Carlsbad Environmental Monitoring & Research Center

2008

Report

2008 Report
Carlsbad Environmental Monitoring & Research Center

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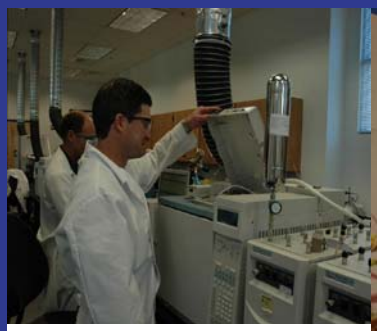
Acronyms and Abbreviations

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



VOC GC-MS Laboratory

Light Hall – Home of CEMRC

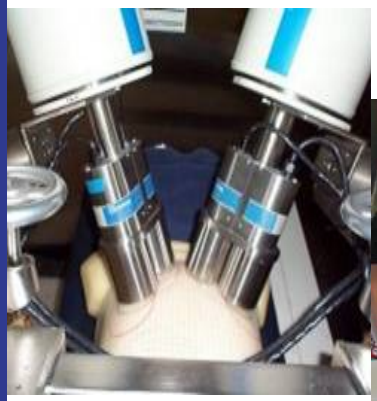
Plutonium-Glove Box in Radiochemistry Laboratory

Inductively Coupled Plasma-Mass Spectrometer

Oxford/Canberra Oasis Alpha Spectrometer

GC-MS for Head Space Gas

Soil Sample Collection



Lung Counter

Student Training in Radiological Issues

Whole Body Count

FOREWARD

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 2008.

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 Foreward 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.

Slightly over half of CEMRC's funding comes from the monitoring mission and the rest is split among three direct contracts through which CEMRC provides facility, safety 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 2008, 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 2008, significant facility

upgrades included roof replacement on the laboratory wings, ventilation upgrades, and installation of 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 six scientific program areas include (1) radiochemistry, (2) environmental chemistry, (3) organic chemistry, (4) informatics and modeling, (5) internal dosimetry, and (6) 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 FY2008, an overall increase from 2007.

DOE CBFO

- $1.897 million for WIPP Environmental Monitoring

URS Corp. (WTS, WRES, and WSMS)

- $259 thousand for Technical Support
- $430 thousand for VOC and WBC

Los Alamos National Laboratory

- $415 thousand for Actinide Chemistry scientific support

Sandia National Laboratory

- $165 thousand for Performance Assessment Scientific Support

LES National Enrichment Facility

- $91 thousand for Uranium Enrichment Analytical Scientific Support (does not include an additional $205 thousand for facility and equipment upgrade)

Other

- $112 thousand from WCS, Korea, IIT and others.

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.

An underground science project was formed in 2008 with a collaboration among CEMRC, NMSU Las Cruces and DOE CBFO to address low-dose biological effects by setting up a shielded chamber in the WIPP underground to study various cell lines. 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 2008 (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 2008, 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 2008, 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 2008 (Appendix D). In particular, The Illinois Institute of Technology (IIT) brought one of its radiation physics classes (Physics 770) to CEMRC as they recently lost the ability to teach it at Argonne National Laboratory and CEMRC was able to provide an appropriate radiological setting, lab space, and equipment for the course.

Table 1: Listing of CEMRC Staff as of the end of 2008

Name	Position
Arimoto, Richard	Senior Scientist
Baker, David	Assistant Scientist
Ballard, Sally	Science Specialist
Brown, Becky	Assistant to Director
Brown, Bill	Facility Manager
Conca, James	Director
French, Carroll	Science Specialist
Ganaway, David	Assistant Scientist
Garrett, Fran	Administrative Secretary II
Greene, Chris	Physicist Scientist III
Grof, Yair	Research Project Manager
Kirchner, Thomas	Senior Scientist
Pennock, Karl	Assistant Scientist
Perry, Adrianne	Technician I
Monk, James	Physical Scientist V
Najera, Angela	Administrative Secretary III
Sage, Sondra	Physical Scientist V
Schoep, David	Radiation Safety Training Specialist
Sneller, Michele	DosimetryTechnician
Sullivan, Tina	Program Analyst II
Ui Chearnaigh, Kim	Assistant Scientist
White, Corey	Assistant Scientist

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 2008 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 2008.

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 2008 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. CEMRC reported in 2007 a small quantity of Pu in composite aerosol samples from the first and third quarters. However, it turns out these resulted from minor contamination during the gross alpha/beta counting measurements which has since been corrected, and no Pu was detected in 2007 above MDC.

This year, CEMRC has detected a small quantity of Pu in composite aerosol samples from the February 2008 composite sample, similar to the 2003 detection, and also corroborated by WTS. The concentrations are so low (all values are orders of magnitude below compliance or action levels, tens of counts per 5,000 minutes) that it is impossible to determine the origin, whether from dust particulates

electrostatically attached to the outside of equipment, personnel or containers, external dust from fallout and the nearby Gnome site chromatographically moving through the underground over years, or Pu actually coming from the waste. Like so much involved in nuclear and environmental issues, detection at these levels becomes a philosophical issue – how low is low enough? Society's obsession with unachievable goals like zero concentrations or zero activities come up against the reality of the physical world.

The choice for CEMRC to monitor at levels orders of magnitude below action or compliance levels, even below background, raises the question as to what does this mean? What should be done, if anything, when positive values are observed? At these levels, even laboratory contamination using traditional procedures becomes more important than for normal situations. It is felt by the authors that, as WIPP fills with waste, such small occasional detections could be expected and the 2003 and 2008 hits provide a baseline for future events. As there are no historic precedents for this, it will be important to continue monitoring to see what actually does evolve as a deep underground geologic repository fills with nuclear waste.

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 2008 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 and 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 the difficulty of attracting new qualified personnel given the continued decrease in the national pool of nuclear and radiochemical personnel, and (3) the increased emphasis at CEMRC on direct research and technical support of WIPP operations. The challenge that has faced CEMRC during 2008 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. In 2008, that media was drinking water.

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 from fixed air samplers (FAS)], a site about 0.1 km northwest (downwind) of the WIPP exhaust shaft (on site station), a site about 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 2008. All FAS samples from 2008 have been analyzed with respect to gross alpha, gross beta, Pu, Am, U, ^{137}Cs, ^{40}K, and inorganics and are reported herein, while 2008 samples from the other aerosol sites are still being analyzed.

SOILS

During 2008, no soil samples were collected or analyzed.

SURFACE WATER AND SEDIMENTS

During 2008, 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 2008, drinking water samples were collected in the spring at five of the six drinking water supplies (the sixth was dry as has been the case for several years), and results are reported herein for 2008.

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 2008 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 2008 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 2008 on the following programmatic areas: Environmental Chemistry, Field Programs, Informatics and Modeling, Internal Dosimetry, Organic Chemistry, Radiobioassay, Administrative Services, and Document Control. In addition, an internal surveillance was performed on the Radiochemistry program. A summary of 2008 audits is reported in Appendix E.

QUALITY ASSURANCE/ QUALITY CONTROL FOR ORGANIC CHEMISTRY AND RADIOBIOASSAY

The following external audits were conducted in 2008 and resulted in recertification of each program:

- A VOCs Confirmatory Monitoring Audit, conducted by WTS QA as part of their routine yearly program audits in compliance with contract requirements, was passed in April 2008.
- A In Vivo Radiobioassay audit was conducted by WTS QA and passed in June 2008.

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 2008, CEMRC participated in 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. MAPEP results 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 2009 (the time period in which the 2008 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

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 2008, CEMRC again detected a small quantity of Pu in one composite aerosol samples from the first calendar quarter similar to the 2003 detection, and also corroborated by WTS. Such small occasional detections are to be expected and the 2003 and 2008 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 1.1). 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 1.2. 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}). In 2008, the average minimum detectable activity concentrations and densities for the gross

alpha emitters were ≈ 0.05 mBq m^{-3} and ≈ 0.9 Bq g^{-1}, respectively, while for gross beta emitters the corresponding values were ≈ 0.09 mBq $m^{-3}$and ≈ 1.6 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.

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 conditions. 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 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 1.3 through 1.8 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 results from naturally occurring radioactive materials, specifically radon daughters. Summary statistics for mass loading and gross

alpha/beta are given in Tables 1-1, 1-2, and 1-3. As shown in Table 1-2, 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 (Figures 1.4 and 1.5), 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 and a overall slightly increasing trend can be seen over the years from 2003 to 2008.

Similar seasonal trends in gross beta data can be seen in Figures 1.6 and 1.7. One entry that stands out in Table 1-3 is the maximum beta activity concentration of 58.4mBq m^{-3} observed in 2001. This sample and another collected around the same time (Figure 1.7) are the ones that were contaminated by material released from an underground fire extinguisher. Beta activities have remained quite consistent over the years.

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 1.3) shows a trend towards lower sample masses beginning in 2004 and also less scatter in the gravimetric data that then increases again in late 2007 and 2008. The latter point is also evident in Table 1-1, 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 six years of the study compared with 10% to 20% in three of the first four years of the program. This decrease in aerosol mass loadings would directly contribute to the high alpha activity densities observed in the more recent years of the WIPP-EM.

ACTINIDE DATA

Results of actinide analyses performed on monthly aerosol composite samples are presented in Table 1-4. Whenever the word "sample" is used in this section, it should be taken to mean "composite sample". ^{239,240}Pu was detected in six samples and ^{238}Pu was detected in one sample in the primary samples of 2007, and were reported in the CEMRC 2007 Annual Report. Because laboratory contamination was suspected, the back-up samples for those months were re-run in 2008.

No detectable concentrations of ^{238}Pu and $^{239+240}$Pu were observed in any of 2007 back-up samples. The Trip Blanks for the months of October and December showed no Pu activities as reported in last year report. However, Pu activity was detected in the Trip Blank for the month of November and resulted from the laboratory contamination. The samples collected and processed by WTS for all of 2007 but using CEMRC procedures and equipment for alpha spectrometry,

counting 5 days are shown in Table 1-5. 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. 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 August and September samples do show Pu activities very close to the MDC.

Naturally occurring U isotopes were detected in samples during all monitoring quarters of 2007 (Table 1-4).^{234}U results were similar to those of ^{238}U for activity concentration and density, indicating secular equilibrium between the two isotopes. Such results are expected for many natural sources of U.

No detectable concentrations of ^{238}Pu, $^{239+240}$Pu or ^{241}were observed in any of 2008 samples except for the month of February 2008. This month samples both primary and back-up showed ^{238}Pu, $^{239+240}$Pu and ^{241}Am activities above detection limit. Similar hits of $^{239+240}$Pu were also observed by WIPP Laboratories for the month of 2008. The Pu hit of 2008 is similar to that which occurred during June 2003 at Station A. Since the MDCs for $^{239+240}$Pu are only approximately a factor of 2-5 higher than the measured concentrations, it appears very probably that $^{239+240}$ Pu could be detected in future samples by dust-loaded ambient air circulating through the underground with environmental levels of Pu from global fallout as opposed to a release from WIPP operations. Such small occasional detections of Pu could provide a baseline for future events.

As stated above, U isotopes were detected in samples during all monitoring quarters of 2008 (Table 1-4). These results are consistent with those reported in the CEMRC, 1999, 2000, 2001 and 2005/2006 reports.

The $^{239+240}$Pu data for each year since 1998 is summarized in Figure 1.10, which shows the results in relation to both the MDC and the activity level of 37 Bq/m^3 which triggers the Continuous Air Alarms (CAMs) that are distributed throughout the WIPP underground. As can be seen, almost all Pu values are below the MDC except for those individual hits in 2003 and 2008. Also shown are the Pu values measured by WIPP laboratory. Notice all measurements are about 7 orders of magnitude below the CAM alarm levels. Similar graphs for ^{241}Am are summarized in Figure 1.11.

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.

With the exception of occasional hits from ^{40}K, no detectable gamma-emitting radionuclides were observed during the monitoring period 2007-2008. The results of ^{137}Cs and ^{40}K in the weekly composites are summarized in Tables 1-6 and 1-7, respectively.

ELEMENTAL DATA

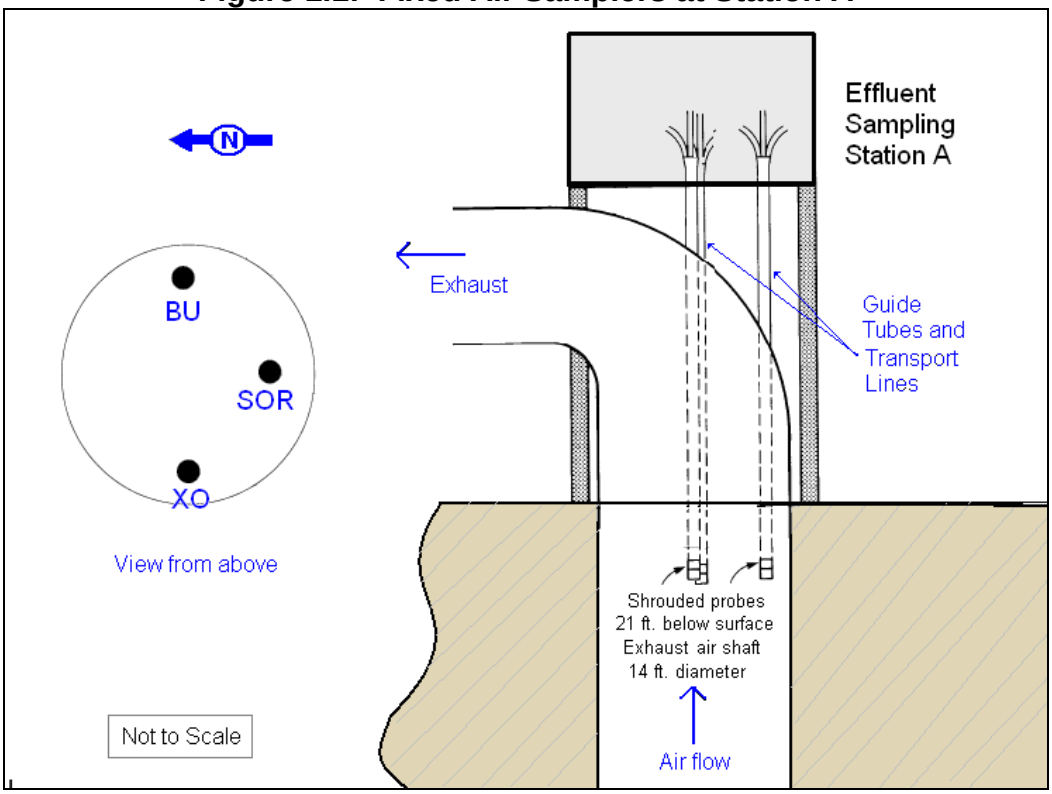
Prior studies at Station A have shown that the concentrations of hazardous metals and various trace elements can be highly variable over time; this was true even in the samples collected prior to receipt of the mixed waste in September 2000. Time-series plots of selected trace element data are presented in Figures 1.8 and 1.9. 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.

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.

Figure 1.1: Fixed Air Samplers at Station A



BU: Backup, SOR: Skid of Record, XO: Extra Probe

Figure 1.2: Flow Diagram Showing the Handling and Analysis of the Aerosol Sample Filters from Station A

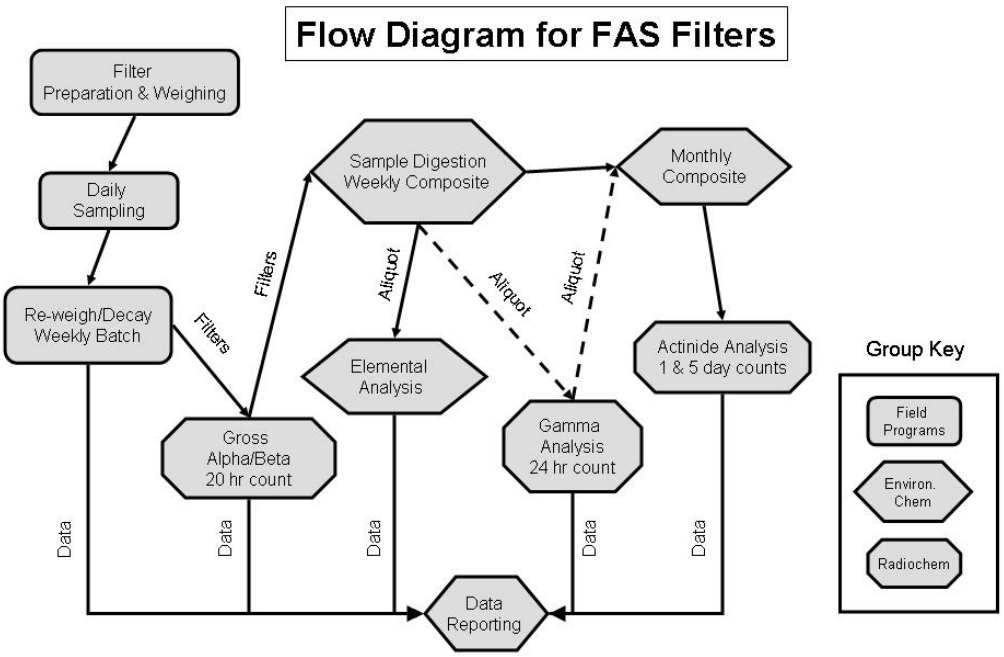


Table 1-1: Summary Statistics for Aerosol Mass Loadings (µg/m^3 per filter) on FAS Filters

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%
2008	431	143.5	11.2	7.8%

[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

Figure 1.3: Time-Series Plot of Aerosol Mass Loadings

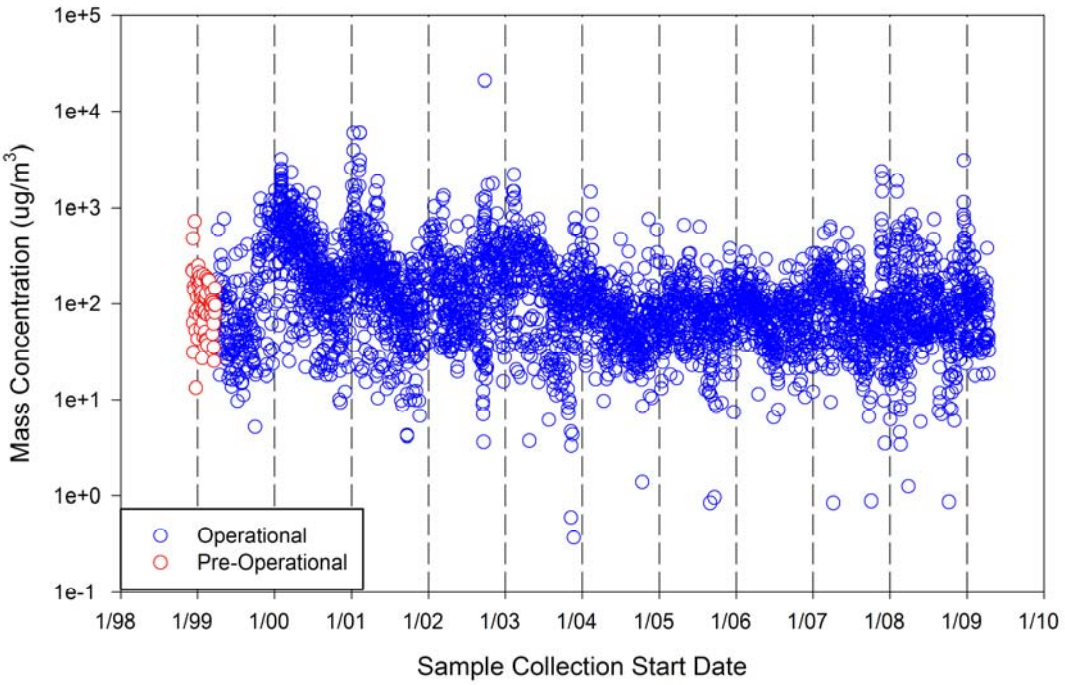


Table 1-2: Summary Statistics for Gross Alpha Analyses of Daily FAS Filters

		Activity Density (Bq/g)				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%	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
2008	431	1%	10.1	1.2	345.1	1%	0.455	0.011	1.53

