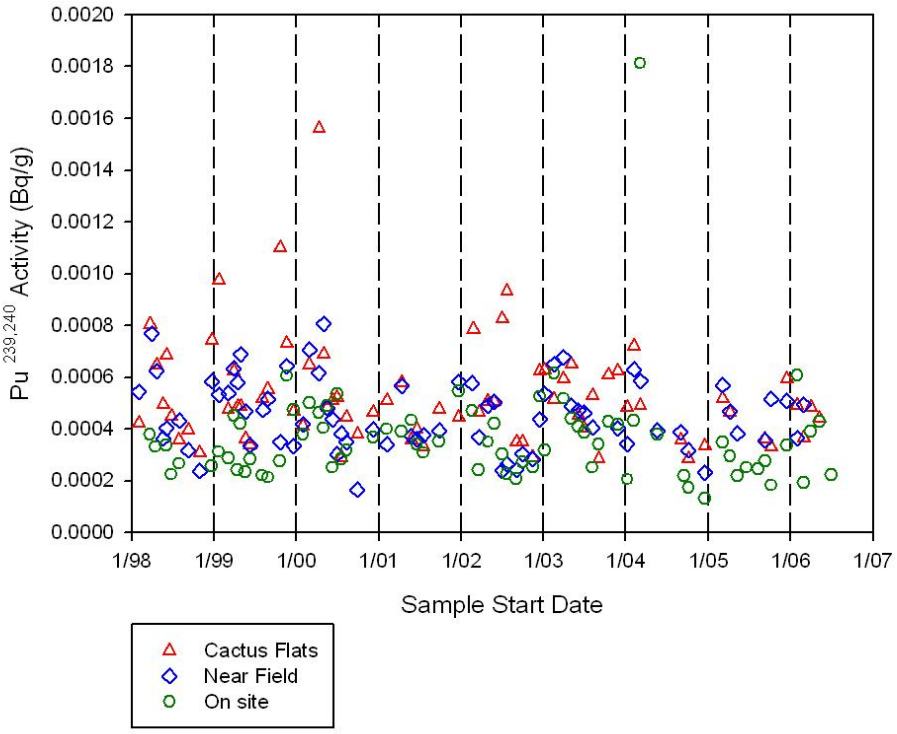

Figure 1.2: High Volume Ambient Aerosol ^{239,240}Pu Activity Density

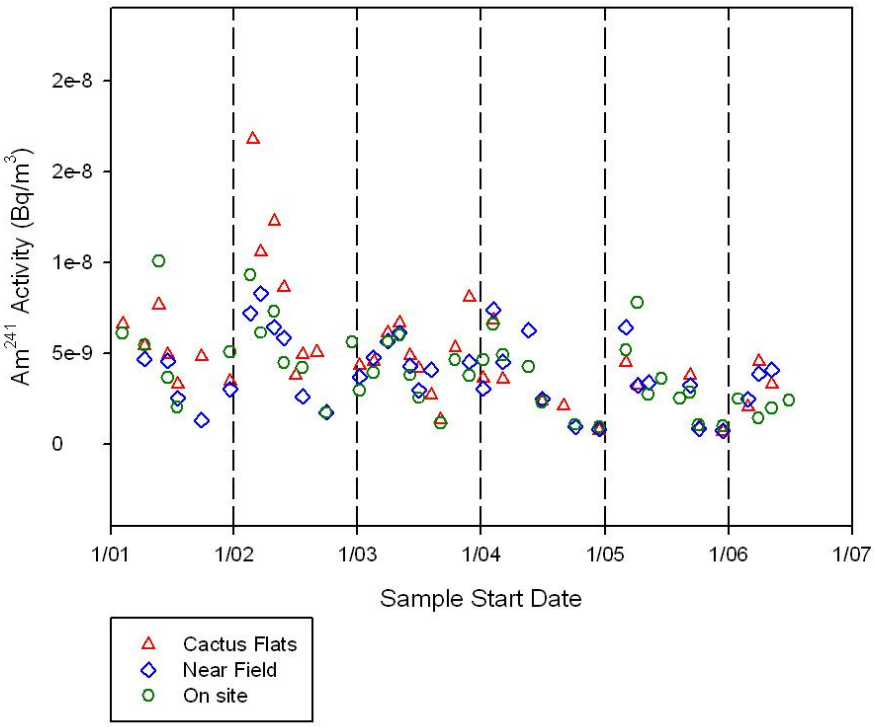

Figure 1.3: High Volume Ambient Aerosol ^{241}Am Activity Concentration

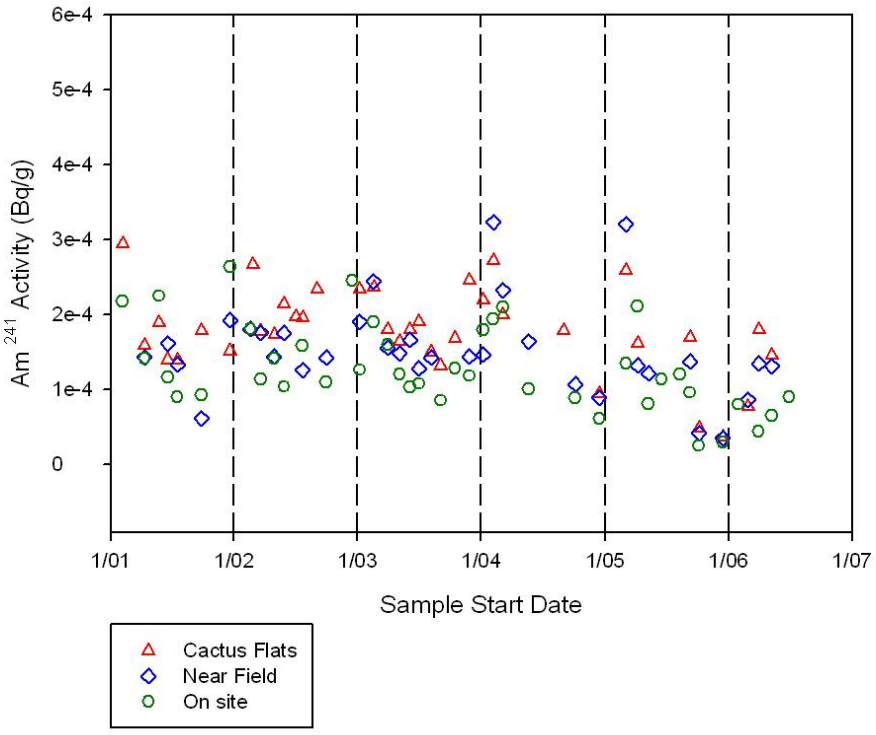

Figure 1.4: High Volume Ambient Aerosol ^{241}Am Activity Density

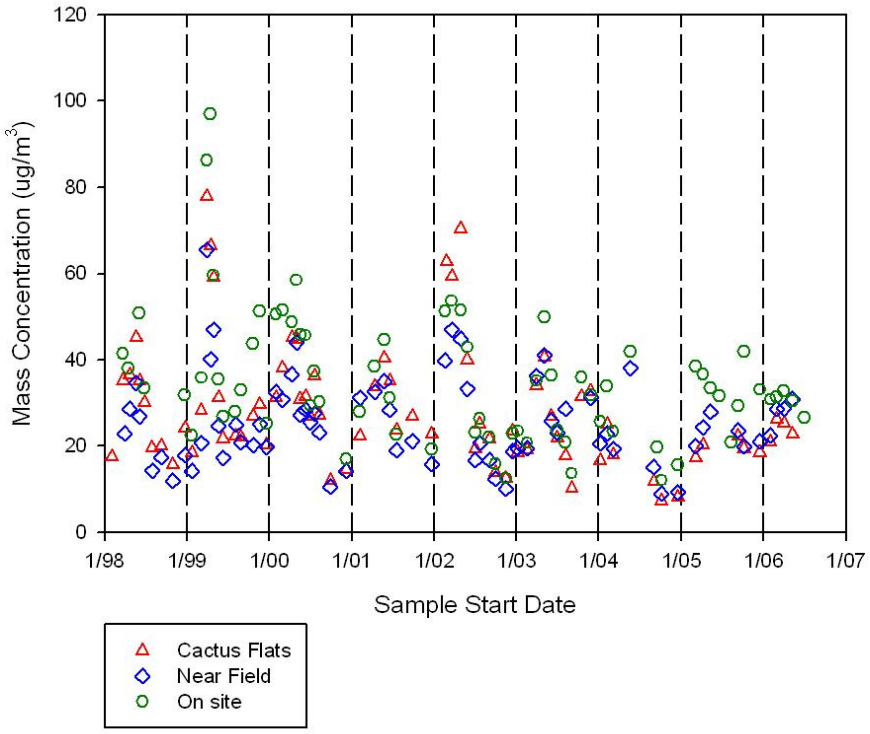

Figure 1.5: High Volume Ambient Aerosol Mass Concentrations

CHAPTER 2

Radionuclides and Inorganics in WIPP Exhaust Air

INTRODUCTION

The aerosol studies at Station A are a major component of CEMRC's WIPP environmental monitoring (WIPP EM) program. Station A is an above-ground air sampling platform shared with several other groups, and sampling operations there 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, the Station A data also would be invaluable for reconstructing exposure scenarios.

From a practical standpoint, Station A is located where radioactive or hazardous materials would most likely first be detected in the event of a release. Therefore, CEMRC has developed procedures and methods to provide a "quick look" (i.e. weeks where possible) at radioactive materials in the exhaust air. This addresses a strategic need for the monitoring program because most of the other WIPP EM analyses require several months or more to complete. That is, the data from Station A provide a preliminary look at the monitoring results; and, while these results are less specific and less detailed than those from the other studies, the data can be used to trigger more detailed investigations when appropriate.

Indeed, the sensitivity of the monitoring program at Station A was dramatically demonstrated in January 2001 when the CEMRC found elevated gross beta radio-activity in the FAS sample filters. Further investigations eventually traced the source of the beta emitter(s) to the discharge of a fire extinguisher underground, but the incident was more notable because it demonstrated for the first time the ability of the monitoring system to detect a non-routine event. A second incident occurred when scientists from CEMRC reported that they had detected a small quantity of Pu in a composite aerosol sample from the second calendar quarter of 2003. This discovery was later corroborated by both EEG and WTS 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 and a briefing presented to the New Mexico Environment Department. The activity was extremely low and well within historic background, but indicated the ability of the monitoring program to detect radionuclides of interest at any level above the MDC. In 2007, CEMRC has again detected a small quantity of Pu in two composite aerosol samples from the first and third calendar quarters of 2007 similar to the 2003 detection, and also corroborated by WTS. Such small occasional detections are to be expected and the 2003 and 2007 hits provide a baseline for future events.

METHODS

CEMRC commenced sampling of the WIPP exhaust air at Station A on 12 December 1998. Detailed descriptions of the sampling and analytical methods have

been included in prior CEMRC Annual Reports. In brief, the 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. The airflow through the FAS is approximately 170 liters per minute.

There are actually three shrouded-probe aerosol samplers at Station A; these are located on three separate sampling skids denoted A1, A2 and A3 (Figure 2.1). The airstream sampled by each skid is split among three legs such that three concurrent samples can be collected from each skid. On 15 January 2000, the CEMRC sampling operations were moved from the original sampling point at Skid A2 (west), leg 1 to Skid A1 (east skid), leg 2 to facilitate more direct data comparisons among the three organizations sampling the effluent air. Since that time all groups, CEMRC plus Washington TRU Solutions (WTS) and the Environmental Evaluation Group (EEG) and later the New Mexico Environment Department (NMED) replacing EEG, have sampled from the same skid. In April 2001, primary sampling operations were transferred from Skid A1 to A3 (south skid) to reduce problems associated with water infiltration into the exhaust shaft.

A summary flow diagram illustrating the handling and analysis of the aerosol sample filters is presented in Figure 2.2.

The FAS sample filters are normally changed daily except on holidays when a filter will run for multiple days. The aerosol sampling operations at Station A have at times been hampered by filter clogging, and during one interval (24 January 2000 to 28 November 2001) CEMRC and the other organizations changed filters twice daily Monday through Friday. Daily sampling resumed when the mass concentrations decreased and flow rates improved. However, occasionally more than one sample per day is still collected, that is, if the flow rate on any of the sampler legs drops below 1.8 cfm, a low-flow alarm on the sampler is activated and the filters are changed.

After the 2003 Pu hit, CEMRC implemented an additional FAS filter, called the Trip Blank, which is a blank filter that accompanies the sample filter through all of the process, including transport to and from the WIPP site and is placed on the collector for approximately 15 seconds, then removed. Unlike the laboratory and reagent blanks, the Trip Blank can reflect sampling errors or field contamination that is independent of laboratory procedures and reagents.

All the analyses of the FAS filters are performed according to methods detailed in CEMRC document-controlled, standard operating procedures. After the samples are returned to the laboratory, the individual filters are first weighed to

determine mass loadings, and after allowing for the decay of short-lived radon daughters, they are counted for gross alpha/beta activities for 1200 minutes using a low-background gas proportional counter (LB4100, Canberra and more recently starting in April 2006, a Protean MPC9604). During a study to investigate fouling of the sample probes, the count times were reduced to 480 minutes to accommodate additional samples from the experimental unit used in some studies of probe-fouling. In preparation for that study, data from the back-up FAS sampler were collected to determine whether gravimetric and gross alpha/beta data were comparable to the data obtained with the sampler of record, which they were (see 2005/2006 Annual Report).

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 (mBq m^{-3}). Second, *activity density* is calculated as the activity per unit aerosol mass collected (Bq g^{-1}). The minimum detectable activity concentrations and densities for the gross alpha emitters were ≈ 0.1 mBq m^{-3} and ≈ 0.7 Bq g^{-1}, respectively, while for gross beta emitters the corresponding values were ≈ 0.2 mBq $m^{-3}$and ≈ 1.7 Bq g^{-1}

Elemental and gamma-ray analyses are conducted on weekly composites of the filters. Quarterly composites were initially used for the determination of actinide activities, but monthly compositing was implemented in July of 2004 for better comparison with other groups who monthly composite. Individual FAS filters are digested using a mixture of strong acids in a microwave digestion unit, and weekly composites were prepared from the digestates of the individual filters. Weekly composites are then analyzed for a suite of trace elements with the use of a Perkin-Elmer Elan inductively coupled plasma-mass spectrometry (ICP-MS). The ICP-MS methods can provide data for up to ~35 elements, but in practice the concentrations of some elements, including As, Be, Cd, Er, Eu, Sc, Se, Sm, Tl and V are often below detectable or quantifiable levels, and a second set of elements (notably Ag, Li and Sn) has variable concentrations in blank filters which makes their quantification difficult. Analyses of gamma emitters are performed on the same weekly composites as used for the elemental studies; the gamma analyses are done using a low-background, high-purity Ge well detector and a count time of 24 hours. No gamma analyses have been performed yet on composite samples from 2007. These analyses will be performed as soon as a trained operator is available to run the gamma counting system.

Finally, quarterly, or more recently, monthly composites are prepared from the weekly composites, and these are used for the determination of actinide activities. Only one half of the composite sample is normally used for the determination of the actinide activities. The remaining aliquot is archived. The composite sample is evaporated to dryness, and the residue is digested in perchloric acid to destroy the black residue, which consists mostly of diesel exhaust particulates. This process ensures that fluorine is completely removed and all traces of organic filter residue have been oxidized. The actinides are then separated as a group by co-precipitation on $Fe(OH)_3$. After dissolution, Pu, U, and Am are separated by anion exchange and extraction chromatography, and the sample planchettes are finally prepared for alpha spectrometry using rare-earth micro-coprecipitation. Count times for alpha spectrometry are unusually long, 5 days, in

order to lower the detection limits.

RESULTS AND DISCUSSION

The essence of the strategic design for the WIPP EM, including the studies at Station A, has been to compare pre- vs. post-disposal data. The first radioactive waste shipments were received at the WIPP on March 26, 1999, and this is considered the cut-off date separating the pre-disposal phase from the post-disposal or operational phase. The WIPP first received mixed waste on September 9, 2000, and therefore data for samples collected prior to that date compose a pre-mixed waste baseline for the elemental data while those collected afterwards are considered operational. In Figures 2.3 through 2.8 discussed below, data points are distinguished by color, with red being pre-disposal, blue being operational.

GROSS ALPHA AND BETA ACTIVITIES AND AEROSOL MASS LOADINGS

The gross alpha and beta activities in the samples collected prior to the receipt of the first waste shipment represent the pre-disposal background, and the bulk of the activity in those samples was due to naturally occurring radioactive materials, specifically radon daughters. As shown in Table 2-1, the pre-operational gross alpha activity densities and concentrations were both high compared with the annual mean values for the next five years. Gross alpha activities exhibit clear seasonal variability with peaks occurring in winter (Figure 2.3), and the pre-disposal samples were collected at that time of year. An especially pronounced annual cycle in alpha activity concentrations, with high values in December and January and low values mid-year is seen in 2004 to 2005. After 2005, activities appear to have gone back up to pre-operational levels.

Similar seasonal trends in gross beta data can be seen in Figure 2.4. One entry that stands out in Table 2-2 is the maximum beta activity concentration of 58.4mBq m^{-3} observed in 2001. This sample and another collected around the same time (Figure 2.4) are the ones that were contaminated by material released from an underground fire extinguisher.

While the activities of the 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 2003 began to increase again to pre-disposal levels. 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 former, that is the activity densities, could either be due to changes in the amount of radioactivity in the sample or the aerosol mass in the samples (the volumes of air sampled, which are not shown, have changed little during the course of the program and so there should be little or no effect on the activity concentrations). A time-series plot of the aerosol mass loadings (Figure 2.5) shows a trend towards lower sample masses beginning in 2004 and also less scatter in the gravimetric data. The latter point is also evident in Table 2-3, which shows that the relative standard error, i.e. the standard error divided by the arithmetic mean and expressed as a percentage, was $\leq$ 8.1% in the last five years of the study compared with 10% to 20% in the three of the first four years of the program. This decrease in aerosol mass loadings would directly contribute to the high alpha and beta activity densities observed in the most recent years of the WIPP-EM.

ACTINIDE DATA

Results of actinide analyses performed on monthly aerosol composite samples are presented in Table 2-4. In the months between January 2006 and December 2007, ^{235}U was detected in two samples. $^{239,240}Pu$ was detected in six samples. ^{238}Pu was detected in one sample.

The U detections are similar to those for the pre-operational baseline. The Pu hits were similar to the 2003 hit and are very close to the detection limits. However, after the September 2007 sample, the Trip Blanks from October, November and December showed Pu activities, suggesting contamination of some sort, whether from collection activities, equipment or another source. To check this, CEMRC analyzed samples collected and processed by WTS for all of 2007 but using CEMRC procedures and equipment for alpha spectrometry, counting 5 days. These samples came from the same sample skid, sampled air from the same overall flow for the same time period, and were collected during the same time as the primary CEMRC samples. The results are shown in Table 2-5. Activity concentrations in Bq/m^3 were determined from activity concentrations in Bq/sample using average flow volumes from the CEMRC legs at Station A. These were 2,533.8 m^3 and 2,402.9 m^3 for August and September, respectively.

The WTS samples from October, November, and December do not show Pu activities above detection. These are the same months in which the CEMRC samples had Trip Blanks that showed Pu activity. The WTS August and September samples do show Pu activities very close to the CEMRC results in Table 2-4. The WTS March sample did not show activity above detection. Therefore, we conclude that there was a small amount of activity similar to 2003 in the August and September composite samples. The activities are so low that no speculation can be made as to their source. CEMRC intends to measure the back-up samples for this period as soon as is possible.

The Pu data for each year is summarized in Figure 2.8, which shows the results in relation to the MDC and the activity level which triggers the continuous air alarms (CAMs) which are distributed throughout the WIPP underground. As can be seen, almost all Pu values are below the MDC except for those in 2003 and 2007. Also shown (in red) are the Pu values from the re-measured WTS samples in 2007. Notice all measurements are about 7 orders of magnitude below the CAM alarm levels.

While it is important to be alert to future trends in the FAS data, it is even more important to emphasize that the amount of Pu involved is extremely small.

ELEMENTAL DATA

Prior studies at Station A have shown that the concentrations of hazardous metals and

various trace elements can be highly variable over time; this was true even in the samples collected prior to receipt of the mixed waste in September 2000. Time-series plots of selected trace element data are presented in Figures 2.6 and 2.7. There is some data missing from the elemental data plots because of a sample holding time issue. This occurred from September through December 2004.

