2001 Report

Carlsbad Environmental Monitoring & Research Center New Mexico State University

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Carlsbad Environmental Monitoring & Research Center

College of Engineering
New Mexico State University

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1400 University Drive
Carlsbad, NM 88220
(505) 887-2759
www.cemrc.org

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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 and 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
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

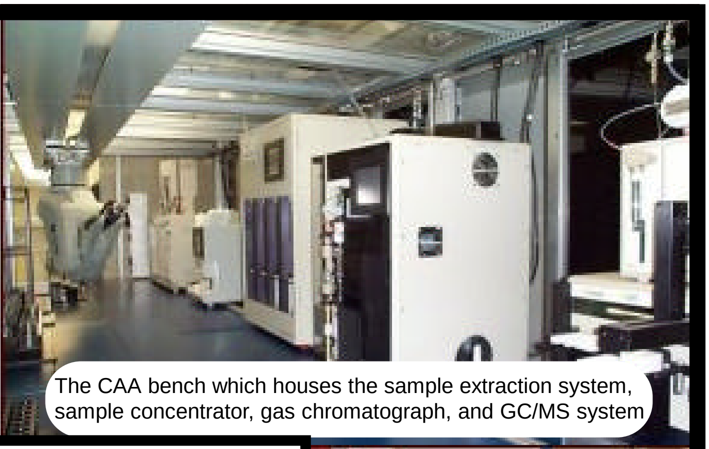
FOREWORD

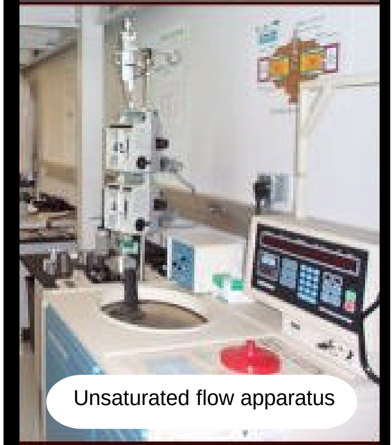
This report was written, edited and produced collaboratively by the staff of the Carlsbad Environmental Monitoring & Research Center (CEMRC), who are hereby acknowledged for their contributions to the report and the project activities described herein. The first section is an overview of the current program activities, structure, resources and quality assurance. The second section consists of data summaries containing methods and descriptions of results of studies in the WIPP Environmental Monitoring project. Tables presenting data from the WIPP Environmental Monitoring Project, and the contents of this report are available for electronic access at http://www.cemrc.org.

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

The cover photograph shows an environmental chemist using an inductively coupled plasma-mass spectrometry (ICP-MS) system for trace element studies.


Contaminant Analysis Automation (CAA) Mobile Environmental Laboratory


The CAA bench which houses the sample extraction system, sample concentrator, gas chromatograph, and GC/MS system


Unsaturated flow apparatus


Lung and whole body counting chamber


Emergency shower safety inspection

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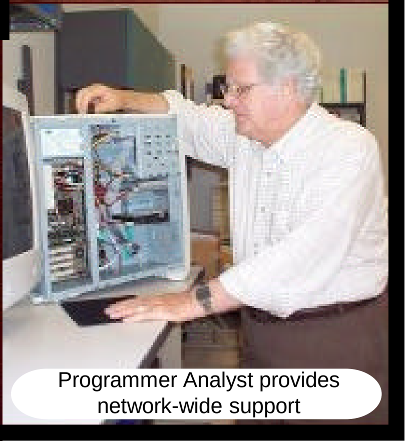
Ion chromatograph


Soil sampling near WIPP


Earth Day 2001 - Recycling Trash into Art


Programmer Analyst provides network-wide support

OVERVIEW

Current Program Status

History and Focus

The Carlsbad Environmental Monitoring and Research Program (CEMRP) was established in 1991 with a grant from the U.S. Department of Energy (DOE). The primary goals of the CEMRP 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.

The Carlsbad Environmental Monitoring & Research Center (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.

Key Activities for Success

The following is a summary of progress and status for nine key enabling activities that are necessary to achieve the goal of establishing and developing the CEMRC. Activities to achieve the second goal of monitoring in the vicinity of the WIPP are presented in the following section (WIPP Environmental Monitoring Project).

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

At the end of 2001, the CEMRC employed 25 personnel (Table 1). Two scientific positions, including the Director, were open and under recruitment.

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

In January 1997, the CEMRC was relocated to Light Hall, a new 26,000 ft^2 laboratory and office facility constructed adjacent to the NMSU-Carlsbad campus. 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, and this type of integrative research is also applied to some newly funded projects. The five scientific program areas include (1) radiochemistry, (2) environmental chemistry, (3) informatics and modeling, (4) internal dosimetry, and (5) field programs. Detailed descriptions of each program area and associated facilities and instrumentation are presented on the CEMRC web site at http://www.cemrc.org.

3. 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 Los Alamos

National Laboratory (LANL) to conduct actinide chemistry research for WIPP. Complimentary research with another division of LANL in 2001 has addressed ecological issues related to the Yucca Mountain assessment.

Program needs for external laboratory services declined in 2001, but some subcontractual agreements were maintained to provide specific specialized services or analyses (Appendix B). The NMSU Fishery and Wildlife Science Department also continued to provide support to the CEMRC through loan of a boat used in lake sampling activities. With respect to collaborative research, sixteen of the publications and presentations by CEMRC staff during 2001 were co-authored with external colleagues, and ten of the CEMRC's proposed and existing new projects involve collaboration with other departments or institutions.

4. Establish an independent advisory body of scientists to provide expert guidance and consultation to CEMRC staff in the focus areas of CEMRC research.

The Scientific Advisory Board (SAB) for the CEMRC is composed of one scientific expert in each of the CEMRC's five scientific areas of specialization (Appendix C). Two SAB members visited the CEMRC during 2001 to review their individual program areas and provide expert guidance and consultation to the program leaders. The program leaders used the SAB observations and recommendations in structuring specific developmental goals, new experiments and methods improvements. Program leaders provided SAB members with follow-up reports prior to each SAB member's visit during 2001. The term of service for SAB members is usually two years; the current members for 2001-2002 terms are listed in Appendix C.

The Program Review Board (PRB) for the CEMRC consists of a minimum of three members selected by the NMSU College of Engineering administration (Appendix C). Members of the PRB are directors or former directors of leading environmental research centers with histories of long-term success in sponsored research. Because of major changes in direction of CEMRC's science program, and a change in its leadership, the annual PRB meeting has been postponed until late 2002.

5. Establish a program of administration to ensure effective operation of the CEMRC.

In July 2001, Dr. Marsha Conley, CEMRC director, retired. Mr. Joel Webb was appointed Director of CEMRC in February 2002. Dr. George Hidy acted as an interim director during the search for the new permanent director. Current administrative staff includes a director, an assistant to the director, a buyer specialist, a technical/facility specialist, a quality assurance manager, a word processing specialist, and an administrative secretary. Cumulative funding from the DOE for the CEMRP totaled approximately $25 million through 1 October 2001. Cumulative expenditures by the CEMRP for the same period totaled approximately $23 million (Fig. 1). Proposed new DOE funding for the 2002 Federal fiscal year is approximately $2.9 million. Combined with carryover funds, the projected CEMRP 2002 budget is approximately $3.1 million.

Formal tracking of CEMRP project schedules and milestones is conducted for current studies, as noted in later sections. Regularly scheduled work sessions for scientific program planning and problem solving are used to define goals and track progress. Administrative and individual program area staff also have regularly scheduled review and planning sessions. During 2001, significant accomplishments and events were reported in quarterly summaries provided to the DOE, NMSU, SAB and PRB.