[a]N represents the number of samples
[b]Percentage of samples less than the MDC (minimum detectable concentration)
[c]Arithmetic mean
[d]SE stands for standard error
[e]Max is the maximum observed value
[f]From 26 March to 31 December 1999

Figure 1.4: Time-Series Plot of Gross Alpha Activity Densities

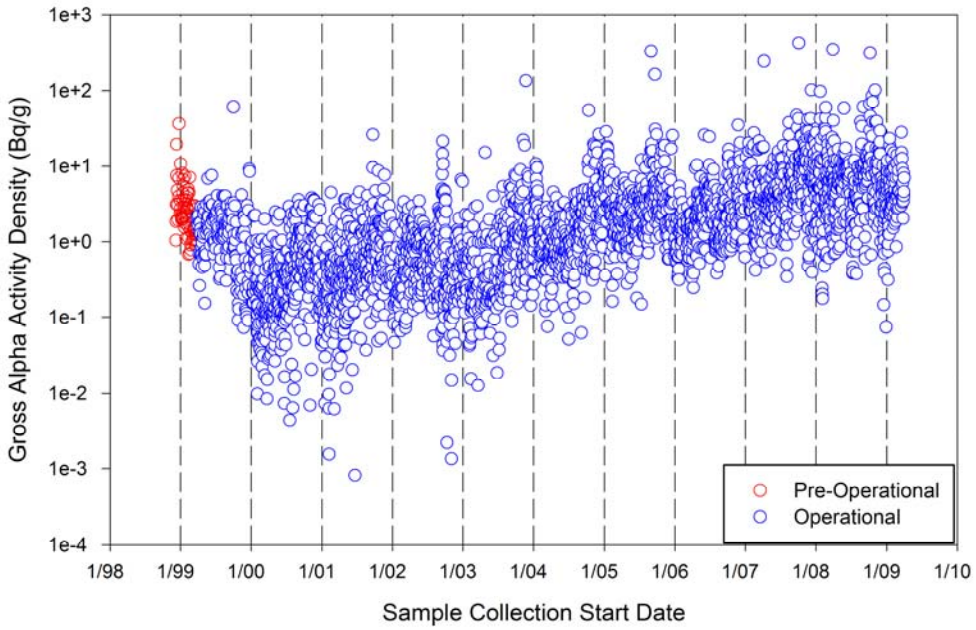


Figure 1.5: Time-Series Plot of Gross Alpha Activity Concentrations

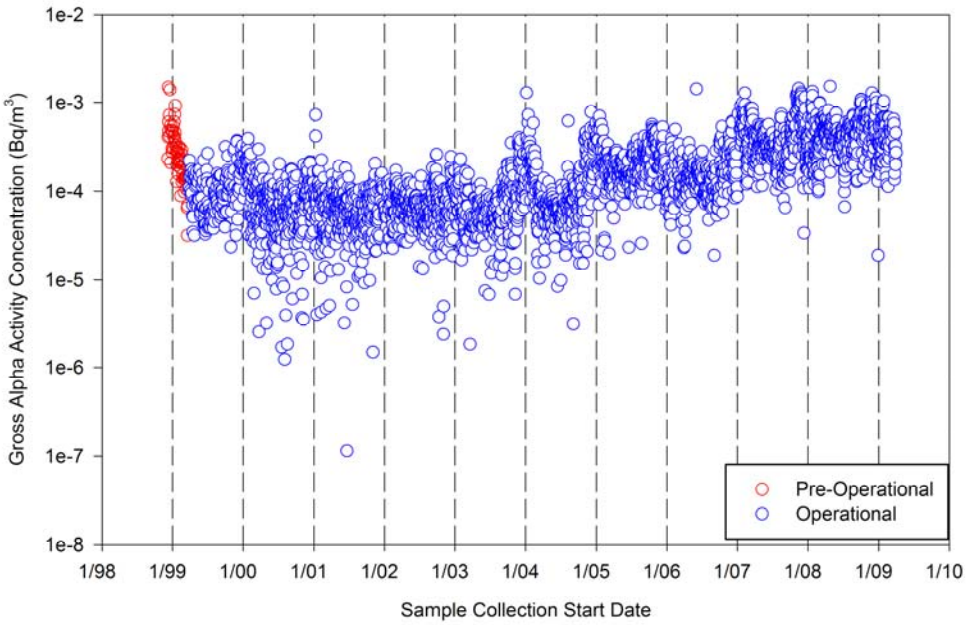


Table 1-3: Summary Statistics for Gross Beta Analyses of Daily FAS Filters

Group	[a]N	Activity Density (Bq/g)				Activity Concentration (mBq/m^3)			
		% < [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
2008	431	3%	12.6	1.53	438	3%	0.52	0.01	2.25

[a]N represents the number of samples
[b]Percentage of samples less than the MDC (minimum detectable concentration)
[c]Arithmetic mean
[d]SE stands for standard error
[e]Max is the maximum observed value
[f]From 26 March to 31 December 1999

Figure 1.6: Time-Series Plot of Gross Beta Activity Densities

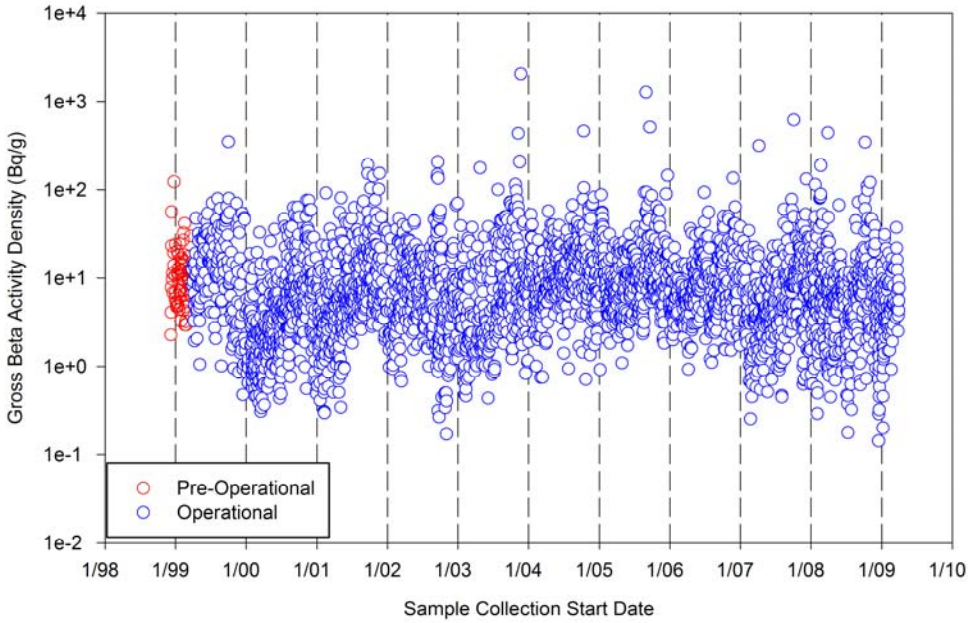


Figure 1.7: Time-Series Plot of Gross Beta Activity Concentrations

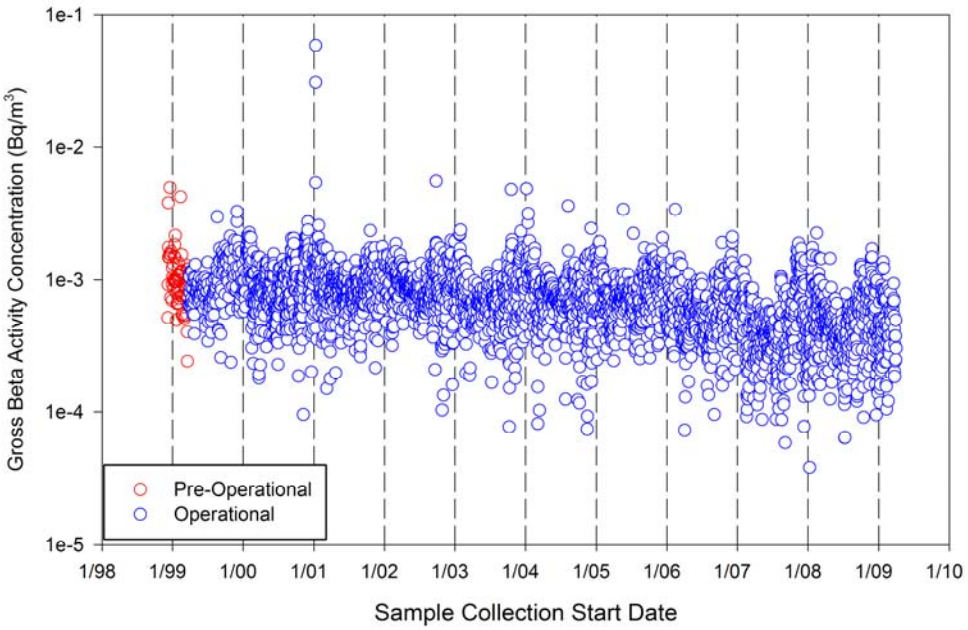


Figure 1.8: Concentrations of Aluminum and Magnesium in WIPP Exhaust Air
Filled circles denote pre-disposal samples and empty circles are for operational samples.

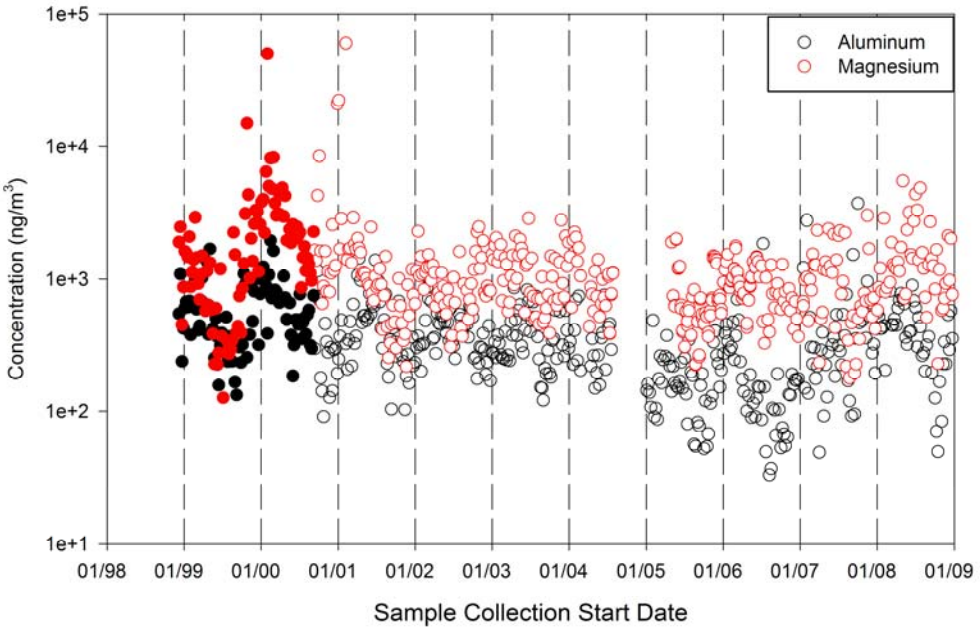


Figure 1.9: Concentrations of Selected Elements (U, Th, Cd, Pb) in WIPP Exhaust Air
Filled circles denote pre-disposal samples and empty circles are for operational samples.

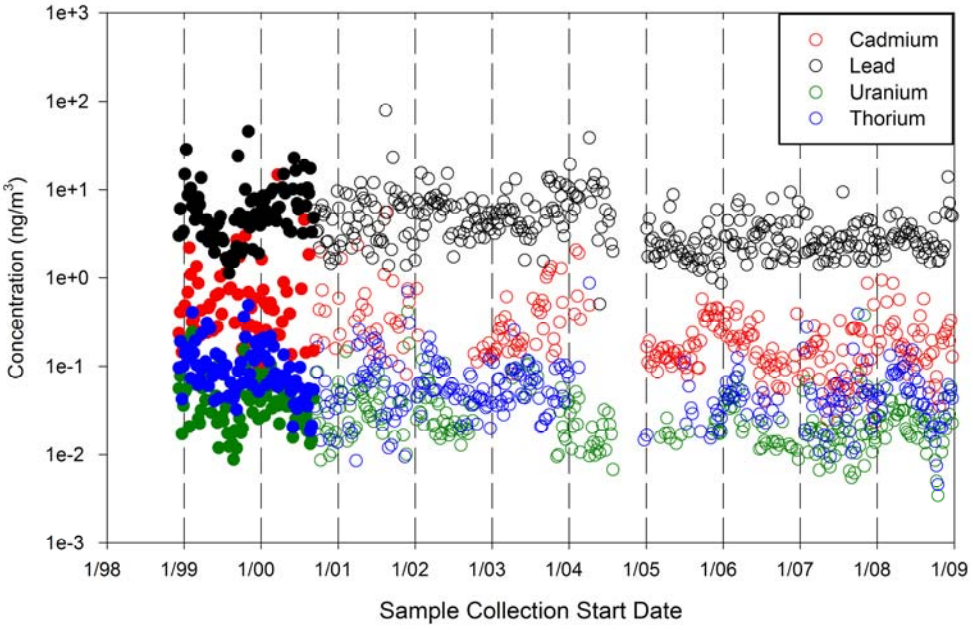


Table 1-4: Results of Actinide Analyses for Monthly FAS Composite Samples

	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 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
Operational Monitoring March 2007*						
^{241}Am	<MDC	NA	7.1E-08	<MDC	NA	4.6E-04
^{238}Pu	<MDC	NA	3.2E-07	<MDC	NA	2.1E-03
^{239,240}Pu	<MDC	NA	4.4E-08	<MDC	NA	2.9E-03
^{234}U	6.4E-07	8.8E-08	1.6E-07	4.2E-03	5.7E-04	1.1E-03
^{235}U	<MDC	NA	1.3E-07	<MDC	NA	8.2E-04
^{238}U	3.2E-07	7.2E-08	1.68E-07	2.0E-03	4.7E-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

Table 1-4: Results of Actinide Analyses 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 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	1.2E-07	<MDC	NA	3.3E-04
^{238}Pu	<MDC	NA	2.6E-07	<MDC	NA	6.7E-04
^{239,240}Pu	<MDC	NA	2.4E-07	<MDC	NA	2.3E-03
^{234}U	3.6E-07	6.9E-08	1.4E-07	1.5E-02	1.5E-03	1.5E-03
^{235}U	2.5E-08	2.5E-08	9.1E-08	1.3E-03	5.3E-04	1.3E-03
^{238}U	2.5E-07	5.4E-08	9.3E-08	5.1E-03	9.0E-04	1.4E-03
Operational Monitoring September 2007*						
^{241}Am	<MDC	NA	1.1E-07	<MDC	NA	2.2E-03
^{238}Pu	<MDC	NA	3.0E-07	<MDC	NA	6.1E-03
^{239,240}Pu	<MDC	NA	4.7E-07	<MDC	NA	9.4E-03
^{234}U	2.4E-07	5.8E-08	1.2E-07	4.9E-03	1.2E-03	2.3E-03
^{235}U	<MDC	NA	1.2E-07	<MDC	NA	2.5E-03
^{238}U	1.5E-07	4.8E-08	1.2E-07	3.0E-03	9.6E-04	2.3E-03
Operational Monitoring October 2007*						
^{241}Am	<MDC	NA	8.9E-08	<MDC	NA	1.3E-03
^{238}Pu	<MDC	NA	6.78E-08	<MDC	NA	6.1E-03
^{239,240}Pu	MDC	NA	8.55E-08	<MDC	NA	7.1E-03
^{234}U	6.24E-07	8.04E-08	8.98E-08	6.3E-02	3.8E-03	6.6E-03
^{235}U	<MDC	NA	1.57E-07	<MDC	NA	6.2E-03
^{238}U	7.10E-07	8.76E-08	1.16E-07	5.5E-02	3.5E-03	7.8E-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	4.2E-03
^{239,240}Pu	<MDC	1.29E-07	2.54E-08	<MDC	NA	3.9E-03
^{234}U	7.82E-07	9.53E-08	1.47E-07	1.9E-02	2.1E-04	4.1E-03
^{235}U	<MDC	NA	8.89E-08	<MDC	NA	3.6E-03
^{238}U	5.94E-07	8.13E-08	1.17E-07	9.5E-03	1.8E-03	3.6E-03