No marked differences are evident in the baseline vs. operational samples. Aluminum is of interest because of relationships observed between the Al concentrations in ambient aerosols and the activities of ^{239,240}Pu and ^{241}Am (Arimoto et al. 2002, 2005 and 2006). Windblown dust is the main source for Al and many other elements (Fe, Mn, Sc, and the rare earth elements) and also represents a source for U, some other naturally occurring radionuclides, and fallout radionuclides such as Pu and Am. Kirchner et al. (2002) have also shown relationships between Al and various radionuclides, both artificial and naturally occurring, in soils. Studies are currently underway to investigate the nature of the relationship between Pu and iron oxides in mineral matter (Tatro et al. 2006), and to elucidate the nature of dust migration into and out of the WIPP.

Several potentially toxic elements (i.e., Pb, Cd, U, Th) that are components of the WIPP mixed waste were already present in measurable amounts in the WIPP aerosol effluent prior to the receipt of mixed waste. The concentrations of these elements, too, change with season and over the course of the monitoring program. Most important, there is no evidence for a long-term increase in the concentrations of any of these elements that can be linked to the WIPP operations in any way.

Table 2-1: Summary Statistics for Gross Alpha Analyses of Daily FAS Filters

		Activity Density (Bq g^{-1})				Activity Concentration (mBq m^{-3})			
Group	**[a]N**	**% < [b]MDA**	**[c]Mean**	**[d]SE**	**[e]Max**	**% < [b]MDA**	**Mean**	**SE**	**Max**
Pre-Disposal	70	0%	3.6	0.59	36.7	0%	0.315	0.031	1.49
1999[f]	185	1%	1.9	0.33	61.4	1%	0.110	0.005	0.37
2000	465	67%	1.0	0.07	3.8	67%	0.112	0.005	0.39
2001	428	65%	1.3	0.12	9.6	65%	0.082	0.004	0.42
2002	382	33%	1.0	0.13	21.5	34%	0.081	0.002	0.26
2003	345	35%	2.1	0.61	135.4	35%	0.104	0.005	0.40
2004	370	17%	2.4	0.18	26.6	17%	0.144	0.008	1.29
2005	361	4%	5.6	1.07	327.8	4%	0.223	0.006	0.71
2006	264	3%	3.1	0.21	35.4	3%	0.166	0.007	1.43
2007	378	0%	9.1	1.3	421.2	0%	0.444	0.014	1.44

[a]N represents the number of samples

[b]Percentage of samples less than the MDC (minimum detectable activity)

[c]Arithmetic mean

[d]SE stands for standard error

[e]Max is the maximum observed value

[f]From 26 March to 31 December 1999

Table 2-2: Summary Statistics for Gross Beta Analyses of Daily FAS Filters

		Activity Density (Bq g^{-1})				Activity Concentration(mBq m^{-3})			
Group	[a]N	% < [b]MDC	[c]Mean	[d]SE	[e]Max	% < [b]MDC	Mean	SE	Max
Pre-Disposal	70	0%	14.0	1.90	120	0%	1.14	0.09	4.94
1999[f]	189	0%	20.0	2.20	350	0%	0.99	0.03	3.25
2000	461	6%	7.7	0.54	76	6%	0.98	0.02	2.73
2001	429	3%	12.0	1.00	190	3%	1.14	0.16	58.41
2002	382	2%	12.0	0.99	200	2%	0.90	0.02	1.97
2003	345	1%	20.0	6.30	2100	1%	0.79	0.02	4.77
2004	369	4%	16.0	1.50	460	4%	0.81	0.02	4.85
2005	361	1%	20.0	3.90	1300	1%	0.78	0.02	2.07
2006	324	1%	9.8	0.57	93	1%	0.61	0.02	2.10
2007	378	2%	11.3	1.89	616	2%	0.50	0.02	1.88

[a]N represents the number of samples

[b]Percentage of samples less than the MDC (minimum detectable activity)

[c]Arithmetic mean

[d]SE stands for standard error

[e]Max is the maximum observed value

[f]From 26 March to 31 December 1999

Table 2-3: Summary Statistics for Aerosol Mass Loadings (micrograms per filter) on FAS Filters

Group	[a]N	[b]Mean	[c]SE	[d]RSE
Pre-Disposal	70	125.0	12.2	9.8%
1999[e]	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%

[a]N represents the number of samples

[b]Arithmetic mean

[c]SE stands for standard error

[d]RSE is the relative standard error expressed as a percentage (the Standard Error divided by the Mean)

[e]From 26 March to 31 December 1999

Table 2-4: Results of Actinide Analysis for Monthly FAS Composite Samples

	Activity Concentration (Bq m^{-3})			Activity Density (Bq g^{-1})		
Radionuclide	[a]C	[b]SD	[c]MDC	[a]C	[b]SD	[c]MDC
Pre-Operational Baseline						
^{241}Am	<[c]MDC	[d]NA	4.0E-08	<MDC	NA	4.3E-04
^{238}Pu	<MDC	NA	3.3E-08	<MDC	NA	3.5E-04
^{239,240}Pu	<MDC	NA	2.7E-08	<MDC	NA	2.9E-04
^{234}U	9.5E-07	5.3E-08	1.3E-08	1.0E-02	5.7E-04	1.3E-04
^{235}U	4.4E-08	1.6E-08	3.7E-08	4.8E-04	1.7E-04	3.9E-04
^{238}U	9.1E-07	5.2E-08	1.6E-08	9.8E-03	5.6E-04	1.8E-04
Operational Monitoring January 2006						
^{241}Am	<MDC	NA	1.2E-07	<MDC	NA	9.7E-04
^{238}Pu	<MDC	NA	3.4E-07	<MDC	NA	2.7E-03

^{239,240}Pu	<MDC	NA	3.4E-07	<MDC	NA	2.6E-03
^{234}U	1.8E-07	5.6E-08	1.5E-07	1.4E-03	4.3E-04	1.2E-03
^{235}U	<MDC	NA	1.4E-07	<MDC	NA	1.1E-03
^{238}U	1.4E-07	4.8E-08	1.1E-07	1.1E-03	3.7E-04	8.6E-04
Operational Monitoring February 2006						
^{241}Am	<MDC	NA	1.7E-07	<MDC	NA	1.6E-03
^{238}Pu	<MDC	NA	4.2E-07	<MDC	NA	4.2E-03
^{239,240}Pu	<MDC	NA	3.7E-07	<MDC	NA	3.6E-03
^{234}U	8.8E-07	1.2E-07	1.7E-07	8.6E-03	1.1E-03	1.7E-03
^{235}U	<MDC	NA	1.8E-07	<MDC	NA	1.8E-03
^{238}U	4.4E-07	8.5E-08	1.6E-07	4.4E-03	8.4E-04	1.6E-03

Table 2-4: Results of Actinide Analysis for Monthly FAS Composite Samples *(Continued)*

Operational Monitoring March 2006						
^{241}Am	<MDC	NA	1.4E-07	<MDC	NA	1.3E-03
^{238}Pu	<MDC	NA	3.2E-07	<MDC	NA	2.9E-03
^{239,240}Pu	<MDC	NA	3.1E-07	<MDC	NA	2.8E-03
^{234}U	3.7E-06	2.4E-07	1.7E-07	3.4E-02	2.2E-03	1.5E-03
^{235}U	<MDC	NA	1.8E-07	<MDC	NA	1.6E-03
^{238}U	2.7E-06	2.0E-07	2.3E-07	2.4E-02	1.8E-03	2.1E-03
Operational Monitoring April 2006						
^{241}Am	<MDC	NA	1.1E-07	<MDC	NA	1.3E-03
^{238}Pu	<MDC	NA	1.2E-07	<MDC	NA	1.4E-03
^{239,240}Pu	<MDC	NA	8.5E-08	<MDC	NA	9.7E-04
^{234}U	5.4E-07	8.3E-08	1.4E-07	6.1E-03	9.5E-04	1.6E-03
^{235}U	<MDC	NA	1.4E-07	<MDC	NA	1.6E-03
^{238}U	2.4E-07	6.6E-08	1.7E-07	2.7E-03	7.5E-04	1.9E-03
Operational Monitoring May 2006						
^{241}Am	<MDC	NA	2.0E-07	<MDC	NA	2.4E-03
^{238}Pu	<MDC	NA	1.1E-07	<MDC	NA	1.3E-03
^{239,240}Pu	<MDC	NA	1.2E-07	<MDC	NA	1.4E-03
^{234}U	4.0E-07	7.3E-08	1.5E-07	5.0E-03	9.0E-04	1.8E-03
^{235}U	<MDC	NA	1.1E-07	<MDC	NA	1.4E-03
^{238}U	2.6E-07	6.2E-08	1.5E-07	3.2E-03	7.7E-04	1.8E-03
Operational Monitoring June 2006						
^{241}Am	<MDC	NA	3.0E-08	<MDC	NA	6.7E-04
^{238}Pu	<MDC	NA	7.3E-08	<MDC	NA	1.6E-03

^{239,240}Pu	<MDC	NA	9.2E-08	<MDC	NA	2.0E-03
^{234}U	6.5E-07	9.9E-08	1.8E-07	1.4E-02	2.2E-03	3.9E-03
^{235}U	1.5E-07	5.1E-08	1.1E-07	3.4E-03	1.1E-03	2.4E-03
^{238}U	4.0E-07	8.5E-08	2.0E-07	9.0E-03	1.9E-03	4.4E-03
Operational Monitoring July 2006						
^{241}Am	<MDC	NA	3.7E-08	<MDC	NA	6.6E-04
^{238}Pu	<MDC	NA	1.2E-07	<MDC	NA	2.2E-03
^{239,240}Pu	<MDC	NA	1.4E-07	<MDC	NA	2.6E-03
^{234}U	7.0E-07	1.1E-07	2.0E-07	1.3E-02	2.0E-03	3.5E-03
^{235}U	<MDC	NA	1.6E-07	<MDC	NA	2.9E-03
^{238}U	4.8E-07	9.2E-08	1.7E-07	8.7E-03	1.7E-03	3.1E-03
Operational Monitoring August 2006						
^{241}Am	<MDC	NA	7.4E-08	<MDC	NA	8.0E-04
^{238}Pu	<MDC	NA	1.3E-07	<MDC	NA	1.4E-03
^{239,240}Pu	<MDC	NA	1.1E-07	<MDC	NA	1.2E-03
^{234}U	5.9E-07	8.2E-08	1.1E-07	6.5E-03	9.0E-04	1.2E-03
^{235}U	<MDC	NA	1.2E-07	<MDC	NA	1.3E-03
^{238}U	4.5E-07	7.5E-08	1.3E-07	4.9E-03	8.2E-04	1.5E-03

Table 2-4: Results of Actinide Analysis for Monthly FAS Composite Samples *(Continued)*

Operational Monitoring September 2006						
^{241}Am	<MDC	NA	1.2E-07	<MDC	NA	1.8E-03
^{238}Pu	<MDC	NA	1.3E-07	<MDC	NA	1.9E-03
^{239,240}Pu	<MDC	NA	7.6E-08	<MDC	NA	1.1E-03
^{234}U	5.0E-07	9.5E-08	2.0E-07	7.5E-03	1.4E-03	3.0E-03
^{235}U	<MDC	NA	1.5E-07	<MDC	NA	2.3E-03
^{238}U	4.6E-07	8.8E-08	1.7E-07	6.9E-03	1.3E-03	2.6E-03
Operational Monitoring October 2006						
^{241}Am	<MDC	NA	6.3E-08	<MDC	NA	9.4E-04
^{238}Pu	<MDC	NA	9.4E-08	<MDC	NA	1.4E-03
^{239,240}Pu	<MDC	NA	9.4E-08	<MDC	NA	1.4E-03
^{234}U	2.6E-07	6.5E-08	1.6E-07	3.9E-03	9.7E-04	2.4E-03
^{235}U	<MDC	NA	1.1E-07	<MDC	NA	1.7E-03
^{238}U	3.3E-07	6.7E-08	1.4E-07	4.9E-03	1.0E-03	2.1E-03
Operational Monitoring November 2006						
^{241}Am	<MDC	NA	1.0E-07	<MDC	NA	1.4E-03
^{238}Pu	<MDC	NA	1.8E-07	<MDC	NA	2.4E-03

^{239,240}Pu	<MDC	NA	1.8E-07	<MDC	NA	2.4E-03
^{234}U	3.9E-07	7.0E-08	1.3E-07	5.1E-03	9.4E-04	1.7E-03
^{235}U	<MDC	NA	1.9E-07	<MDC	NA	2.6E-03
^{238}U	2.5E-07	5.7E-08	1.1E-07	3.3E-03	7.6E-04	1.5E-03
Operational Monitoring December 2006						
^{241}Am	<MDC	NA	5.7E-08	<MDC	NA	7.3E-04
^{238}Pu	<MDC	NA	1.0E-07	<MDC	NA	1.3E-03
^{239,240}Pu	<MDC	NA	1.0E-07	<MDC	NA	1.3E-03
^{234}U	2.7E-07	5.4E-08	9.6E-08	3.4E-03	6.8E-04	1.2E-03
^{235}U	<MDC	NA	8.1E-08	<MDC	NA	1.0E-03
^{238}U	1.7E-07	5.1E-08	1.3E-07	2.2E-03	6.5E-04	1.7E-03
Operational Monitoring January 2007						
^{241}Am	<MDC	NA	3.4E-08	<MDC	NA	2.7E-04
^{238}Pu	<MDC	NA	1.3E-07	<MDC	NA	1.1E-03
^{239,240}Pu	<MDC	NA	1.6E-07	<MDC	NA	1.3E-03
^{234}U	7.7E-07	1.1E-07	1.5E-07	6.2E-03	8.7E-04	1.2E-03
^{235}U	<MDC	NA	2.0E-07	<MDC	NA	1.6E-03
^{238}U	5.4E-07	9.6E-08	1.8E-07	4.4E-03	7.7E-04	1.4E-03
Operational Monitoring February 2007						
^{241}Am	<MDC	NA	1.5E-07	<MDC	NA	9.4E-04
^{238}Pu	<MDC	NA	2.3E-07	<MDC	NA	1.4E-03
^{239,240}Pu	<MDC	NA	1.8E-07	<MDC	NA	1.1E-03
^{234}U	1.2E-06	1.5E-07	1.8E-07	7.5E-03	9.3E-04	1.1E-03
^{235}U	<MDC	NA	1.5E-07	<MDC	NA	9.5E-04
^{238}U	4.7E-07	9.6E-08	1.7E-07	2.9E-03	5.9E-04	1.0E-03

Table 2-4: Results of Actinide Analysis for Monthly FAS Composite Samples *(Continued)*

Operational Monitoring March 2007						
^{241}Am	<MDC	NA	7.8E-08	<MDC	NA	4.8E-04
^{238}Pu	<MDC	NA	2.3E-07	<MDC	NA	1.4E-03
^{239,240}Pu	1.3E-07	4.9E-08	4.4E-08	8.0E-04	3.0E-04	2.7E-04
^{234}U	4.3E-07	9.2E-08	2.1E-07	2.6E-03	5.6E-04	1.3E-03
^{235}U	<MDC	NA	1.5E-07	<MDC	NA	9.2E-04
^{238}U	3.8E-07	8.4E-08	1.8E-07	2.3E-03	5.1E-04	1.1E-03
Operational Monitoring April 2007						
^{241}Am	<MDC	NA	1.2E-07	<MDC	NA	1.1E-03
^{238}Pu	<MDC	NA	1.6E-07	<MDC	NA	1.5E-03

^{239,240}Pu	<MDC	NA	1.6E-07	<MDC	NA	1.5E-03
^{234}U	5.7E-07	9.7E-08	1.6E-07	5.2E-03	8.8E-04	1.5E-03
^{235}U	<MDC	NA	2.4E-07	<MDC	NA	2.2E-03
^{238}U	3.6E-07	7.7E-08	1.5E-07	3.2E-03	7.0E-04	1.3E-03
Operational Monitoring May 2007						
^{241}Am	<MDC	NA	1.02E-07	<MDC	NA	1.11E-03
^{238}Pu	<MDC	NA	3.26E-07	<MDC	NA	3.56E-03
^{239,240}Pu	<MDC	NA	1.37E-06	<MDC	NA	1.18E-02
^{234}U	3.24E-07	8.54E-08	1.84E-07	3.54E-03	9.33E-04	2.00E-03
^{235}U	<MDC	NA	1.55E-07	<MDC	NA	1.69E-03
^{238}U	1.13E-06	3.37E-07	8.70E-07	9.74E-03	2.91E-03	7.52E-03
Operational Monitoring June 2007						
^{241}Am	<MDC	NA	3.7E-08	<MDC	NA	4.3E-04
^{238}Pu	<MDC	NA	1.1E-07	<MDC	NA	1.3E-03
^{239,240}Pu	<MDC	NA	1.4E-07	<MDC	NA	1.6E-03
^{234}U	3.9E-07	8.2E-08	1.5E-07	4.6E-03	9.6E-04	1.8E-03
^{235}U	<MDC	NA	1.3E-07	<MDC	NA	1.5E-03
^{238}U	3.0E-07	7.2E-08	1.4E-07	3.5E-03	8.4E-04	1.6E-03
Operational Monitoring July 2007						
^{241}Am	<MDC	NA	1.3E-07	<MDC	NA	1.5E-03
^{238}Pu	<MDC	NA	1.4E-07	<MDC	NA	1.7E-03
^{239,240}Pu	<MDC	NA	1.3E-07	<MDC	NA	1.4E-03
^{234}U	5.4E-07	9.3E-08	1.6E-07	6.2E-03	1.1E-03	1.8E-03
^{235}U	<MDC	NA	1.2E-07	<MDC	NA	1.4E-03
^{238}U	3.6E-07	8.0E-08	1.7E-07	4.1E-03	9.3E-04	2.0E-03
Operational Monitoring August 2007						
^{241}Am	<MDC	NA	2.7E-08	<MDC	NA	3.3E-04
^{238}Pu	1.0E-07	4.9E-08	5.5E-08	1.2E-03	6.0E-04	6.7E-04
^{239,240}Pu	2.0E-07	7.5E-08	1.9E-07	2.4E-03	9.2E-04	2.3E-03
^{234}U	1.3E-06	1.2E-07	1.2E-07	1.5E-02	1.5E-03	1.5E-03
^{235}U	1.1E-07	4.4E-08	1.0E-07	1.3E-03	5.3E-04	1.3E-03
^{238}U	4.2E-07	7.3E-08	1.1E-07	5.1E-03	9.0E-04	1.4E-03

Table 2-4: Results of Actinide Analysis for Monthly FAS Composite Samples *(Continued)*

	Activity Concentration (Bq m^{-3})			Activity Density (Bq g^{-1})		
Radionuclide	**[a]C**	**[b]SD**	**[c]MDC**	**[a]C**	**[b]SD**	**[c]MDC**

Operational Monitoring September 2007						
^{241}Am	[e]NR	NR	NR	NR	NR	NR
^{238}Pu	<MDC	NA	1.5E-07	<MDC	NA	3.0E-03
^{239,240}Pu	3.6E-06	2.6E-07	2.2E-07	7.1E-02	5.0E-03	4.2E-03
^{234}U	5.8E-07	9.0E-08	1.4E-07	1.1E-02	1.8E-03	2.8E-03
^{235}U	<MDC	NA	1.1E-07	<MDC	NA	2.2E-03
^{238}U	4.9E-07	8.6E-08	1.6E-07	9.6E-03	1.7E-03	3.1E-03
Operational Monitoring October 2007*						
^{241}Am	<MDC	NA	8.9E-08	<MDC	NA	1.77E-03
^{238}Pu	<MDC	NA	6.78E-08	<MDC	NA	1.35E-03
^{239,240}Pu	1.86E-06	1.34E-07	8.55E-08	3.71E-02	2.68E-03	1.71E-03
^{234}U	6.24E-07	8.04E-08	8.98E-08	1.24E-02	1.60E-03	1.79E-03
^{235}U	<MDC	NA	1.57E-07	<MDC	NA	3.13E-03
^{238}U	7.10E-07	8.76E-08	1.16E-07	1.42E-02	1.75E-03	2.31E-03
Operational Monitoring November 2007*						
^{241}Am	<MDC	NA	1.03E-07	<MDC	NA	5.99E-04
^{238}Pu	<MDC	NA	6.91E-08	<MDC	NA	4.02E-04
^{239,240}Pu	1.72E-06	1.29E-07	2.54E-08	1.00E-02	7.52E-04	1.48E-04
^{234}U	7.82E-07	9.53E-08	1.47E-07	4.55E-03	5.55E-04	8.55E-04
^{235}U	<MDC	NA	8.89E-08	<MDC	NA	5.18E-04
^{238}U	5.94E-07	8.13E-08	1.17E-07	3.46E-03	4.74E-04	6.82E-04
Operational Monitoring December 2007*						
^{241}Am	<MDC	NA	1.17E-07	<MDC	NA	1.84E-03
^{238}Pu	<MDC	NA	1.29E-07	<MDC	NA	2.03E-03
^{239,240}Pu	1.08E-06	1.06E-07	9.14E-08	1.71E-02	1.67E-03	1.44E-03
^{234}U	5.19E-07	7.77E-08	1.2E-07	8.17E-03	1.22E-03	1.89E-03
^{235}U	<MDC	NA	1.15E-07	<MDC	NA	1.80E-03
^{238}U	2.89E-07	6.70E-08	1.58E-07	4.55E-03	1.05E-03	2.49E-03