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

CEMRC staff authored or co-authored 12 presentations at international, national and regional scientific meetings and 18 papers were published, are in press, or have been submitted for publication in peer-reviewed scientific journals and books during 2001 (Appendix D). A cumulative list of publications by CEMRC staff since 1996 is presented on the CEMRC web page.

The CEMRC issued a 2000 report that presented extensive data on radionuclides, non-radioactive constituents and other basic environmental parameters from the WIPP Environmental Monitoring project. This report and other CEMRC information are available via the CEMRC web site, and data tables referenced in this report are also presented on the web site at http://www.cemrc.org. Also included as part of the website are samples collected and analyzed since the most recent Center report.

7. Establish regional, national and international outreach and collaboration.

During 2001, the CEMRC hosted 5 colloquia presented by visiting scientists (Appendix E). Each colloquium was advertised locally, resulting in participation by representatives from local scientific, educational, technical and natural resource management organizations, as well as the general public. Consistent with the Center's efforts to become recognized as an international center of research excellence, CEMRC also hosted 3 visiting scientists in 2000/2001. Mr. Hongbin Wang, a Ph.D. student at the Institute of Earth Environment, Xi'an, People's Republic of China worked in the environmental chemistry laboratory for 11 weeks developing and then using ion chromatographic methods to analyze Chinese loess samples. Mr. Wang is currently in the process of finishing his dissertation, which will be based to a large degree on the results obtained at CEMRC. Sponsored by the Worldbank Loan Project, Dr. Apichai Shuprisha, of the Department of Physiology at Prince of Songkla University, Thailand, received a week of training in the EC laboratory, and he also accompanied the field team on several sampling trips. The primary purpose of Dr. Shuprisha's visit to CEMRC was to obtain hands-on training for using IC techniques to monitor and evaluate water and air quality in Thailand. Ms. Tracy Jue, Idaho National Environmental Laboratory (DOELAP) spent a one-month practicum at CEMRC to obtain training on the routine operation of a lung and whole body counter from the internal dosimetry staff. The CEMRC was involved in many other outreach activities including presentations for local civic and professional groups and exhibits for various school and community events (Appendix F). As described in a later section, over 600 volunteers from the local community have participated in the "Lie Down and Be Counted" project. In addition, CEMRC scientists provided leadership in a variety of professional and scientific organizations and meetings (Appendix G).

During 2001, the CEMRC distributed 1 issue of its newsletter, *The Monitor*. The newsletter summarized progress achieved in the various laboratory projects, and provided general information about the CEMRC. Over 2500 copies of this newsletter were distributed to local residents and regular recipients of CEMRC reports.

8. Procure additional research grants and service contracts from external sources.

CEMRC scientists generated 23 proposals, pre-proposals and contract modifications during 2001 (Appendix H). Important among these is the new contract with LANL of $704,975 for actinide chemistry research. New funding and amendments were achieved on nine projects totaling over $2,225,000, six proposals are pending, and ten proposals were not funded. A total of 12 projects (external to the CEMRP) were in progress during 2001, with a combined value over $1.5 million. These projects represent a wide array of activities, and they have resulted in significant expansion and diversification of the scientific program. During 1996-2001, CEMRC has received funding from a total of 11 different federal and private sponsors.

9. 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 2001, two undergraduate students worked in laboratory aide and technician positions at the CEMRC; these positions provide training and basic skills development relevant to the position assignments. Two CEMRC scientists hold Graduate Faculty appointments at NMSU. CEMRC staff presented 1 invited seminar for the NMSU Department of Fishery & Wildlife Sciences, and 6 major presentations and special programs were provided for student groups (Appendix F).

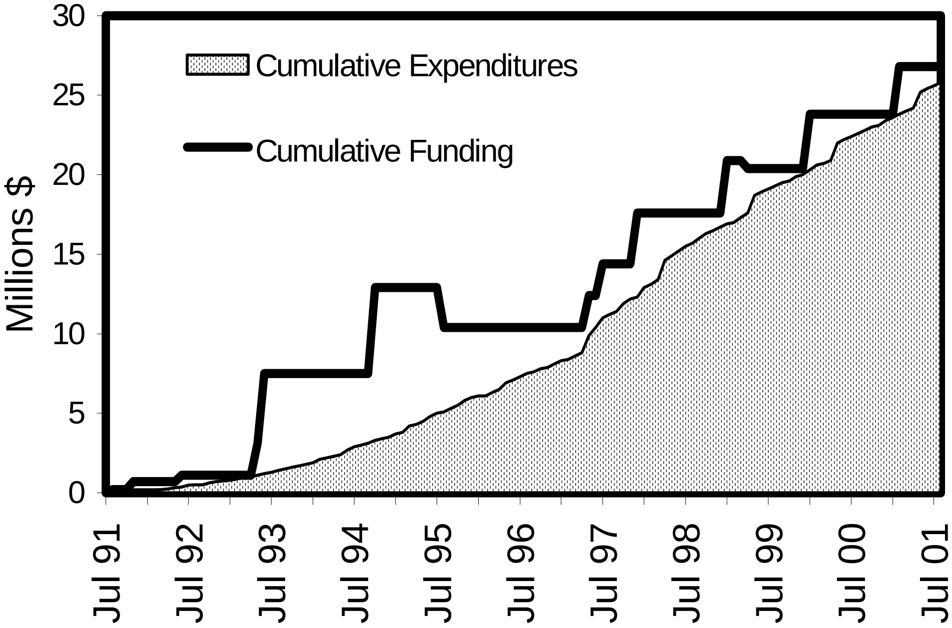


Figure 1. History of CEMRP Funding and Expenditures

Table 1. Listing of CEMRC Staff as of 31 December 2001

Name	Position
Arimoto, Richard	Senior Scientist-Environmental Chemistry
Brown, Becky	Assistant to the Director
Cook, Diana	Administrative Secretary I
Fraire, Joe	Assistant Scientist-Radiochemistry
Ganaway, David	Assistant Scientist-Field Programs; Chemical Hygiene Officer
[a]Hidy, George	Interim Director
Khaing, Hnin	Specialist
Kirchner, Thomas	Senior Scientist-Informatics & Modeling
Lippis, Joe	Technical/Facility Specialist
McCauley, Sharyl	Quality Assurance Manager
McNutt, Damon	Programmer Analyst II
Moir, Deborah	Senior Scientist-Radiochemistry
Monk, James	Associate Health Physicist
Nesbit, Curtis	Associate Health Physicist
Sage, Sondra	Assistant Scientist-Environmental Chemistry
Schloesslin, Carl	Assistant Scientist-Radiochemistry
Schloesslin, Cheryl	Assistant Scientist-Environmental Chemistry
Schoep, David	Science Specialist-Internal Dosimetry
Spruiell, Roy	Programmer Analyst II
Stewart, Barry	Associate Scientist-Radiochemistry
Stroble, Carolyn	Buyer Specialist I
Walthall, Mark	Senior Scientist-Environmental Science
[b]Webb, Joel	Manager, Program Development; Radiation Safety Officer
York, Larry	Technician II-Radiochemistry
Young, Karen	Word Processing Specialist

[a] Interim term ended January 31, 2002
[b] Assumed permanent Director position on February 1, 2002

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 2000-2001 activities for each major environmental medium in the WIPP EM. It is important to note that mixed waste was first received by the WIPP on 9 September 2000. The results summarized in this report cover samples collected through November 2001.

Based on the radiological analyses of monitoring phase samples (collected since 26 March 1999) completed to date for area residents and for selected aerosols, soils, drinking water and surface water, there is no evidence of increases in radiological contaminants in the region of the WIPP that could be attributed to releases from the WIPP. In most cases, levels of radiological and non-radiological analytes measured in 2001 were within the range of baseline levels measured previously by CEMRC for the targeted analytes.