Table 1-4: Results of Actinide Analyses 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 December 2007*						
^{241}Am	<MDC	NA	1.17E-07	<MDC	NA	4.7E-03
^{238}Pu	<MDC	NA	1.29E-07	<MDC	NA	1.1E-03
^{239,240}Pu	<MDC	NA	9.14E-08	<MDC	NA	4.3E-03
^{234}U	5.19E-07	7.77E-08	1.2E-07	7.4E-03	1.4E-03	2.7E-03
^{235}U	<MDC	NA	1.15E-07	<MDC	NA	3.3E-03
^{238}U	2.89E-07	6.70E-08	1.58E-07	4.5E-03	1.1E-03	2.2E-03
Operational Monitoring January 2008*						
^{241}Am	<MDC	NA	5.7E-08	<MDC	NA	9.7E-04
^{238}Pu	<MDC	NA	1.0E-07	<MDC	NA	1.8E-03
^{239,240}Pu	<MDC	NA	7.5E-08	<MDC	NA	1.3E-03
^{234}U	2.5E-07	3.7E-08	4.6E-07	4.3E-03	6.3E-04	7.9E-03
^{235}U	<MDC	2.1E-08	7.4E-08	<MDC	NA	1.3E-03
^{238}U	2.2E-07	3.6E-08	5.6E-08	3.8E-03	6.1E-04	9.6E-04
Operational Monitoring February 2008*						
^{241}Am	1.3E-06	8.5E-08	3.8E-08	1.0E-02	6.7E-04	3.0E-04
^{238}Pu	1.5E-07	2.2E-07	6.1E-08	1.2E-03	1.8E-04	4.9E-04
^{239,240}Pu	3.8E-06	2.2E-07	6.1E-08	3.0E-02	1.8E-04	4.2E-04
^{234}U	4.8E-07	5.5E-07	7.8E-08	3.9E-03	4.4E-04	6.2E-04
^{235}U	1.3E-08	1.6E-08	6.1E-08	1.1E-04	1.3E-04	4.9E-04
^{238}U	4.4E-07	4.3E-08	6.4E-08	2.3E-03	3.4E-04	5.1E-04
Operational Monitoring March 2008*						
^{241}Am	<MDC	NA	3.9E-08	<MDC	NA	2.5E-04
^{238}Pu	<MDC	NA	1.4E-07	<MDC	NA	8.8E-04
^{239,240}Pu	<MDC	NA	1.3E-07	<MDC	NA	8.1E-04
^{234}U	4.4E-07	5.1E-08	7.0E-08	7.4E-03	3.3E-04	4.5E-04
^{235}U	7.0E-08	2.2E-08	4.5E-08	1.2E-03	1.5E-04	2.9E-04
^{238}U	3.2E-07	4.1E-08	4.6E-08	5.3E-03	2.7E-04	3.0E-04
Operational Monitoring April 2008						
^{241}Am	<MDC	NA	3.2E-07	<MDC	NA	2.4E-03
^{238}Pu	<MDC	NA	4.1E-07	<MDC	NA	3.0E-03
^{239,240}Pu	<MDC	NA	2.9E-07	<MDC	NA	2.2E-04
^{234}U	2.6E-06	3.0E-07	4.2E-07	1.9E-02	2.2E-03	3.1E-03
^{235}U	<MDC	NA	4.1E-07	<MDC	NA	3.6E-03
^{238}U	1.2E-06	2.2E-07	4.6E-07	9.2E-03	1.6E-03	3.4E-03
Operational Monitoring May 2008						
^{241}Am	<MDC	NA	2.0E-07	<MDC	NA	2.0E-03
^{238}Pu	<MDC	NA	2.0E-07	<MDC	NA	2.1E-03
^{239,240}Pu	<MDC	NA	1.6E-07	<MDC	NA	1.6E-03
^{234}U	6.9E-07	9.9E-08	1.4E-07	7.0E-03	1.0E-03	1.5E-03
^{235}U	<MDC	NA	1.1E-07	<MDC	NA	1.2E-03
^{238}U	4.2E-07	8.3E-08	1.6E-07	4.3E-03	8.5E-04	1.7E-03

Table 1-4: Results of Actinide Analyses 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 June 2008						
^{241}Am	<MDC	NA	5.9E-08	<MDC	NA	8.0E-04
^{238}Pu	<MDC	NA	2.8E-07	<MDC	NA	3.8E-03
^{239,240}Pu	<MDC	NA	1.4E-07	<MDC	NA	2.0E-03
^{234}U	1.6E-06	1.4E-07	1.3E-07	2.2E-02	1.9E-03	1.8E-03
^{235}U	3.3E-07	6.8E-08	9.6E-08	4.4E-03	9.2E-04	1.3E-03
^{238}U	5.1E-07	8.4E-08	2.0E-07	6.9E-03	1.1E-03	2.2 E-03
Operational Monitoring July 2008						
^{241}Am	<MDC	NA	2.0E-07	<MDC	NA	1.3E-03
^{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	6.7E-06	3.5E-07	2.2E-07	4.3E-02	2.2E-03	1.4E-03
^{235}U	<MDC	NA	1.6E-07	<MDC	NA	1.0E-03
^{238}U	6.5E-06	3.5E-07	2.9E-07	4.2E-02	2.2E-03	1.8E-03
Operational Monitoring August 2008*						
^{241}Am	<MDC	NA	4.3E-07	<MDC	NA	7.3E-04
^{238}Pu	<MDC	NA	5.7E-07	<MDC	NA	9.6E-04
^{239,240}Pu	<MDC	NA	8.3E-07	<MDC	NA	1.4E-03
^{234}U	2.1E-06	3.4E-07	5.0E-07	3.5E-03	5.7E-04	8.4E-04
^{235}U	<MDC	NA	6.1E-07	<MDC	NA	1.0E-03
^{238}U	9.7E-07	2.5E-07	5.5E-07	1.6E-03	4.2E-04	9.3E-04
Operational Monitoring September 2008*						
^{241}Am	<MDC	NA	4.4E-07	<MDC	NA	3.8E-05
^{238}Pu	<MDC	NA	1.3E-07	<MDC	NA	3.5E-04
^{239,240}Pu	<MDC	NA	1.3E-07	<MDC	NA	3.5E-04
^{234}U	1.2E-06	3.2E-07	6.8E-07	3.5E-04	9.4E-05	2.0E-04
^{235}U	<MDC	NA	7.3E-07	<MDC	NA	2.1E-04
^{238}U	1.1E-06	1.3E-07	6.8E-07	3.4E-04	9.2E-05	2.0E-04
Operational Monitoring October 2008						
^{241}Am	<MDC	NA	2.1E-07	<MDC	NA	2.4E-03
^{238}Pu	<MDC	NA	2.3E-07	<MDC	NA	2.5 E-03
^{239,240}Pu	<MDC	NA	2.3E-07	<MDC	NA	2.5 E-03
^{234}U	6.5E-07	1.4E-07	3.1E-07	3.9E-03	1.6E-03	3.4E-03
^{235}U	<MDC	NA	2.0E-07	<MDC	NA	2.2E-03
^{238}U	4.4E-07	6.7E-08	3.6E-07	4.8E-03	1.5E-03	4.0E-03
Operational Monitoring November 2008						
^{241}Am	<MDC	NA	7.7E-08	<MDC	NA	1.0E-03
^{238}Pu	<MDC	NA	2.2E-07	<MDC	NA	2.8E-03
^{239,240}Pu	<MDC	NA	2.2E-07	<MDC	NA	2.8E-03
^{234}U	7.6E-07	1.4E-07	1.9E-07	9.9E-03	1.3E-03	2.5E-03
^{235}U	<MDC	NA	1.4E-07	<MDC	NA	1.8E-03
^{238}U	3.8E-07	6.7E-08	9.8E-08	4.9E-04	8.7E-04	1.3E-03

Table 1-4: Results of Actinide Analyses 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 December 2008						
^{241}Am	<MDC	NA	9.7E-08	<MDC	NA	7.1E-04
^{238}Pu	<MDC	NA	2.7E-07	<MDC	NA	8.7E-04
^{239,240}Pu	<MDC	NA	1.6E-07	<MDC	NA	7.1E-04
^{234}U	5.7E-06	3.4E-07	1.8E-07	1.1E-03	2.6E-04	8.0E-04
^{235}U	<MDC	NA	2.1E-07	<MDC	NA	8.9E-04
^{238}U	5.6E-06	3.4E-07	1.4E-07	9.4E-04	2.0E-04	6.2E-04

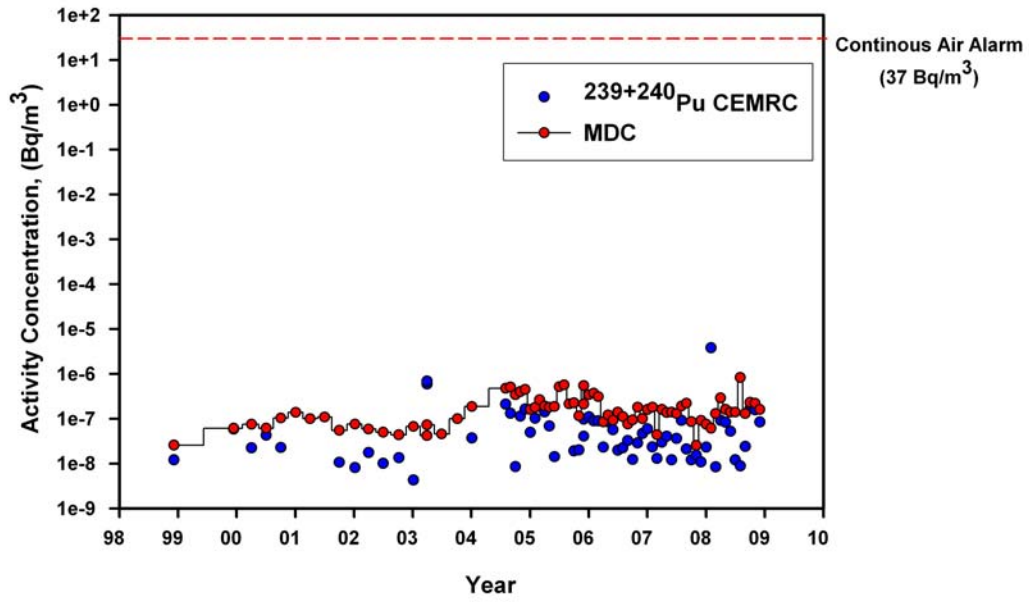
[a]C = Concentration
[b]SD = Standard Deviation
[c]MDC = Minimum Detectable Concentration
[d]NA = Not Applicable
* these months backup samples were analyzed

Table 1-5: Results of Actinide Analyses 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 1.10: CEMRC and WTS ^{239,240}Pu Analyses of FAS Samples



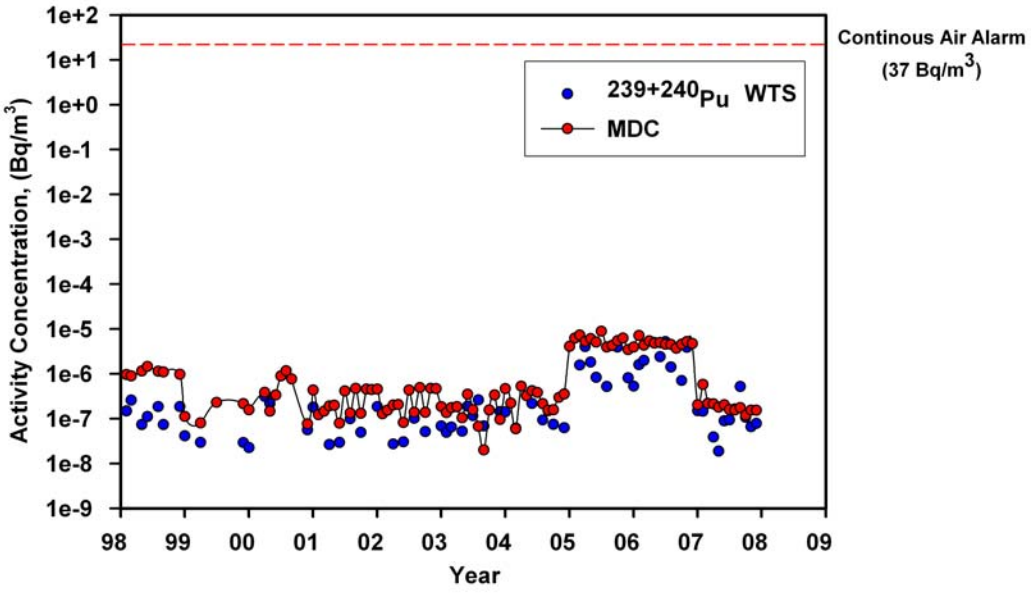
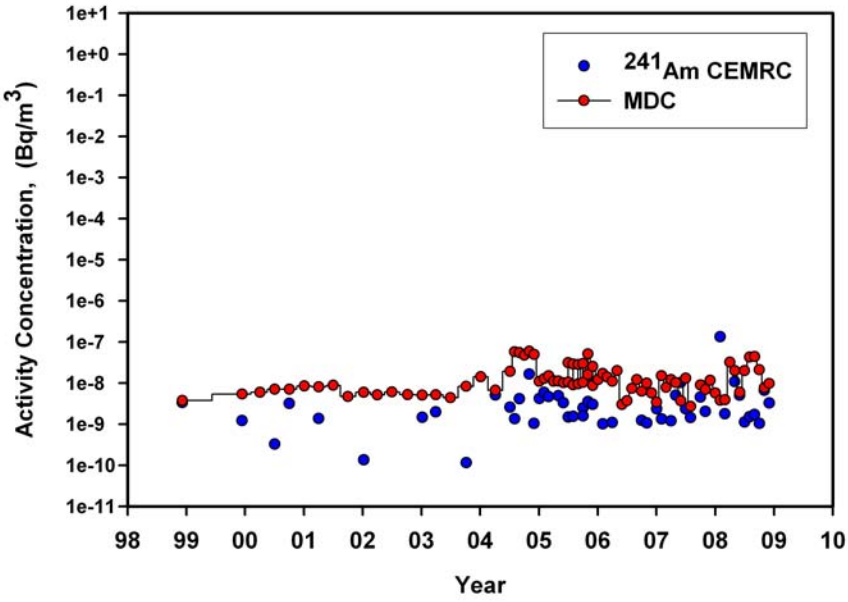


Figure 1.11: CEMRC and WTS ^{241}Am Analyses of FAS Samples



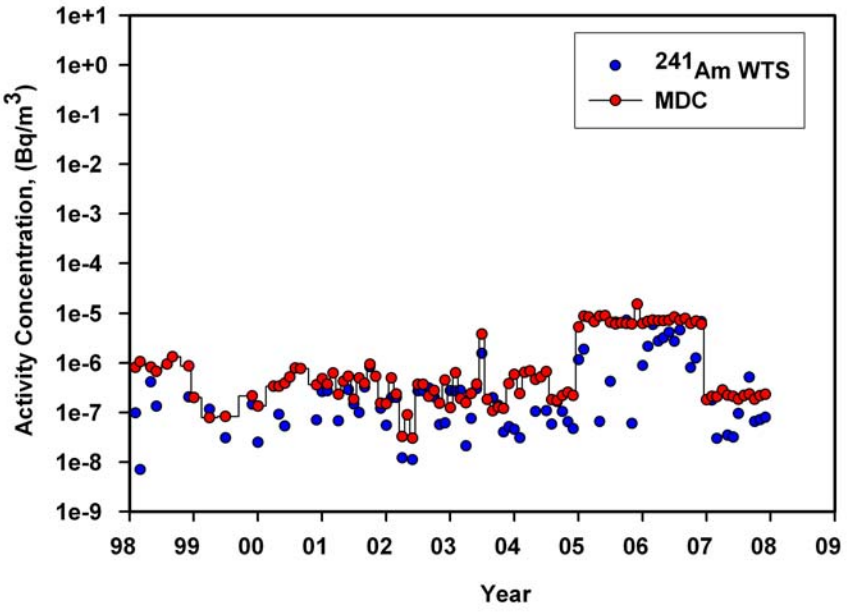


Table 1-6: Results of ^{137}Cs Analyses for Weekly FAS Composites 2007-2008

Week	Activity Concentration (Bq m^{-3})			Activity Density (Bq g^{-1})		
Operational Monitoring January 2007						
1/1/2007	<MDC	NA	2.06E-03	<MDC	NA	1.37E+01
1/82007	<MDC	NA	1.27E-03	<MDC	NA	8.56E+00
1/15/2007	<MDC	NA	8.92E-04	<MDC	NA	1.19E+01
1/22/2007	<MDC	NA	1.60E-03	<MDC	NA	1.29E+01
Operational Monitoring February 2007						
2/1/2007	<MDC	NA	1.02E-03	<MDC	NA	5.84E+00
2/8/2007	<MDC	NA	1.12E-03	<MDC	NA	9.17E+00
2/15/2007	<MDC	NA	1.20E-03	<MDC	NA	7.39E+00
2/22/2007	<MDC	NA	1.06E-03	<MDC	NA	5.61E+00
Operational Monitoring March 2007						
3/1/2007	<MDC	NA	1.05E-03	<MDC	NA	4.66E+00
3/8/2007	<MDC	NA	1.46E-03	<MDC	NA	1.39E+01
3/15/2007	<MDC	NA	1.09E-03	<MDC	NA	5.75E+00
3/22/2007	<MDC	NA	1.91E-03	<MDC	NA	1.37E+01
Operational Monitoring April 2007						
4/1/2007	<MDC	NA	1.02E-03	<MDC	NA	1.24E+01
4/8/2007	<MDC	NA	1.06E-03	<MDC	NA	8.08E+00
4/15/2007	<MDC	NA	1.23E-03	<MDC	NA	1.11E+01
4/22/2007	<MDC	NA	1.06E-03	<MDC	NA	8.78E+00
Operational Monitoring May 2007						
5/1/2007	<MDC	NA	1.51E-03	<MDC	NA	1.30E+01
5/8/2007	<MDC	NA	1.10E-03	<MDC	NA	1.28E+01
5/15/2007	<MDC	NA	1.19E-03	<MDC	NA	1.02E+01
5/22/2007	<MDC	NA	1.06E-03	<MDC	NA	1.37E+01
Operational Monitoring June 2007						
6/1/2007	<MDC	NA	1.33E-03	<MDC	NA	1.36E+01
6/8//2007	<MDC	NA	1.23E-03	<MDC	NA	9.63E+00
6/15/2007	<MDC	NA	1.08E-03	<MDC	NA	2.51E+01
6/22/2007	<MDC	NA	1.07E-03	<MDC	NA	1.35E+01
Operational Monitoring July 2007						
7/1/2007	<MDC	NA	1.01E-03	<MDC	NA	1.03E+01
7/8//2007	<MDC	NA	9.03E-04	<MDC	NA	8.56E+00
7/15/2007	<MDC	NA	1.60E-03	<MDC	NA	2.60E+01
7/22/2007	<MDC	NA	1.19E-03	<MDC	NA	1.41E+01
Operational Monitoring August 2007						
8/1/2007	<MDC	NA	1.29E-03	<MDC	NA	6.61E+00
8/8//2007	<MDC	NA	1.07E-03	<MDC	NA	2.17E+01
8/15/2007	<MDC	NA	1.09E-03	<MDC	NA	1.42E+01
8/22/2007	<MDC	NA	1.01E-03	<MDC	NA	3.43E+01
Operational Monitoring September 2007						
9/1/2007	<MDC	NA	1.09E-03	<MDC	NA	2.67E+01
9/8//2007	<MDC	NA	1.14E-03	<MDC	NA	1.74E+01
9/15/2007	<MDC	NA	8.68E-04	<MDC	NA	1.81E+01
9/22/2007	<MDC	NA	1.56E-03	<MDC	NA	3.13E+01

Table 1-6: Results of ^{137}Cs Analyses for Weekly FAS Composites 2007-2008 *(Continued)*