[a]C = Concentration

[b]SD = standard deviation

[c]MDC = Minimum Detectable Concentration

[d]NA = Not Applicable

[e]NR = Not Reported

*these months showed contaminated Trip Blanks

Table 2-5: Results of Actinide Analysis for FAS Samples Collected by WTS During 2007, ^{239,240}Pu

	Activity Concentration (Bq/m^3)			Activity Concentration (Bq/Sample)		
Month	**[e]C**	**[b]SD**	**[c]MDA**	**[a]C**	**[b]SD**	**[c]MDA**
January	<MDA	[d]NA	1.61E-07	<MDA	NA	4.03E-04
February	<MDA	NA	6.28E-07	<MDA	NA	1.57E-03
March	<MDA	NA	2.05E-07	<MDA	NA	5.13E-04
April	<MDA	NA	1.25E-07	<MDA	NA	3.12E-04
May	<MDA	NA	3.93E-07	<MDA	NA	9.82E-04
June	<MDA	NA	2.15E-07	<MDA	NA	5.38E-04
July	<MDA	NA	1.05E-07	<MDA	NA	2.62E-04
August	1.69E-07	1.11E-07	6.00E-08	4.27E-04	2.82E-04	1.52E-04
September	5.16E-07	2.31E-07	2.55E-07	1.24E-03	5.54E-04	6.13E-04
October	<MDA	NA	9.12E-08	<MDA	NA	2.28E-04
November	<MDA	NA	1.80E-07	<MDA	NA	4.50E-04
December	<MDA	NA	2.04E-07	<MDA	NA	5.10E-04

[a]C = Concentration

[b]SD = standard deviation

[c]MDC = Minimum Detectable Concentration

[d]NA = Not Applicable

[e]Using average flow volumes from the CEMRC legs at Station A

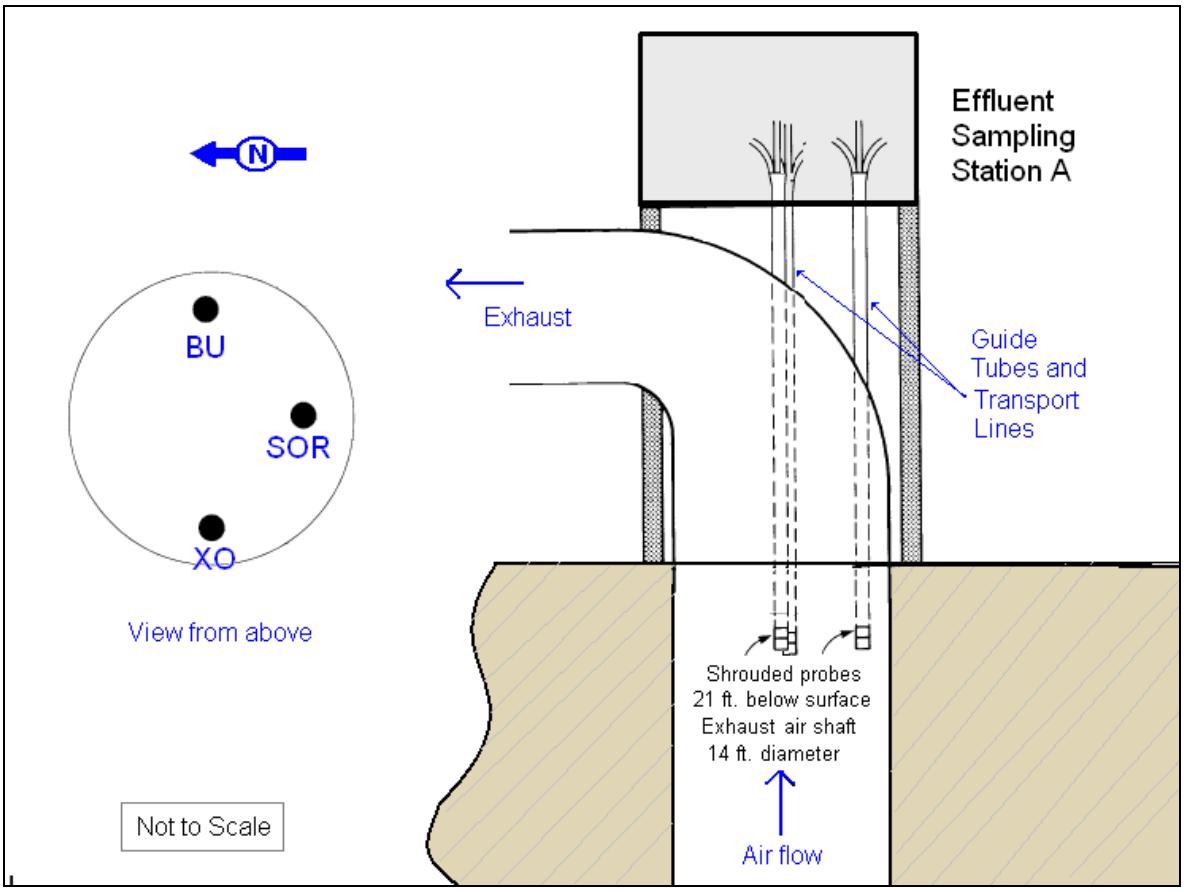

Figure 2.1: Fixed Air Samplers at Station A
BU: Backup, SOR: Skid of Record, XO: Extra Probe

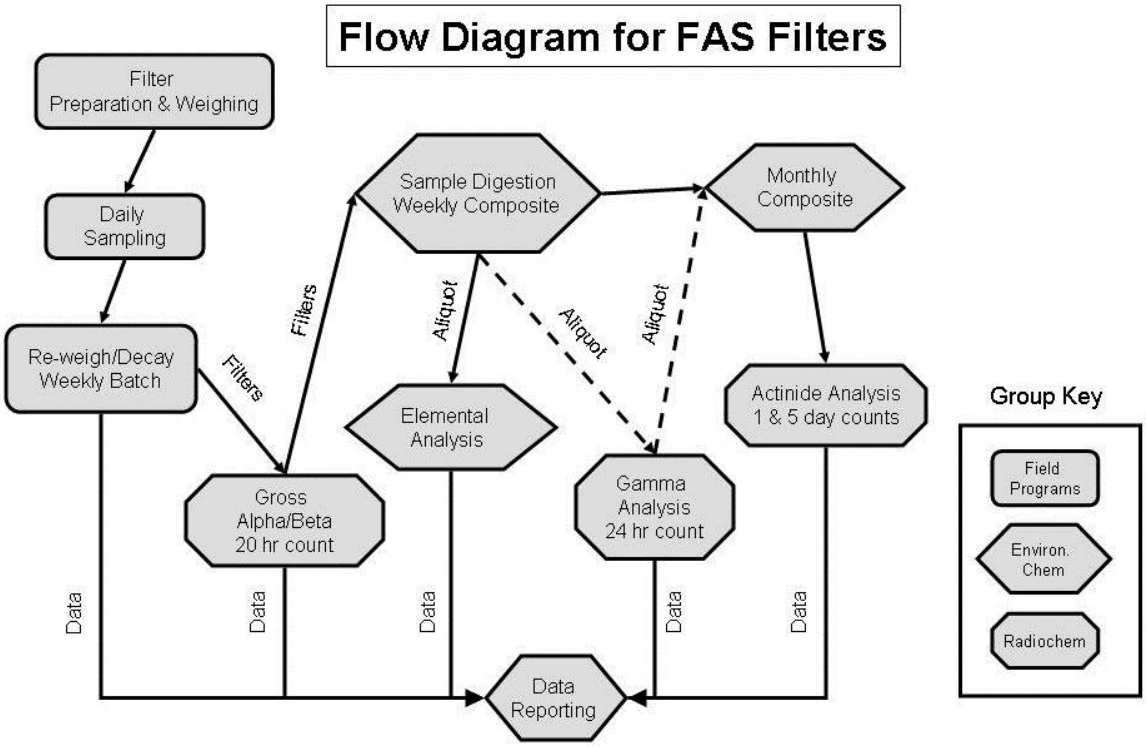

Figure 2.2: Flow diagram showing the handling and analysis of the aerosol sample filters from Station A

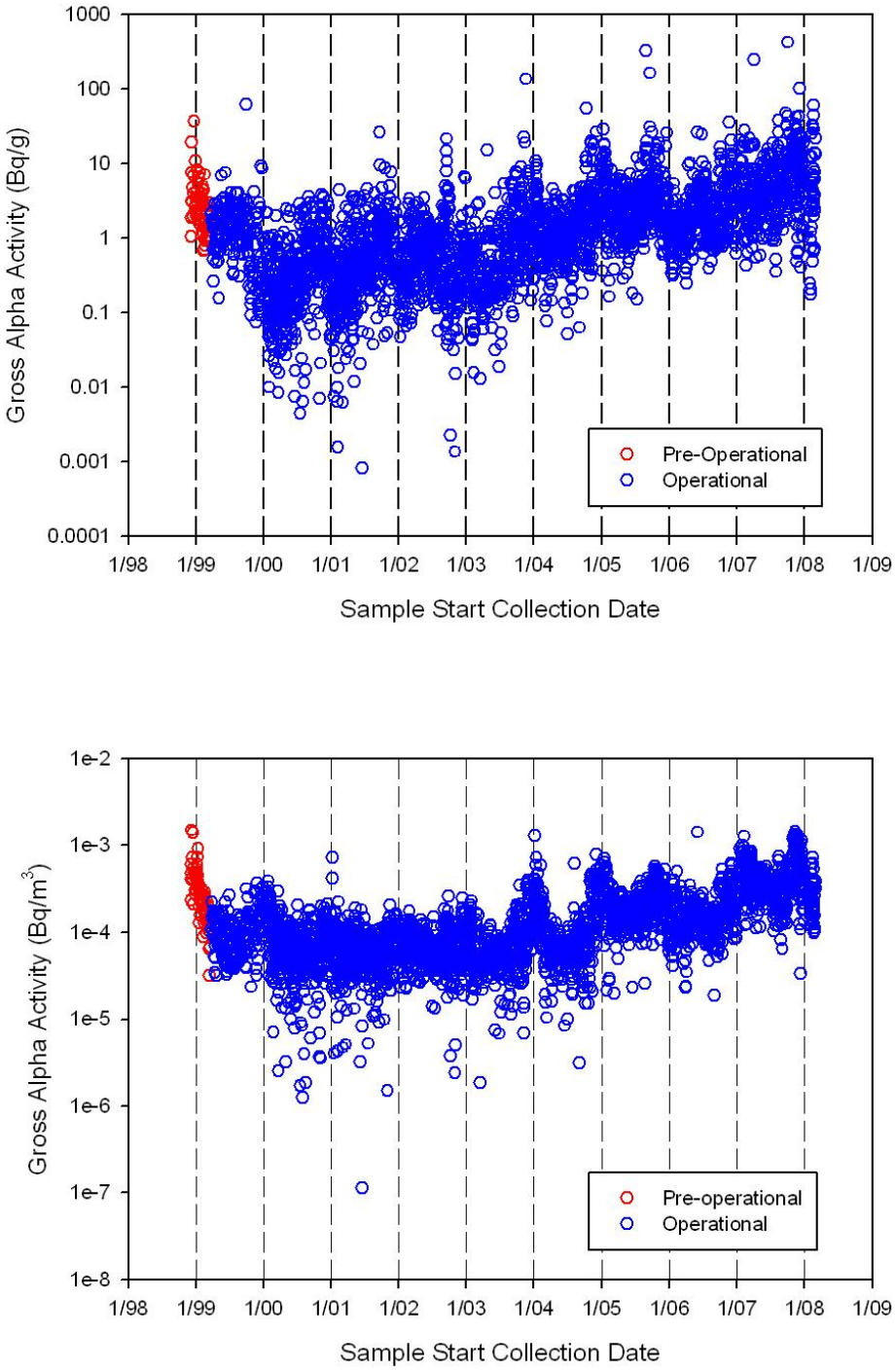

Figure 2.3: Time-series plots of gross alpha activity densities (upper panel) and activity concentrations (lower panel). Red points denote pre-disposal samples and blue points are for operational samples.

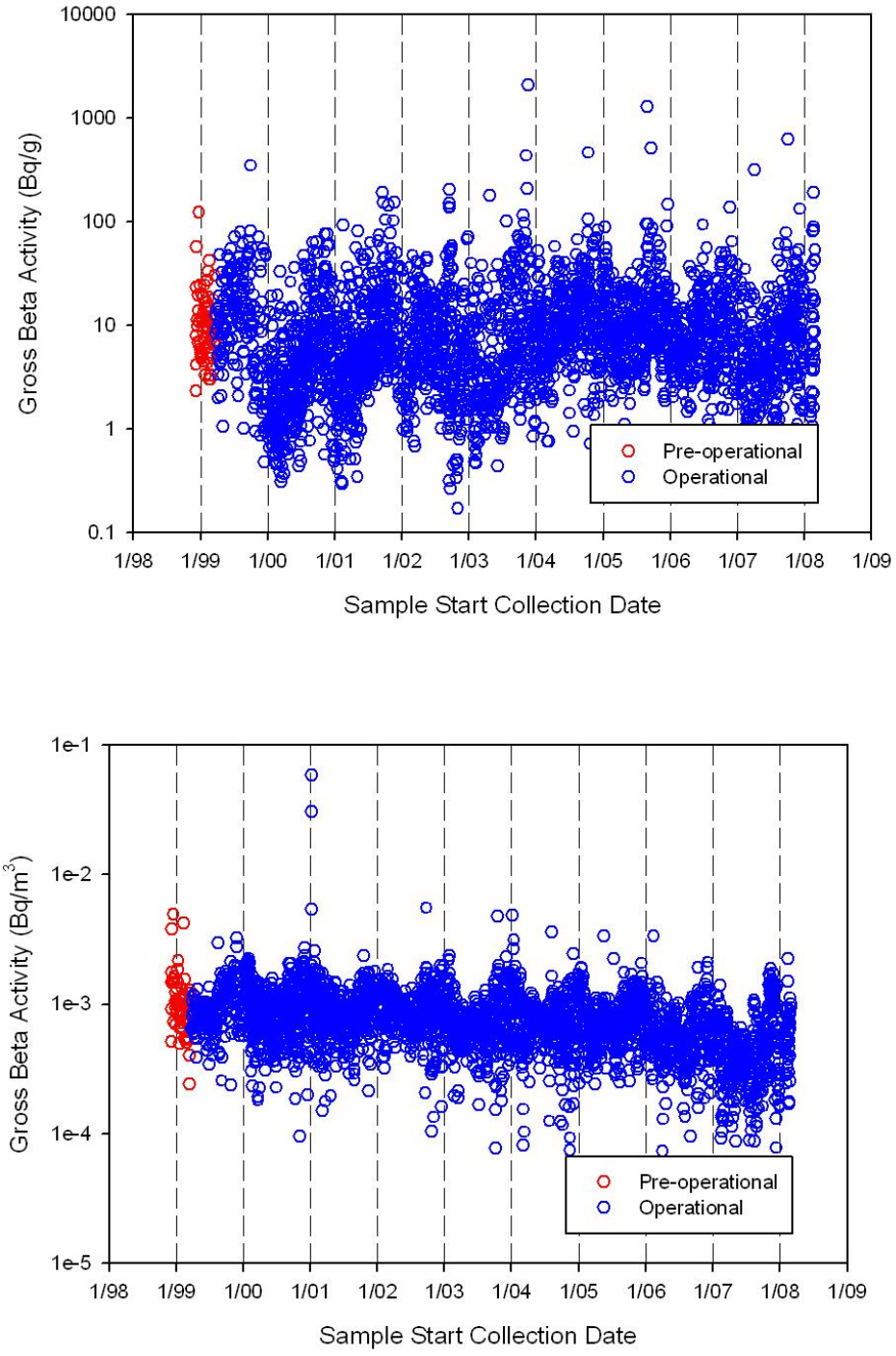

Figure 2.4: Time-series plots of gross beta activity densities (upper panel) and activity concentrations (lower panel). Red points denote pre-disposal samples

and blue points are for operational samples.

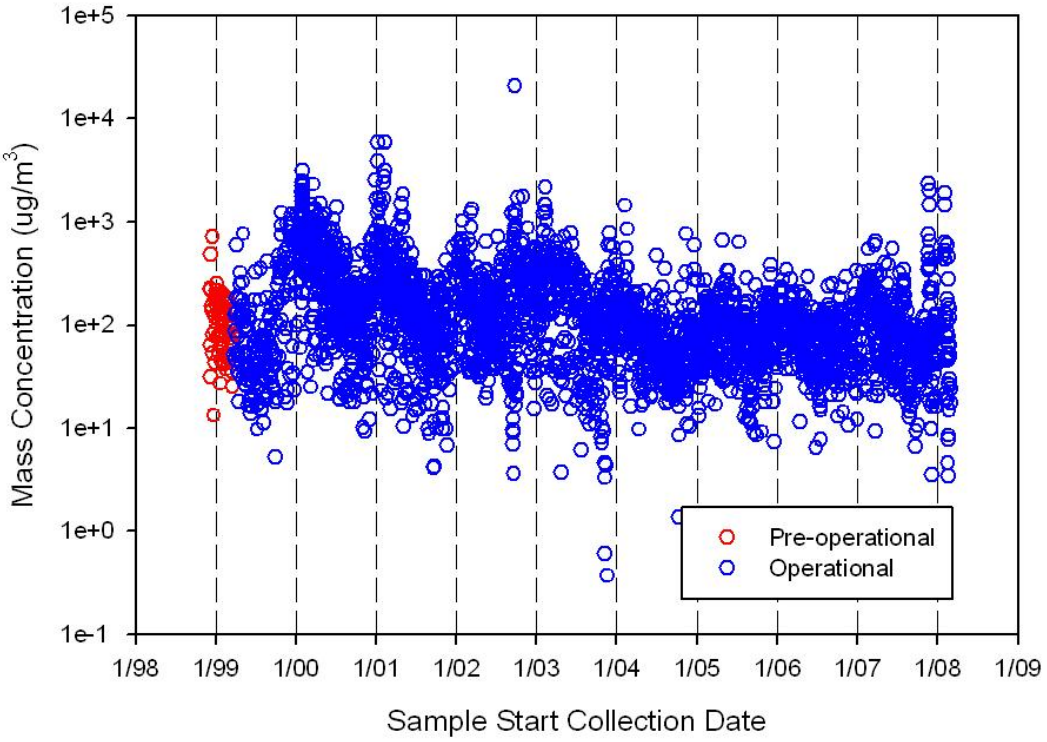

Figure 2.5: Time-series plot of aerosol mass loadings. Red points denote pre-disposal samples and blue points are for operational samples.