Aerosols

Aerosol particle sampling is conducted at five locations, with samplers operating continuously at each location. The locations include a port inside the WIPP exhaust shaft, a site approximately 0.1 km northwest (downwind) of the WIPP exhaust shaft (On Site station), a site approximately 1 km northwest (downwind) of the WIPP (Near Field station), a site approximately 19 km southeast (upwind) of the WIPP (Cactus Flats station) (Fig. 2), and a site located in Hobbs, NM approximately 75 km northeast of the WIPP.

Continuous sampling of aerosol particles was conducted through July 2001 using the same instruments, frequencies and locations as were previously established in the baseline phase. Analyses of all particle samples collected through July 2001 for both radiological and non-radiological constituents were completed and are reported herein. Web site posting of results of radiological and non-radiological analyses of particle samples collected in the WIPP exhaust shaft (FAS) began in July 1999, and are updated weekly. A summary of the 2001 data is also presented herein.

During the period July 2000 - September 2001, minor changes were implemented to improve the aerosol particle sampling design. These changes include (1) standardizing the height of all sampler intakes at the On Site, Near Field and Cactus Flats stations to 4.3 meters, with one meter between sampler intakes and underlying solid surfaces; (2) addition of a high volume TSP sampler at a location approximately 75 km northeast of the WIPP site, in Hobbs, New Mexico; (3) elimination of collection of $PM_{2.5}$ and PM_{10} low-volume samples for inorganic analyses and (4) modification of low-volume sample collection periods from two, two-day and one three-day cycle each week, to one three-day and one four-day cycle each week.

Soils

Soil sampling is conducted within a 166 km^2 area centered on the WIPP operations facility, and at a comparable area encompassing the Cactus Flats aerosol sampling station. Within each of these two areas, samples are collected at 16 locations positioned in concentric rectangular grids

(Fig. 2). During 2001, two soil samples were collected at each of the 32 locations during January-February. One soil sample of each pair was analyzed and the other was archived.

Surface Water and Sediments

The WIPP EM incorporates studies at three reservoirs on the Pecos River, which is the major perennial fresh water system closest to the WIPP that has extensive human usage. The three reservoirs are (1) Brantley Lake, located approximately 64 km northwest of the WIPP, (2) Lake Carlsbad, located in Carlsbad and approximately 40 km northwest of the WIPP and (3) Red Bluff Reservoir, located approximately 48 km southwest of the WIPP.

Radiological and non-radiological analyses of 2001 (monitoring phase) surface water and sediment samples are reported herein.

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 2001, drinking water samples were collected in the spring at five of the six drinking water supplies, and results of radiological and non-radiological analyses are reported herein. The private water well was dry during the 2001 sampling period. The six drinking water supplies will continue to be sampled periodically for selected radiological and inorganic testing.

Biota

Studies of biota for the WIPP EM have focused on native vegetation because the vegetation is consumed by beef cattle, and consumption of beef from cattle pastured in the vicinity of the WIPP could serve as an exposure pathway to humans for contaminants released from the WIPP. During baseline studies, vegetation samples were collected from a total of six species of plants that serve as preferred forage species for cattle during at least some portion of the year. During 1997-1998 baseline studies, vegetation was sampled twice annually during the two major periods of new growth for native vegetation (March-May and August-October). Six samples of each of three species (contingent on availability) were collected during each sampling period from selected sites on the sampling grid surrounding the WIPP (which encompasses the Near Field aerosol sampling station).

Radiochemical analyses of the baseline and initial monitoring phase samples have been held in abeyance pending development of a practical means of preparing samples for analysis. Analytical methods for gamma-ray emitting radionuclides were completed in 2001, and baseline and monitoring results will be presented in 2002.

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. 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, with a target of 100 new volunteers annually to establish new study cohorts and replacement of volunteer attrition.

Results of the LDBC project through 1 October 2001 are reported herein, and are updated quarterly on the CEMRC web site.

Meteorological Monitoring

Fully automated meteorological stations are operated by the CEMRC at the Near Field aerosol station and the Cactus Flats aerosol station. Details concerning the sensors and operation of the equipment and a summary of the last year's meteorological patterns are presented herein.

Organization of 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 in a timely manner, (2) relative risks of human exposure to contaminants among the various media sampled, (3) needs for stringent data validation and verification prior to release and (4) time constraints resulting from sample preparation and analysis procedures.

The management plan for the WIPP EM incorporates milestones representing significant products and progress, including both routine sampling and analyses and special studies. Key performance indicators that integrate groups of milestones are identified and reviewed annually to serve as metrics of the successful progress of the project. Completion of 2001 key performance indicators is summarized in Appendix I. Out of seventeen indicators for 2001, 12 were completed on time, 3 were delayed but completed, and 2 were partially completed. Key performance indicators for 2002 have been identified to serve as the basis for the 2002 WIPP EM project schedule (Table 2). Also during 2002, the elements of the monitoring will be reviewed and evaluated as part of the strategic planning for CEMRC activities in the next few years.

Table 2. Key Monitoring Performance Indicators for the WIPP Environmental Monitoring Project in 2002

Focus Area	Key Performance Indicator
Aerosol particles	Continue concurrent high-volume and low-volume/dichotomous sampling at current four locations through 2002.
Soils	Review sampling program for redesign to facilitate efficient monitoring studies.
Meteorology	Continue concurrent operation of sampling stations at two current sites through 2002.
Drinking water	Review sampling program for redesign to facilitate efficient monitoring studies.
Sediment and surface water	Review sampling program for redesign to facilitate efficient monitoring studies
Human studies	Complete repeat counts for original volunteer cohort, and initial counts for a minimum of 100 new volunteers
	Complete analyses of soil, aerosol, sediment, surface water and drinking water samples (collected through June 2002) by October 2002
	Continue FAS sample analyses to meet weekly and quarterly posting schedule.
Non-radiological analyses	Complete analyses of representative subset of 2002 low-volume aerosol particles, soil, sediment, surface water and drinking water samples within three months after each sample collection
	Continue FAS sample analyses to meet weekly and quarterly posting schedule
Data management and dissemination	Post results of radioanalyses of 2002 and pre-2002 samples within two months after completion of analyses of each set of samples
	Post results of non-radiological analyses of 2002 samples within two months after completion of analyses of each set of samples
	Issue CEMRC 2001 Report; post report and background data to CEMRC web site by May 2002 (web site currently under development)

Management of CEMRC Redirection

The Carlsbad Field Office (CBFO) of DOE has requested CEMRC to investigate whether the Center's direction can become more closely aligned with scientific and analytical activities foreseen by the CBFO to support the safe operation of the WIPP. Specifically, as a functioning deep-geologic repository for nuclear waste, the WIPP requires scientific and analytical services to address specific needs related to regulatory compliance, environmental monitoring, occupational health, waste characterization, repository performance, enhanced operations and the five year re-certification cycle mandated by title 40CFR194. To further develop the CEMRC program, the Center is working closely 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 in the Carlsbad area.

The new emphasis on research and other environmental services is a logical development for CEMRC in view of the present collection of baseline data in the Carlsbad region. The present data collection serves the Carlsbad community, DOE and the State of New Mexico well in establishing the environmental conditions in the WIPP surroundings. While the monitoring needs to be continued at a reduced level to establish the natural variability of environmental conditions in the region, parallel sampling programs need not overlap one another as they have in the past. The redundancy in WIPP monitoring conducted by different organizations was reviewed in a September 2001 conference organized by CEMRC for CBFO. The conclusions of this conference will assist CEMRC in updating its program for improved effectiveness.