Week	Activity Concentration (Bq m^{-3})			Activity Density (Bq g^{-1})		
Operational Monitoring October 2007						
10/1/2007	<MDC	NA	1.24E-03	<MDC	NA	3.14E+01
10/8//2007	<MDC	NA	1.07E-03	<MDC	NA	2.13E+01
10/15/2007	<MDC	NA	8.89E-04	<MDC	NA	1.56E+01
10/22/2007	<MDC	NA	1.12E-03	<MDC	NA	2.14E+01
Operational Monitoring November 2007						
11/1/2007	<MDC	NA	1.10E-03	<MDC	NA	1.52E+01
11/8//2007	<MDC	NA	1.19E-03	<MDC	NA	1.62E+01
11/15/2007	<MDC	NA	1.44E-03	<MDC	NA	5.22E+00
11/22/2007	<MDC	NA	1.77E-03	<MDC	NA	7.34E+00
Operational Monitoring December 2007						
12/1/2007	<MDC	NA	1.27E-03	<MDC	NA	2.16E+01
12/8//2007	<MDC	NA	1.57E-03	<MDC	NA	2.09E+01
12/15/2007	<MDC	NA	1.45E-03	<MDC	NA	2.05E+01
12/22/2007	<MDC	NA	1.45E-03	<MDC	NA	2.63E+01
Operational Monitoring January 2008						
1/1/2008	<MDC	NA	1.65E-03	<MDC	NA	2.33E+01
1/82008	<MDC	NA	1.74E-03	<MDC	NA	2.57E+01
1/15/208	<MDC	NA	1.33E-03	<MDC	NA	1.18E+01
1/22/2008	<MDC	NA	1.64E-03	<MDC	NA	2.38E+01
Operational Monitoring February 2008						
2/1/2008	<MDC	NA	1.01E-03	<MDC	NA	2.66E+00
2/8/2008	<MDC	NA	8.08E-04	<MDC	NA	9.14E+00
2/15/2008	<MDC	NA	2.89E-03	<MDC	NA	4.21E+01
2/22/2008	<MDC	NA	1.10E-03	<MDC	NA	2.27E+01
Operational Monitoring March 2008						
3/1/2008	<MDC	NA	1.71E-03	<MDC	NA	2.65E+01
3/8/2008	<MDC	NA	1.20E-03	<MDC	NA	6.89E+00
3/15/2008	<MDC	NA	1.01E-03	<MDC	NA	4.61E+00
3/22/2008	<MDC	NA	1.87E-03	<MDC	NA	2.83E+01
Operational Monitoring April 2008						
4/1/2008	<MDC	NA	1.90E-03	<MDC	NA	1.65E+01
4/8/2008	<MDC	NA	1.14E-03	<MDC	NA	6.20E+00
4/15/2008	<MDC	NA	1.65E-03	<MDC	NA	1.16E+01
4/22/2008	<MDC	NA	1.74E-03	<MDC	NA	1.58E+01
Operational Monitoring May 2008						
5/1/2008	<MDC	NA	1.09E-03	<MDC	NA	6.69E+00
5/8/2008	<MDC	NA	6.50E-04	<MDC	NA	7.70E+00
5/15/2008	<MDC	NA	8.55E-04	<MDC	NA	1.54E+01
5/22/2008	<MDC	NA	1.34E-03	<MDC	NA	1.48E+01

Table 1-6: Results of ^{137}Cs Analyses for Weekly FAS Composites 2007-2008 *(Continued)*

Week	Activity Concentration (Bq m^{-3})			Activity Density (Bq g^{-1})		
Operational Monitoring June 2008						
6/1/2008	<MDC	NA	7.65E-04	<MDC	NA	8.48E+00
6/8//2008	<MDC	NA	1.28E-03	<MDC	NA	2.38E+01
6/15/2008	<MDC	NA	7.05E-04	<MDC	NA	1.28E+01
6/22/2008	<MDC	NA	1.33E-03	<MDC	NA	1.45E+01
Operational Monitoring July 2008						
7/1/2008	<MDC	NA	1.09E-03	<MDC	NA	6.49E+00
7/8//2008	<MDC	NA	1.57E-03	<MDC	NA	1.13E+01
7/15/2008	<MDC	NA	1.54E-03	<MDC	NA	1.59E+01
7/22/2008	<MDC	NA	1.52E-03	<MDC	NA	7.45E+00
Operational Monitoring August 2008						
8/1/2008	<MDC	NA	9.88E-04	<MDC	NA	9.69E+00
8/8//2008	<MDC	NA	1.31E-03	<MDC	NA	1.23E+01
8/15/2008	<MDC	NA	7.81E-04	<MDC	NA	1.06E+01
8/22/2008	<MDC	NA	1.17E-03	<MDC	NA	2.25E+01
Operational Monitoring September 2008						
9/1/2008	<MDC	NA	1.30E-03	<MDC	NA	2.75E+01
9/8//2008	<MDC	NA	1.53E-03	<MDC	NA	1.68E+01
9/15/2008	<MDC	NA	7.94E-04	<MDC	NA	1.37E+01
9/22/2008	<MDC	NA	1.34E-03	<MDC	NA	1.50E+01
Operational Monitoring October 2008						
10/1/2008	<MDC	NA	9.22E-04	<MDC	NA	1.67E+01
10/8//2008	<MDC	NA	8.07E-04	<MDC	NA	1.23E+01
10/15/2008	<MDC	NA	1.16E-03	<MDC	NA	3.45E+01
10/22/2008	<MDC	NA	1.41E-03	<MDC	NA	8.16E+00
Operational Monitoring November 2008						
11/1/2008	<MDC	NA	6.00E-04	<MDC	NA	1.22E+01
11/8//2008	<MDC	NA	1.35E-03	<MDC	NA	1.94E+01
11/15/2008	<MDC	NA	6.46E-04	<MDC	NA	1.38E+01
11/22/2008	<MDC	NA	7.51E-04	<MDC	NA	5.80E+00
Operational Monitoring December 2008						
12/1/2008	<MDC	NA	3.98E-04	<MDC	NA	2.63E+00
12/8//2008	<MDC	NA	7.33E-04	<MDC	NA	6.86E+00
12/15/2008	<MDC	NA	2.58E-03	<MDC	NA	3.89E+00
12/22/2008	<MDC	NA	9.19E-04	<MDC	NA	3.45E+01

Table 1-7: Results of ^{40}K Analyses for Weekly FAS Composites 2007-2008

Week	Activity Concentration (Bq m^{-3})			Activity Density (Bq g^{-1})		
Operational Monitoring January 2007						
1/1/2007	<MDC	NA	2.82E-02	<MDC	NA	1.87E+02
1/82007	<MDC	NA	1.38E-02	<MDC	NA	9.26E+01
1/15/2007	9.19E-05	2.64E-03	8.92E-03	1.23E+00	3.53E+01	1.19E+02
1/22/2007	<MDC	NA	2.26E-02	<MDC	NA	1.82E+02
Operational Monitoring February 2007						
2/1/2007	<MDC	NA	1.14E-02	<MDC	NA	6.52E+01
2/8/2007	<MDC	NA	1.11E-02	<MDC	NA	9.07E+01
2/15/2007	3.26E-03	3.54E-03	1.18E-02	2.01E+01	2.18E+01	7.25E+01
2/22/2007	2.33E-03	3.14E-03	1.05E-02	1.22E+01	1.65E+01	5.51E+01
Operational Monitoring March 2007						
3/1/2007	4.22E-03	3.02E-03	9.99E-03	1.87E+01	1.34E+01	4.43E+01
3/8/2007	<MDC	NA	1.98E-02	<MDC	NA	1.89E+02
3/15/2007	<MDC	NA	1.06E-02	<MDC	NA	5.56E+01
3/22/2007	<MDC	NA	2.54E-02	<MDC	NA	1.82E+02
Operational Monitoring April 2007						
4/1/2007	<MDC	NA	1.07E-02	<MDC	NA	1.31E+02
4/8/2007	4.47E-03	3.21E-03	1.06E-02	3.42E+01	2.45E+01	8.11E+01
4/15/2007	3.63E-03	3.43E-03	1.14E-02	3.27E+01	3.09E+01	1.03E+02
4/22/2007	5.12E-03	3.02E-03	9.91E-03	4.24E+01	2.50E+01	8.21E+01
Operational Monitoring May 2007						
5/1/2007	<MDC	NA	1.37E-02	<MDC	NA	1.19E+02
5/8/2007	<MDC	NA	1.19E-02	<MDC	NA	1.38E+02
5/15/2007	<MDC	NA	1.31E-02	<MDC	NA	1.12E+02
5/22/2007	<MDC	NA	1.03E-02	<MDC	NA	1.33E+02
Operational Monitoring June 2007						
6/1/2007	<MDC	NA	1.27E-02	<MDC	NA	1.30E+02
6/8//2007	<MDC	NA	1.31E-02	<MDC	NA	1.02E+02
6/15/2007	<MDC	NA	1.08E-02	<MDC	NA	2.50E+02
6/22/2007	<MDC	NA	1.13E-02	<MDC	NA	1.43E+02
Operational Monitoring July 2007						
7/1/2007	<MDC	NA	1.06E-02	<MDC	NA	1.08E+02
7/8//2007	<MDC	NA	1.70E-02	<MDC	NA	1.61E+02
7/15/2007	<MDC	NA	2.05E-02	<MDC	NA	3.34E+02
7/22/2007	<MDC	NA	1.24E-02	<MDC	NA	1.47E+02
Operational Monitoring August 2007						
8/1/2007	<MDC	NA	1.25E-02	<MDC	NA	6.42E+01
8/8//2007	<MDC	NA	1.12E-02	<MDC	NA	2.28E+02
8/15/2007	<MDC	NA	1.10E-02	<MDC	NA	1.42E+02
8/22/2007	<MDC	NA	1.04E-02	<MDC	NA	3.53E+02

Table 1-7: Results of ^{40}K Analyses for Weekly FAS Composites 2007-2008 *(Continued)*

Week	Activity Concentration (Bq m^{-3})			Activity Density (Bq g^{-1})		
Operational Monitoring September 2007						
9/1/2007	<MDC	NA	1.15E-02	<MDC	NA	2.83E+02
9/8//2007	<MDC	NA	1.13E-02	<MDC	NA	1.73E+02
9/15/2007	<MDC	NA	1.87E-02	<MDC	NA	3.91E+02
9/22/2007	<MDC	NA	1.98E-02	<MDC	NA	3.96E+02
Operational Monitoring October 2007						
10/1/2007	<MDC	NA	1.19E-02	<MDC	NA	3.02E+02
10/8//2007	<MDC	NA	1.24E-02	<MDC	NA	2.46E+02
10/15/2007	<MDC	NA	9.04E-03	<MDC	NA	1.58E+02
10/22/2007	<MDC	NA	1.13E-02	<MDC	NA	2.16E+02
Operational Monitoring November 2007						
11/1/2008	<MDC	NA	1.14E-02	<MDC	NA	1.57E+02
11/8//2008	<MDC	NA	1.26E-02	<MDC	NA	1.72E+02
11/15/2008	<MDC	NA	1.41E-02	<MDC	NA	5.11E+01
11/22/2008	<MDC	NA	2.08E-02	<MDC	NA	8.64E+01
Operational Monitoring December 2007						
12/1/2008	<MDC	NA	1.38E-02	<MDC	NA	2.34E+02
12/8//2008	<MDC	NA	1.59E-02	<MDC	NA	2.11E+02
12/15/2008	<MDC	NA	1.36E-02	<MDC	NA	1.92E+02
12/22/2008	<MDC	NA	1.58E-02	<MDC	NA	2.86E+02
Operational Monitoring January 2008						
1/1/2008	<MDC	NA	1.62E-02	<MDC	NA	2.28E+02
1/82008	1.86E-03	5.07E-03	1.70E-02	2.75E+01	7.47E+01	2.51E+02
1/15/208	<MDC	NA	1.33E-02	<MDC	NA	1.18E+02
1/22/2008	<MDC	NA	1.81E-02	<MDC	NA	2.62E+02
Operational Monitoring February 2008						
2/1/2008	<MDC	NA	2.33E-02	<MDC	NA	6.11E+01
2/8/2008	<MDC	NA	1.68E-02	<MDC	NA	1.90E+02
2/15/2008	<MDC	NA	3.93E-02	<MDC	NA	5.73E+02
2/22/2008	<MDC	NA	2.57E-02	<MDC	NA	5.29E+02
Operational Monitoring March 2008						
3/1/2008	<MDC	NA	1.67E-02	<MDC	NA	2.59E+02
3/8/2008	<MDC	NA	1.31E-02	<MDC	NA	7.55E+01
3/15/2008	<MDC	NA	1.03E-02	<MDC	NA	4.71E+01
3/22/2008	<MDC	NA	1.90E-02	<MDC	NA	2.87E+02
Operational Monitoring April 2008						
4/1/2008	<MDC	NA	1.94E-02	<MDC	NA	1.69E+02
4/8/2008	<MDC	NA	2.39E-02	<MDC	NA	1.29E+02
4/15/2008	<MDC	NA	1.99E-02	<MDC	NA	1.40E+02
4/22/2008	<MDC	NA	2.09E-02	<MDC	NA	1.90E+02

Table 1-7: Results of ^{40}K Analyses for Weekly FAS Composites 2007-2008 *(Continued)*

Week	Activity Concentration (Bq m^{-3})			Activity Density (Bq g^{-1})		
Operational Monitoring May 2008						
5/1/2008	<MDC	NA	2.16E-02	<MDC	NA	1.33E+02
5/8/2008	<MDC	NA	1.40E-02	<MDC	NA	1.66E+02
5/15/2008	<MDC	NA	1.63E-02	<MDC	NA	2.93E+02
5/22/2008	<MDC	NA	1.83E-02	<MDC	NA	2.01E+02
Operational Monitoring June 2008						
6/1/2008	<MDC	NA	1.62E-02	<MDC	NA	1.79E+02
6/8//2008	<MDC	NA	1.59E-02	<MDC	NA	2.97E+02
6/15/2008	<MDC	NA	1.37E-02	<MDC	NA	2.49E+02
6/22/2008	<MDC	NA	1.71E-02	<MDC	NA	1.87E+02
Operational Monitoring July 2008						
7/1/2008	<MDC	NA	2.29E-02	<MDC	NA	1.36E+02
7/8//2008	<MDC	NA	2.13E-02	<MDC	NA	1.53E+02
7/15/2008	<MDC	NA	2.15E-02	<MDC	NA	2.22E+02
7/22/2008	<MDC	NA	1.86E-02	<MDC	NA	9.08E+01
Operational Monitoring August 2008						
8/1/2008	<MDC	NA	1.85E-02	<MDC	NA	1.81E+02
8/8//2008	<MDC	NA	1.75E-02	<MDC	NA	1.64E+02
8/15/2008	<MDC	NA	1.68E-02	<MDC	NA	2.27E+02
8/22/2008	<MDC	NA	1.60E-02	<MDC	NA	3.06E+02
Operational Monitoring September 2008						
9/1/2008	<MDC	NA	1.71E-02	<MDC	NA	3.61E+02
9/8//2008	<MDC	NA	2.21E-02	<MDC	NA	2.43E+02
9/15/2008	<MDC	NA	1.79E-02	<MDC	NA	3.11E+02
9/22/2008	<MDC	NA	1.72E-02	<MDC	NA	1.92E+02
Operational Monitoring October 2008						
10/1/2008	<MDC	NA	1.81E-02	<MDC	NA	3.26E+02
10/8//2008	<MDC	NA	1.76E-02	<MDC	NA	2.68E+02
10/15/2008	<MDC	NA	1.52E-02	<MDC	NA	4.51E+02
10/22/2008	<MDC	NA	1.63E-02	<MDC	NA	9.45E+01
Operational Monitoring November 2008						
11/1/2008	<MDC	NA	1.24E-02	<MDC	NA	2.52E+02
11/8//2008	<MDC	NA	1.76E-02	<MDC	NA	2.53E+02
11/15/2008	<MDC	NA	1.34E-02	<MDC	NA	2.87E+02
11/22/2008	<MDC	NA	1.42E-02	<MDC	NA	1.09E+02
Operational Monitoring December 2008						
12/1/2008	<MDC	NA	8.74E-03	<MDC	NA	5.78E+01
12/8//2008	<MDC	NA	1.57E-02	<MDC	NA	1.47E+02
12/15/2008	<MDC	NA	3.38E-02	<MDC	NA	5.09E+01
12/22/2008	4.66E-03	5.20E-03	1.73E-03	5.58E+01	6.22E+01	2.07E+01

CHAPTER 2

Radionuclides and Inorganics in Selected Water Sources

INTRODUCTION

During 2008, 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 2008 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 2-1. 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 Pu or Am was measured above MDC (0.00008 Bq/L) in 2008 or in any drinking water samples since monitoring commenced in 1997. The federal and state action level for gross alpha emitters, which includes isotopes of Pu and U, is 15 pCi/L (0.56 Bq/L). This 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 2.1, 2.2 and 2.3 show the historic values for ^{239,240}Pu, ^{238}Pu and ^{241}Am at all sites. Results are averaged for each site from 1998 to 2008. All are below the MDC. Values for 2008 are listed in Table 2-1.

Figure 2.4 shows the uranium isotopes measured in drinking water samples, averaged for each year The low concentration of ^{235}U in waters samples is consistent with the lower concentration of ^{235}U in the natural environmental as compared to the concentrations of ^{234}U and ^{238}U (^{234}U is in secular equilibrium from decay of ^{238}U). One microgram of natural uranium contains 12.4 mBq [0.33 pCi (picocurie)] of ^{238}U, 0.37 mBq [0.01 pCi] of ^{235}U, and 12.4 mBq [0.33 pCi] of ^{234}U.

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 2008 measurements exhibit a high level of consistency with past results that provides a useful characterization of each source (Table 2-2).

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 2008 agreed well with, and were generally below, measurements for the same elements published in 2008 by the City of Carlsbad Municipal Water System (*2008 Annual Consumer Report on the Quality of Your Drinking Water (www.cityofcarlsbadnm.com/documents/CCR2008.pdf).*

Figure 2.1: ^{239,240}Pu in Bq/L in Regional Drinking Water

Results from 1998 to 2008 are averaged for each site. 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.

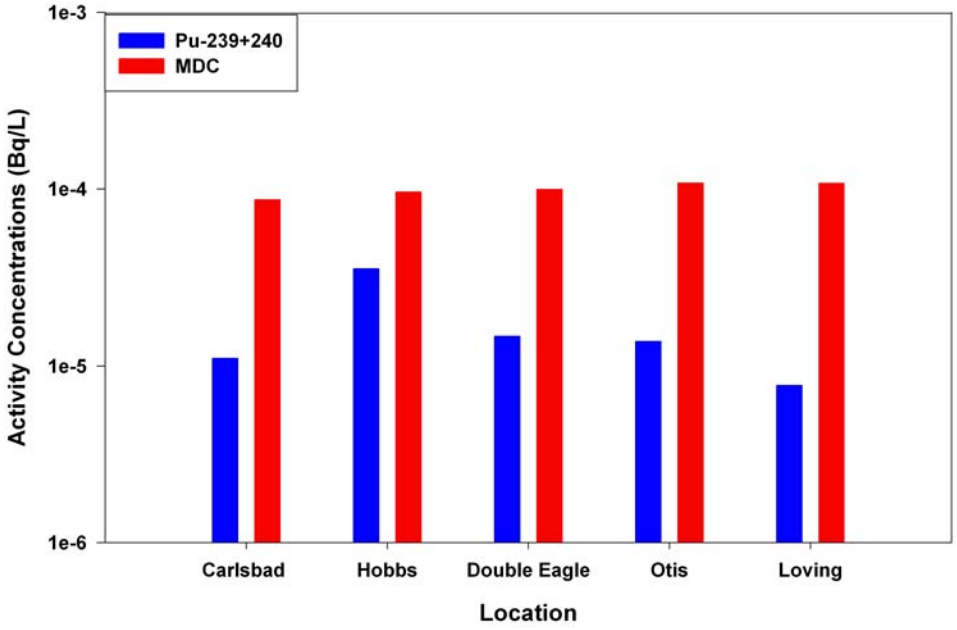


Figure 2.2: ^{238}Pu in Bq/L in Regional Drinking Water

Results from 1998 to 2008 are averaged for each site. 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.