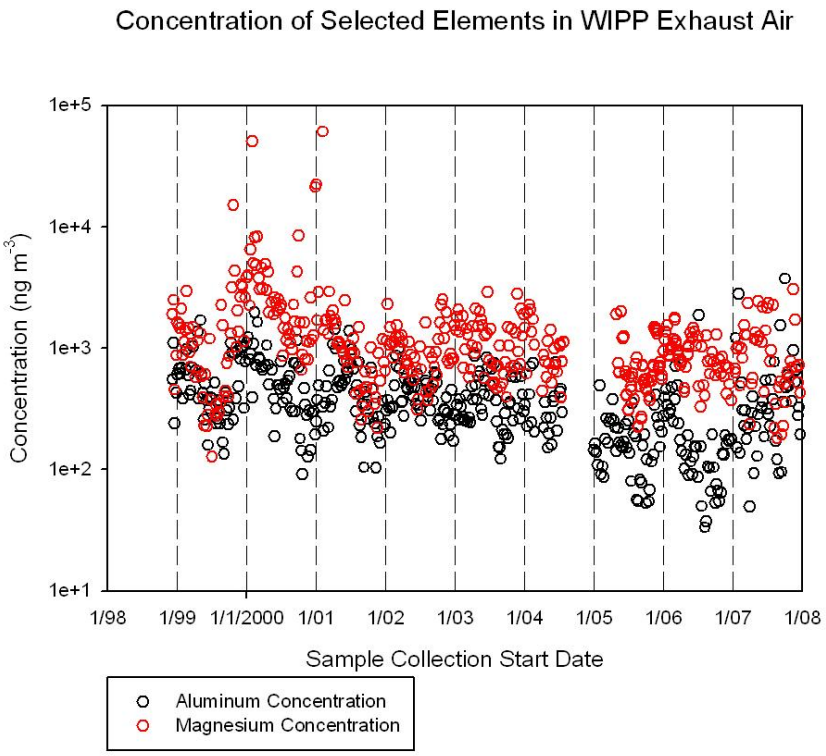

Figure 2.6: Concentration of Selected Elements (Al, Mg) in WIPP Exhaust Air

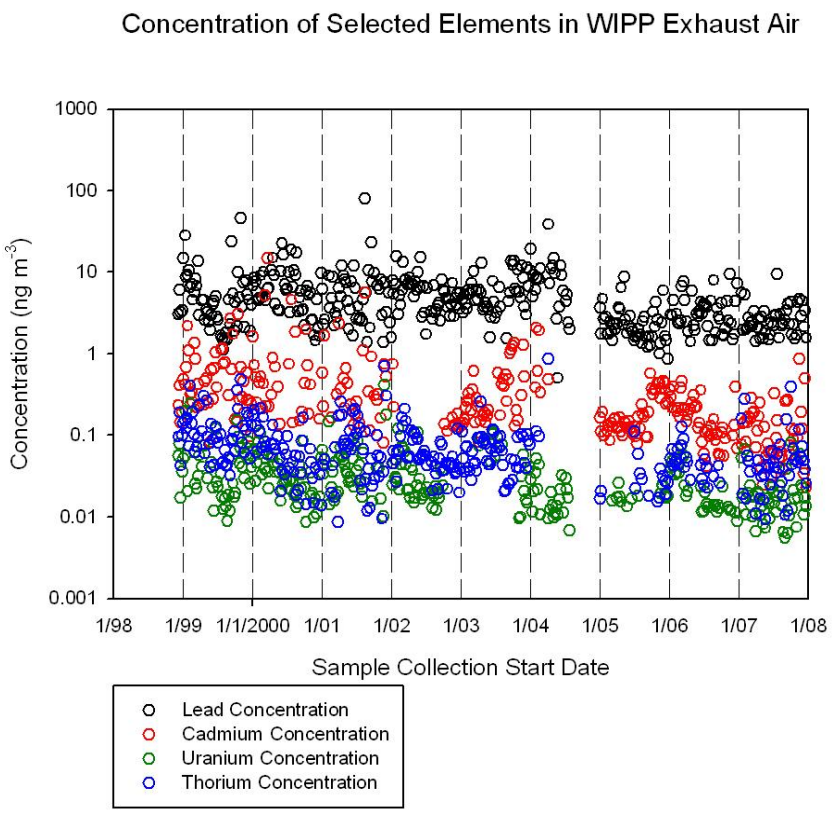

Figure 2.7: Concentration of Selected Elements (U, Th, Pb, Cd) in WIPP Exhaust Air

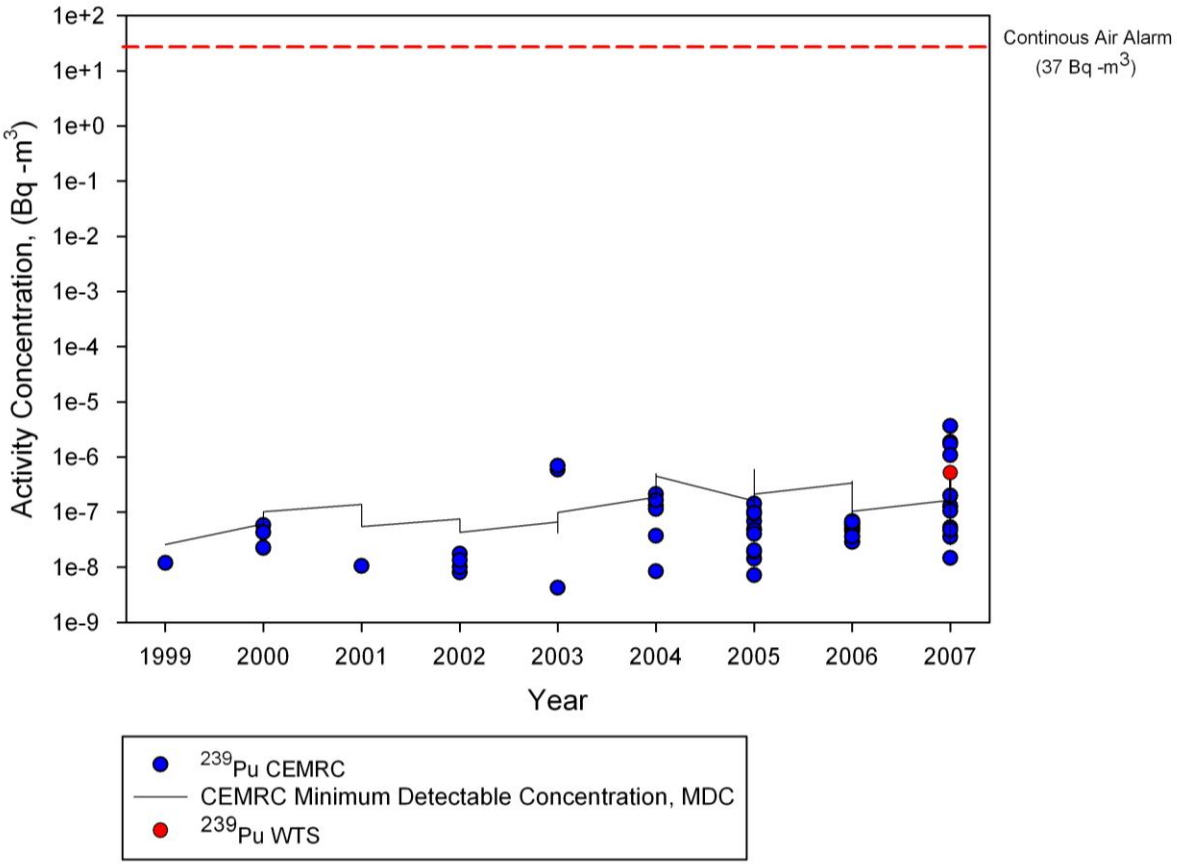

Figure 2.8: ^{238}Pu Analysis of FAS Composite Samples

CHAPTER 3

Radionuclides and Inorganics in Selected Water Sources

INTRODUCTION

During 2007, water samples were collected for CEMRC environmental monitoring studies from five drinking water sources in the region of the WIPP. The drinking water wells in the vicinity of the WIPP site provide water primarily for livestock, industrial usage by oil and gas production operations, and monitoring studies conducted by various groups. The sources included the community water supplies of Carlsbad, Loving, Otis, and Hobbs, and the water supply for the WIPP site (Double Eagle). An additional source

in the past, a private well, has been dry for the last several years.

Aquifers in the region surrounding the WIPP include Dewey Lake, Culebra-Magenta, Ogalalla, 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 water supplies are drawn from the Ogalalla aquifer, while the Loving/Malaga and Otis supply wells draw from deposits that are hydraulically linked to the flow of the Pecos River. The source for the private well sampling site is a well seven miles southwest of the WIPP; this water is drawn from the Culebra aquifer when it is not dry.

CEMRC began collecting drinking water samples in 1997, and summaries of methods, data and results from previous sampling were reported in previous CEMRC reports (available at http://www.cemrc.org). Present results as well as the results of previous analyses of drinking water were consistent for each source across sampling periods, with few organic contaminants detected and inorganic substances mostly below levels specified under the Safe Drinking Water Act.

Analyses reported herein are for 2007 for drinking water samples, analyzed for both inorganics and radionuclides.

METHODS

The alpha-emitting radionuclides ^{238}Pu and ^{239,240}Pu were analyzed in these drinking water samples. Discussions with stakeholders will determine if further analyses of other radioanalytes will be performed on these samples.

All drinking water samples were collected according to CEMRC protocols for the collection, handling and preservation of drinking water as follows: (1) 4 L for radiological analyses, (2) 1 L for elemental analyses, (3) 1 L for anion tests and (4) 500 mL for Hg analysis. None of the samples were filtered before analysis, but a portion of the 4 L sample was transferred to a 3 L Marinelli beaker for possible future gamma spectroscopy analyses.

CEMRC performed non-radiological analyses of drinking water samples using ICP-MS and IC, shown in Table 3-1. Radiochemistry was then applied to each sample for actinide separation and purification using multiple precipitation, co-precipitation and ion-exchange and/or extraction chromatography. Once the actinides were separated elementally, they were co-precipitated with LaF_3 and deposited onto filters, which were then counted on an alpha spectroscopy system. Aliquots were blank-corrected after application of dilution factors. In cases where blank corrections lowered solution concentrations below MDC values, concentrations greater than zero are reported; negative concentrations are reported as less than MDC.

RESULTS AND DISCUSSION

Radiological Drinking Water

No radionuclides were measured above MDC in 2007. The federal and state action level for gross alpha emitters, which includes isotopes of Pu and U, is 15 pCi/L (0.56 Bq/L). This is over 10,000 times the levels measured by CEMRC in any drinking water sample over the last nine years.

Since 1998, Pu has not been measured above the MDC in any samples. Figures 3.1 and 3.2 show the historic values for ^{239,240}Pu and ^{238}Pu at all sites. All are below the MDC.

Non-Radiological Results Drinking Water

Measurements of inorganic analytes by CEMRC from the five drinking water sources showed little variation between years for each source. Differences of a factor of two or three between one set of successive years is common, as it is for all natural waters.

The 2007 measurements exhibit a high level of consistency with past results that provides a useful characterization of each source (Table 3-1).

As per the grant requirements and the fact that CEMRC does not use EPA compliance procedures, these results are not appropriate for use in assessing regulatory compliance. However, CEMRC results for drinking water collected during 2007 agreed well with, and were generally below, measurements for the same elements published in 2006 by the City of Carlsbad Municipal Water System (*2006 Annual Consumer Report on the Quality of Your Drinking Water (www.cityofcarlsbadnm .com/documents/CCR2006.pdf).*

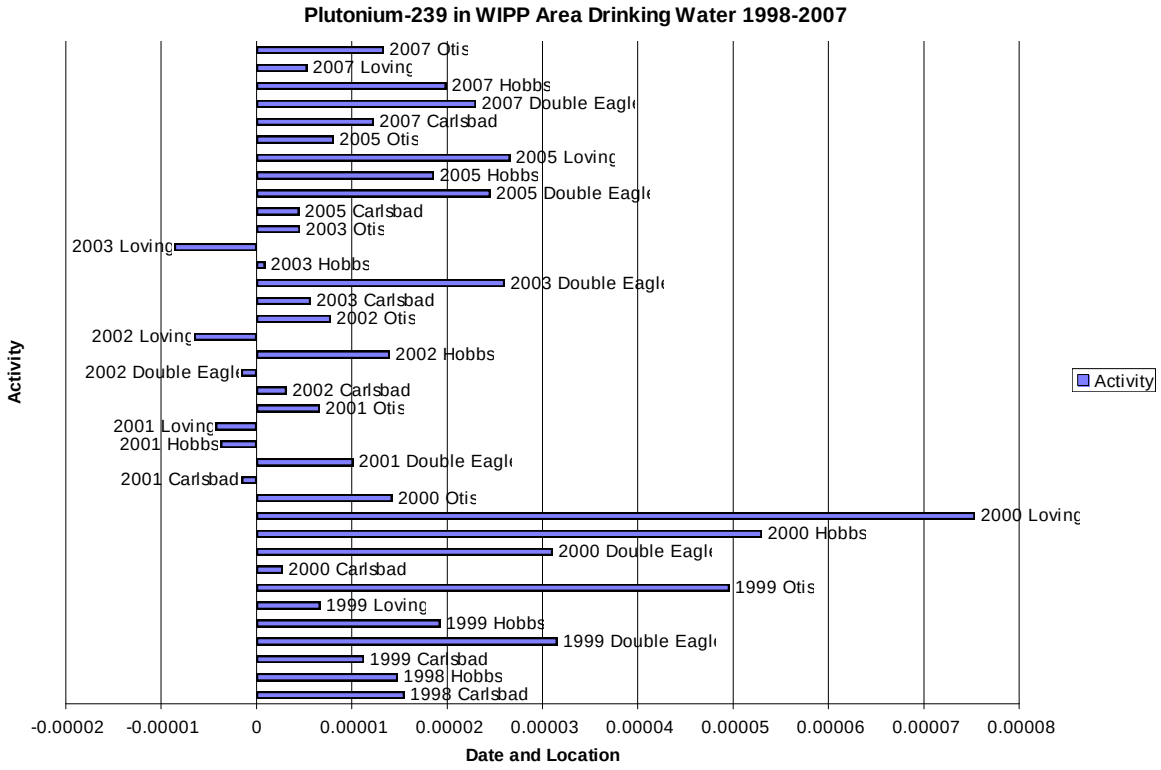

Figure 3.1: ^{239,240}Pu in Bq/L in regional drinking water from 1998 to 2007, all are about 10,000 times below the EPA Action level of 0.56 Bq/L. The EPA Action level is for all alpha-emitters, including U plus Pu.

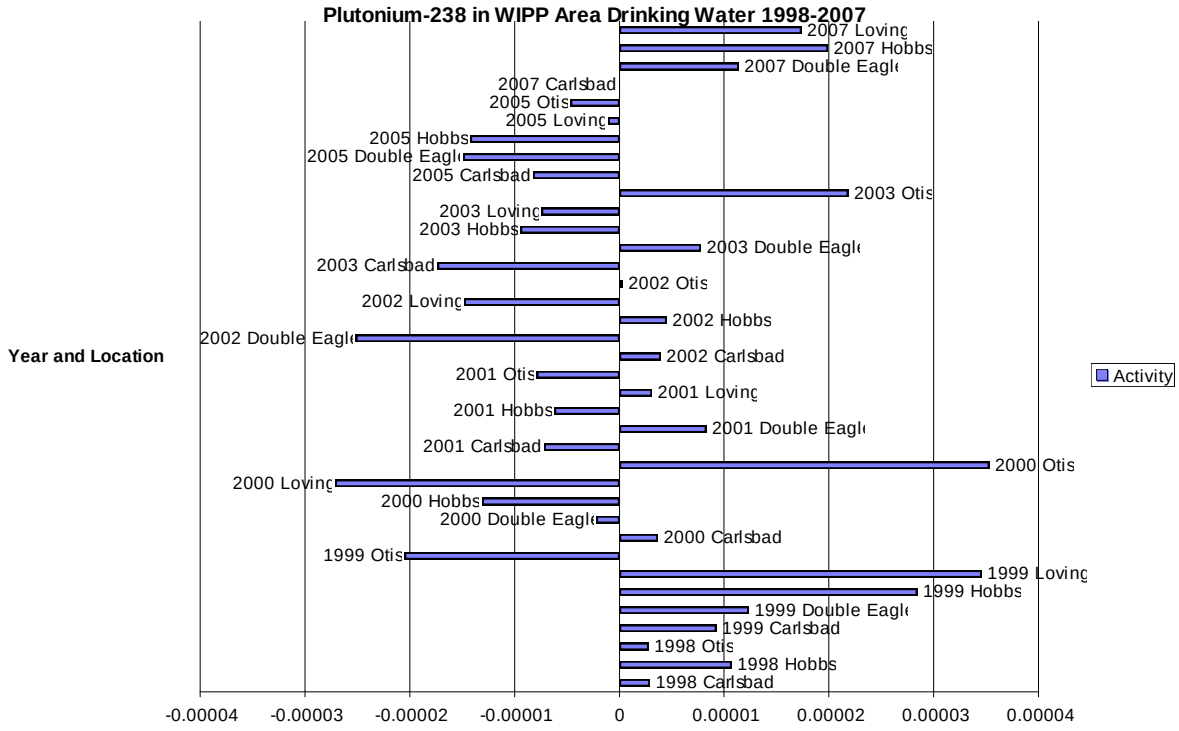

Figure 3.2: ^{238}Pu in Bq/L in regional drinking water from 1998 to 2007, all are about 10,000 times below the EPA Action level of 0.56 Bq/L. The EPA Action level is for all alpha-emitters, including U plus Pu.

Table 3-1: Measured Concentration of Selected Inorganic Analytes in Drinking Water from 1998 to 2007 at Five Locations

Carlsbad												
	1998-2005				2005				2007			
EL[1]	N[2]	N_{DET}[2]	Min[3]	Max[3]	MDC[4] (ug/L)	Blank Conc. (ug/L)	Avg Conc. w/Blank Subt[5] (ug/L)	Avg Conc. w/o Blank Subt[5] (ug/L)	MDC[4] (ug/L)	Blank Conc. (ug/L)	Avg Conc. w/Blank Subt[5] (ug/L)	Avg Conc. w/o Blank Subt[5] (ug/L)
Ag	8	2	1.23E-02	1.75E-02	2.30E-02	1.11E-01	<MDC	<MDC	N/A	N/A	N/A	N/A
Al	10	4	2.34E+00	3.17E+01	1.49E+01	-2.80E+01	<MDC	<MDC	2.34E+01	1.92E+02	<MDC	<MDC
As	10	7	3.45E-01	1.10E+00	2.01E+00	3.19E+01	<MDC	<MDC	7.12E-01	3.15E+00	1.10E+00	1.10E+00
B	1	1	3.07E+01	3.07E+01	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ba	10	10	6.64E+01	7.62E+01	1.24E-01	-5.63E+00	7.62E+01	7.62E+01	1.99E-01	-1.36E+00	7.15E+01	7.15E+01
Be	8	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ca	9	9	6.32E+04	8.06E+04	N/A	N/A	N/A	N/A	1.80E+03	1.43E+04	6.32E+04	7.76E+04
Cd	8	0	N/A	N/A	6.73E-02	1.91E+00	<MDC	<MDC	N/A	N/A	N/A	N/A
Ce	8	0	N/A	N/A	N/A	N/A	N/A	N/A	3.20E-02	-7.02E-01	<MDC	<MDC
Co	9	7	8.80E-02	3.41E-01	7.21E-01	8.25E-01	<MDC	<MDC	6.40E-02	-1.82E-01	1.38E-01	1.38E-01
Cr	10	8	1.24E+00	7.15E+00	7.82E+00	9.24E+01	<MDC	<MDC	2.87E-01	1.11E+00	1.24E+00	1.24E+00
Cu	10	9	1.23E+00	1.67E+01	8.98E-02	3.68E+01	1.67E+01	1.67E+01	1.17E+00	4.23E+01	6.55E+00	6.55E+00
Dy	9	0	N/A	N/A	2.79E-02	-1.77E-01	<MDC	<MDC	5.80E-02	1.49E-01	<MDC	<MDC
Er	9	0	N/A	N/A	1.21E-02	-5.61E-02	<MDC	<MDC	3.70E-02	1.33E-01	<MDC	<MDC
Eu	9	6	1.35E-02	2.43E-02	1.64E-02	-1.04E-01	<MDC	<MDC	9.30E-02	-7.61E-02	<MDC	<MDC
Fe	9	3	2.14E+01	3.85E+01	2.94E+02	3.66E+03	<MDC	<MDC	N/A	N/A	N/A	N/A
Ga	2	2	3.24E+00	3.25E+00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Gd	7	0	N/A	N/A	N/A	N/A	N/A	N/A	5.30E-02	6.00E-02	<MDC	<MDC
Hg	7	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
K	9	8	1.04E+03	3.56E+03	N/A	N/A	N/A	N/A	2.33E+01	2.26E+03	<MDC	1.08E+03
La	9	5	1.41E-02	4.48E-02	1.36E-02	1.00E-01	<MDC	<MDC	1.25E-01	2.07E-02	<MDC	<MDC
Li	7	7	6.09E+00	7.87E+00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mg	9	9	3.14E+04	3.47E+04	5.97E+00	-8.94E+01	3.47E+04	3.47E+04	3.43E+02	-2.56E+02	3.40E+04	3.40E+04
Mn	10	8	5.50E-02	9.40E-01	1.60E+00	1.97E+01	<MDC	<MDC	1.64E-01	3.22E+00	<MDC	<MDC