Quality Assurance

The CEMRC is currently 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. The CEMRC has adopted a general quality assurance policy (Appendix J) that includes development and implementation of appropriate standards, performance assessment, quality improvement, provision of infrastructure, professional staff development, personal accountability and commitment to compliance.

The CEMRC's quality assurance policy and implementation plans recognize that there are distinctions between standard analytical activities and experimental research settings. For experimental research settings, there are frequently few if any recognized analytical standards or procedures for the analyses of interest, and a major task is to develop such procedures, or to modify the application of standard procedures for new media. Likewise, research sampling designs are typically unique to the underlying scientific hypotheses and may not follow any standardized external formats. Therefore, the quality control measures applied to research contrast with those applied in programs driven by regulatory requirements, where the sampling frequency and methodologies and the analytical procedures typically are spelled out by various compliance guidelines.

In the WIPP Environmental Monitoring project, the CEMRC's strategy is to develop a set of independent data for a variety of parameters of interest, frequently involving sampling and analytical procedures that are different from those dictated by the regulatory requirements that govern the WIPP's certification and operation. In many cases, these data will target a larger suite of parameters or lower detection limits than are of concern from a regulatory perspective. Although this approach may include some sampling and analyses similar to those conducted by other groups associated with the WIPP, other activities are unique to the CEMRC's projects.

Personnel

Program managers provide training to laboratory and field workers in methodologies, general laboratory protocol, procedures, maintenance routines, and good safety practices. CEMRC laboratory and technical support staff receive specialized training for operation of specific equipment or systems, generally offered through equipment vendors. To support continued professional development, staff members are also provided opportunities for membership and participation in professional organizations, including attendance at conferences and workshops. Access to current scientific literature is provided through a current publications bulletin, a variety of journal subscriptions and inter-library loans.

Regulatory Compliance

To promote good health and safety practices in the laboratories, the CEMRC maintains a Chemical Hygiene Plan and associated training of personnel, in compliance with the requirements of 29 CFR 1910.1450, "Occupational Exposure to Chemical Hazardous Chemicals in Laboratories." A Hazard Communication Plan and associated training are also maintained for all employees, in compliance with requirements of 29 CFR 1910.200. A Chemical Hygiene Officer and Hazard Communications Coordinator are responsible for management of the chemical and laboratory safety programs, including maintenance of chemical inventories, periodic audits and management of any hazardous wastes generated by laboratory activities.

The CEMRC is a conditionally-exempt small quantity generator of hazardous wastes, as defined and regulated under the Resource Conservation and Recovery Act. Hazardous waste thus generated is disposed of through licensed treatment, storage and disposal facilities. Based on current chemical inventories, the CEMRC is exempt from the reporting requirements in Section 313 of the Emergency Planning and Community Right-to-Know Act. The CEMRC has had no spills of hazardous substances that exceeded the reportable quantity limits under the Comprehensive Environmental Response, Compensation and Liability Act. The CEMRC currently has no air contaminant emissions subject to regulation under the Clean Air Act, and no wastewater discharges subject to regulation under the Clean Water Act beyond normal sanitary sewer discharges.

Use of radioactive materials is governed by the CEMRC's Radioactive Materials License, issued by the New Mexico Environment Department. A Radiation Control Manual and Implementation Plan and associated training are provided for staff who deal with radioactive materials. A Radiation Safety Officer is responsible for management of the radiation safety program, including maintenance of a radioactive materials inventory, periodic radiation contamination surveys, radiation safety audits and management of any radioactive waste generated by laboratory activities. The CEMRC generates a small amount (< 100 lb) of solid, low-level radioactive waste annually, which is disposed of through a licensed commercial disposal facility.

Field Sampling Program Quality Assurance

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^3min^{-1}, but the frequency of filter replacement is based on optimal loading for radioanalysis.

Sampling procedures used for collection and preparation of environmental samples for the WIPP EM project are described in the individual data summaries that follow. 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. Original logbooks and field data forms are kept on file in the program manager's office. 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. Records of calibration and maintenance are maintained in instrument-specific files in the program manager's office or laboratory.

Environmental Chemistry Program Quality Assurance

The analytical methods employed in the environmental chemistry program at CEMRC are based, when applicable, on various standard procedures (EPA, 1983, M*ethods for Chemical Analysis of Water and Wastes*, EPA/600/4-79-020; EPA, 1997, *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods*; EPA/SW-846; American Public Health Association, 1981, *Standard Methods for the Examination of Water and Wastewater, 20th Edition*).

For the WIPP EM, an ion chromatograph (IC) was used to determine the concentrations of a suite of major ions in water samples and aqueous extracts of all media sampled during 2001. An atomic absorption spectrometer (AAS) and inductively coupled plasma-mass spectrometer (ICP-MS) were used to analyze aqueous or acid extracts of samples.

For some matrix/analyte combinations, appropriate external standard procedures do not exist, and CEMRC has developed specialized standard procedures to meet the needs of the WIPP EM. A set of standard operating procedures and a formal quality assurance plan have been developed and implemented for the inorganic analyses performed at CEMRC. A summary of the quality assurance/quality control procedures and results for the environmental chemistry program for WIPP EM studies is presented in Appendix K. As part of CEMRC participation in the National Voluntary Laboratory Accreditation Program during 2000-2001, the environmental chemistry laboratory conducted analyses under the InterLaB WatR^{TM} Pollution WS-58 Proficiency Testing Program sponsored by Environmental Resource Associates. Results for 27 of the reported 30 analytes were rated "acceptable", for an overall rating of "Very Good" (90.3% score).

In July 2001, the Environmental Chemistry Laboratory received accreditation for environmental testing by the American Association for Laboratory Accreditation (A2LA). A2LA is one of the leading lab accreditation bodies in the Americas and the third in the world. A2LA maintains bilateral agreements with the European Cooperation of Accreditation and the Asia-Pacific Laboratory Accreditation Cooperation. Accreditation consists of proficiency testing and on-site assessments, along with meeting the standards of the ISO/IEC 17025-1999 General Requirements of the Competence of Testing and Calibration Laboratories.

Radiochemistry Program Quality Assurance

During 2001, the CEMRC radioanalytical program participated in four rounds of the NIST Radiochemistry Intercomparison Program (NRIP) and achieved traceability for all analytes reported. The radioanalytical program also participated in the DOE Environmental Measurement Laboratory Quality Assurance Program (EML QAP), resulting in "acceptable" ratings for 67 results from glass fiber filters, soil, vegetation and water samples.

CEMRC has undertaken an extensive method development and validation project that began in May 1998, with special emphasis on measures necessary to ensure quantification of background levels of ^{239,240}Pu and other actinides. During 2001, revised standard procedures were developed and implemented for WIPP EM analyses of high-volume aerosol filters and soils/sediments. In addition, ^{241}Pu analysis was newly implemented for high volume air filters and FAS quarterly composite samples. Method development will continue for brine during 2002 as well as ^{90}Sr analysis of many WIPP EM media. A formal quality assurance plan was completed and adopted, and a variety of implementing procedures for radioanalyses in the WIPP EM project were also developed and issued. A summary of general quality assurance/quality control procedures used by the radioanalytical program is presented in Appendix L.

In Vivo Radiobioassay Quality Assurance

In vivo radiobioassays are performed in accordance with a formal quality assurance plan and related documentation that were developed to meet the requirements of the Department of Energy Laboratory Accreditation Program (DOELAP) for Radiobioassay. CEMRC provides *in vivo* radiobioassay services for WIPP radiation workers, and this program received DOELAP certification in 1999.