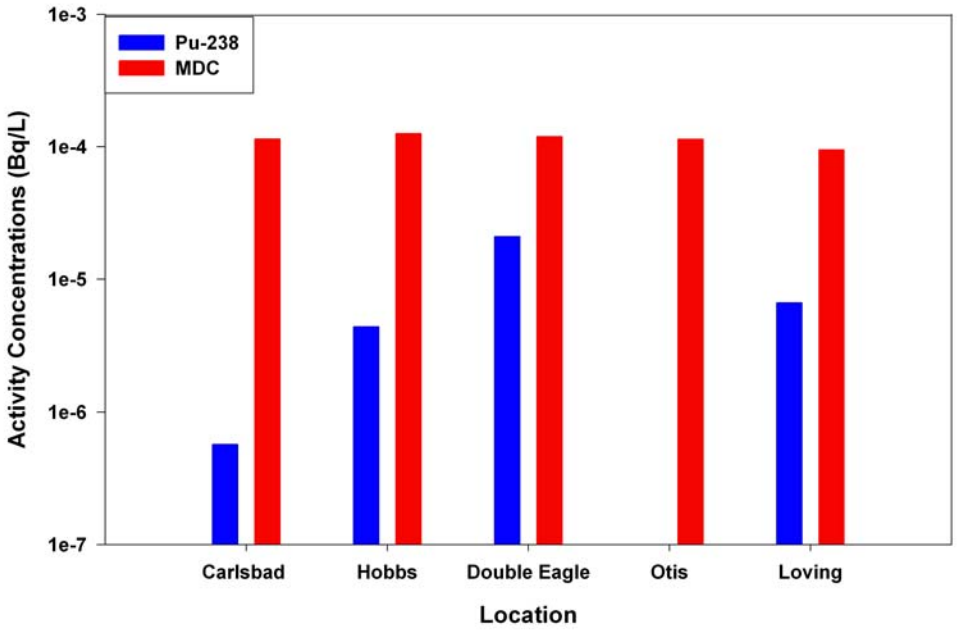


Figure 2.3: ^{241}Am in Bq/L in Regional Drinking Water

Results from 1998 to 2008 are averaged for each site. 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.

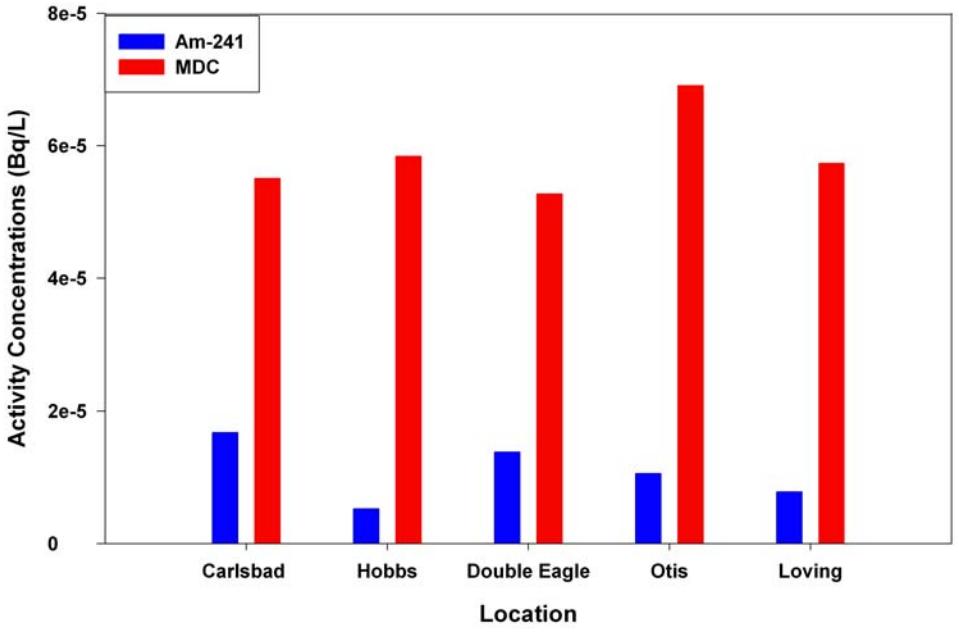


Figure 2.4: ^{234}U, ^{235}U, and ^{238}U in Bq/L in Regional Drinking Water

Results from 1998 to 2008 are averaged for each site. All are below the EPA Action level of 0.56 Bq/L and within the range expected in waters from this region.

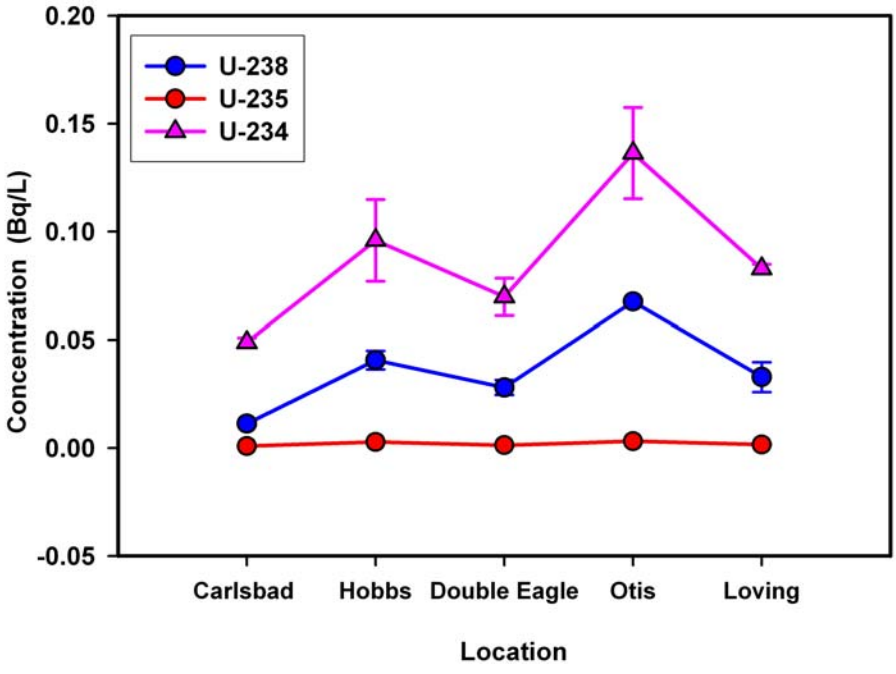


Table 2-1: Radionuclide Activity Concentrations in Drinking Water Sources

Location and Date of Sample Collection	Radionuclide	Activity[a] Concentration	SD[b] (Bq/L)	MDC[c] (Bq/L)
Carlsbad	$^{239+240}$Pu	2.13E-5	5.62E-5	2.29E-4
12/2/2008	^{238}Pu	2.37E-5	6.41E-5	2.55E-4
	^{241}Am	-7.79E-6	7.79E-6	4.19E-5
	^{238}U	8.63E-3	2.49E-4	8.38E-5
	^{235}U	7.80E-4	6.95E-5	5.29E-5
	^{234}U	2.38E-2	5.93E-4	7.34E-5
	^{137}Cs	2.34E-2	2.11E-2	6.96E-2
	^{40}K	5.33E-1	1.86E-1	5.93E-1
Hobbs				
12/2/2008	$^{239+240}$Pu	1.21E-4	5.69E-5	1.48E-4
	^{238}Pu	-6.04E-5	6.04E-5	2.84E-4
	^{241}Am	5.08E-6	7.16E-6	2.56E-5
	^{238}U	4.35E-2	1.06E-3	9.05E-5
	^{235}U	3.94E-3	1.82E-4	8.40E-5
	^{234}U	9.56E-2	2.20E-3	4.83E-5
	^{137}Cs	-2.77E-2	2.00E-2	6.67E-2
	^{40}K	4.10E-1	2.02E-1	6.58E-1
Double Eagle				
12/2/2008	$^{239+240}$Pu	-4.36E-5	6.17E-5	2.86E-4
	^{238}Pu	-8.14E-5	8.08E-5	3.59E-4
	^{241}Am	7.05E-6	9.83E-6	3.53E-5
	^{238}U	2.65E-2	9.72E-4	9.17E-5
	^{235}U	2.22E-3	1.44E-4	9.74E-5
	^{234}U	6.20E-2	2.18E-3	9.19E-5
	^{137}Cs	2.44E-2	1.98E-2	6.53E-2
	^{40}K	2.98E-1	1.93E-1	6.31E-1
Otis				
12/2/2008	$^{239+240}$Pu	-3.86E-5	4.00E-5	2.15E-4
	^{238}Pu	2.02E-5	6.71E-5	2.65E-4
	^{241}Am	-9.38E-6	2.48E-5	1.13E-4
	^{238}U	5.09E-2	1.59E-3	2.16E-4
	^{235}U	4.49E-3	2.60E-4	1.05E-4
	^{234}U	1.29E-1	3.84E-3	6.77E-5
	^{137}Cs	-2.26E-2	2.17E-2	7.24E-2
	^{40}K	9.39E-1	1.84E-1	5.51E-1
Loving				
12/2/2008	$^{239+240}$Pu	-4.02E-5	6.36E-5	2.84E-4
	^{238}Pu	-2.01E-5	4.50E-5	2.16E-4
	^{241}Am	4.13E-6	1.60E-5	6.21E-5
	^{238}U	2.57E-2	6.46E-4	8.08E-5
	^{235}U	1.71E-3	1.08E-4	5.56E-5
	^{234}U	8.53E-2	1.91E-3	6.38E-5
	^{137}Cs	-1.94E-2	2.06E-2	6.86E-2
	^{40}K	5.43E-1	2.05E-1	6.60E-1

[a] Activity concentration as defined in CEMRC report 1997
[b] SD = Standard Deviation as defined in CEMRC report 1997
[c] MDC= Minimum Detectable Concentration as defined in CEMRC report 1997

Table 2-2: Measured Concentration of Selected Inorganic Analytes in Drinking Water from 1998 to 2008 at Five Locations

Carlsbad												
	1998-2008				2007				2008			
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	2	1.23E-02	1.75E-02	N/A	N/A	N/A	N/A	1.20E-01	1.57E-02	<MDC	<MDC
Al	12	6	2.34E+00	2.98E+02	2.34E+01	1.92E+02	<MDC	<MDC	3.10E+01	9.04E+01	2.05E+02	2.05E+02
As	12	7	3.45E-01	1.10E+00	7.12E-01	3.15E+00	1.10E+00	1.10E+00	2.89E+01	2.74E+01	<MDC	<MDC
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	12	12	6.64E+01	4.13E+02	1.99E-01	-1.36E+00	7.15E+01	7.15E+01	1.24E+00	1.08E+00	4.09E+02	4.09E+02
Be	10		N/A	N/A	N/A	N/A	N/A	N/A	1.94E+00	-1.58E+00	<MDC	<MDC
Ca	11	11	6.32E+04	3.50E+05	1.80E+03	1.43E+04	6.32E+04	7.76E+04	1.00E+04	-3.29E+03	3.41E+05	3.41E+05
Cd	10		N/A	N/A	N/A	N/A	N/A	N/A	4.17E-01	-1.20E+00	<MDC	<MDC
Ce	10	2	1.71E-01	2.10E-01	3.20E-02	-7.02E-01	<MDC	<MDC	1.00E-01	-1.56E-01	1.71E-01	1.71E-01
Co	11	9	8.80E-02	1.07E+00	6.40E-02	-1.82E-01	1.38E-01	1.38E-01	2.54E-01	1.49E-01	1.04E+00	1.04E+00
Cr	12	10	1.24E+00	3.38E+01	2.87E-01	1.11E+00	1.24E+00	1.24E+00	5.27E-01	-5.48E-01	3.30E+01	3.30E+01
Cu	12	11	1.23E+00	1.67E+01	1.17E+00	4.23E+01	6.55E+00	6.55E+00	8.81E-01	6.81E+00	8.81E+00	8.81E+00
Dy	11		N/A	N/A	5.80E-02	1.49E-01	<MDC	<MDC	3.42E-01	-3.39E-01	<MDC	<MDC
Er	11		N/A	N/A	3.70E-02	1.33E-01	<MDC	<MDC	4.60E-02	-1.95E-03	<MDC	<MDC
Eu	9	6	1.35E-02	2.43E-02	9.30E-02	-7.61E-02	<MDC	<MDC	N/A	N/A	N/A	N/A
Fe	11	5	2.14E+01	1.12E+03	N/A	N/A	N/A	N/A	2.02E+02	1.46E+02	1.07E+03	1.07E+03
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	9		N/A	N/A	5.30E-02	6.00E-02	<MDC	<MDC	4.75E-02	-5.18E-02	<MDC	<MDC
Hg	9		N/A	N/A	N/A	N/A	N/A	N/A	2.05E-01	2.54E+00	<MDC	<MDC
K	11	10	1.04E+03	5.41E+03	2.33E+01	2.26E+03	<MDC	1.08E+03	5.00E+02	-5.15E+02	5.24E+03	5.24E+03
La	9	5	1.41E-02	4.48E-02	1.25E-01	2.07E-02	<MDC	<MDC	N/A	N/A	N/A	N/A
Li	9	9	6.09E+00	2.57E+01	N/A	N/A	N/A	N/A	4.93E-01	-1.32E+00	2.57E+01	2.57E+01
Mg	11	11	3.14E+04	1.67E+05	3.43E+02	-2.56E+02	3.40E+04	3.40E+04	1.71E+02	-6.67E+00	1.61E+05	1.61E+05
Mn	12	8	5.50E-02	9.40E-01	1.64E-01	3.22E+00	<MDC	<MDC	3.93E+00	1.64E+00	<MDC	<MDC
Mo	11	10	7.03E-01	5.95E+00	N/A	N/A	N/A	N/A	6.25E-01	-4.48E-01	5.46E+00	5.46E+00
Na	11	11	8.47E+03	9.94E+04	8.01E+02	2.91E+02	8.47E+03	8.47E+03	8.70E+01	9.16E+01	4.08E+04	4.08E+04
Nd	11		N/A	N/A	8.80E-02	1.76E-01	<MDC	<MDC	6.80E-01	-3.71E-01	<MDC	<MDC
Ni	11	10	1.01E+00	7.87E+00	1.14E+00	6.04E-01	2.06E+00	2.06E+00	2.52E-01	-5.70E-01	7.47E+00	7.47E+00
P	3	2	7.45E+01	8.03E+01	N/A	N/A	N/A	N/A	2.49E+01	-1.25E+01	7.45E+01	7.45E+01
Pb	10	8	1.63E-01	8.53E+00	N/A	N/A	N/A	N/A	3.20E+00	4.53E+00	<MDC	<MDC
Pr	11		N/A	N/A	3.80E-02	6.63E-02	<MDC	<MDC	4.54E-01	-9.00E-03	<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	11	6	3.00E-02	6.67E-01	N/A	N/A	N/A	N/A	1.85E-01	1.40E+00	3.36E-01	3.36E-01
Sc	8	8	1.72E+00	9.29E+00	N/A	N/A	N/A	N/A	5.02E+00	-2.01E+01	6.59E+00	6.59E+00
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	6	6	5.31E+03	2.82E+04	N/A	N/A	N/A	N/A	5.00E+03	-4.87E+04	2.69E+04	2.69E+04
Sm	9	7	2.34E-02	3.64E-02	5.30E-02	1.70E-02	<MDC	<MDC	N/A	N/A	N/A	N/A
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	12	12	3.23E+02	1.31E+03	9.30E-01	9.59E-02	3.28E+02	3.28E+02	1.02E+01	4.86E+00	1.30E+03	1.30E+03
Th	8	1	1.98E-02	1.98E-02	N/A	N/A	N/A	N/A	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	10	10	9.97E-02	4.48E-01	N/A	N/A	N/A	N/A	1.92E-01	-6.82E-02	4.10E-01	4.10E-01
U	11	11	8.21E-01	4.35E+00	6.10E-02	1.09E-02	1.04E+00	1.04E+00	4.20E-02	-1.68E-02	4.29E+00	4.29E+00
V	12	12	3.82E+00	2.82E+01	1.07E-01	4.84E+00	4.09E+00	4.09E+00	1.11E+01	1.60E+00	2.75E+01	2.75E+01
Zn	12	11	2.36E+00	5.37E+01	1.78E+00	1.02E+02	<MDC	6.25E+00	4.20E+00	-4.30E+01	5.04E+01	7.33E+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 2-2: Measured Concentration of Selected Inorganic Analytes in Drinking Water from 1998 to 2008 at Five Locations (C*ontinued)*