Mo	9	8	7.03E-01	1.26E+00	1.35E+00	-3.05E+01	<MDC	<MDC	N/A	N/A	N/A	N/A
Na	9	9	8.47E+03	9.94E+04	N/A	N/A	N/A	N/A	8.01E+02	2.91E+02	8.47E+03	8.47E+03
Nd	9	0	N/A	N/A	1.65E-02	3.60E-01	<MDC	<MDC	8.80E-02	1.76E-01	<MDC	<MDC
Ni	9	8	1.01E+00	2.89E+00	1.74E+00	1.14E+01	<MDC	<MDC	1.14E+00	6.04E-01	2.06E+00	2.06E+00
P	1	0	N/A	N/A	2.27E+01	-2.59E+02	<MDC	<MDC	N/A	N/A	N/A	N/A
Pb	8	8	1.63E-01	8.53E+00	3.16E-02	-7.17E+00	8.53E+00	1.36E+00	N/A	N/A	N/A	N/A
Pr	9	0	N/A	N/A	1.29E-02	-1.81E-01	<MDC	<MDC	3.80E-02	6.63E-02	<MDC	<MDC
Rh	2	1	1.10E-02	1.10E-02	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sb	9	4	3.00E-02	1.99E-01	1.02E-01	1.96E-01	<MDC	<MDC	N/A	N/A	N/A	N/A
Sc	6	6	1.72E+00	3.11E+00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Se	8	3	9.25E-02	1.75E+00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Si	4	4	5.31E+03	1.68E+04	7.32E+01	-1.01E+04	1.68E+04	6.77E+03	N/A	N/A	N/A	N/A
Sm	9	7	2.34E-02	3.64E-02	1.62E-02	-2.01E-01	<MDC	<MDC	5.30E-02	1.70E-02	<MDC	<MDC
Sn	5	1	5.97E-02	5.97E-02	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sr	10	10	3.23E+02	4.59E+02	2.51E-01	-1.19E-01	3.48E+02	3.48E+02	9.30E-01	9.59E-02	3.28E+02	3.28E+02
Th	8	1	1.98E-02	1.98E-02	1.49E-02	6.30E-03	<MDC	<MDC	N/A	N/A	N/A	N/A
Ti	4	3	3.64E-01	4.22E+00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Tl	8	8	9.97E-02	1.54E-01	1.07E-02	2.05E-02	9.97E-02	9.97E-02	N/A	N/A	N/A	N/A
U	9	9	8.21E-01	1.04E+00	7.76E-03	-9.50E-04	8.60E-01	8.60E-01	6.10E-02	1.09E-02	1.04E+00	1.04E+00
V	10	10	3.82E+00	5.90E+00	2.75E+00	-2.71E+00	4.53E+00	4.53E+00	1.07E-01	4.84E+00	4.09E+00	4.09E+00
Zn	10	9	2.36E+00	1.52E+01	7.92E-01	-3.37E+01	3.32E+00	3.32E+00	1.78E+00	1.02E+02	<MDC	6.25E+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]Average sample values with and without subtraction of the blank value; when blank subtraction is performed, it is only done when the blank value falls outside of the range (–MDC < blank < +MDC)

[6]N/A = Not Applicable

Table 3-1: Measured Concentration of Selected Inorganic Analytes in Drinking Water from 1998 to 2007 at Five Locations (C*ontinued)*

Double Eagle												
	1998-2005				2005				2007			
EL[1]	N[2]	N_{DET}[2]	Min[3]	Max[3]	MDC[4] (ug/L)	Blank Conc. (ug/L)	Avg Conc. w/Blank Subt[5] (ug/L)	Avg Conc. w/o Blank Subt[5] (ug/L)	MDC[4] (ug/L)	Blank Conc. (ug/L)	Avg Conc. w/Blank Subt[5] (ug/L)	Avg Conc. w/o Blank Subt[5] (ug/L)
Ag	8	1	3.62E-03	3.62E-03	2.30E-02	1.11E-01	<MDC	<MDC	N/A	N/A	N/A	N/A
Al	10	5	2.57E+00	7.22E+01	1.49E+01	-2.80E+01	<MDC	<MDC	2.34E+01	1.92E+02	<MDC	<MDC
As	10	10	4.26E+00	7.80E+00	2.01E+00	3.19E+01	7.80E+00	7.80E+00	7.12E-01	3.15E+00	7.14E+00	7.14E+00
B	1	1	7.00E+01	7.00E+01	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ba	9	9	7.93E+01	1.26E+02	1.24E-01	-5.63E+00	7.93E+01	7.93E+01	1.99E-01	-1.36E+00	8.54E+01	8.54E+01
Be	7	1	3.63E-02	3.63E-02	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ca	9	9	5.18E+03	5.83E+04	N/A	N/A	N/A	N/A	1.80E+03	1.43E+04	4.24E+04	5.67E+04
Cd	8	3	1.87E-02	1.85E-01	6.73E-02	1.91E+00	<MDC	<MDC	N/A	N/A	N/A	N/A
Ce	8	2	3.18E-03	3.63E-03	N/A	N/A	N/A	N/A	3.20E-02	-7.02E-01	<MDC	<MDC
Co	10	6	8.45E-02	1.12E+00	7.21E-01	8.25E-01	<MDC	<MDC	6.40E-02	-1.82E-01	8.45E-02	8.45E-02
Cr	10	10	1.22E+00	3.25E+01	7.82E+00	9.24E+01	3.25E+01	3.25E+01	2.87E-01	1.11E+00	2.10E+00	2.10E+00
Cu	10	10	8.09E-01	5.69E+00	8.98E-02	3.68E+01	3.26E+00	3.26E+00	1.17E+00	4.23E+01	3.56E+00	3.56E+00
Dy	10	0	N/A	N/A	2.79E-02	-1.77E-01	<MDC	<MDC	5.80E-02	1.49E-01	<MDC	<MDC
Er	10	0	N/A	N/A	1.21E-02	-5.61E-02	<MDC	<MDC	3.70E-02	1.33E-01	<MDC	<MDC
Eu	10	6	1.68E-02	2.86E-02	1.64E-02	-1.04E-01	<MDC	<MDC	9.30E-02	-7.61E-02	<MDC	<MDC
Fe	8	5	7.93E+01	9.32E+02	2.94E+02	3.66E+03	9.32E+02	9.32E+02	N/A	N/A	N/A	N/A
Ga	1	1	4.46E+00	4.46E+00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Gd	8	0	N/A	N/A	N/A	N/A	N/A	N/A	5.30E-02	6.00E-02	<MDC	<MDC
Hg	6	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
K	9	9	7.79E+02	2.94E+04	N/A	N/A	N/A	N/A	2.33E+01	2.26E+03	7.79E+02	3.04E+03
La	10	5	1.19E-02	6.26E-02	1.36E-02	1.00E-01	<MDC	<MDC	1.25E-01	2.07E-02	<MDC	<MDC
Li	7	7	1.29E+01	1.90E+01	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mg	9	9	1.09E+03	1.25E+04	5.97E+00	-8.94E+01	1.01E+04	1.01E+04	3.43E+02	-2.56E+02	1.25E+04	1.25E+04
Mn	10	10	1.91E-01	6.04E+00	1.60E+00	1.97E+01	5.89E+00	5.89E+00	1.64E-01	3.22E+00	1.91E-01	1.91E-01

Mo	8	8	1.48E+00	6.70E+00	1.35E+00	-3.05E+01	6.70E+00	6.70E+00	N/A	N/A	N/A	N/A
Na	9	9	3.84E+03	4.04E+04	N/A	N/A	N/A	N/A	8.01E+02	2.91E+02	4.02E+04	4.02E+04
Nd	10	1	5.37E-03	5.37E-03	1.65E-02	3.60E-01	<MDC	<MDC	8.80E-02	1.76E-01	<MDC	<MDC
Ni	10	10	8.00E-01	4.03E+00	1.74E+00	1.14E+01	4.03E+00	4.03E+00	1.14E+00	6.04E-01	1.24E+00	1.24E+00
P	1	0	N/A	N/A	2.27E+01	-2.59E+02	<MDC	<MDC	N/A	N/A	N/A	N/A
Pb	8	8	2.56E-01	7.70E+00	3.16E-02	-7.17E+00	7.70E+00	5.28E-01	N/A	N/A	N/A	N/A
Pr	10	1	9.05E-04	9.05E-04	1.29E-02	-1.81E-01	<MDC	<MDC	3.80E-02	6.63E-02	<MDC	<MDC
Rh	1	1	1.56E-02	1.56E-02	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sb	8	5	2.41E-02	1.39E-01	1.02E-01	1.96E-01	<MDC	<MDC	N/A	N/A	N/A	N/A
Sc	6	6	4.61E+00	9.08E+01	2.68E-01	-8.94E+01	9.08E+01	1.40E+00	N/A	N/A	N/A	N/A
Se	7	4	2.28E+00	3.53E+00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Si	3	3	1.53E+04	2.64E+04	7.32E+01	-1.01E+04	2.64E+04	1.64E+04	N/A	N/A	N/A	N/A
Sm	10	6	2.69E-02	4.26E-02	1.62E-02	-2.01E-01	<MDC	<MDC	5.30E-02	1.70E-02	<MDC	<MDC
Sn	4	2	9.41E-02	3.36E-01	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sr	10	10	5.06E+01	5.63E+02	2.51E-01	-1.19E-01	5.28E+02	5.28E+02	9.30E-01	9.59E-02	5.52E+02	5.52E+02
Th	8	3	4.32E-03	1.36E-02	1.49E-02	6.30E-03	<MDC	<MDC	N/A	N/A	N/A	N/A
Ti	4	3	2.62E+00	2.87E+00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Tl	7	2	2.73E-02	4.84E-02	1.07E-02	2.05E-02	<MDC	<MDC	N/A	N/A	N/A	N/A
U	10	10	1.34E+00	2.34E+00	7.76E-03	-9.50E-04	1.99E+00	1.99E+00	6.10E-02	1.09E-02	2.34E+00	2.34E+00
V	10	10	2.46E+01	3.26E+01	2.75E+00	-2.71E+00	3.01E+01	3.01E+01	1.07E-01	4.84E+00	2.46E+01	2.46E+01
Zn	10	8	1.80E+00	1.25E+01	7.92E-01	-3.37E+01	2.72E+00	2.72E+00	1.78E+00	1.02E+02	<MDC	4.99E+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]Average sample values with and without subtraction of the blank value; when blank subtraction is performed, it is only done when the blank value falls outside of the range (–MDC < blank < +MDC)

[6]N/A = Not Applicable

Table 3-1: Measured Concentration of Selected Inorganic Analytes in Drinking Water from 1998 to 2007 at Five Locations (C*ontinued)*

Hobbs												
	1998-2005				2005				2007			
EL[1]	N[2]	N_{DET}[2]	Min[3]	Max[3]	MDC[4] (ug/L)	Blank Conc. (ug/L)	Avg Conc. w/Blank Subt[5] (ug/L)	Avg Conc. w/o Blank Subt[5] (ug/L)	MDC[4] (ug/L)	Blank Conc. (ug/L)	Avg Conc. w/Blank Subt[5] (ug/L)	Avg Conc. w/o Blank Subt[5] (ug/L)
Ag	7	2	3.86E-03	1.04E-01	2.30E-02	1.11E-01	<MDC	<MDC	N/A	N/A	N/A	N/A
Al	8	5	3.03E+00	1.14E+02	1.49E+01	-2.80E+01	<MDC	<MDC	2.34E+01	1.92E+02	<MDC	<MDC
As	8	8	4.51E+00	7.37E+00	2.01E+00	3.19E+01	6.78E+00	6.78E+00	7.12E-01	3.15E+00	6.70E+00	6.70E+00
B	1	1	1.41E+02	1.41E+02	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ba	8	8	5.65E+01	6.52E+01	1.24E-01	-5.63E+00	6.06E+01	6.06E+01	1.99E-01	-1.36E+00	6.52E+01	6.52E+01
Be	6	1	5.39E-02	5.39E-02	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ca	7	7	8.09E+03	9.06E+04	N/A	N/A	N/A	N/A	1.80E+03	1.43E+04	8.63E+04	1.01E+05
Cd	7	1	1.57E-01	1.57E-01	6.73E-02	1.91E+00	<MDC	<MDC	N/A	N/A	N/A	N/A
Ce	7	4	5.10E-03	2.23E-02	N/A	N/A	N/A	N/A	3.20E-02	-7.02E-01	<MDC	<MDC
Co	8	6	9.78E-02	3.61E-01	7.21E-01	8.25E-01	<MDC	<MDC	6.40E-02	-1.82E-01	1.88E-01	1.88E-01
Cr	8	8	7.33E-01	1.13E+01	7.82E+00	9.24E+01	1.13E+01	1.13E+01	2.87E-01	1.11E+00	8.45E-01	8.45E-01
Cu	8	8	1.06E+00	6.93E+00	8.98E-02	3.68E+01	6.93E+00	6.93E+00	1.17E+00	4.23E+01	4.86E+00	4.86E+00
Dy	8	1	4.18E-03	4.18E-03	2.79E-02	-1.77E-01	<MDC	<MDC	5.80E-02	1.49E-01	<MDC	<MDC
Er	8	0	N/A	N/A	1.21E-02	-5.61E-02	<MDC	<MDC	3.70E-02	1.33E-01	<MDC	<MDC
Eu	8	5	1.31E-02	1.97E-02	1.64E-02	-1.04E-01	<MDC	<MDC	9.30E-02	-7.61E-02	<MDC	<MDC
Fe	6	4	3.64E+01	4.44E+02	2.94E+02	3.66E+03	4.44E+02	4.44E+02	N/A	N/A	N/A	N/A
Ga	1	1	2.56E+00	2.56E+00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Gd	7	0	N/A	N/A	N/A	N/A	N/A	N/A	5.30E-02	6.00E-02	<MDC	<MDC
Hg	5	2	1.06E-02	1.42E-02	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
K	7	7	4.12E+02	2.53E+04	N/A	N/A	N/A	N/A	2.33E+01	2.26E+03	4.12E+02	2.68E+03
La	8	4	1.51E-02	5.01E-02	1.36E-02	1.00E-01	<MDC	<MDC	1.25E-01	2.07E-02	<MDC	<MDC
Li	6	6	2.65E+01	3.18E+01	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mg	7	7	2.11E+03	2.51E+04	5.97E+00	-8.94E+01	2.08E+04	2.08E+04	3.43E+02	-2.56E+02	2.51E+04	2.51E+04
Mn	8	8	3.79E-01	2.67E+00	1.60E+00	1.97E+01	2.67E+00	2.67E+00	1.64E-01	3.22E+00	1.78E+00	1.78E+00

Mo	7	7	2.60E+00	3.31E+00	1.35E+00	-3.05E+01	3.31E+00	3.31E+00	N/A	N/A	N/A	N/A
Na	7	7	4.97E+03	5.46E+04	N/A	N/A	N/A	N/A	8.01E+02	2.91E+02	5.46E+04	5.46E+04
Nd	8	3	3.01E-03	1.28E-02	1.65E-02	3.60E-01	<MDC	<MDC	8.80E-02	1.76E-01	<MDC	<MDC
Ni	8	8	1.08E+00	2.77E+00	1.74E+00	1.14E+01	2.01E+00	2.01E+00	1.14E+00	6.04E-01	2.46E+00	2.46E+00
P	1	0	N/A	N/A	2.27E+01	-2.59E+02	<MDC	<MDC	N/A	N/A	N/A	N/A
Pb	7	7	9.44E-02	7.72E+00	3.16E-02	-7.17E+00	7.72E+00	5.50E-01	N/A	N/A	N/A	N/A
Pr	8	1	1.57E-03	1.57E-03	1.29E-02	-1.81E-01	<MDC	<MDC	3.80E-02	6.63E-02	<MDC	<MDC
Rh	1	1	2.52E-02	2.52E-02	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sb	6	5	3.88E-02	7.02E-02	1.02E-01	1.96E-01	<MDC	<MDC	N/A	N/A	N/A	N/A
Sc	5	5	7.17E+00	9.25E+01	2.68E-01	-8.94E+01	9.25E+01	3.06E+00	N/A	N/A	N/A	N/A
Se	5	3	3.50E+00	6.23E+00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Si	3	3	2.54E+04	3.59E+04	7.32E+01	-1.01E+04	3.59E+04	2.58E+04	N/A	N/A	N/A	N/A
Sm	8	6	1.93E-02	3.27E-02	1.62E-02	-2.01E-01	<MDC	<MDC	5.30E-02	1.70E-02	<MDC	<MDC
Sn	3	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sr	8	8	7.89E+01	1.06E+03	2.51E-01	-1.19E-01	9.92E+02	9.92E+02	9.30E-01	9.59E-02	1.06E+03	1.06E+03
Th	7	2	4.54E-03	4.56E-03	1.49E-02	6.30E-03	<MDC	<MDC	N/A	N/A	N/A	N/A
Ti	3	3	3.14E+00	7.47E+00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Tl	5	2	2.24E-02	2.31E-02	1.07E-02	2.05E-02	<MDC	<MDC	N/A	N/A	N/A	N/A
U	8	8	2.90E+00	3.77E+00	7.76E-03	-9.50E-04	3.43E+00	3.43E+00	6.10E-02	1.09E-02	3.77E+00	3.77E+00
V	8	8	3.23E+01	3.71E+01	2.75E+00	-2.71E+00	3.30E+01	3.30E+01	1.07E-01	4.84E+00	3.23E+01	3.23E+01
Zn	8	7	1.47E+00	4.37E+00	7.92E-01	-3.37E+01	2.31E+00	2.31E+00	1.78E+00	1.02E+02	<MDC	3.60E+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]Average sample values with and without subtraction of the blank value; when blank subtraction is performed, it is only done when the blank value falls outside of the range (–MDC < blank < +MDC)

[6]N/A = Not Applicable

Table 3-1: Measured Concentration of Selected Inorganic Analytes in Drinking Water from 1998 to 2007 at Five Locations (C*ontinued)*

Loving												
	1998-2005				2005				2007			
EL[1]	N[2]	N_{DET}[2]	Min[3]	Max[3]	MDC[4] (ug/L)	Blank Conc. (ug/L)	Avg Conc. w/Blank Subt[5] (ug/L)	Avg Conc. w/o Blank Subt[5] (ug/L)	MDC[4] (ug/L)	Blank Conc. (ug/L)	Avg Conc. w/Blank Subt[5] (ug/L)	Avg Conc. w/o Blank Subt[5] (ug/L)
Ag	9	3	2.55E-03	1.30E-01	2.30E-02	1.11E-01	<MDC	<MDC	N/A	N/A	N/A	N/A
Al	9	3	3.76E+00	5.19E+01	1.49E+01	-2.80E+01	<MDC	<MDC	2.34E+01	1.92E+02	4.42E+01	4.42E+01
As	9	7	1.20E+00	2.16E+00	2.01E+00	3.19E+01	2.16E+00	2.16E+00	7.12E-01	3.15E+00	1.70E+00	1.70E+00
B	1	1	7.55E+01	7.55E+01	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ba	9	9	2.86E+01	3.37E+01	1.24E-01	-5.63E+00	3.06E+01	3.06E+01	1.99E-01	-1.36E+00	3.37E+01	3.37E+01
Be	6	1	9.35E-02	9.35E-02	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ca	7	7	9.14E+03	1.04E+05	N/A	N/A	N/A	N/A	1.80E+03	1.43E+04	7.54E+04	8.98E+04
Cd	8	0	N/A	N/A	6.73E-02	1.91E+00	<MDC	<MDC	N/A	N/A	N/A	N/A
Ce	7	1	9.74E-04	9.74E-04	N/A	N/A	N/A	N/A	3.20E-02	-7.02E-01	<MDC	<MDC
Co	9	6	1.02E-01	4.04E-01	7.21E-01	8.25E-01	<MDC	<MDC	6.40E-02	-1.82E-01	1.33E-01	1.33E-01
Cr	9	7	1.21E+00	7.44E+00	7.82E+00	9.24E+01	<MDC	<MDC	2.87E-01	1.11E+00	4.24E+00	4.24E+00
Cu	9	8	1.71E+00	5.59E+00	8.98E-02	3.68E+01	1.71E+00	1.71E+00	1.17E+00	4.23E+01	<MDC	<MDC
Dy	9	0	N/A	N/A	2.79E-02	-1.77E-01	<MDC	<MDC	5.80E-02	1.49E-01	<MDC	<MDC
Er	9	0	N/A	N/A	1.21E-02	-5.61E-02	<MDC	<MDC	3.70E-02	1.33E-01	<MDC	<MDC
Eu	9	5	7.00E-03	1.01E-02	1.64E-02	-1.04E-01	<MDC	<MDC	9.30E-02	-7.61E-02	<MDC	<MDC
Fe	8	3	1.56E+01	2.24E+02	2.94E+02	3.66E+03	<MDC	<MDC	N/A	N/A	N/A	N/A
Ga	1	1	1.26E+00	1.26E+00	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Gd	7	2	2.15E-03	2.26E-03	N/A	N/A	N/A	N/A	5.30E-02	6.00E-02	<MDC	<MDC
Hg	4	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
K	7	6	1.85E+03	1.98E+04	N/A	N/A	N/A	N/A	2.33E+01	2.26E+03	<MDC	2.04E+03
La	9	4	7.27E-03	2.22E-02	1.36E-02	1.00E-01	<MDC	<MDC	1.25E-01	2.07E-02	<MDC	<MDC
Li	6	6	1.66E+01	1.96E+01	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mg	8	8	4.04E+03	4.02E+04	5.97E+00	-8.94E+01	3.53E+04	3.53E+04	3.43E+02	-2.56E+02	3.99E+04	3.99E+04
Mn	9	7	1.43E-02	1.77E+00	1.60E+00	1.97E+01	1.77E+00	1.77E+00	1.64E-01	3.22E+00	5.48E-01	5.48E-01