During 2001, the CEMRC *in vivo* radiobioassay program continued participation in the Intercomparison Studies *In Vivo* Program administered by Oak Ridge National Laboratory (ORNL). This program provides quarterly testing for ^{137}Cs, ^{60}Co, ^{57}Co, ^{88}Y and ^{133}Ba deposited in whole body. For all radionuclides, the percent differences between the values reported by CEMRC and the ORNL known values ranged from -2.7% to 3.6%.

WIPP ENVIRONMENTAL MONITORING DATA SUMMARIES

Meteorological Conditions in the Vicinity of the WIPP Site

Methods

CEMRC operates two identical meteorological towers at sampling sites in the vicinity of the WIPP (Fig. 2). The Near Field site is approximately 1 km northwest of the WIPP site at an elevation of 1088 m (latitude 32°22'40.385"N; longitude 103°47'55.425"W). The Cactus Flats site is approximately 19 km southeast of the WIPP site at an elevation of 1041 m (latitude 32°13'05.451"N; longitude 103°41'42.583"W).

Each station consists of a 10-meter tower equipped with sensors for temperature, relative humidity, barometric pressure, total solar radiation, Ultra-Violet B (UVB) radiation, wind speed and direction, and vertical wind speed. Data are collected every second, with averaging times of ten minutes. In addition, the maximum wind speed and total precipitation occurring over the 10-min averaging period are recorded.

Temperature, relative humidity and all wind parameters are measured at a height of 10 meters above ground level. Precipitation, barometric pressure, solar radiation and UVB are measured at heights of 0.4, 1, 2, and 3 m, respectively. The barometric pressure sensors are compensated for temperature, but are not referenced to mean sea level. The solar radiation sensors (pyranometers) measure the energy flux per unit area (W m^{-2}) of both direct and diffuse sky radiation. The UVB sensor measures direct and diffuse UVB in the 280-320 nm band.

The data are stored in electronic dataloggers and downloaded twice weekly. Once downloaded, the data are screened for outliers and other anomalies and uploaded to a main database. Performance checks of the sensors are conducted semi-annually, and sensors are re-calibrated at the manufacturers' specified intervals.

This report summarizes meteorological data collected over the 12-month period from December 2000 through November 2001. In addition, data collected at the sites from December 1999 through November 2000 (12 month period) are compared with data from the same time interval during 2000-2001.

Results

For the 2001 sampling period, data recovery exceeded 99% for all sensors, except the UVB sensor at Cactus Flats. The Cactus Flats UVB sensor failed in July due to a nearby lightning strike and has not yet been repaired. Short-term data losses from all sensors occurred throughout the year due to sensor malfunction, repair, maintenance, and/or performance testing (typically less than one hour).

Averaged over the year, winds were from the east and southeasterly direction (E, ESE, SE and SSE quadrants, inclusive) 53% of the time at the Cactus Flats and Near Field sites (Fig. 3). However, there were some distinctive seasonal variations in wind direction (Figs. 4-5). Both sites were dominated by SE winds in the fall, but switched to more variable wind directions in the spring. The two sites contrasted strongly in the winter and summer quarters. Near Field was dominated by directional winds in the winter and variable winds in the summer, while Cactus Flats experienced the opposite behavior. The inter-annual and intra-annual variability in wind direction are important parameters in modeling dispersion pathways for potential airborne releases from the WIPP.

Wind velocities were very similar between sites. Wind velocities (10-min means) were less than 5.4 m s^{-1} over 77% of the time, with speeds frequently from 3.1 to 5.4 m s^{-1}. Wind velocities > 10.7 m s^{-1} typically came from the west. The highest wind velocities recorded at each site were 33.0 m s^{-1} (75 mph) on 10 April at the Cactus Flats site, and 31.8 m s^{-1} (72 mph) on 6 April at the Near Field site.

Air temperatures at Near Field ranged from –6.7 to 40.1 ^{o}C and from –6.8 to 39.7 ^{o}C at Cactus Flats. The maximum temperatures were recorded in June 2001 at both locations. The lowest temperatures were recorded in November 2001 at both sites. The annual mean temperatures were 17.9 °C at Near Field and 17.5 °C at Cactus Flats. At both locations, December 2000 was the coldest month (mean = 5.2 °C at Near Field; mean = 4.9 °C at Cactus Flats) and July was the hottest month (mean = 29.7 °C at Near Field; mean = 29.2 °C at Cactus Flats) (Fig. 6).

The annual mean relative humidity at Near Field was 44% and ranged from 4 to 100%. Humidity at the Cactus Flats site was nearly identical to Near Field, averaging 45% and ranging from 3 to 100%. Mean relative humidities were lowest when temperatures peaked in late spring and early summer (Fig. 7). It should be noted that the accuracy of the relative humidity sensors declines at relative humidities below 12% and above 94%, and readings outside these ranges should be interpreted with caution.

Barometric pressure did not exhibit an obvious seasonal trend at either site (Fig. 8). The annual mean was 894.1 mb at Cactus Flats and 898.6 mb at the Near Field site. The apparent 4.5-mb difference between the sites can be attributed to a 41-m difference in elevation. This difference is not significant if corrected using standard barometric conversions that incorporate elevation (U.S. Department of Commerce Weather Bureau, 1963, *Manual of Barometry*, *Vol. 1*, Washington D.C.).

Total solar radiation flux (W m^{-2}) was integrated over daily intervals to calculate total energy received per unit area (MJ m^{-2}). As is typical, solar radiation received at the sites peaked in the summer and was lowest during the winter months (Fig. 9). This pattern is due to a combination of increasing solar radiation intensity, less cloud cover and additional hours of daylight during the summer months. Over the year, the daily total solar radiation ranged from 2 to 55 MJ m^{-2} at both Near Field and Cactus Flats.

Solar UVB flux (W m^{-2}) was integrated over daily intervals to calculate total energy received per unit area (MJ m^{-2}). The UVB radiation followed a pattern similar to that of the total solar radiation (Fig. 10).

Over the year, a total of 19.5 cm of precipitation was measured at Cactus Flats and 22.1 cm of precipitation was measured at Near Field (Fig. 11). Both locations recorded the highest precipitation during the months of March and July.

Tables presenting meteorological data summarized herein are available on the CEMRC web site at http://www.cemrc.org.