Double Eagle												
	1998-2008				2007				2008			
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	1	3.62E-03	3.62E-03	N/A	N/A	N/A	N/A	1.20E-01	1.57E-02	<MDC	<MDC
Ag	9	1	3.62E-03	3.62E-03	N/A	N/A	N/A	N/A	1.20E-01	1.57E-02	<MDC	<MDC
Al	11	6	2.57E+00	1.98E+02	2.34E+01	1.92E+02	<MDC	<MDC	3.10E+01	9.04E+01	1.98E+02	1.98E+02
As	11	11	4.26E+00	3.35E+01	7.12E-01	3.15E+00	7.14E+00	7.14E+00	2.89E+01	2.74E+01	3.35E+01	3.35E+01
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	10	10	7.93E+01	4.17E+02	1.99E-01	-1.36E+00	8.54E+01	8.54E+01	1.24E+00	1.08E+00	4.17E+02	4.17E+02
Be	8	1	3.63E-02	3.63E-02	N/A	N/A	N/A	N/A	1.94E+00	-1.58E+00	<MDC	<MDC
Ca	10	10	5.18E+03	2.66E+05	1.80E+03	1.43E+04	4.24E+04	5.67E+04	1.00E+04	-3.29E+03	2.66E+05	2.66E+05
Cd	9	3	1.87E-02	1.85E-01	N/A	N/A	N/A	N/A	4.17E-01	-1.20E+00	<MDC	<MDC
Ce	9	3	3.18E-03	1.61E-01	3.20E-02	-7.02E-01	<MDC	<MDC	1.00E-01	-1.56E-01	1.61E-01	1.61E-01
Co	11	7	8.45E-02	1.12E+00	6.40E-02	-1.82E-01	8.45E-02	8.45E-02	2.54E-01	1.49E-01	7.10E-01	7.10E-01
Cr	11	11	1.22E+00	3.25E+01	2.87E-01	1.11E+00	2.10E+00	2.10E+00	5.27E-01	-5.48E-01	1.60E+01	1.60E+01
Cu	11	11	8.09E-01	1.30E+01	1.17E+00	4.23E+01	3.56E+00	3.56E+00	8.81E-01	6.81E+00	1.30E+01	1.30E+01
Dy	11		N/A	N/A	5.80E-02	1.49E-01	<MDC	<MDC	3.42E-01	-3.39E-01	<MDC	<MDC
Er	11		N/A	N/A	3.70E-02	1.33E-01	<MDC	<MDC	4.60E-02	-1.95E-03	<MDC	<MDC
Eu	10	6	1.68E-02	2.86E-02	9.30E-02	-7.61E-02	<MDC	<MDC	N/A	N/A	N/A	N/A
Fe	9	6	7.93E+01	9.32E+02	N/A	N/A	N/A	N/A	2.02E+02	1.46E+02	7.99E+02	7.99E+02
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	9		N/A	N/A	5.30E-02	6.00E-02	<MDC	<MDC	4.75E-02	-5.18E-02	<MDC	<MDC
Hg	7		N/A	N/A	N/A	N/A	N/A	N/A	2.05E+00	2.54E+00	<MDC	<MDC
K	10	10	7.79E+02	2.94E+04	2.33E+01	2.26E+03	7.79E+02	3.04E+03	5.00E+02	-5.15E+02	1.49E+04	1.49E+04
La	10	5	1.19E-02	6.26E-02	1.25E-01	2.07E-02	<MDC	<MDC	N/A	N/A	N/A	N/A
Li	8	8	1.29E+01	9.29E+01	N/A	N/A	N/A	N/A	4.93E-01	-1.32E+00	9.29E+01	9.29E+01
Mg	10	10	1.09E+03	5.21E+04	3.43E+02	-2.56E+02	1.25E+04	1.25E+04	1.71E+01	-6.67E+00	5.21E+04	5.21E+04
Mn	11	10	1.91E-01	6.04E+00	1.64E-01	3.22E+00	1.91E-01	1.91E-01	3.93E+00	1.64E+00	<MDC	<MDC
Mo	9	9	1.48E+00	7.14E+00	N/A	N/A	N/A	N/A	6.25E-01	-4.48E-01	7.14E+00	7.14E+00
Na	10	10	3.84E+03	1.65E+05	8.01E+02	2.91E+02	4.02E+04	4.02E+04	8.70E+02	9.16E+01	1.65E+05	1.65E+05
Nd	11	1	5.37E-03	5.37E-03	8.80E-02	1.76E-01	<MDC	<MDC	6.80E-01	-3.71E-01	<MDC	<MDC
Ni	11	11	8.00E-01	5.78E+00	1.14E+00	6.04E-01	1.24E+00	1.24E+00	2.52E-01	-5.70E-01	5.78E+00	5.78E+00
P	2	1	5.22E+01	5.22E+01	N/A	N/A	N/A	N/A	2.49E+01	-1.25E+01	5.22E+01	5.22E+01
Pb	9	9	2.56E-01	7.79E+00	N/A	N/A	N/A	N/A	3.20E+00	4.53E+00	7.79E+00	7.79E+00
Pr	11	1	9.05E-04	9.05E-04	3.80E-02	6.63E-02	<MDC	<MDC	4.54E-01	-9.00E-03	<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	9	6	2.41E-02	2.86E-01	N/A	N/A	N/A	N/A	1.85E-01	1.40E+00	2.86E-01	2.86E-01
Sc	7	7	4.61E+00	9.08E+01	N/A	N/A	N/A	N/A	5.02E+00	-2.01E+01	1.32E+01	1.32E+01
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	4	4	1.53E+04	7.82E+04	N/A	N/A	N/A	N/A	5.00E+03	-4.87E+04	7.82E+04	7.82E+04
Sm	10	6	2.69E-02	4.26E-02	5.30E-02	1.70E-02	<MDC	<MDC	N/A	N/A	N/A	N/A
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	11	11	5.06E+01	2.47E+03	9.30E-01	9.59E-02	5.52E+02	5.52E+02	1.02E+01	4.86E+00	2.47E+03	2.47E+03
Th	8	3	4.32E-03	1.36E-02	N/A	N/A	N/A	N/A	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	8	2	2.73E-02	4.84E-02	N/A	N/A	N/A	N/A	1.92E-01	-6.82E-02	<MDC	<MDC
U	11	11	1.34E+00	1.19E+01	6.10E-02	1.09E-02	2.34E+00	2.34E+00	4.20E-02	-1.68E-02	1.19E+01	1.19E+01
V	11	11	2.46E+01	1.23E+02	1.07E-01	4.84E+00	2.46E+01	2.46E+01	1.11E+01	1.60E+00	1.23E+02	1.23E+02
Zn	11	9	1.80E+00	5.38E+01	1.78E+00	1.02E+02	<MDC	4.99E+00	4.20E+00	-4.30E+01	5.38E+01	1.07E+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 2-2: Measured Concentration of Selected Inorganic Analytes in Drinking Water from 1998 to 2008 at Five Locations (C*ontinued)*

Hobbs												
	1998-2008				2007				2008			
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	3.86E-03	1.04E-01	N/A	N/A	N/A	N/A	1.20E-01	1.57E-02	<MDC	<MDC
Al	9	6	3.03E+00	1.69E+02	2.34E+01	1.92E+02	<MDC	<MDC	3.10E+01	9.04E+01	1.69E+02	1.69E+02
As	9	9	4.51E+00	3.21E+01	7.12E-01	3.15E+00	6.70E+00	6.70E+00	2.89E+01	2.74E+01	3.21E+01	3.21E+01
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	9	9	5.65E+01	3.09E+02	1.99E-01	-1.36E+00	6.52E+01	6.52E+01	1.24E+00	1.08E+00	3.09E+02	3.09E+02
Be	7	1	5.39E-02	5.39E-02	N/A	N/A	N/A	N/A	1.94E+00	-1.58E+00	<MDC	<MDC
Ca	8	8	8.09E+03	4.60E+05	1.80E+03	1.43E+04	8.63E+04	1.01E+05	1.00E+04	-3.29E+03	4.60E+05	4.60E+05
Cd	8	1	1.57E-01	1.57E-01	N/A	N/A	N/A	N/A	4.17E-01	-1.20E+00	<MDC	<MDC
Ce	8	5	5.10E-03	1.30E-01	3.20E-02	-7.02E-01	<MDC	<MDC	1.00E-01	-1.56E-01	1.30E-01	1.30E-01
Co	9	7	9.78E-02	1.19E+00	6.40E-02	-1.82E-01	1.88E-01	1.88E-01	2.54E-01	1.49E-01	1.19E+00	1.19E+00
Cr	9	9	7.33E-01	1.24E+01	2.87E-01	1.11E+00	8.45E-01	8.45E-01	5.27E-01	-5.48E-01	1.24E+01	1.24E+01
Cu	9	9	1.06E+00	1.65E+01	1.17E+00	4.23E+01	4.86E+00	4.86E+00	8.81E-01	6.81E+00	1.65E+01	1.65E+01
Dy	9	1	4.18E-03	4.18E-03	5.80E-02	1.49E-01	<MDC	<MDC	3.42E-01	-3.39E-01	<MDC	<MDC
Er	9		N/A	N/A	3.70E-02	1.33E-01	<MDC	<MDC	4.60E-02	-1.95E-03	<MDC	<MDC
Eu	8	5	1.31E-02	1.97E-02	9.30E-02	-7.61E-02	<MDC	<MDC	N/A	N/A	N/A	N/A
Fe	7	5	3.64E+01	1.67E+03	N/A	N/A	N/A	N/A	1.01E+03	1.46E+02	1.67E+03	1.67E+03
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	8		N/A	N/A	5.30E-02	6.00E-02	<MDC	<MDC	4.75E-02	-5.18E-02	<MDC	<MDC
Hg	6	2	1.06E-02	1.42E-02	N/A	N/A	N/A	N/A	2.05E-01	2.54E+00	<MDC	<MDC
K	8	8	4.12E+02	2.53E+04	2.33E+01	2.26E+03	4.12E+02	2.68E+03	5.00E+02	-5.15E+02	1.16E+04	1.16E+04
La	8	4	1.51E-02	5.01E-02	1.25E-01	2.07E-02	<MDC	<MDC	N/A	N/A	N/A	N/A
Li	7	7	2.65E+01	1.34E+02	N/A	N/A	N/A	N/A	4.93E-01	-1.32E+00	1.34E+02	1.34E+02
Mg	8	8	2.11E+03	1.11E+05	3.43E+02	-2.56E+02	2.51E+04	2.51E+04	3.41E+01	-6.67E+00	1.11E+05	1.11E+05
Mn	9	9	3.79E-01	1.17E+01	1.64E-01	3.22E+00	1.78E+00	1.78E+00	3.93E+00	1.64E+00	1.17E+01	1.17E+01
Mo	8	8	2.60E+00	1.36E+01	N/A	N/A	N/A	N/A	6.25E-01	-4.48E-01	1.36E+01	1.36E+01
Na	8	8	4.97E+03	2.49E+05	8.01E+02	2.91E+02	5.46E+04	5.46E+04	8.70E+02	9.16E+01	2.49E+05	2.49E+05
Nd	9	3	3.01E-03	1.28E-02	8.80E-02	1.76E-01	<MDC	<MDC	6.80E-01	-3.71E-01	<MDC	<MDC
Ni	9	9	1.08E+00	2.08E+01	1.14E+00	6.04E-01	2.46E+00	2.46E+00	2.52E-01	-5.70E-01	2.08E+01	2.08E+01
P	2	1	1.26E+02	1.26E+02	N/A	N/A	N/A	N/A	2.49E+01	-1.25E+01	1.26E+02	1.26E+02
Pb	8	7	9.44E-02	7.72E+00	N/A	N/A	N/A	N/A	3.20E+00	4.53E+00	<MDC	<MDC
Pr	9	1	1.57E-03	1.57E-03	3.80E-02	6.63E-02	<MDC	<MDC	4.54E-01	-9.00E-03	<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	7	6	3.88E-02	3.47E-01	N/A	N/A	N/A	N/A	1.85E-01	1.40E+00	3.47E-01	3.47E-01
Sc	6	6	7.17E+00	9.25E+01	N/A	N/A	N/A	N/A	5.02E+00	-2.01E+01	2.20E+01	2.20E+01
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	4	4	2.54E+04	1.32E+05	N/A	N/A	N/A	N/A	1.00E+04	-4.87E+04	1.32E+05	1.32E+05
Sm	8	6	1.93E-02	3.27E-02	5.30E-02	1.70E-02	<MDC	<MDC	N/A	N/A	N/A	N/A
Sn	3		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sr	9	9	7.89E+01	4.49E+03	9.30E-01	9.59E-02	1.06E+03	1.06E+03	1.02E+01	4.86E+00	4.49E+03	4.49E+03
Th	7	2	4.54E-03	4.56E-03	N/A	N/A	N/A	N/A	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	6	2	2.24E-02	2.31E-02	N/A	N/A	N/A	N/A	1.92E-01	-6.82E-02	<MDC	<MDC
U	9	9	2.90E+00	1.77E+01	6.10E-02	1.09E-02	3.77E+00	3.77E+00	4.20E-02	-1.68E-02	1.77E+01	1.77E+01
V	9	9	3.23E+01	1.64E+02	1.07E-01	4.84E+00	3.23E+01	3.23E+01	1.11E+01	1.60E+00	1.64E+02	1.64E+02
Zn	9	8	1.47E+00	5.93E+01	1.78E+00	1.02E+02	<MDC	3.60E+00	4.20E+00	-4.30E+01	5.93E+01	1.63E+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 2-2: Measured Concentration of Selected Inorganic Analytes in Drinking Water from 1998 to 2008 at Five Locations (C*ontinued)*

Loving												
	1998-2008				2007				2008			
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	10	3	2.55E-03	1.30E-01	N/A	N/A	N/A	N/A	1.20E-01	1.57E-02	<MDC	<MDC
Al	10	4	3.76E+00	1.88E+03	2.34E+01	1.92E+02	4.42E+01	4.42E+01	3.10E+02	9.04E+01	1.88E+03	1.88E+03
As	10	7	1.20E+00	2.16E+00	7.12E-01	3.15E+00	1.70E+00	1.70E+00	2.89E+01	2.74E+01	<MDC	<MDC
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	10	10	2.86E+01	1.73E+02	1.99E-01	-1.36E+00	3.37E+01	3.37E+01	1.24E+00	1.08E+00	1.73E+02	1.73E+02
Be	7	1	9.35E-02	9.35E-02	N/A	N/A	N/A	N/A	1.94E+00	-1.58E+00	<MDC	<MDC
Ca	8	8	9.14E+03	4.59E+05	1.80E+03	1.43E+04	7.54E+04	8.98E+04	1.00E+04	-3.29E+03	4.59E+05	4.59E+05
Cd	9		N/A	N/A	N/A	N/A	N/A	N/A	4.17E-01	-1.20E+00	<MDC	<MDC
Ce	8	2	9.74E-04	1.26E+00	3.20E-02	-7.02E-01	<MDC	<MDC	1.00E-01	-1.56E-01	1.26E+00	1.26E+00
Co	10	7	1.02E-01	1.15E+00	6.40E-02	-1.82E-01	1.33E-01	1.33E-01	2.54E-01	1.49E-01	1.15E+00	1.15E+00
Cr	10	8	1.21E+00	3.68E+01	2.87E-01	1.11E+00	4.24E+00	4.24E+00	5.27E-01	-5.48E-01	3.68E+01	3.68E+01
Cu	10	9	1.71E+00	9.88E+00	1.17E+00	4.23E+01	<MDC	<MDC	8.81E-01	6.81E+00	9.88E+00	9.88E+00
Dy	10		N/A	N/A	5.80E-02	1.49E-01	<MDC	<MDC	3.42E-01	-3.39E-01	<MDC	<MDC
Er	10		N/A	N/A	3.70E-02	1.33E-01	<MDC	<MDC	4.60E-02	-1.95E-03	<MDC	<MDC
Eu	9	5	7.00E-03	1.01E-02	9.30E-02	-7.61E-02	<MDC	<MDC	N/A	N/A	N/A	N/A
Fe	9	4	1.56E+01	1.28E+03	N/A	N/A	N/A	N/A	2.02E+02	1.46E+02	1.28E+03	1.28E+03
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	8	3	2.15E-03	5.19E-02	5.30E-02	6.00E-02	<MDC	<MDC	4.75E-02	-5.18E-02	5.19E-02	5.19E-02
Hg	5		N/A	N/A	N/A	N/A	N/A	N/A	2.05E-01	2.54E+00	<MDC	<MDC
K	8	7	1.85E+03	1.98E+04	2.33E+01	2.26E+03	<MDC	2.04E+03	5.00E+02	-5.15E+02	1.08E+04	1.08E+04
La	9	4	7.27E-03	2.22E-02	1.25E-01	2.07E-02	<MDC	<MDC	N/A	N/A	N/A	N/A
Li	7	7	1.66E+01	8.69E+01	N/A	N/A	N/A	N/A	4.93E-01	-1.32E+00	8.69E+01	8.69E+01
Mg	9	9	4.04E+03	2.07E+05	3.43E+02	-2.56E+02	3.99E+04	3.99E+04	1.71E+02	-6.67E+00	2.07E+05	2.07E+05
Mn	10	7	1.43E-02	1.77E+00	1.64E-01	3.22E+00	5.48E-01	5.48E-01	3.93E+00	1.64E+00	<MDC	<MDC
Mo	9	7	1.41E+00	8.34E+00	N/A	N/A	N/A	N/A	6.25E-01	-4.48E-01	8.34E+00	8.34E+00
Na	8	8	2.33E+03	1.27E+05	8.01E+02	2.91E+02	2.73E+04	2.73E+04	8.70E+02	9.16E+01	1.27E+05	1.27E+05
Nd	10	1	3.37E-03	3.37E-03	8.80E-02	1.76E-01	<MDC	<MDC	6.80E-01	-3.71E-01	<MDC	<MDC
Ni	10	8	1.19E+00	9.57E+00	1.14E+00	6.04E-01	2.15E+00	2.15E+00	2.52E-01	-5.70E-01	9.57E+00	9.57E+00
P	3	1	1.69E+02	1.69E+02	N/A	N/A	N/A	N/A	2.49E+01	-1.25E+01	1.69E+02	1.69E+02
Pb	9	8	6.33E-01	7.34E+00	N/A	N/A	N/A	N/A	3.20E+00	4.53E+00	<MDC	<MDC
Pr	9		N/A	N/A	3.80E-02	6.63E-02	<MDC	<MDC	4.54E-01	-9.00E-03	<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	8	5	3.51E-02	2.54E-01	N/A	N/A	N/A	N/A	1.85E-01	1.40E+00	2.54E-01	2.54E-01
Sc	7	7	3.22E+00	8.97E+01	N/A	N/A	N/A	N/A	5.02E+00	-2.01E+01	9.54E+00	9.54E+00
Se	5		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Si	5	5	8.54E+03	5.13E+04	N/A	N/A	N/A	N/A	5.00E+03	-4.87E+04	5.13E+04	5.13E+04
Sm	9	3	8.43E-03	1.30E-02	5.30E-02	1.70E-02	<MDC	<MDC	N/A	N/A	N/A	N/A
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	10	10	7.60E+01	3.78E+03	9.30E-01	9.59E-02	7.67E+02	7.67E+02	1.02E+01	4.86E+00	3.78E+03	3.78E+03
Th	8	2	5.69E-03	9.63E-03	N/A	N/A	N/A	N/A	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	8	1	4.32E-02	4.32E-02	N/A	N/A	N/A	N/A	1.92E-01	-6.82E-02	<MDC	<MDC
U	10	10	1.98E+00	1.06E+01	6.10E-02	1.09E-02	2.13E+00	2.13E+00	4.20E-02	-1.68E-02	1.06E+01	1.06E+01
V	10	10	1.19E+01	7.22E+01	1.07E-01	4.84E+00	1.22E+01	1.22E+01	1.11E+01	1.60E+00	7.22E+01	7.22E+01
Zn	10	9	4.13E+00	1.23E+02	1.78E+00	1.02E+02	<MDC	1.21E+01	4.20E+00	-4.30E+01	1.23E+02	7.98E+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 2-2: Measured Concentration of Selected Inorganic Analytes in Drinking Water from 1998 to 2008 at Five Locations (C*ontinued)*