Mo	8	6	1.41E+00	1.81E+00	1.35E+00	-3.05E+01	<MDC	<MDC	N/A	N/A	N/A	N/A
Na	7	7	2.33E+03	2.73E+04	N/A	N/A	N/A	N/A	8.01E+02	2.91E+02	2.73E+04	2.73E+04
Nd	9	1	3.37E-03	3.37E-03	1.65E-02	3.60E-01	<MDC	<MDC	8.80E-02	1.76E-01	<MDC	<MDC
Ni	9	7	1.19E+00	3.43E+00	1.74E+00	1.14E+01	<MDC	<MDC	1.14E+00	6.04E-01	2.15E+00	2.15E+00
P	2	0	N/A	N/A	2.27E+01	-2.59E+02	<MDC	<MDC	N/A	N/A	N/A	N/A
Pb	8	8	6.33E-01	7.34E+00	3.16E-02	-7.17E+00	7.34E+00	1.71E-01	N/A	N/A	N/A	N/A
Pr	8	0	N/A	N/A	1.29E-02	-1.81E-01	<MDC	<MDC	3.80E-02	6.63E-02	<MDC	<MDC
Rh	1	1	3.07E-02	3.07E-02	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sb	7	4	3.51E-02	1.84E-01	1.02E-01	1.96E-01	<MDC	<MDC	N/A	N/A	N/A	N/A
Sc	6	6	3.22E+00	8.97E+01	2.68E-01	-8.94E+01	8.96E+01	<MDC	N/A	N/A	N/A	N/A
Se	5	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Si	4	4	8.54E+03	2.01E+04	7.32E+01	-1.01E+04	1.99E+04	9.85E+03	N/A	N/A	N/A	N/A
Sm	9	3	8.43E-03	1.30E-02	1.62E-02	-2.01E-01	<MDC	<MDC	5.30E-02	1.70E-02	<MDC	<MDC
Sn	4	1	4.45E-01	4.45E-01	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sr	9	9	7.60E+01	9.37E+02	2.51E-01	-1.19E-01	8.07E+02	8.07E+02	9.30E-01	9.59E-02	7.67E+02	7.67E+02
Th	8	2	5.69E-03	9.63E-03	1.49E-02	6.30E-03	<MDC	<MDC	N/A	N/A	N/A	N/A
Ti	3	3	2.68E+00	1.04E+01	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Tl	7	1	4.32E-02	4.32E-02	1.07E-02	2.05E-02	<MDC	<MDC	N/A	N/A	N/A	N/A
U	9	9	1.98E+00	2.26E+00	7.76E-03	-9.50E-04	2.10E+00	2.10E+00	6.10E-02	1.09E-02	2.13E+00	2.13E+00
V	9	9	1.19E+01	1.44E+01	2.75E+00	-2.71E+00	1.21E+01	1.21E+01	1.07E-01	4.84E+00	1.22E+01	1.22E+01
Zn	9	8	4.13E+00	2.09E+01	7.92E-01	-3.37E+01	2.01E+01	2.01E+01	1.78E+00	1.02E+02	<MDC	1.21E+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]Average sample values with and without subtraction of the blank value; when blank subtraction is performed, it is only done when the blank value falls outside of the range (–MDC < blank < +MDC)

[6]N/A = Not Applicable

Table 3-1: Measured Concentration of Selected Inorganic Analytes in Drinking Water from 1998 to 2007 at Five Locations (C*ontinued)*

Otis												
	1998-2005				2005				2007			
EL[1]	N[2]	N_{DET}[2]	Min[3]	Max[3]	MDC[4] (ug/L)	Blank Conc. (ug/L)	Avg Conc. w/Blank Subt[5] (ug/L)	Avg Conc. w/o Blank Subt[5] (ug/L)	MDC[4] (ug/L)	Blank Conc. (ug/L)	Avg Conc. w/Blank Subt[5] (ug/L)	Avg Conc. w/o Blank Subt[5] (ug/L)
Ag	7	1	2.63E-02	2.63E-02	2.30E-02	1.11E-01	<MDC	<MDC	N/A	N/A	N/A	N/A
Al	8	1	5.74E+00	5.74E+00	1.49E+01	-2.80E+01	<MDC	<MDC	2.34E+01	1.92E+02	<MDC	<MDC
As	9	5	6.53E-01	2.34E+00	2.01E+00	3.19E+01	<MDC	<MDC	7.12E-01	3.15E+00	2.34E+00	2.34E+00
B	2	2	1.46E+02	1.52E+02	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ba	9	9	1.35E+01	1.75E+01	1.24E-01	-5.63E+00	1.44E+01	1.44E+01	1.99E-01	-1.36E+00	1.60E+01	1.60E+01
Be	6	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Ca	8	8	2.14E+05	3.83E+05	N/A	N/A	N/A	N/A	1.80E+04	1.43E+04	2.67E+05	2.82E+05
Cd	7	0	N/A	N/A	6.73E-02	1.91E+00	<MDC	<MDC	N/A	N/A	N/A	N/A
Ce	6	0	N/A	N/A	N/A	N/A	N/A	N/A	3.20E-02	-7.02E-01	<MDC	<MDC
Co	8	7	1.19E-01	9.51E-01	7.21E-01	8.25E-01	<MDC	<MDC	6.40E-02	-1.82E-01	4.14E-01	4.14E-01
Cr	9	8	8.76E-01	6.67E+00	7.82E+00	9.24E+01	<MDC	<MDC	2.87E-01	1.11E+00	8.76E-01	8.76E-01
Cu	9	8	2.43E+00	6.02E+00	8.98E-02	3.68E+01	2.43E+00	2.43E+00	1.17E+00	4.23E+01	3.00E+00	3.00E+00
Dy	8	1	3.39E-03	3.39E-03	2.79E-02	-1.77E-01	<MDC	<MDC	5.80E-02	1.49E-01	<MDC	<MDC
Er	8	0	N/A	N/A	1.21E-02	-5.61E-02	<MDC	<MDC	3.70E-02	1.33E-01	<MDC	<MDC
Eu	8	3	3.42E-03	9.48E-03	1.64E-02	-1.04E-01	<MDC	<MDC	9.30E-02	-7.61E-02	<MDC	<MDC
Fe	8	8	2.87E+00	8.53E+02	2.94E+02	3.66E+03	4.60E+02	4.60E+02	N/A	N/A	N/A	N/A
Ga	1	1	6.54E-01	6.54E-01	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Gd	6	0	N/A	N/A	N/A	N/A	N/A	N/A	5.30E-02	6.00E-02	<MDC	<MDC
Hg	6	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
K	8	8	6.81E+02	4.01E+03	N/A	N/A	N/A	N/A	2.33E+01	2.26E+03	6.81E+02	2.94E+03
La	8	2	3.97E-03	6.30E-03	1.36E-02	1.00E-01	<MDC	<MDC	1.25E-01	2.07E-02	<MDC	<MDC
Li	6	6	4.11E+01	4.85E+01	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mg	8	8	5.16E+04	1.08E+05	5.97E+00	-8.94E+01	5.16E+04	5.16E+04	3.43E+02	-2.56E+02	7.77E+04	7.77E+04
Mn	8	6	1.78E-01	2.32E+00	1.60E+00	1.97E+01	<MDC	<MDC	1.64E-01	3.22E+00	<MDC	<MDC

Mo	7	7	2.39E+00	3.13E+00	1.35E+00	-3.05E+01	3.13E+00	3.13E+00	N/A	N/A	N/A	N/A
Na	8	8	7.83E+04	1.62E+05	N/A	N/A	N/A	N/A	8.01E+02	2.91E+02	1.02E+05	1.02E+05
Nd	8	3	4.80E-03	3.97E-02	1.65E-02	3.60E-01	<MDC	<MDC	8.80E-02	1.76E-01	<MDC	<MDC
Ni	8	8	2.45E+00	1.06E+01	1.74E+00	1.14E+01	2.62E+00	2.62E+00	1.14E+00	6.04E-01	5.91E+00	5.91E+00
P	1	1	4.54E+01	4.54E+01	2.27E+01	-2.59E+02	4.54E+01	4.54E+01	N/A	N/A	N/A	N/A
Pb	7	7	1.08E-01	7.20E+00	3.16E-02	-7.17E+00	7.20E+00	<MDC	N/A	N/A	N/A	N/A
Pr	8	0	N/A	N/A	1.29E-02	-1.81E-01	<MDC	<MDC	3.80E-02	6.63E-02	<MDC	<MDC
Rh	1	1	1.29E-01	1.29E-01	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sb	7	5	3.50E-02	4.10E-01	1.02E-01	1.96E-01	<MDC	<MDC	N/A	N/A	N/A	N/A
Sc	6	6	3.53E+00	8.95E+01	2.68E-01	-8.94E+01	8.95E+01	<MDC	N/A	N/A	N/A	N/A
Se	7	0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Si	4	4	9.77E+03	1.99E+04	7.32E+01	-1.01E+04	1.99E+04	9.83E+03	N/A	N/A	N/A	N/A
Sm	8	1	3.56E-03	3.56E-03	1.62E-02	-2.01E-01	<MDC	<MDC	5.30E-02	1.70E-02	<MDC	<MDC
Sn	4	1	9.71E-02	9.71E-02	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sr	9	9	2.38E+03	3.61E+03	2.51E-01	-1.19E-01	2.41E+03	2.41E+03	9.30E+00	9.59E-02	2.81E+03	2.81E+03
Th	7	2	3.44E-03	2.67E-02	1.49E-02	6.30E-03	<MDC	<MDC	N/A	N/A	N/A	N/A
Ti	4	4	5.68E+00	3.79E+01	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Tl	6	0	N/A	N/A	1.07E-02	2.05E-02	<MDC	<MDC	N/A	N/A	N/A	N/A
U	8	8	3.73E+00	5.34E+00	7.76E-03	-9.50E-04	3.73E+00	3.73E+00	6.10E-02	1.09E-02	4.42E+00	4.42E+00
V	9	9	1.05E+01	1.29E+01	2.75E+00	-2.71E+00	1.05E+01	1.05E+01	1.07E-01	4.84E+00	1.08E+01	1.08E+01
Zn	9	8	1.54E+00	1.64E+01	7.92E-01	-3.37E+01	1.54E+00	1.54E+00	1.78E+00	1.02E+02	<MDC	3.21E+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]Average sample values with and without subtraction of the blank value; when blank subtraction is performed, it is only done when the blank value falls outside of the range (–MDC < blank < +MDC)

[6]N/A = Not Applicable

CHAPTER 4

Occurrence of Radionuclides in Residents of the Carlsbad, New Mexico Area

INTRODUCTION

Citizen volunteers from the Carlsbad, New Mexico area were monitored for internally deposited radionuclides through a project entitled "Lie Down and Be Counted" (LDBC). This project is provided 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 WIPP. The data collected prior to the opening of the WIPP facility (26 March 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. It is important to note that these data represent an interim summary (through 31 December 2007) of an ongoing study.

Participating in the LDBC consists of having a lung and whole body count. Volunteers are recruited through presentations to local community groups and businesses. The entire measurement process takes approximately one hour. 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 are available on the CEMRC website (http://www.cemrc.org).

BIOASSAY RESULTS

As of 31 December 2007, 810 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 constitutes 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 EM. Recounts began in July 1999, and 254 recount bioassays had been performed through 31 December 2007. In addition, 239 new volunteers have participated in the program since 1 October 2002.

While not part of the LDBC program, CEMRC has also counted over 3,000 rad-trained workers in the region from WIPP, WCS, and NEF.

Demographic characteristics (Table 4-1) of the current LDBC cohort are statistically[2] unchanged from those reported in previous CEMRC reports, and are generally consistent with those

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

[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.

reported in the 2000 census for citizens living in Carlsbad. The largest deviation between the LDBC cohort and 2000 census is under-sampling of Hispanics. In addition, it is important to note that if the presence of a radionuclide is dependent on a subclass of interest (gender, ethnicity, etc.), valid population estimates can still be made by correcting for the proportion of under- or over-sampling for the particular subclass.

Baseline monitoring includes only the initial count of individuals made prior to 26 March 1999. Seven people were recounted during the baseline interval but these data are not reported in order to remain consistent with previous reports. Operational monitoring includes the counting of new individuals and the recounting of previously measured participants. Based on the data reported herein, there is no evidence of an increase in the frequency of detection of internally deposited radionuclides for citizens living within the vicinity of the WIPP since the WIPP began receipt of 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 exceeds background, and the use of this criterion will result in a statistically inherent 5% false-positive error rate per pair-wise comparison (5% of all measurements will be determined to be positive when there is no activity present in the person). The radionuclides being investigated and their minimum detectable activities are listed in Table 4-2 for 2006/2007 and 2007/2008. For the baseline measurements (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 (Table 4-2). As discussed in detail in the 1998 report, five of these [^{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 (Table 4-3, N = 690), the percentage of results greater than L_C were consistent with baseline at a 95% confidence level (margin of error), except for ^{60}Co and ^{232}Th (via ^{228}Ac). For these radionuclides, the percentage of results greater than L_C decreased relative to the baseline. This would be expected for ^{60}Co, since the radionuclide has a relatively short half life (5.2 years), and the content within the shield has decreased via decay by approximately 59% since the baseline phase of monitoring. 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 2007 and ranged from 792 to 5558 Bq per person with an overall mean (± SE) of 2526 (± 26) Bq per person. Such results are expected since K is an essential biological element contained primarily in muscle,

and a theoretical constant fraction of all naturally occurring K is the radioactive isotope ^{40}K. The mean ^{40}K value for males (± SE), was 3104 (± 30) Bq per person, which was significantly greater ($p < 0.0001$) than that of females, which was 1900 (± 22) 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 23 ± 3% (95% confidence level, baseline and operational monitoring counts) of citizens living in the Carlsbad area. These results are consistent 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 mean (± SE) of 10.6 (± 0.6) Bq per person. The mean ^{137}Cs body burden for males (± SE), was 11.5 (± 0.8) Bq per person, which was significantly greater ($p = 0.002$) than that of females, which was 8.7 (± 0.3) Bq per person. As previously reported (CEMRC Reports; Webb and Kirchner, 2000) the presence of ^{137}Cs was independent of ethnicity, age, radiation work history, consumption of wild game, nuclear medical treatments and European travel. However, the occurrence of detectable ^{137}Cs was associated with gender where males had higher prevalence of ^{137}Cs relative to females. Furthermore, the presence of ^{137}Cs was associated with smoking. Smokers had a higher prevalence of detectable ^{137}Cs (29.7 %) as compared to non-smokers (24.1 %). It is likely that the association with gender is related to the tendency for larger muscle mass in males than in females, as supported by the ^{40}K results. The association of ^{137}Cs with smoking could be related to the presence of fallout ^{137}Cs in tobacco, decreased pulmonary clearing capability in smokers, or other as yet unidentified factors.

These results, particularly the absence of detectable levels of plutonium, suggest that there have been no significant releases from WIPP.

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 the signal is the result of ^{226}Ra because the natural abundance of ^{226}Ra is much greater than that of ^{235}U.

Table 4-1: Demographic Characteristics of the "Lie Down and Be Counted" Population Sample through December 31, 2007

Characteristic		2006 Sample Group	[b]Census, 2000
Gender	Male	49.9% (46.9 to 53.8%)	48.2 %
	Female	49.6% (46.2 to 53.1%)	51.8 %
Ethnicity	Hispanic	15.2% (12.7 to 17.7%)	36.7 %
	Non-hispanic	83.7% (82.3 to 87.3%)	63.3 %
Age 60 or older		26.6% (24.0 to 29.2%)	24.5 %
Currently or previously classified as a radiation worker		7.7% (6.1 to 9.3%)	[c]NA
Consumption of wild game within 3 months prior to count		21.5% (19.1 to 24.0%)	NA
Medical treatment other than x-rays using radionuclides		7.7% (6.1 to 9.3%)	NA
European travel within 2 years prior to the count		5.4% (4.1 to 6.8%)	NA
Current smoker		13.4% (11.4 to 15.5%)	NA

[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://quickfacts.census.gov. United States Department of Commerce, Economics and Statistics Administration, Bureau of the Census.
[c] NA = not available

Table 4-2: Minimum Detectable Activities

2006-2007 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	0.29	0.33	0.44	0.60	0.81
Ce-144	133.50	0.47	0.56	0.69	0.76	0.95	1.23	1.57
Cf-252	19.20	16.41	32.73	78.83	112.79	290.17	808.62	2199.46
Cm-244	18.10	15.35	32.95	87.42	129.26	368.87	1145.73	3476.70
Eu-155	105.30	0.28	0.34	0.43	0.47	0.61	0.80	1.06
Np-237	86.50	0.50	0.61	0.78	0.86	1.13	1.52	2.02
Pu-238	17.10	16.38	38.20	112.73	174.23	555.50	1952.28	6685.42
Pu-239	17.10	40.75	95.05	280.49	433.48	1382.11	4857.35	16633.59
Pu-240	17.10	16.01	37.34	110.19	170.30	542.97	1908.24	6534.63
Pu-242	17.10	19.31	45.05	132.93	205.44	655.02	2302.01	7883.04
Ra-226	186.10	1.68	1.95	2.35	2.54	3.11	3.88	4.82
Th-232 Via Pb-212	238.60	0.16	0.18	0.22	0.24	0.30	0.37	0.46
Th-232							111.39	151.30
Th-232 via Th-228)							15.46	20.59
U-233	440.30	0.66	0.76	0.91	0.98	1.19	1.48	1.81
U-235	185.70	0.10	0.12	0.15	0.16	0.19	0.24	0.30
Nat U via Th-234	63.30	1.59	2.13	2.54	2.83	3.76	5.12	6.92

Radionuclide	Energy (keV)	MDA (nCi)
Ba-133	356	0.76
Ba-140	537	1.45
Ce-141	145	1.70
Co-58	811	0.34
Co-60	1333	0.37
Cr-51	320	4.34
Cs-134	604	0.33
Cs-137	662	0.43

Radionuclides Deposited in the Whole Body

Eu-152	344	1.52
Eu-154	1275	0.92
Eu-155	105	4.00
Fe-59	1099	0.63
I-131	365	0.46
I-133	530	0.41
Ir-192	317	0.56
Mn-54	835	0.45
Ru-103	497	0.38
Ru-106	622	3.19
Sb-125	428	1.29
Th-232 via Ac-228	911	1.15
Y-88	898	0.35
Zn-65	1116	1.08
Zr-95	757	0.57

Table 4-2: Minimum Detectable Activities

(Continued)