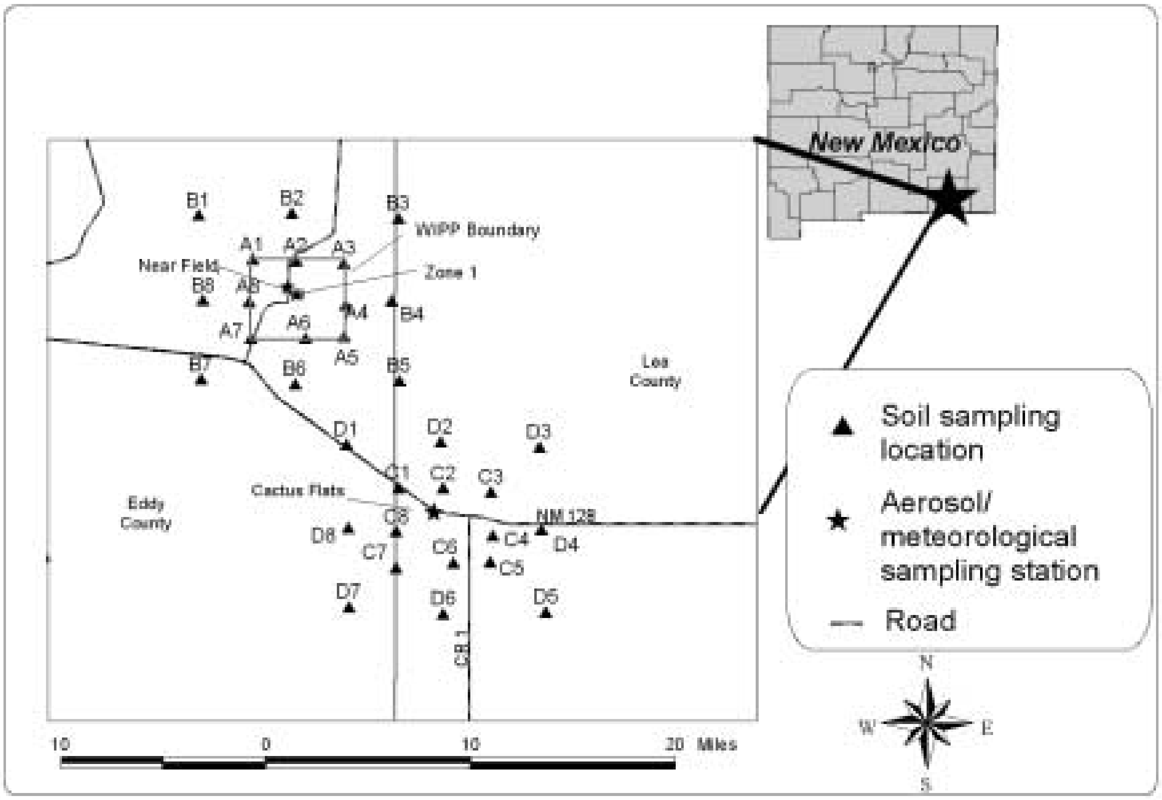
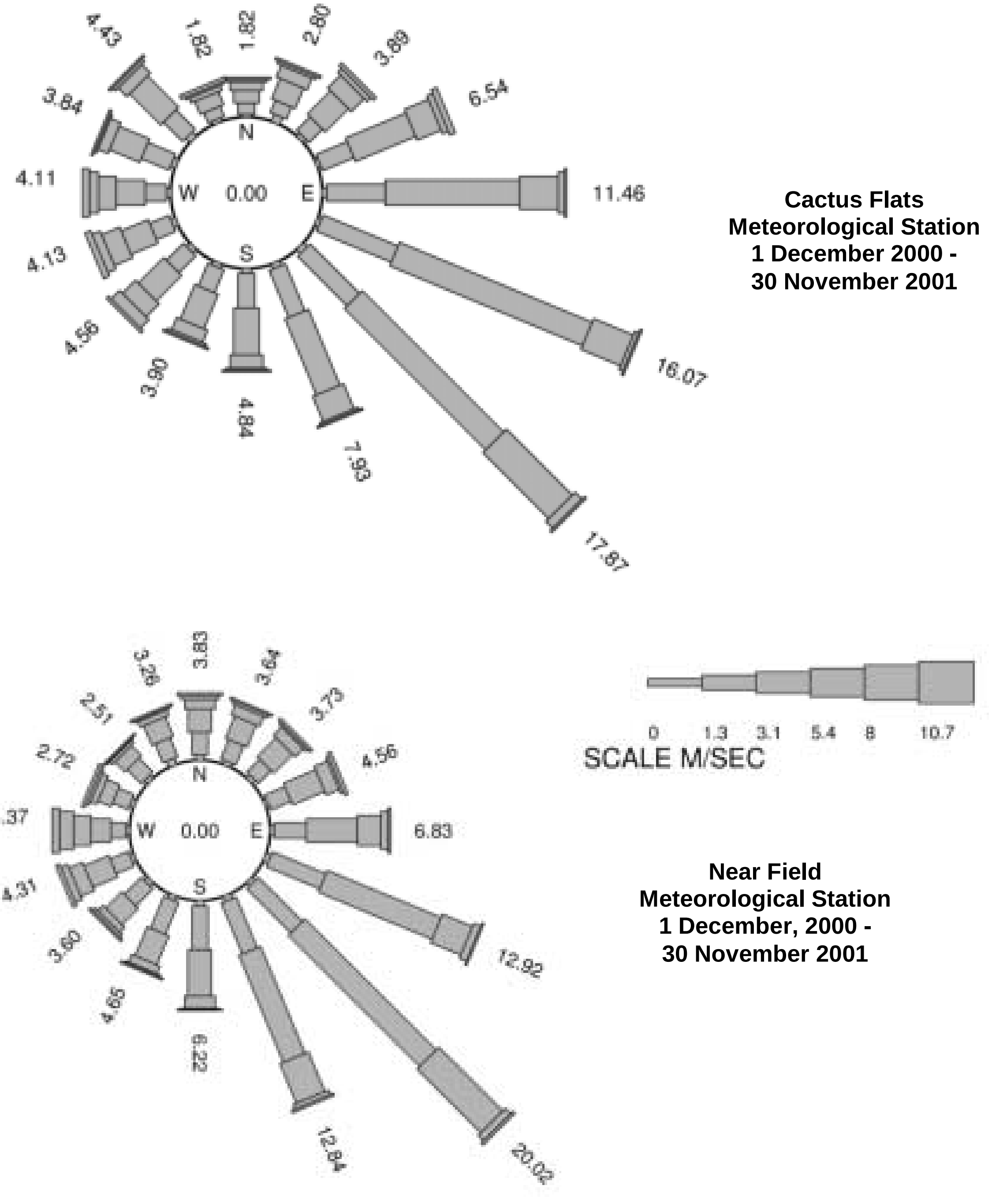


Figure 2. Sampling Locations in the Vicinity of the WIPP

Aerosol sampling and meteorological monitoring is conducted at Near Field and Cactus Flats.



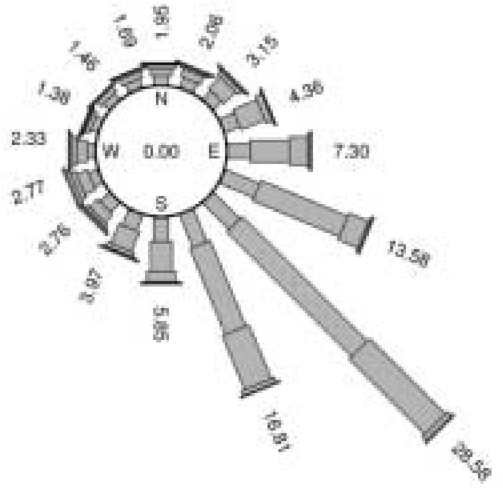
Cactus Flats
Meteorological Station
1 December 2000 -
30 November 2001

Near Field
Meteorological Station
1 December, 2000 -
30 November 2001

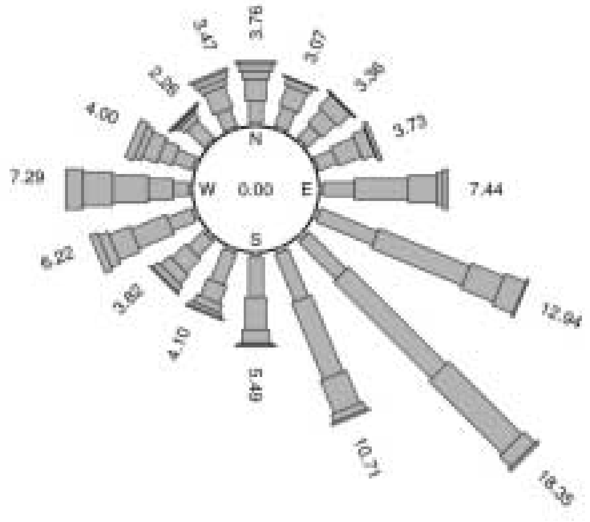
Figure 3. Annual Wind Roses for Near Field and Cactus Flats