Otis												
	1998-2008				2007				2008			
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	2.63E-02	2.63E-02	N/A	N/A	N/A	N/A	1.20E-01	1.57E-02	<MDC	<MDC
Al	9	2	5.74E+00	2.10E+02	2.34E+01	1.92E+02	<MDC	<MDC	3.10E+01	9.04E+01	2.10E+02	2.10E+02
As	10	5	6.53E-01	2.34E+00	7.12E-01	3.15E+00	2.34E+00	2.34E+00	2.89E+01	2.74E+01	<MDC	<MDC
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	10	10	1.35E+01	7.31E+01	1.99E-01	-1.36E+00	1.60E+01	1.60E+01	1.24E+00	1.08E+00	7.31E+01	7.31E+01
Be	7		N/A	N/A	N/A	N/A	N/A	N/A	1.94E+00	-1.58E+00	<MDC	<MDC
Ca	8	8	2.14E+05	3.83E+05	1.80E+04	1.43E+04	2.67E+05	2.82E+05	N/A	N/A	N/A	N/A
Cd	8		N/A	N/A	N/A	N/A	N/A	N/A	4.17E-01	-1.20E+00	<MDC	<MDC
Ce	7	1	1.38E-01	1.38E-01	3.20E-02	-7.02E-01	<MDC	<MDC	1.00E-01	-1.56E-01	1.38E-01	1.38E-01
Co	9	8	1.19E-01	3.17E+00	6.40E-02	-1.82E-01	4.14E-01	4.14E-01	2.54E-01	1.49E-01	3.17E+00	3.17E+00
Cr	10	9	8.76E-01	2.20E+01	2.87E-01	1.11E+00	8.76E-01	8.76E-01	5.27E-01	-5.48E-01	2.20E+01	2.20E+01
Cu	10	9	2.43E+00	1.93E+01	1.17E+00	4.23E+01	3.00E+00	3.00E+00	8.81E-01	6.81E+00	1.93E+01	1.93E+01
Dy	9	1	3.39E-03	3.39E-03	5.80E-02	1.49E-01	<MDC	<MDC	3.42E-01	-3.39E-01	<MDC	<MDC
Er	9		N/A	N/A	3.70E-02	1.33E-01	<MDC	<MDC	4.60E-02	-1.95E-03	<MDC	<MDC
Eu	8	3	3.42E-03	9.48E-03	9.30E-02	-7.61E-02	<MDC	<MDC	N/A	N/A	N/A	N/A
Fe	9	9	2.87E+00	5.08E+03	N/A	N/A	N/A	N/A	1.01E+03	1.46E+02	5.08E+03	5.08E+03
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	7		N/A	N/A	5.30E-02	6.00E-02	<MDC	<MDC	4.75E-02	-5.18E-02	<MDC	<MDC
Hg	7		N/A	N/A	N/A	N/A	N/A	N/A	2.05E-01	2.54E+00	<MDC	<MDC
K	9	9	6.81E+02	1.61E+04	2.33E+01	2.26E+03	6.81E+02	2.94E+03	5.00E+02	-5.15E+02	1.61E+04	1.61E+04
La	8	2	3.97E-03	6.30E-03	1.25E-01	2.07E-02	<MDC	<MDC	N/A	N/A	N/A	N/A
Li	7	7	4.11E+01	1.87E+02	N/A	N/A	N/A	N/A	4.93E-01	-1.32E+00	1.87E+02	1.87E+02
Mg	9	9	5.16E+04	4.37E+05	3.43E+02	-2.56E+02	7.77E+04	7.77E+04	1.71E+02	-6.67E+00	4.37E+05	4.37E+05
Mn	9	6	1.78E-01	2.32E+00	1.64E-01	3.22E+00	<MDC	<MDC	3.93E+00	1.64E+00	<MDC	<MDC
Mo	8	8	2.39E+00	1.23E+01	N/A	N/A	N/A	N/A	6.25E-01	-4.48E-01	1.23E+01	1.23E+01
Na	9	9	5.81E+03	1.62E+05	8.01E+02	2.91E+02	1.02E+05	1.02E+05	8.70E+01	9.16E+01	5.81E+03	5.81E+03
Nd	9	3	4.80E-03	3.97E-02	8.80E-02	1.76E-01	<MDC	<MDC	6.80E-01	-3.71E-01	<MDC	<MDC
Ni	9	9	2.45E+00	2.65E+01	1.14E+00	6.04E-01	5.91E+00	5.91E+00	2.52E-01	-5.70E-01	2.65E+01	2.65E+01
P	2	2	4.54E+01	4.99E+02	N/A	N/A	N/A	N/A	2.49E+01	-1.25E+01	4.99E+02	4.99E+02
Pb	8	7	1.08E-01	7.20E+00	N/A	N/A	N/A	N/A	3.20E+00	4.53E+00	<MDC	<MDC
Pr	9		N/A	N/A	3.80E-02	6.63E-02	<MDC	<MDC	4.54E-01	-9.00E-03	<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	8	6	3.50E-02	4.10E-01	N/A	N/A	N/A	N/A	1.85E-01	1.40E+00	3.91E-01	3.91E-01
Sc	7	7	3.53E+00	8.95E+01	N/A	N/A	N/A	N/A	5.02E+00	-2.01E+01	1.29E+01	1.29E+01
Se	7		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Si	5	5	9.77E+03	4.99E+04	N/A	N/A	N/A	N/A	5.00E+03	-4.87E+04	4.99E+04	4.99E+04
Sm	8	1	3.56E-03	3.56E-03	5.30E-02	1.70E-02	<MDC	<MDC	N/A	N/A	N/A	N/A
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	10	10	1.65E+02	3.61E+03	9.30E+00	9.59E-02	2.81E+03	2.81E+03	1.02E+00	4.86E+00	1.65E+02	1.65E+02
Th	7	2	3.44E-03	2.67E-02	N/A	N/A	N/A	N/A	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	7		N/A	N/A	N/A	N/A	N/A	N/A	1.92E-01	-6.82E-02	<MDC	<MDC
U	9	9	3.73E+00	2.14E+01	6.10E-02	1.09E-02	4.42E+00	4.42E+00	4.20E-02	-1.68E-02	2.14E+01	2.14E+01
V	10	10	1.05E+01	5.74E+01	1.07E-01	4.84E+00	1.08E+01	1.08E+01	1.11E+01	1.60E+00	5.74E+01	5.74E+01
Zn	10	9	1.54E+00	7.44E+01	1.78E+00	1.02E+02	<MDC	3.21E+00	4.20E+00	-4.30E+01	7.44E+01	3.13E+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

CHAPTER 3

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 2008) 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 2008, 827 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 289 recount bioassays had been performed through 31 December 2008. In addition, 258 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 3-1) of the current LDBC cohort are statistically[2] unchanged from those reported in previous CEMRC reports, and are generally consistent with those reported in the 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,

[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.

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 3-2 for 2007/2008 and 2008/2009. 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 3-2). 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 3-3, N = 743), 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 74% 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 2008 and ranged from 792 to 5558 Bq per person with an overall mean (± SE) of 2517 (± 25) 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 3073 (± 28) Bq per person, which was significantly greater ($p < 0.0001$) than that of females, which was 1897 (± 21) 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 132 Bq per person with an overall mean (± SE) of 11.3 (± 0.8) Bq per person. The mean ^{137}Cs body burden for males (± SE), was 12.6 (± 1.2) 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 (29.1 %) as compared to non-smokers (24.3 %). 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 has been no observable effects 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 3-1: Demographic Characteristics of the "Lie Down and Be Counted" Population Sample through December 31, 2008

Characteristic		2006 Sample Group [a](margin of error)	[b]Census, 2000
Gender	Male	50.2% (46.8 to 53.7%)	48.2 %
	Female	49.8% (46.3 to 53.2%)	51.8 %
Ethnicity	Hispanic	15.5% (13 to 18%)	36.7 %
	Non-hispanic	83.7% (81.1 to 86.2%)	63.3 %
Age 60 or older		26.3% (23.7 to 28.9%)	24.5 %
Currently or previously classified as a radiation worker		8.0% (6.4 to 9.6%)	[c]NA
Consumption of wild game within 3 months prior to count		21.4% (19.0 to 23.8%)	NA
Medical treatment other than x-rays using radionuclides		7.7% (6.1 to 9.2%)	NA
European travel within 2 years prior to the count		5.4% (4.1 to 6.7%)	NA
Current smoker		13.9% (11.8 to 15.9%)	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 3-2: Minimum Detectable Activities

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 3-2: Minimum Detectable Activities *(Continued)*

2008-2009 Calibration

Radionuclides Deposited in the Lungs

Radionuclide	Energy (keV)	CWT = 1.6 MDA (nCi)	CWT = 2.22 MDA (nCi)	CWT = 3.01 MDA (nCi)	CWT = 3.33 MDA (nCi)	CWT = 4.18 MDA (nCi)	CWT = 5.10 MDA (nCi)	CWT = 6.0 MDA (nCi)
AM-241	59.50	0.17	0.23	0.31	0.35	0.49	0.70	1.00
CE-144	133.50	0.48	0.56	0.72	0.80	1.05	1.40	1.86
CF-252	19.20	19.47	34.24	79.93	112.80	280.03	749.63	1962.46
CM-244	18.10	17.10	33.96	87.90	128.41	357.32	1081.36	3179.24
EU-155	105.30	0.26	0.34	0.45	0.49	0.68	0.94	1.30
NP-237	86.50	0.46	0.61	0.82	0.93	1.29	1.83	2.57
Pu-238	17.10	17.47	40.20	116.57	179.34	564.87	1945.76	6542.12
Pu-239	17.10	43.46	100.01	290.03	446.20	1405.42	4841.12	16277.04
Pu-240	17.10	17.08	39.29	113.94	175.29	552.13	1901.87	6394.55
Pu-242	17.10	20.60	47.40	137.45	211.46	666.06	2294.32	7714.06
Ra-226	186.10	1.78	1.92	2.37	2.58	3.23	4.13	5.24
Th-232 Via Pb-212	238.60	0.15	0.18	0.22	0.24	0.31	0.40	0.52
Th-232	59.00	33.23	44.39	60.25	68.21	95.02	135.74	192.74
Th-232 via Th-228)	84.30	4.63	6.23	8.40	9.50	13.15	18.71	26.39
U-233	440.30	0.63	0.74	0.92	1.00	1.25	1.56	2.00
U-235	185.70	0.11	0.12	0.15	0.16	0.20	0.26	0.32
Nat U via Th-234	63.30	1.50	2.02	2.76	3.13	4.36	6.23	8.85

Radionuclides Deposited in the Whole Body

Radionuclide	Energy (keV)	MDA (nCi)
Ba-133	356	0.77
Ba-140	537	1.50
Ce-141	145	1.70
Co-58	811	0.36
Co-60	1333	0.35
Cr-51	320	4.46
Cs-134	604	0.34
Cs-137	662	0.42
Eu-152	344	1.57
Eu-154	1275	0.93
Eu-155	105	4.06
Fe-59	1099	0.66
I-131	365	0.46
I-133	530	0.36
Ir-192	317	0.57
Mn-54	835	0.44
Ru-103	497	0.38
Ru-106	622	3.22
Sb-125	428	0.13
Th-232 via Ac-228	911	1.24
Y-88	898	0.38
Zn-65	1116	1.09
Zr-95	757	0.58

Table 3-3: "Lie Down and Be Counted" Results through December 31, 2008

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 2008) N = 743
		% of Results ≥ [b]L_C	% of Results ≥ L_C
^{241}Am	Lung	5.2 (4.0 to 6.4)	4.0 (3.3 to 4.8)
^{144}Ce	Lung	4.6 (3.5 to 5.7)	3.4 (2.7 to 4.0)
^{252}Cf	Lung	4.1 (3.1 to 5.1)	5.8 (4.9 to 6.6)
^{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)	4.8 (4.1 to 5.6)
^{237}Np	Lung	3.6 (2.6 to 4.5)	4.2 (3.4 to 4.9)
^{210}Pb	Lung	4.4 (3.3 to 5.4)	6.1 (5.2 to 7.0)
Plutonium Isotope	Lung	5.7 (4.5 to 7.0)	5.7 (4.8 to 6.5)
[d] ^{232}Th via ^{212}Pb	Lung	34.2 (31.7 to 36.6)	34.1 (32.4 to 35.9)
^{232}Th	Lung	4.9 (3.8 to 6.0)	5.1 (4.3 to 5.9)
^{232}Th via ^{228}Th	Lung	4.1 (3.1 to 5.1)	4.9 (4.1 to 5.6)
^{233}U	Lung	5.7 (4.5 to 7.0)	9.8 (8.7 to 10.9)
^{235}U/^{226}Ra	Lung	10.7 (9.0 to 12.3)	11.2 (10.0 to 12.3)
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)	3.0 (2.3 to 3.6)
^{140}Ba	Whole Body	5.2 (4.0 to 6.4)	4.0 (3.3 to 4.8)
^{141}Ce	Whole Body	3.6 (2.6 to 4.5)	4.6 (3.8 to 5.3)
^{58}Co	Whole Body	4.4 (3.3 to 5.4)	2.4 (1.9 to 3.0)
[d] ^{60}Co	Whole Body	54.6 (52.0 to 57.2)	27.8 (26.1 to 29.4)
^{51}Cr	Whole Body	5.7 (4.5 to 7.0)	3.9 (3.2 to 4.6)
^{134}Cs	Whole Body	1.6 (1.0 to 2.3)	2.4 (1.9 to 3.0)
^{137}Cs	Whole Body	28.4 (26.1 to 30.8)	20.9 (19.4 to 22.4)
^{152}Eu	Whole Body	7.4 (6.0 to 8.7)	6.5 (5.6 to 7.4)
^{154}Eu	Whole Body	3.8 (2.8 to 4.8)	2.8 (2.2 to 3.4)
^{155}Eu	Whole Body	3.8 (2.8 to 4.8)	3.6 (3.0 to 4.3)
^{59}Fe	Whole Body	3.8 (2.8 to 4.8)	5.9 (5.1 to 6.8)
^{131}I	Whole Body	5.2 (4.0 to 6.4)	3.9 (3.2 to 4.6)
^{133}I	Whole Body	3.3 (2.3 to 4.2)	3.8 (3.1 to 4.5)
^{193}Ir	Whole Body	4.1 (3.1 to 5.1)	3.9 (3.2 to 4.6)
^{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)	11.7 (10.5 to 12.9)
^{103}Ru	Whole Body	2.2 (1.4 to 3.0)	1.5 (1.0 to 1.9)
^{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 (3.0 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)	6.2 (5.3 to 7.1)
^{95}Zr	Whole Body	6.6 (5.3 to 7.9)	3.9 (3.2 to 4.6)

[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 4

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. The current list of analytes is presented in Table 4-1.

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. In 2008, a total of 608 samples were analyzed for VOCs and 254 samples were analyzed 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 4-2 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 4-1.

METHODS FOR HYDROGEN AND METHANE ANALYSIS

The analysis of hydrogen and methane in closed room samples began in August 2007. Under the analysis scheme used at CEMRC, sample canisters 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 608 routine ambient air samples for VOCs during 2008 with 100% completeness. 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 80 additional samples with 100% completeness. A total of 254 samples were analyzed for hydrogen and methane, with 100% completeness.

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 4-1: 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

Table 4-2: CEMRC Procedures for Confirmatory Volatile Organic Compounds Monitoring Program

Procedure Number	Procedure Title
OC-PLAN-001	Quality Assurance Plan for Analysis of Volatile Organic Compounds in Canister Samples
OC-PROC-002	Preparation of Canisters for Ambient Air
OC-PROC-003	Gas Chromatography-Mass Spectrometry of Volatile Organic Compounds (VOCs) in Ambient Air from Canisters at PPBV Concentration Levels
OC-PROC-004	Preparation of Calibration Standards in Specially Prepared Canisters for Analysis by Gas Chromatography/Mass Spectrometry
OC-PROC-005	Data Validation and Reporting of Volatile Organic Compounds from Gas Chromatography/Mass Spectrometry Analysis of Ambient Air in Canisters for the WIPP Volatile Organic Compound Monitoring Plan
OC-PROC-006	Receipt, Control, and Storage of Gas Samples in Passivated Canisters
OC-PROC-009	Analysis of Hydrogen and Methane in Passivated Canisters Using Gas Chromatography with Thermal Conductivity Detection

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 in exchange for radiochemistry collaborations under contract at CEMRC which included residence of their staff in office and laboratory space at CEMRC. In September 2004, Dr. James Conca was appointed Director of CEMRC. In FY2005 the CEMRP grant was 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 2009.

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. Replacement of major portions of the facility began in 2008 and will continue to 2010, including replacement of the roof, major detectors, the phone system, upgrade of the electrical system and ventilation system, and upgrade of the Radioactive Materials License to accommodate higher activities.

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
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,* vol. 45, p. 13-21, 2008
J. Conca and J. Wright	Nuclear Energy and Radioactive Waste Disposal", in *International Seminars on Nuclear War and Planetary Emergencies, 38th Session*	The Science and Culture Series – Nuclear Strategy and Peace Technology, R. Ragaini, editor, World Scientific - Imperial College Press, 2008
Kirchner, T. B.	Generation of the LHS Samples for the AP-137 Revision 0 (CRA09) PA Calculations	Report to Sandia National Laboratories, Carlsbad, NM. 2008
Kirchner, T. B.	Generation of the LHS Samples for the AP-132 PA Calculations Revision 1	Report to Sandia National Laboratories, Carlsbad, NM. 2008
Kirchner, T. B.	Sensitivity of the CRA-2009 Performance Assessment Calculation Releases to Parameters	Report to Sandia National Laboratories, Carlsbad, NM. 2008
Kirchner, T. B.	Concepts and statistical distributions. 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.	Addendum To The Design Document And User's Manual For CCDFGF (Version 5.00).	Report to Sandia National Laboratories, Carlsbad, NM. 2008
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.	Addendum To The Requirements Document For LHS Version 2.42	Report to Sandia National Laboratories, Carlsbad, NM. 2008
Kirchner, T. B.	Estimating and applying uncertainty in assessment models.	In Till, J. E. and H. A. Grogan (eds.) Radiological Risk Assessment and Environmental Analysis. Oxford University Press, New York. 2008

Appendix C: Tours, Public Presentations and Other Outreach

Group/Activity
CEMRC hosted the State MESA schools science program for developing energy curricula in public schools, June 2008.
CEMRC worked with local Carlsbad high school science teachers and students in 2008 to obtain science teaching grants.
CEMRC participated in the annual Relay for Life.
CEMRC participated in the annual Riverblitz.
2008 Dr. James Conca gave seminars to five classes at NMSU Las Cruces, four at NMSU Carlsbad branch, five to Carlsbad High School and middle school classes – many CEMRC tours and presentations.
2008 host of the monthly American Nuclear Society section meeting.
American Nuclear Society Seminar, February 12, 2008 "The Geopolitics of Energy: Achieving a Just and Sustainable Energy Distribution by 2040" Dr. James Conca, NMSU/CEMRC.
American Nuclear Society Seminar, May 14, 2008 "250Ma Cellulose Visualized in WIPP: A "Paper Trail" in the Search for Life on Other Planets" Roger Nelson, Chief Scientist, US DOE/CBFO.
American Nuclear Society Seminar, June 11, 2008 "Underground Nuclear Energy Parks: An Old Idea, with a New Twist!" Wes Myers, LANL.
American Nuclear Society Seminar, July 9, 2008 "Status of the HT3R Project at UTPB" James F. Wright, Director, HT3R Project.
American Nuclear Society Seminar, July 21, 2008 "The Meuse/Haute-Marne Underground Research Laboratory On Going Activities and Future Developments" Thibaud Labalette, French National Radioactive Waste Management Agency (ANDRA).
American Nuclear Society Seminar, September 30, 2008 "Los Alamos National Laboratory's WIPP Support Mission" Ned Elkins, LANL.
American Nuclear Society Seminar, October 20, 2008 "The Pu(IV) Polymer Story: From Discovery to Current Knowledge" Heino Nitsche, Professor, University of California Berkeley.
American Nuclear Society Seminar, December 11, 2008 "Biology of Submarines" Tom Goff, WTS Radiological Engineering.
American Nuclear Society Seminar, December 15, 2008 "Microbial Transformations of Actinides in Transuranic and Mixed Wastes and Implications on Radioactive Waste Disposal" A.J. Francis, Brookhaven National Laboratory.
On Thursday April 17, 2008, Jef Lucchini (CEMRC LANL) organized, for the third year in a row, a daylong Nuclear Symposium for about 150 students learning physics and chemistry at the Carlsbad High School. The goal of this outreach program was to provide the students with a basic knowledge on nuclear science and technology. The American Nuclear Society (ANS), Carlsbad Section, sponsored the event that was held at the Carlsbad High School and the NMSU/CEMRC facility. Sixty students started the day with a tour of the CEMRC facility. Scientists from the different organizations in CEMRC (Don Reed, Marian Borkowski, Jef Lucchini, Mansour Akbarzadeh, Sondra Sage, Lisa Hudston) guided the students throughout the facility, showing them the various techniques and equipments (spectrophotometry, ICP-MS, gloveboxes, etc.) as well as the safety (personal protective equipment, hand/shoe monitor) associated with the work. For the first time, the students could see a uranium (VI) solution (yellow) and a plutonium (IV) solution (blue) and their corresponding absorption spectra. Chris Greene and Jim Monk (CEMRC) presented the Whole

Group/Activity
Body Counting program, and David Ganaway (CEMRC) gave a presentation of the VOC lab equipment. Later, about 100 other students joined the first 60 ones for the lectures given by local scientists affiliated with LANL-CO (Jef Lucchini), DOE (Roger Nelson), SNL (Joe Kanney) and WTS (Norbert Rempe, Tom Goff). The seniors who attended to the whole Symposium participated in a contest to win two scholarships offered by the local ANS Chapter. The goal was to respond correctly to 20 questions of a quiz relative to the talks. All the sixteen seniors who participated got excellent grades on this test.