2007-2008 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	0.16	0.21	0.29	0.32	0.45	0.64	0.90
CE-144	133.50	0.47	0.55	0.70	0.78	1.01	1.34	1.76
CF-252	19.20	18.63	33.57	76.77	107.19	261.50	686.54	1761.58
CM-244	18.10	16.37	32.80	83.42	121.22	330.83	982.02	2831.38
EU-155	105.30	0.26	0.33	0.44	0.49	0.66	0.91	1.25
NP-237	86.50	0.44	0.58	0.78	0.88	1.22	1.73	2.42
Pu-238	17.10	16.27	37.02	106.40	162.23	502.57	1706.71	5650.94
Pu-239	17.10	40.48	92.12	264.73	403.64	1250.42	4246.37	14059.75
Pu-240	17.10	15.90	36.19	104.00	158.57	491.24	1668.22	5523.47
Pu-242	17.10	19.18	43.66	125.46	191.29	592.60	2012.45	6663.24
Ra-226	186.10	1.75	1.94	2.37	2.57	3.20	4.04	5.08
Th-232 Via Pb-212	238.60	0.15	0.18	0.22	0.24	0.31	0.40	0.51
Th-232	59.00	32.50	42.46	57.54	65.08	90.16	128.42	181.56
Th-232 via Th-228)	84.30	4.57	6.01	8.07	9.15	12.66	17.97	25.32
U-233	440.30	0.61	0.72	0.89	0.97	1.21	1.55	1.96
U-235	185.70	0.11	0.12	0.15	0.16	0.20	0.25	0.31
Nat U via Th-234	63.30	1.45	1.92	2.59	2.94	4.08	5.81	8.23

Radionuclides Deposited in the Whole Body

Radionuclide	Energy (keV)	MDA (nCi)
Ba-133	356	0.75
Ba-140	537	1.46
Ce-141	145	1.67
Co-58	811	0.34
Co-60	1333	0.35
Cr-51	320	4.28
Cs-134	604	0.32
Cs-137	662	0.42
Eu-152	344	1.51
Eu-154	1275	0.90
Eu-155	105	4.06
Fe-59	1099	0.64
I-131	365	0.45
I-133	530	0.41
Ir-192	317	0.56
Mn-54	835	0.43
Ru-103	497	0.36
Ru-106	622	3.16
Sb-125	428	1.30
Th-232 via Ac-228	911	1.16
Y-88	898	0.37
Zn-65	1116	1.06
Zr-95	757	0.56

Table 4-3: "Lie Down and Be Counted" Results through December 31, 2007

Radionuclide	*In Vivo* Count Type	Baseline Counts [c](margin of error) (data prior to 27 March 1999) [a]N = 366	Operational Monitoring Counts (margin of error) (27 March 1999 – 31 December 2007) N = 690
		% of Results ≥ [b]L_C	% of Results ≥ L_C
^{241}Am	Lung	5.2 (4.0 to 6.4)	3.9 (3.2 to 4.6)
^{144}Ce	Lung	4.6 (3.5 to 5.7)	3.5 (2.8 to 4.2)
^{252}Cf	Lung	4.1 (3.1 to 5.1)	5.8 (5.0 to 6.7)
^{244}Cm	Lung	5.7 (4.5 to 7.0)	4.7 (3.9 to 5.5)
^{155}Eu	Lung	7.1 (5.8 to 8.4)	4.9 (4.1 to 5.7)
^{237}Np	Lung	3.6 (2.6 to 4.5)	4.0 (3.3 to 4.8)
^{210}Pb	Lung	4.4 (3.3 to 5.4)	5.9 (5.0 to 6.7)
Plutonium Isotope	Lung	5.7 (4.5 to 7.0)	5.6 (4.7 to 6.4)
[d] ^{232}Th via ^{212}Pb	Lung	34.2 (31.7 to 36.6)	33.8 (32.0 to 35.5)
^{232}Th	Lung	4.9 (3.8 to 6.0)	5.3 (4.5 to 6.1)
^{232}Th via ^{228}Th	Lung	4.1 (3.1 to 5.1)	5.0 (4.2 to 5.8)
^{233}U	Lung	5.7 (4.5 to 7.0)	9.5 (8.4 to 10.5)
^{235}U/^{226}Ra	Lung	10.7 (9.0 to 12.3)	11.3 (10.1 to 12.4)
Natural Uranium via ^{234}Th	Lung	5.2 (4.0 to 6.4)	6.3 (5.4 to 7.2)
^{133}Ba	Whole Body	3.6 (2.6 to 4.5)	2.9 (2.3 to 3.6)
^{140}Ba	Whole Body	5.2 (4.0 to 6.4)	3.9 (3.2 to 4.6)
^{141}Ce	Whole Body	3.6 (2.6 to 4.5)	4.7 (3.9 to 5.5)
^{58}Co	Whole Body	4.4 (3.3 to 5.4)	2.4 (1.8 to 2.9)
[d] ^{60}Co	Whole Body	54.6 (52.0 to 57.2)	28.3 (26.6 to 30.0)
^{51}Cr	Whole Body	5.7 (4.5 to 7.0)	4.0 (3.3 to 4.8)
^{134}Cs	Whole Body	1.6 (1.0 to 2.3)	2.5 (1.9 to 3.1)
^{137}Cs	Whole Body	28.4 (26.1 to 30.8)	21.4 (19.9 to 23.0)
^{152}Eu	Whole Body	7.4 (6.0 to 8.7)	6.3 (5.4 to 7.2)
^{154}Eu	Whole Body	3.8 (2.8 to 4.8)	2.6 (2.0 to 3.2)
^{155}Eu	Whole Body	3.8 (2.8 to 4.8)	3.6 (2.9 to 4.3)
^{59}Fe	Whole Body	3.8 (2.8 to 4.8)	6.0 (5.1 to 6.9)
^{131}I	Whole Body	5.2 (4.0 to 6.4)	4.0 (3.3 to 4.8)
^{133}I	Whole Body	3.3 (2.3 to 4.2)	3.9 (3.2 to 4.6)
^{193}Ir	Whole Body	4.1 (3.1 to 5.1)	4.1 (3.3 to 4.8)
^{40}K	Whole Body	100.0 (100.0 to 100.0)	100.0 (100.0 to 100.0)
[d] ^{54}Mn	Whole Body	12.3 (10.6 to 14.0)	11.8 (10.6 to 13.0)
^{103}Ru	Whole Body	2.2 (1.4 to 3.0)	1.5 (1.1 to 2.0)
^{106}Ru	Whole Body	4.4 (3.3 to 5.4)	3.8 (3.1 to 4.5)
^{125}Sb	Whole Body	5.2 (4.0 to 6.4)	3.6 (2.9 to 4.3)
^{232}Th via ^{228}Ac	Whole Body	34.7 (32.2 to 37.2)	25.7 (24.1 to 27.3)
^{88}Y	Whole Body	7.7 (6.3 to 9.0)	6.3 (5.4 to 7.2)
^{95}Zr	Whole Body	6.6 (5.3 to 7.9)	4.0 (3.3 to 4.8)

[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

CHAPTER 5

Analysis of Volatile Organic Compounds

INTRODUCTION

The WIPP Hazardous Waste Facility Permit, Attachment N, issued by the New Mexico Environment Department under the Resource Conservation and Recovery Act (RCRA), mandates the monitoring of nine volatile organic compounds (VOCs) in the ambient air in the WIPP underground to assure that their respective concentrations of concern are not exceeded. Compounds consistently detected in ambient air samples in the underground may be added to the list of compounds of interest. Trichloroethylene was added to the analyte list beginning with batch 112907_001. The current list of analytes is presented in Table 5-1.

Monitoring is conducted in accordance with the "*Volatile Organic Compound Confirmatory Monitoring Plan"*, prepared by the WIPP management and operations contractor, Washington TRU Solutions (WTS). Ambient air samples are collected in six liter Summa or equivalent canisters by Washington Regulatory and Environmental Services (WRES) personnel and delivered for analysis to CEMRC in weekly batches.

CEMRC first began analysis of samples for the Confirmatory VOCs Monitoring Plan in April 2004, using analysts from the Environmental Chemistry (EC) Group. The program was established and successfully audited by the WTS QA group prior to acceptance of actual samples and is audited at yearly since 2004. At that time, 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. In addition, CEMRC purchased an Entech 3100 Canister Cleaning System for cleaning and evacuation of canisters after analysis.

VOCs PROJECT EXPANSION

The original VOCs laboratory was set up in a small 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 required under the WIPP Permit, Attachment B. In preparation for this expansion of scope, CEMRC purchased a HSG analysis system consisting of a 6890/5973N Agilent GC/MS with a loop injection system and three Entech 7032 Autosamplers installed in series was purchased from Entech Instruments, Inc. 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 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. Due to the need to maximize efficiency, an Entech 7016 canister autosampler was obtained in June 2005. This autosampler allows for up to sixteen samples to be run in sequence with minimal operator supervision.

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. A backup autosampler for HSG analysis was also purchased by CEMRC. Shortly thereafter a new Agilent 6890/5975 GC/MS was obtained with a portion of the lab setup funding to be used as a backup analysis system for the Confirmatory VOCs Monitoring.

The Volatile Organic Compound 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, CEMRC analyzed a total of 749 samples for VOCs and 182 samples for hydrogen and methane.

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 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 in the lower 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 flowing the sample through three consecutive cryogenic traps at different controlled temperatures. This results in very low detection limits not obtainable without cryogenic preconcentration.

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

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

Special quality assurance requirements for these activities were detailed in the "*Quality Assurance Project Plan for Volatile Organic Compound Monitoring*", prepared by WTS. 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 5-2 for a list of CEMRC Procedures for Confirmatory Monitoring.

In November, 2006, a WIPP permit modification incorporated an expansion of sampling in the Volatile Organic Compounds Monitoring Program. Originally, the samples were collected from only two stations in the WIPP underground (VOC-A and VOC-B). The permit change requires sampling from closed rooms within the current panel until the entire panel is full. Therefore, Attachment N now refers to both Repository VOCs Monitoring and Disposal Room Monitoring. The required detection limits for different types of samples are summarized in Table 5-1.

METHODS FOR HYDROGEN AND METHANE ANALYSIS

The analysis of hydrogen and methane in closed room samples began with batch 082707_001. Under the analysis scheme used at CEMRC, sample canisters would be pressurized to twice atmospheric 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 GC/Thermal Conductivity Detector (TCD) and screened for VOCs by GCMS. The sampling system incorporates three autosamplers in series to allow for the analysis of two complete batches of six 6L samples per run. Samples

from the autosamplers 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.

RESULTS AND DISCUSSION

The OC laboratory analyzed 701 routine ambient air samples for VOCs during 2007. Sets of blank and recovery gas samples collected by Shaw Environmental as part of the sampler cleaning and certification were analyzed in expedited turnaround batches at various times throughout the years, resulting in analysis of 48 additional samples.

Batch reports for VOCs results are submitted in hardcopy in the EPA Contract Laboratory Program format. An electronic report in the client's specified format is also provided for each batch.

Hardcopy and electronic reports for hydrogen and methane analyses are submitted in the formats specified by the client.

Copies of batch reports and all QA records associated with these analyses are maintained according to the CEMRC records management policies, detailed in the QAP.

Summary Statements

Because of the proprietary nature of the VOC data, none are reported herein.

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.

Table 5-1: 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-Dichloroethene	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
Trichloroethylene	2	500

Table 5-2: CEMRC Procedures for Confirmatory Volatile Organic Compounds Monitoring Program

Procedure Number	Procedure Title	Rev.
OC-PLAN-001	Quality Assurance Plan for Analysis of Volatile Organic Compounds in Canister Samples	2
OC-PROC-002	Preparation of Canisters for Ambient Air	3
OC-PROC-003	Gas Chromatography-Mass Spectrometry of Volatile Organic Compounds (VOCs) in Ambient Air from Canisters at PPBV Concentration Levels	2
OC-PROC-004	Preparation of Calibration Standards in Specially Prepared Canisters for Analysis by Gas Chromatography/Mass Spectrometry	3

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	3
OC-PROC-006	Receipt, Control, and Storage of Gas Samples in Passivated Canisters	2
OC-PROC-009	Analysis of Hydrogen and Methane in Passivated Canisters Using Gas Chromatography with Thermal Conductivity Detection	0

APPENDICES

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 grant entitled "Carlsbad Environmental Monitoring and Research Program" (CEMRP) from DOE to NMSU. The CEMRP initially was 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 WTS and LANL provided operating funds to CEMRC 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 re-instated 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. LES NEF in Eunice began developing a program with CEMRC which was implemented in 2008. Dr. Conca still holds the Director position as of December 2008.

Temporary office accommodations for the CEMRC initially were provided at NMSU-Carlsbad 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 new facilities. 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 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 and the unit returned 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 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 performance assessments with respect to actinide elements in brine under repository conditions. This was completed in 2006. Subsequently, other laboratory improvements occurred in 2006 such as building of a new VOC laboratory and replacement of most of the ventilation system, jointly funded by DOE, WTS and CEMRC. A new sector-field mass spectrometry laboratory for uranium analysis was completed at CEMRC in 2008.

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) that is managed by Dr. Abbas Ghassemi, the Associate Dean of Engineering.

Appendix B: Recent Publications

Author	Title	Publisher/Conference
Y. Grof, J. Monk, and M. Akbarzadeh	Real Time Detection, Ultra Low Radiation From Air Filters	Journal of the Health Physics Society 2008 (in press)
W. Weber, R. Marr, D. Kracko, Z. Gao, J. McDonald and **K. Ui Chearnaigh**	Disposition of tungsten in rodents after repeat oral and drinking water exposures	Toxicological and Environmental Chemistry, 90, 445-455, 2008
J. Conca, S. Sage and J. Wright	Nuclear Energy and Waste Disposal in the Age of Recycling	*Journal of the New Mexico Academy of Sciences, 2008 (in press)*
J. Wright and **J. Conca**	*The Geopolitics of Energy: Achieving a Just and Sustainable Energy Distribution by 2040*	Booksurge Publishing, Charleston, SC. ISBN 1-4196-7588-5, 2007
J. L. Conca and M. Apted	Nuclear Energy and Radioactive Waste Disposal in the Age of Recycling	In *GLOBAL '07 - Advanced Nuclear Fuel Cycles and Systems*, American Nuclear Soc, p. 1-8, 2007
W.A. Martin, S. L. Larson, D.R. Felt, J. Wright, C.S. Griggs, M. Thompson, **J.L. Conca**, and C. Nestler	The effect of organics on lead sorption onto Apatite II	*Applied Geochemistry*, 23, 34 - 43, 2007
M. Campbell, H. Wise, J. Evensen, B. Handley, S. Testa, **J. Conca** and H. Moore	Nuclear Power: Winds of Change	Uranum Committee Annual Report, Amer. Assoc. of Petroleum Geologists Energy Minerals Division, Tulsa, OK, 2007 www.mdcampbell.com/EMDUraniumCommitteeReport031907Rev.doc
Kirchner, T. B.	Removal Of Unused Parameters From MATSET File	Produced For PRECCDFGF. Sandia National Laboratories, Carlsbad, NM. 2007
Kirchner, T. B.	Methods and examples of propagating uncertainty and analyzing sensitivity.	In Uncertainties in the Measurement and Dosimetry of External Radiation. NCRP Report No. 158. National Council on Radiation Protection and Measurements, Bethesda, MD. 2008
Kirchner, T. B.	Estimating and applying	In Till, J. E. and H. A. Grogan (eds.)

Author	Title	Publisher/Conference
	uncertainty in assessment models.	Radiological Risk Assessment and Environmental Analysis. Oxford University Press, New York. 2008

Appendix C: Tours, Public Presentations and Other Outreach

Group/Activity
CEMRC worked with State Senate and House to craft and pass bills in 2007 for funding to the MESA schools program for developing energy curricula in public schools: SB0424 & HB0795
November 2007 Sondra Sage *Science in Schools* presentations to Alta Vista Middle School and Craft Elementary School
May 2007 NM State MESA Program Coordinators - tour and presentation
CEMRC worked with local Carlsbad high school science teachers in 2007 to obtain science teaching grants from BP and Idaho National Laboratory for $20k.
October 2007 Sondra Sage, seminar on *Revisiting Recycling* to the CDCA
CEMRC participated in the annual Relay For Life
2007-2008 Conca - nine high school and middle school classes – CEMRC tours and presentations
2007-2008 host of the monthly American Nuclear Society section meeting

Appendix D: Students/Visiting Scientists supported at CEMRC 2007

Student/Scientist	Support Period
Students (12) – Illinois Institute of Tech	Summer 2007
Dr. Jeff Terry, Illinois Institute of Tech	Summer 2007
Dr. Geof Smith, NMSU Las Cruces	Sabbatical 2007
Dr. Sarah Pepper, LANL	Post-doctoral Research Associate 2007

Appendix E: Performance Tests and Audits

Below are summaries of external and internal (Table E-1) audits, and results for three performance tests run in 2007/2008; one for Whole Body Dosimetry (Table E-2, Table E-3, and Figure E-1), one for ICP-MS (Table E-4) and one for radiochemical analyses (Table E-5). Since samples were collected in 2007 but run in 2008, most performance data is for 2008. Table E-6 shows two examples of the daily performance tests for ICP-MS. Table E-4 shows that all analytes run were acceptable within 10% of the assigned value. In addition, daily QA/QC checks using NIST-traceable must show acceptable within 5% before work can begin (Table E-6).

Table E-5 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 for. Ref Values are the nominally correct answer and the Acceptance Range gives the range of values that are acceptable. Flag A means the result was acceptable and NR means that analyte was not tested for. Results for an analyte that has no Ref Value or Acceptance Range means the MAPEP sample was not spiked for that analyte but it may exist naturally in that sample matrix. As examples, because of CEMRC's low detection limits, ^{238}Pu was found in the soil sample, $^{239/240}$Pu and ^{241}Am in the water sample, and ^{241}Am in the filter sample in ranges acceptably close to MAPEP's uncontrolled values and were considered acceptable by MAPEP.

The end of Table E-5 shows that there was a false positive for gross alpha, however, CEMRC counts for 5 days, about a hundred times longer than most labs. Therefore, the value was likely not a false positive, but an actual value. Special care has to be taken to provide CEMRC with a sample that has alpha-emissions below our detection limits.

CEMRC Management Assessment Quality Assurance Report

November 1, 2006 – December, 2007

Prepared by: Sharyl McCauley

December 20, 2007

This report serves as a periodic summary of the quality assurance program at the Carlsbad Environmental Monitoring and 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, external audits, internal surveillance and nonconformance / non-routine events from November 1, 2006 through December 20, 2007.

Since the implementation of CP-PROC-023 and CP-PROC-024, which enables CEMRC to qualify potential vendors, 23 vendors are currently qualified.

During the year external audits were performed on two of the programmatic areas at CEMRC. The programmatic areas audited were Internal Dosimetry (also referred to as Radiobioassay), for In Vivo Radiobioassay, and Organic Chemistry (formerly under the Environmental Chemistry program) for Volatile Organic Compounds (VOCs). Washington Tru Solutions (WTS) performed these external audits. Summaries and conclusions from the audits are not maintained by the QA Manager but can be found in the records file of these programmatic areas.

Internal audits were performed on all of the programmatic areas, which are as follows: Administration (ADAR-06), Document Control (DCAR-08), Environmental Chemistry (ECAR-07), Field Programs (FPAR-06), Informatics and Modeling (IMAR-06), Organic Chemistry (OCAR-02), and Radiobioassay (RBAR-06). To date, all seven of the audits are closed out. A summary of the programmatic area internal audits can be found in Table E-1. Additionally, due to major staffing changes that occurred in the Radiochemistry Group, a surveillance was conducted (RCAR-06). The surveillance is to be used as a guideline to address areas that need improvement.

There were no non-routine events during this assessment time for a center wide implementation procedure.

The QA system has been consistently and effectively implemented as demonstrated by the decreasing number and diminished severity of the findings in all of the programmatic areas. Overall, the quality assurance program has made huge strides in its development and must maintain this level for continued success.