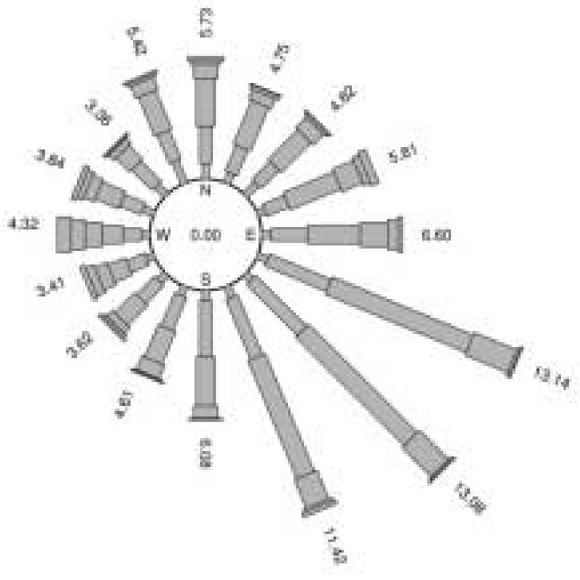
Value in center of a rose is % time with no recordable wind. Value at outer end of each tube is % time wind blew from the direction of the tube outer opening. Within each tube, segment lengths indicate relative frequency of wind speeds (m sec^{-1}) given on scale.

**Near Field
Meteorological Station
1 December 2000 -
28 February 2001**

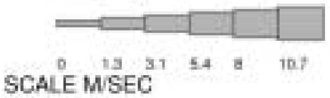


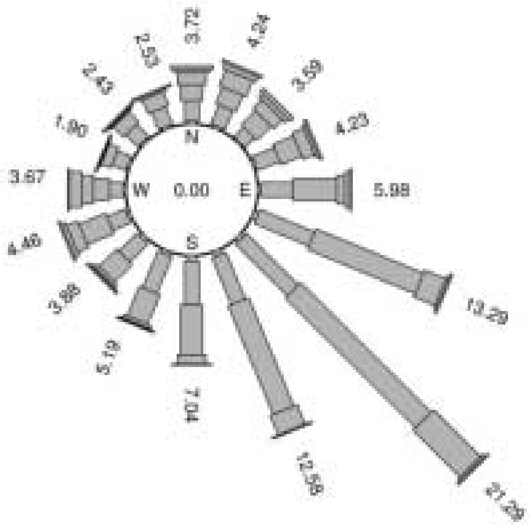
**Near Field
Meteorological Station
1 March, 2001 -
31 May 2001**





**Near Field
Meteorological Station
1 June 2001 -
31 August 2001**





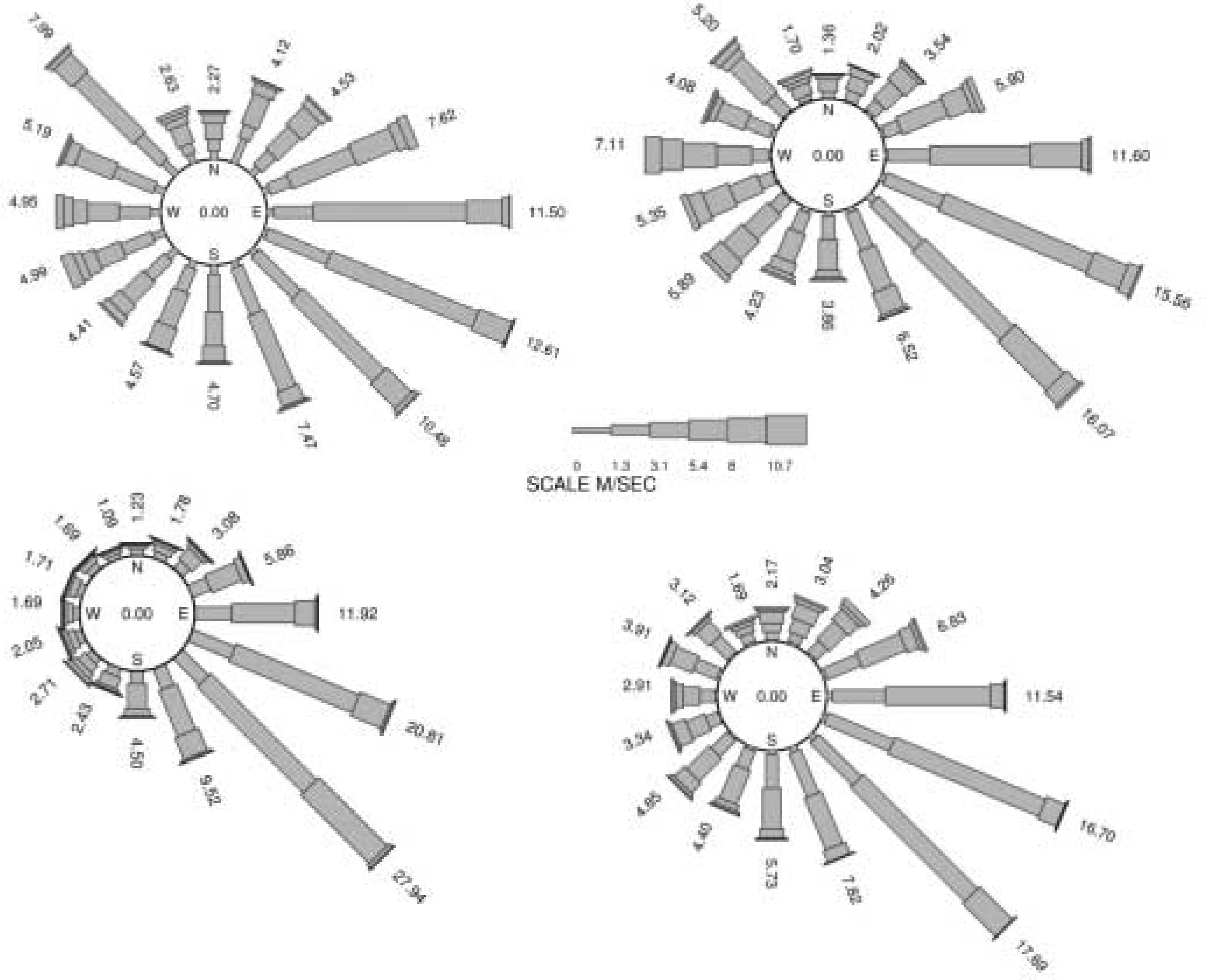
**Near Field
Meteorological Station
1 September 2001 -
30 November 2001**

Figure 4. Seasonal Wind Roses, Near Field

Value in center of a rose is % time with no recordable wind. Value at outer end of each tube is % time wind blew from the direction of the tube outer opening. Within each tube, segment lengths indicate relative frequency of wind speeds (m sec^{-1}) given on scale.