Appendix D: Students/Visiting Scientists Supported At CEMRC 2008

Student/Scientist	Support Period
Students (7) – Illinois Institute of Tech	Summer 2008 Radiation Physics 770 at ITT
Dr. Jeff Terry, Illinois Institute of Tech	Summer 2008 training
Dr. Geof Smith, NMSU Las Cruces	Visiting Professor 2008
Brenda Mota, UTEP	Grad student
Darlene Martin, NMSU	Grad student
Dan Olive, Illinois Institute of Tech	Post doctoral Research Associate 2008
Jason Dugger, UNM	Undergrad student
Sarah Pepper, LANL	Post-doctoral Research Associate 2008

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 that are reported were acceptable within 10% of the assigned value. Fluoride and boron were slightly outside of 10% but are not reported. 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

December 21, 2007 – December 19, 2008

Prepared by: Karl Pennock

December 20, 2008

This report serves as a periodic review 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, vendor qualification, external audits, internal assessments and nonconformance / non-routine events from December 21, 2007 through December 19, 2008.

Currently, there are 73 active procedures under the CEMRC Controlled Document Program. These procedures are scheduled for review every two years. One procedure, RB-TBM-003, has been rescheduled for revision beyond this period to permit incorporation of new technical guidance. Two procedures, CP-PROC-023 and CP-PROC-024, enable CEMRC to qualify potential vendors. 23 vendors are currently qualified.

External audits were conducted during the past year on two CEMRC programmatic areas: Organic Chemistry and Internal Dosimetry. In April 2008, Washington TRU Solutions (WTS) audited the Volatile Organic Compound Monitoring Program (Organic Chemistry), which was followed in June by an audit of the In Vivo Radiobioassay Program (Internal Dosimetry). The audits led to recertification of each program with two conditions closed during audit and one observation for the Volatile Organic Compound Monitoring Program audit (E08-06), and three noteworthy practices for the In Vivo Radiobioassay Program audit (E08-09). From this quality assurance perspective both programs continue to demonstrate sound performance.

In addition to the WTS audits cited above, internal audits or surveillances were conducted on all nine CEMRC programmatic areas in 2008. Internal audits were conducted on seven of nine programmatic areas, while surveillances were performed on the remaining areas, Document Control (DC) and Quality Assurance (QA). A summary of the internal audit findings is presented in Table 1, none of which significantly impacted CEMRC activities.[1] The surveillances will be used as a guideline to address areas that need improvement. Since aspects of the surveillances will be ongoing and checked periodically in the upcoming year, a summary of the surveillances has not been included in Table 1.

30 non-routine events (NREs) and 2 nonconformances (NCRs) were recorded for the most recent assessment period compared with 16 NREs and 3 NCRs in Calendar Year 2007. As with the previous annual assessment none of the incidents involved implementation of a center-wide procedure. Since 2003, the first year for which full-year tracking data is

1 Consequences identified as Grade A (High Impact) or Grade B (Moderate Impact)--as stated in Appendix 13.2 of current revision of CP-ROC-012 (*Nonconformances and Non-Routine Events*).

available, there has been an average of 25 NREs and 1.5 NCRs recorded annually. The NCR/NRE trend indicates that while a greater number of NREs were recorded during the most recent assessment period, even as the number of NCRs declined, both sets of data are conforming closely to the long-term average. It should also be noted that NREs, per se, do not necessarily indicate a weakness in any particular programmatic area, but rather may reflect a more robust corrective action program, which benefits Center activities.

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

Table E-1: Internal Audit Summaries 2008 (# 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 2008 by the ORNL Intercomparison Studies In-Vivo Program

Oak Ridge National Laboratory

Intercomparison Studies In-Vivo Program Report
4th Quarter Calendar Year 2008

Carlsbad Environmental Monitoring & Research Center
Set D

ISOTOPE	SPIKE ACTIVITY AS OF 12-02-08 +/- 2 sigma (nCi)	REPORTED ACTIVITY AS OF 12-02-08 +/- 2 sigma (nCi)	% RELATIVE BIAS
Cs-137	124.8 +/- 6.2	125.24 +/- 6.26	0.4
Co-60	110.9 +/- 5.5	110.95 +/- 5.55	0.05
Y-88	39.18 +/- 1.96	39.61 +/- 1.98	1.1
Ba-133	289.4 +/- 14.5	290.68 +/- 14.53	0.4

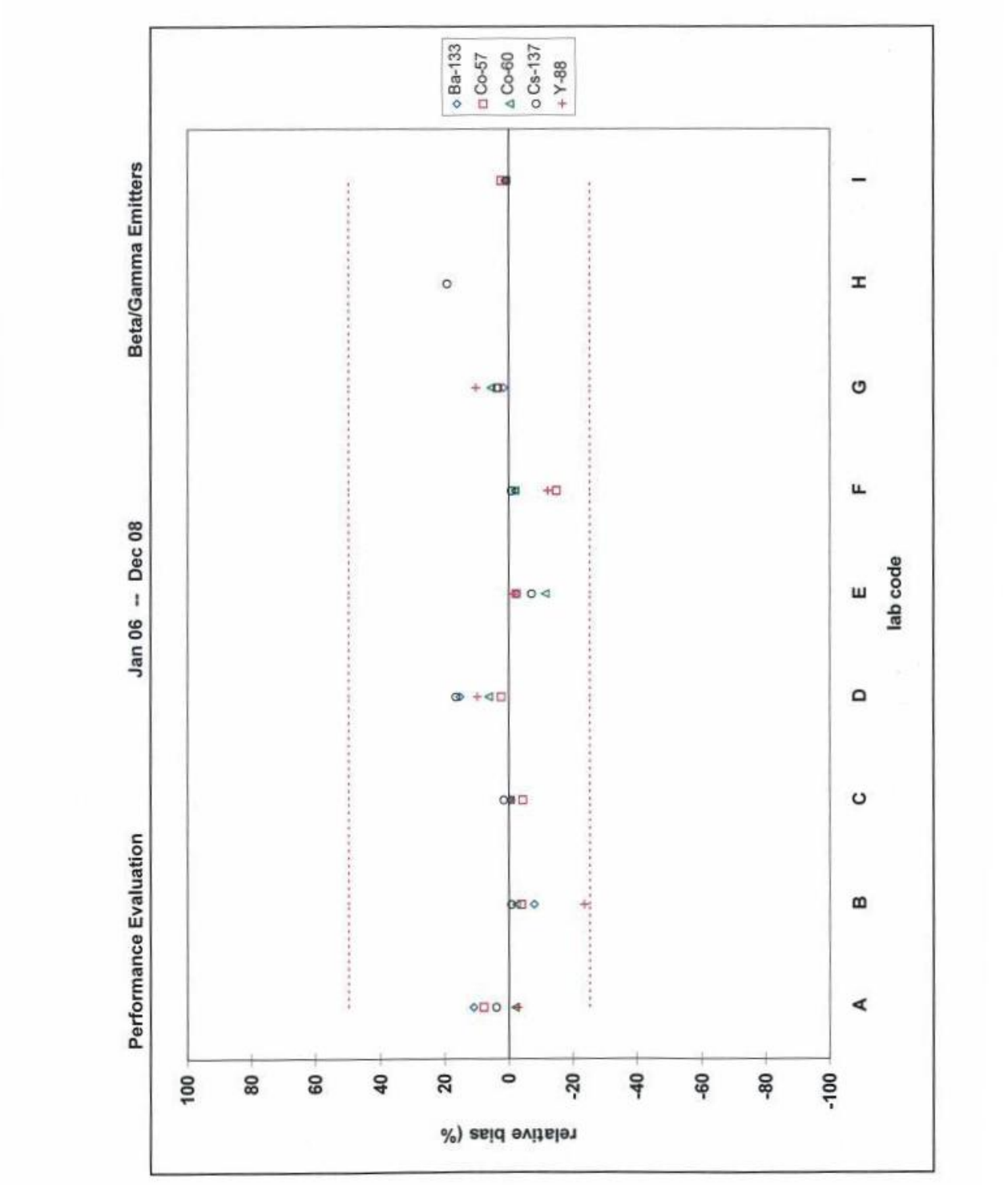


Figure E.1: Comparison of Results for Ten Internal Dosimetry Laboratories in the U.S. During 2008 by the ORNL Intercomparison Studies In-Vivo Program

CEMRC is Lab I. 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 2008 Audits

Agency	Date	Conclusion	Reason
CEMRC Self Assessment	06/11/08 – 06/12/08	2 findings. Pass	Quality System
Oak Ridge National Lab, Intercomparison Studies Program	Quarterly	Pass	External QC
WTS	06/24/08 – 06/25/08	No findings, no observations, and 3 noteworthy practices. Pass	Annual

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

WS-156 Final Complete Report

Kim UiChearnaigh
Environmental Scientist
New Mexico State University
1400 University Dr
CEMRC
Carlsbad, NM 88220-3575
(575) 234-5506

EPA ID: Not Reported
ERA Customer Number: N215603
Report Issued: 09/09/09
Study Dates: 07/07/09 - 08/20/09

Anal. No.	Analyte	Units	Reported Value	Assigned Value	Acceptance Limits	Performance Evaluation	Method Description
WS Inorganics (cat# 591)							
0027	Alkalinity as CaCO3	mg/L		37.4	33.7 - 41.4	Not Reported	
1575	Chloride	mg/L	45.0	45.2	40.6 - 49.9	Acceptable	EPA 300.1
1610	Conductivity at 25°C	µmhos/cm		598	538 - 658	Not Reported	
0010	Fluoride	mg/L	2.91	3.25	2.92 - 3.58	Not Acceptable	EPA 300.1
1820	Nitrate + Nitrite as N	mg/L		6.51	5.84 - 7.16	Not Reported	
0009	Nitrate as N	mg/L	6.84	6.51	5.86 - 7.16	Acceptable	EPA 300.1
1125	Potassium	mg/L		24.9	21.5 - 28.5	Not Reported	
0145	Sulfate	mg/L	123	123	108 - 137	Acceptable	EPA 300.1
0024	Total Dissolved Solids at 180°C	mg/L		383	246 - 519	Not Reported	
WS Metals (cat# 590)							
1000	Aluminum	µg/L	1570	1650	1420 - 1830	Acceptable	EPA 200.8
0140	Antimony	µg/L	44.5	45.7	32.0 - 59.4	Acceptable	EPA 200.8
0001	Arsenic	µg/L	31.0	31.4	22.0 - 40.8	Acceptable	EPA 200.8
0002	Barium	µg/L	1510	1520	1290 - 1750	Acceptable	EPA 200.8
0141	Beryllium	µg/L	3.39	3.35	2.85 - 3.85	Acceptable	EPA 200.8
0226	Boron	µg/L	1380	1150	1010 - 1270	Not Acceptable	EPA 200.8
0003	Cadmium	µg/L	25.7	27.1	21.7 - 32.5	Acceptable	EPA 200.8
0004	Chromium	µg/L	53.8	55.3	47.0 - 63.6	Acceptable	EPA 200.8
0091	Copper	µg/L	971	969	872 - 1060	Acceptable	EPA 200.8
1070	Iron	µg/L	736	732	647 - 806	Acceptable	EPA 200.8
0005	Lead	µg/L	57.6	56.4	39.5 - 73.3	Acceptable	EPA 200.8
0236	Manganese	µg/L	93.8	92.0	82.0 - 102	Acceptable	EPA 200.8
0237	Molybdenum	µg/L	67.9	74.2	64.2 - 82.4	Acceptable	EPA 200.8
0142	Nickel	µg/L	193	198	168 - 228	Acceptable	EPA 200.8
0007	Selenium	µg/L	48.1	52.7	42.2 - 63.2	Acceptable	EPA 200.8
1150	Silver	µg/L	269	271	240 - 299	Acceptable	EPA 200.8
0143	Thallium	µg/L	3.10	3.02	2.11 - 3.93	Acceptable	EPA 200.8
1185	Vanadium	µg/L	551	551	496 - 606	Acceptable	EPA 200.8
0239	Zinc	µg/L	1340	1370	1230 - 1510	Acceptable	EPA 200.8

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

Table E-5: Radiochemistry MAPEP 2008 Intercomparison Results

MAPEP Mixed Analyte Performance Evaluation Program

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

Laboratory Results For MAPEP Series 19
(CMRC01) Carlsbad Environmental Monitoring and Research Center
1400 University Dr.
Carlsbad, NM 88220

MAPEP-08-MaS19: Radiological, inorganic and semi-volatile organics combined soil standard

Inorganic — Units: (mg/kg)

Analyte	Result	Ref Value	Flag	Notes	Bias	Acceptance Range	Unc Value	Unc Flag
Antimony	NR	69.49				48.64 - 90.34		
Arsenic	NR	79.93				55.95 - 103.91		
Barium	NR	248				174 - 322		
Beryllium	NR	36.61				25.63 - 47.59		
Cadmium	NR	12.02				8.41 - 15.63		
Chromium	NR	81.23				56.86 - 105.60		
Cobalt	NR	88.57				62.00 - 115.14		
Copper	NR	79.02				55.31 - 102.73		
Lead	NR	60.15				42.11 - 78.20		
Mercury	NR	0.0167				0.0117 - 0.0217		
Nickel	NR	124.49				87.14 - 161.84		
Selenium	NR	12.99				9.09 - 16.89		
Silver	NR	61.6				43.1 - 80.1		
Thallium	NR	89.71				62.80 - 116.62		
Vanadium	NR	35.8				25.1 - 46.5		
Zinc	NR	242.35				169.65 - 315.06		
Technetium-99	NR	0.0005341				0.0003739 - 0.0006943		
Uranium-Total	NR	24.5				17.2 - 31.9		
Uranium-235	NR	0.171				0.120 - 0.222		
Uranium-238	NR	24.4				17.1 - 31.7		

Organic — Units: (ug/kg)

Analyte	Result	Ref Value	Flag	Notes	Z-	Acceptance Range	Unc Value	Unc Flag
Aldrin	NR	127				45 - 210		
gamma-BHC (Lindane)	NR	78				14 - 142		
Dieldrin	NR	215				88 - 342		
Endosulfan sulfate	NR	270				71 - 468		
Heptachlor epoxide	NR	96				37 - 154		
1,2,4-Trichlorobenzene	NR	1401				236 - 2567		
Anthracene	NR	1456				369 - 2543		
Benzo(b)fluoranthene	NR	1002				222 - 1782		
Butylbenzylphthalate	NR	2684				739 - 4628		
4-Chloro-3-methylphenol	NR	4064				1359 - 6770		
2-Chloronaphthalene	NR	1993				538 - 3449		

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 2009
(Proficiency Test WS-156 was measured on July 20, 2009)

	Acceptable Ranges		7/15/2009			7/20/2009		
	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%	1936.3	2.7	Acceptable	2632.0	2.7	Acceptable
Mg	20,000-80,000	0.0 - 5.0%	59232.0	1.1	Acceptable	64750.1	2.1	Acceptable
In	120,000-300,000	0.0 - 5.0%	310313.8	0.6	Check for high counts	299513.7	2.1	Acceptable
Pb	70,000-180,000	0.0 - 5.0%	165700.8	1.4	Acceptable	164317.5	1.1	Acceptable
Ba	900,000-2,500,000	0.0 - 5.0%	2550005.2	0.8	Acceptable	2435096.3	2.4	Acceptable
Ba++	≤ 5.0% Ba value	N/A	2.3%	N/A	Acceptable	2.2%	N/A	Acceptable
Ce	900,000-3,300,000	0.0 - 5.0%	3122177.7	1.8	Acceptable	2957342.2	1.3	Acceptable
CeO	≤ 5.0% Ce value	N/A	2.3%	N/A	Acceptable	2.1%	N/A	Acceptable
Bkgd	≤ 25.0	N/A	10.4	N/A	Acceptable	8.2	N/A	Acceptable

	Acceptable Ranges		8/20/2009			8/31/2009		
	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%	3005.3	0.7	Acceptable	1965.7	3.7	Acceptable
Mg	20,000-80,000	0.0 - 5.0%	49010.4	2.4	Acceptable	33195.9	1.4	Acceptable
In	120,000-300,000	0.0 - 5.0%	336983.6	1.4	Check for high counts	222036.9	2.6	Acceptable
Pb	70,000-180,000	0.0 - 5.0%	144062.0	0.9	Acceptable	114955.8	2.1	Acceptable
Ba	900,000-2,500,000	0.0 - 5.0%	2544956.7	1.9	Check for high counts	1877067.4	4.8	Acceptable
Ba++	≤ 5.0% Ba value	N/A	2.7%	N/A	Acceptable	1.9%	N/A	Acceptable
Ce	900,000-3,300,000	0.0 - 5.0%	3271672.9	1.4	Acceptable	2293197.5	1.0	Acceptable
CeO	≤ 5.0% Ce value	N/A	2.6%	N/A	Acceptable	2.8%	N/A	Acceptable
Bkgd	≤ 25.0	N/A	8.8	N/A	Acceptable	7.6	N/A	Acceptable

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

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