Table E-1: Internal Audit Summaries 2007 (# of Findings)

Area	AD	DC	OC	EC	FP	IM	RB
Personnel Qualification & Training	1	NF	1	NF	NF	NF	NF
Quality Improvement	NF	NF	NF	NF	NF	NF	NF
Document Control	NF	NF	NF	NF	NF	NF	NF
QA Records	NF	NF	NF	1	NF	1	1
Procurement	NF	NF	NF	NF	NF	NF	NF
Work Processes	NF	NF	1	2	NF	NF	NF
Audits/Assessments	NF	NF	NF	1	1	NF	NF
Sample Control	NF	NF	NF	NF	NF	NF	NF
Scientific Investigations	NF	NF	1	NF	NF	NF	NF
Scientific Notebooks	NF	NF	NF	NF	NF	NF	NF
Procedure Violation	NF	3	NF	1	NF	1	NF

Table Guide

Laboratory Section

AD = Administrative

DC = Document Control

EC = Environmental Chemistry

FP = Field Programs

IM = Informatics & Modeling

OC = Organic Chemistry

QA = Quality Assurance

RB = Radiobioassay (Internally, within CEMRC, it is known as Internal Dosimetry)

RC = Radiochemistry

Table Results

NF = No Findings

Table E-2: Blind Check Study for Internal Dosimetry 2007 by the ORNL Intercomparison Studies In-vivo Program

Oak Ridge National Laboratory

Intercomparison Studies In-vivo Program Report

1st Quarter Calendar Year 2007

Carlsbad Environmental Monitoring & Research Center

Set E

ISOTOPE	SPIKE ACTIVITY AS OF 3-9-07 +/- 2 sigma (nCi)	REPORTED ACTIVITY AS OF 3-9-07 +/- 2 sigma (nCi)	% RELATIVE BIAS
Cs-137	178.8 +/- 8.7	175.71 +/- 8.79	1.1
Co-60	195.3 +/- 9.8	196.59 +/- 9.83	0.7
Co-57	89.71 +/- 4.49	93.55 +/- 4.68	4.3
Y-88	201.0 +/- 10.0	204.7 +/- 10.24	1.8
Ba-133	302.3 +/- 15.1	309.81 +/- 15.49	2.5

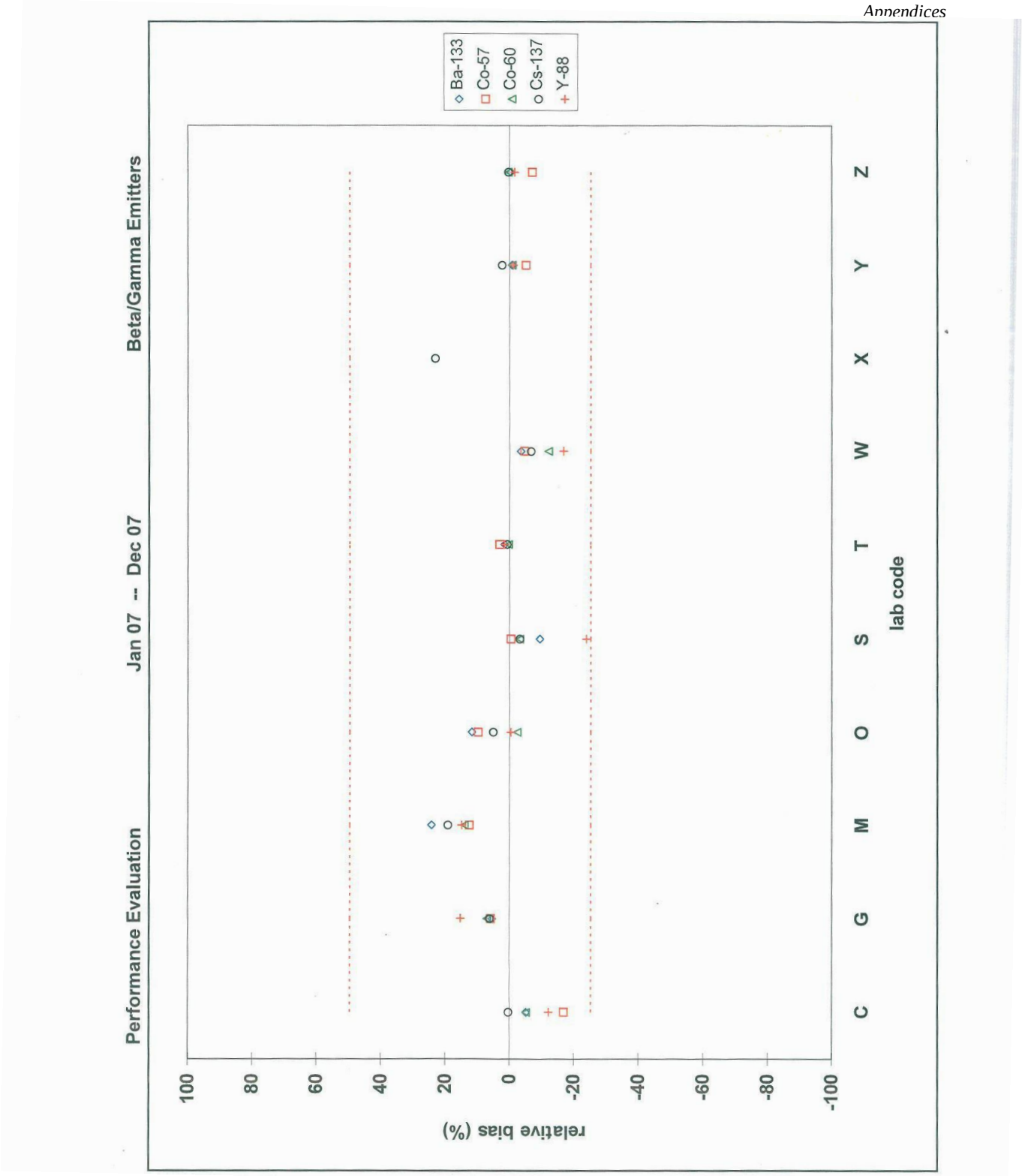

Figure E.1: Comparison of Results for Ten Internal Dosimetry Laboratories in the U.S. During 2007 by the ORNL Intercomparison Studies In-vivo Program

CEMRC is Lab T. For all years that CEMRC has participated in the ORNL program, CEMRC has consistently performed better than all other labs in this area.

Table E-3: Quality Assurance/Quality Control for Internal Dosimetry
2007 Audits

Agency	Date	Conclusion	Reason
CEMRC Self Assessment	3/14-15/07	1 finding and 1 observation. Pass	Quality System
CEMRC Self Assessment	10/18-20/07	Three findings. Pass	Quality System
Oak Ridge National Lab, Intercomparison Studies Program	Quarterly	Pass	External QC
WTS	6/26-27/07	No findings, 1 observation, 2 conditions corrected during audit, and 1 noteworthy practice. Pass	Annual

Table E-4: Blind Check 2008 Environmental Chemistry Inorganic Analyses

WS-144 Final Complete Report

Kim UiChearnaigh
Environmental Scientist
New Mexico State University
1400 University Dr
CEMRC
Carlsbad, NM 88220-3575
(505) 234-5506

EPA ID: Not Reported
ERA Customer Number: N215603
Report Issued: 09/10/08
Study Dates: 07/07/08 - 08/21/08

Anal. No.	Analyte	Units	Reported Value	Assigned Value	Acceptance Limits	Performance Evaluation	Method Description
WS Metals							
1000	Aluminum	µg/L	450.	420	354 - 484	Acceptable	EPA 200.8
0140	Antimony	µg/L	25.2	24.0	16.8 - 31.2	Acceptable	EPA 200.8
0001	Arsenic	µg/L	40.6	36.7	25.7 - 47.7	Acceptable	EPA 200.8
0002	Barium	µg/L	1270	1190	1010 - 1370	Acceptable	EPA 200.8
0141	Beryllium	µg/L	8.05	8.19	6.96 - 9.42	Acceptable	EPA 200.8
0226	Boron	µg/L	1420	1500	1310 - 1660	Acceptable	EPA 200.8
0003	Cadmium	µg/L	31.3	31.2	25.0 - 37.4	Acceptable	EPA 200.8
0004	Chromium	µg/L	65.4	63.0	53.6 - 72.4	Acceptable	EPA 200.8
0091	Copper	µg/L	412	393	354 - 432	Acceptable	EPA 200.8
1070	Iron	µg/L	1190	1130	1010 - 1240	Acceptable	EPA 200.8
0005	Lead	µg/L	17.0	16.1	11.3 - 20.9	Acceptable	EPA 200.8
0236	Manganese	µg/L	127	118	105 - 130	Acceptable	EPA 200.8
0237	Molybdenum	µg/L	32.2	31.1	26.1 - 35.4	Acceptable	EPA 200.8
0142	Nickel	µg/L	51.1	48.5	41.2 - 55.8	Acceptable	EPA 200.8
0007	Selenium	µg/L	45.6	40.9	32.7 - 49.1	Acceptable	EPA 200.8
1150	Silver	µg/L	32.4	30.7	25.7 - 35.6	Acceptable	EPA 200.8
0143	Thallium	µg/L	9.47	8.86	6.20 - 11.5	Acceptable	EPA 200.8
1185	Vanadium	µg/L	1210	1160	1040 - 1280	Acceptable	EPA 200.8
0239	Zinc	µg/L	2090	2020	1820 - 2220	Acceptable	EPA 200.8
WS Inorganics							
0027	Alkalinity as CaCO3	mg/L		87.9	79.1 - 96.7	Not Reported	
1575	Chloride	mg/L	17.5	16.4	14.1 - 18.9	Acceptable	EPA 300.1
1610	Conductivity at 25°C	µmhos/cm		334	301 - 367	Not Reported	
0010	Fluoride	mg/L	4.13	4.32	3.89 - 4.75	Acceptable	EPA 300.1
1820	Nitrate + Nitrite as N	mg/L		8.62	7.76 - 9.48	Not Reported	
0009	Nitrate as N	mg/L	9.55	8.62	7.76 - 9.48	Not Acceptable	EPA 300.1
1125	Potassium	mg/L		32.9	28.4 - 37.2	Not Reported	
0145	Sulfate	mg/L	13.7	13.0	10.2 - 15.3	Acceptable	EPA 300.1
0024	Total Dissolved Solids at 180°C	mg/L		294	192 - 396	Not Reported	

All analytes are included in ERA's A2LA accreditation. Lab Code: 1539-01

Table E-5: Radiochemistry MAPEP 2008 Intercomparison Results

Department

Laborator
(CMRC01
1400 Univ
Carlsbad,

MAPEP-

Inorgan

Analyte
Antimony
Arsenic
Barium
Beryllium
Cadmium
Chromium
Cobalt
Copper
Lead
Mercury
Nickel
Selenium
Silver
Thallium
Vanadium
Zinc
Technetium
Uranium-Tc
Uranium-23
Uranium-23

Organic

Analyte
Aldrin
gamma-BH
Dieldrin
Endosulfan
Heptachlor
1,2,4-Trichl
Anthracene
Benzo(b)flu
Butylbenzyl
4-Chloro-3-
2-Chlorona

Organic — Units: (ug/kg)

Analyte	Result	Ref Value	Flag	Notes	Z-	Acceptance Range	Unc Value	Unc Flag
2-Chlorophenol	NR	1229				123 - 2411		
Chrysene	NR	1284				455 - 2113		
Di-n-butylphthalate	NR	2009				364 - 3654		
2,4-Dichlorophenol	NR	1747				183 - 3310		
Diethylphthalate	NR	1659				308 - 3010		
Dimethylphthalate	NR	1459				292 - 2625		
2,4-Dinitrotoluene	NR	1238				124 - 2514		
2,6-Dinitrotoluene	NR	1311				280 - 2342		
Bis(2-ethylhexyl)phthalate	NR	2570				642 - 4498		
Fluoranthene	NR	1130				400 - 1860		
Fluorene	NR	2259				780 - 3738		
Hexachlorobenzene	NR	1610				595 - 2625		
2-Methylnaphthalene	NR	3532				1705 - 5360		
2-Nitrophenol	NR	3344				445 - 6243		
2,4,6-Trichlorophenol	NR	2322				441 - 4203		

Radiological — Units: (Bq/kg)

Analyte	Result	Ref Value	Flag	Notes	Bias	Acceptance Range	Unc Value	Unc Flag
Americium-241	62.67	69.1	A		-9.3	48.4 - 89.8	3.33	
Antimony-125	NR	22.8				16.0 - 29.6		
Cesium-134	NR	581				407 - 755		
Cesium-137	NR	2.8						
Cobalt-57	NR	333				233 - 433		
Cobalt-60	NR	145				102 - 189		
Iron-55	NR	676				473 - 879		
Manganese-54	NR	415				291 - 540		
Nickel-63	NR	760				532 - 988		
Plutonium-238	.34		A				.12	
Plutonium-239/240	53.67	55.6	A		-3.5	38.9 - 72.3	2.44	
Potassium-40	NR	570				399 - 741		
Strontium-90	NR							
Technetium-99	NR	335				235 - 436		
Uranium-234/233	293.65	292	A		0.6	204 - 380	11.74	
Uranium-238	298.85	303	A		-1.4	212 - 394	12.88	
Zinc-65	NR							

Radiological Reference Date: August 1, 2008

MAPEP-08-MaW19: Radiological, inorganic combined water standard

Inorganic — Units: (mg/L)

Analyte	Result	Ref Value	Flag	Notes	Bias	Acceptance Range	Unc Value	Unc Flag
Antimony	NR	1.044				0.731 - 1.357		
Arsenic	NR	3.692				2.584 - 4.800		

Inorganic								Units: (mg/L)
Analyte	Result	Ref Value	Flag	Notes	Bias	Acceptance Range	Unc Value	Unc Flag
Barium	NR	1.79				1.25 - 2.33		
Beryllium	NR	<0.005						
Cadmium	NR	.78				0.55 - 1.01		
Chromium	NR	1.277				0.894 - 1.660		
Cobalt	NR	2.672				1.870 - 3.474		
Copper	NR	3.671				2.570 - 4.772		
Lead	NR	<0.01						
Mercury	NR	.01885				0.01320 - 0.02451		
Nickel	NR	2.499				1.749 - 3.249		
Selenium	NR	.646				0.452 - 0.840		
Thallium	NR	2.637				1.846 - 3.428		
Vanadium	NR	2.254				1.578 - 2.930		
Zinc	NR	2.549				1.784 - 3.314		
Technetium-99	NR	0.0000060				0.00000420 - 0.00000780		
Uranium-Total	NR	0.287				0.201 - 0.373		
Uranium-238	NR	0.285				0.200 - 0.371		
Uranium-235	NR	0.00201				0.00141 - 0.00261		

Radiological								Units: (Bq/L)
Analyte	Result	Ref Value	Flag	Notes	Bias	Acceptance Range	Unc Value	Unc Flag
Americium-241	-.001025		A				.	
Cesium-134	NR	19.5				13.7 - 25.4		
Cesium-137	NR	23.6				16.5 - 30.7		
Cobalt-57	NR							
Cobalt-60	NR	11.6				8.1 - 15.1		
Hydrogen-3	NR	341				239 - 443		
Iron-55	NR	46.2				32.3 - 60.1		
Manganese-54	NR	13.7				9.6 - 17.8		
Nickel-63	NR							
Plutonium-238	.43	0.5	A		-14.0	0.4 - 0.7	.02	
Plutonium-239/240	.006		A				.002	
Strontium-90	NR	6.45				4.52 - 8.39		
Technetium-99	NR	3.76				2.63 - 4.89		
Uranium-234/233	3.28	3.44	A		-4.7	2.41 - 4.47	0.15	
Uranium-238	3.48	3.55	A		-2.0	2.49 - 4.62	.51	
Zinc-65	NR	17.1				12.0 - 22.2		

Radiological Reference Date: August 1, 2008

MAPEP-08-RdF19: Radiological air filter

Inorganic								Units: (ug/sample)
Analyte	Result	Ref Value	Flag	Notes	Bias	Acceptance Range	Unc Value	Unc Flag
Uranium-Total	NR	22.0				15.4 - 28.6		

Inorganic								Units: (ug/sample)
Analyte	Result	Ref Value	Flag	Notes	Bias	Acceptance Range	Unc Value	Unc Flag
Uranium-235	NR	0.157				0.110 - 0.204		
Uranium-238	NR	21.9				15.3 - 28.5		

Radiological								Units: (Bq/sample)
Analyte	Result	Ref Value	Flag	Notes	Bias	Acceptance Range	Unc Value	Unc Flag
Americium-241	.00015		A				.0003	
Cesium-134	NR	2.63				1.84 - 3.42		
Cesium-137	NR							
Cobalt-57	NR	1.50				1.05 - 1.95		
Cobalt-60	NR							
Manganese-54	NR	2.64				1.85 - 3.43		
Plutonium-238	.12	0.118	A		1.7	0.083 - 0.153	.01	
Plutonium-239/240	.15	0.152	A		-1.3	0.106 - 0.198	.02	
Strontium-90	NR	1.12				0.78 - 1.46		
Uranium-234/233	.27	0.262	A		3.1	0.183 - 0.341	.02	
Uranium-238	.28	0.272	A		2.9	0.190 - 0.354	.02	
Zinc-65	NR	0.94				0.66 - 1.22		

Radiological Reference Date: August 1, 2008

MAPEP-08-GrF19: Gross alpha/beta air filter

Radiological								Units: (Bq/sample)
Analyte	Result	Ref Value	Flag	Notes	Bias	Acceptance Range	Unc Value	Unc Flag
Gross beta	.520	0.525	A		-1.0	0.263 - 0.788	.004	L
Gross alpha	.00013		N	(1)			.00001	

Radiological Reference Date: August 1, 2008

Notes:

(1) = False Positive

A = Acceptable
N = Not Acceptable
Unc = Uncontrolled
NR = Not Run

Table E-6: An Example of the Daily Performance Tests for ICP-MS

Sample Daily Performance Data of the Elan 6100 ICP-MS for July-August 2008

(Proficiency Test WS-144 was measured on July 22, 2008)

	Acceptable Ranges		7/17/08			7/22/08		
	Recommended Net Intensity Mean of 5 replicate readings*	*Required* Relative Standard Deviation (%)	Measured Mean Intensity	Relative Standard Deviation	Performance Evaluation	Measured Mean Intensity	Relative Standard Deviation	Performance Evaluation
Be	1,000-3,000	0.0 - 5.0%	1450.9	2.2	Acceptable	2102.8	1.0	Acceptable
Mg	20,000-80,000	0.0 - 5.0%	16419.8	2.1	Check for low counts	21670.6	1.6	Acceptable
In	120,000-250,000	0.0 - 5.0%	224993.3	1.0	Acceptable	268839.1	2.5	Acceptable
Pb	70,000-180,000	0.0 - 5.0%	151956.6	1.2	Acceptable	167021.3	0.8	Acceptable
Ba	900,000-2,300,000	0.0 - 5.0%	2032880.9	2.6	Acceptable	2440974.7	2.3	Acceptable
Ba++	≤ 5.0% Ba value	N/A	1.40%	3.9	Acceptable	1.50%	2.5	Acceptable
Ce	900,000-3,300,000	0.0 - 5.0%	2603869.4	1.9	Acceptable	3137983.4	0.9	Acceptable
CeO	≤ 5.0% Ce value	N/A	1.30%	3.5	Acceptable	1.50%	1.6	Acceptable
Bkgd	≤ 25.0	N/A	17.0	N/A	Acceptable	17.4	N/A	Acceptable

	Acceptable Ranges		8/19/2008			8/25/2008		
	Recommended Net Intensity Mean of 5 replicate readings*	*Required* Relative Standard Deviation (%)	Measured Mean Intensity	Relative Standard Deviation	Performance Evaluation	Measured Mean Intensity	Relative Standard Deviation	Performance Evaluation
Be	1,000-3,000	0.0 - 5.0%	1388.1	1.2	Acceptable	1706.9	1.9	Acceptable
Mg	20,000-80,000	0.0 - 5.0%	17418.4	2.3	Check for low counts	20088.1	1.6	Acceptable
In	120,000-250,000	0.0 - 5.0%	185525.8	0.8	Acceptable	236953.6	2.1	Acceptable
Pb	70,000-180,000	0.0 - 5.0%	110303.9	1.3	Acceptable	145631.6	1.3	Acceptable
Ba	900,000-2,300,000	0.0 - 5.0%	1628944.3	1.7	Acceptable	2121194.9	1.4	Acceptable
Ba++	≤ 5.0% Ba value	N/A	1.40%	1.8	Acceptable	1.50%	3.1	Acceptable
Ce	900,000-3,300,000	0.0 - 5.0%	2083317.8	1.3	Acceptable	2737480.7	0.7	Acceptable
CeO	≤ 5.0% Ce value	N/A	1.40%	2.1	Acceptable	1.30%	2.6	Acceptable
Bkgd	≤ 25.0	N/A	22.0	N/A	Acceptable	16.4	N/A	Acceptable

*Recommended ranges show typical instrument performance--higher values are acceptable but possible interferences should be explored

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