Cactus Flats
Meteorological Station
1 December 2000 -
28 February 2001

Cactus Flats
Meteorological Station
1 March 2001 -
31 May 2001

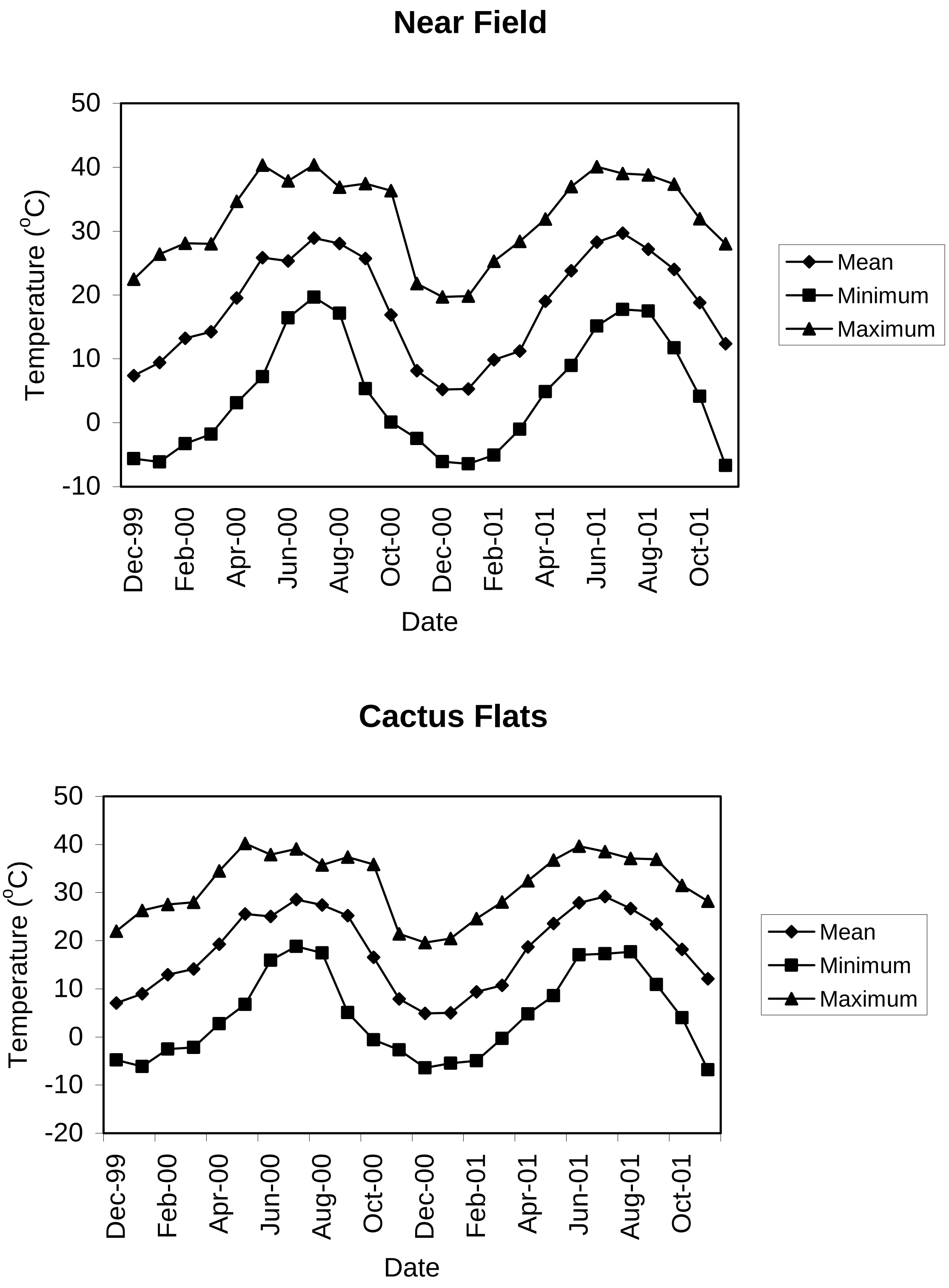


Cactus Flats
Meteorological Station
1 June 2001 -
31 August 2001

Cactus Flats
Meteorological Station
1 September 2001 -
30 November 2001

Figure 5. Seasonal Wind Roses, Cactus Flats

Value in center of a rose is % time with no recordable wind. Value at outer end of each tube is % time wind blew from the direction of the tube outer opening. Within each tube, segment lengths indicate relative frequency of wind speeds (m sec^{-1}) given on scale.



Near Field

Cactus Flats

Figure 6. Monthly Mean, Minimum and Maximum Temperature at Near Field and Cactus Flats during December 1999 - November 2001

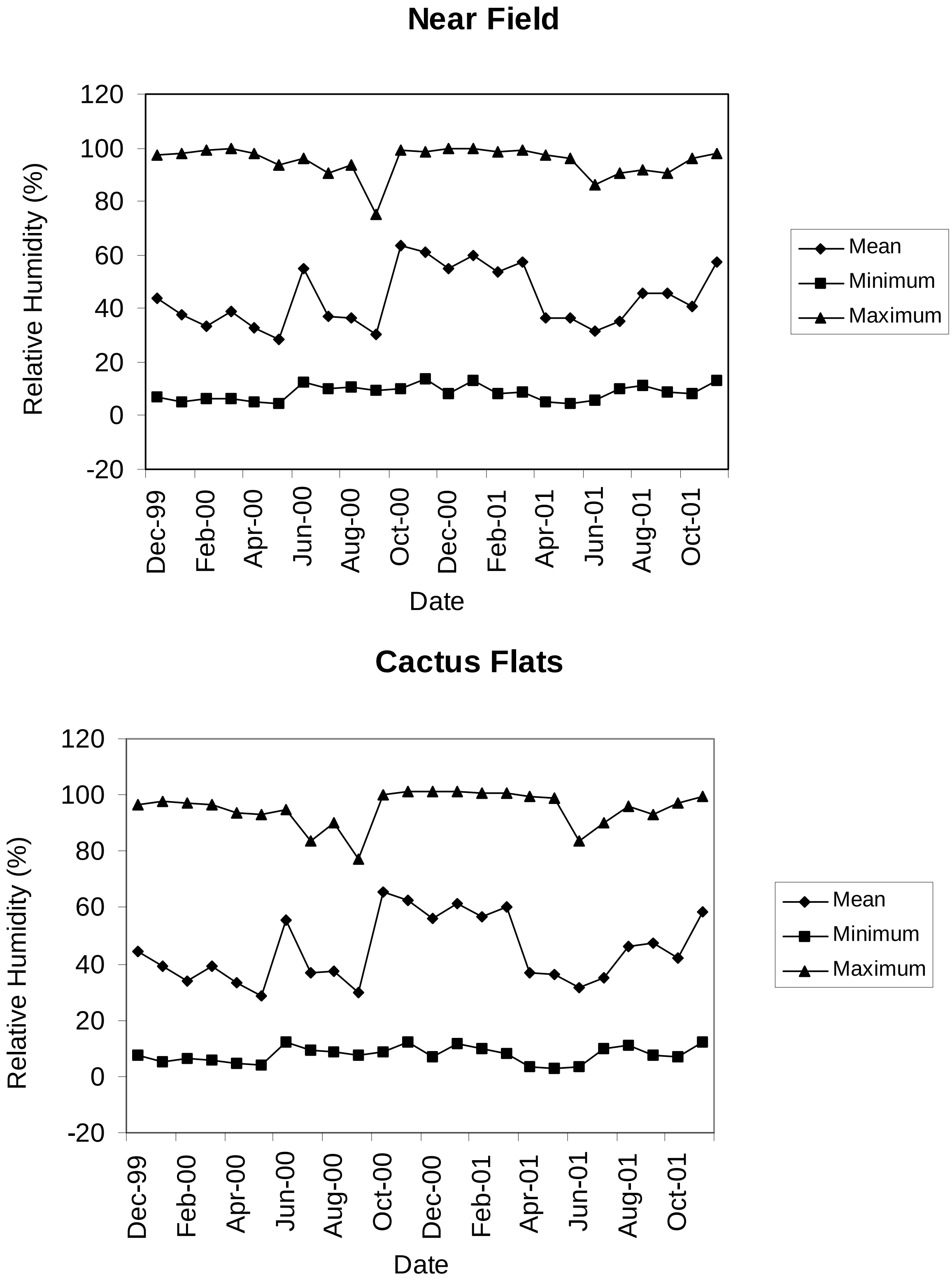
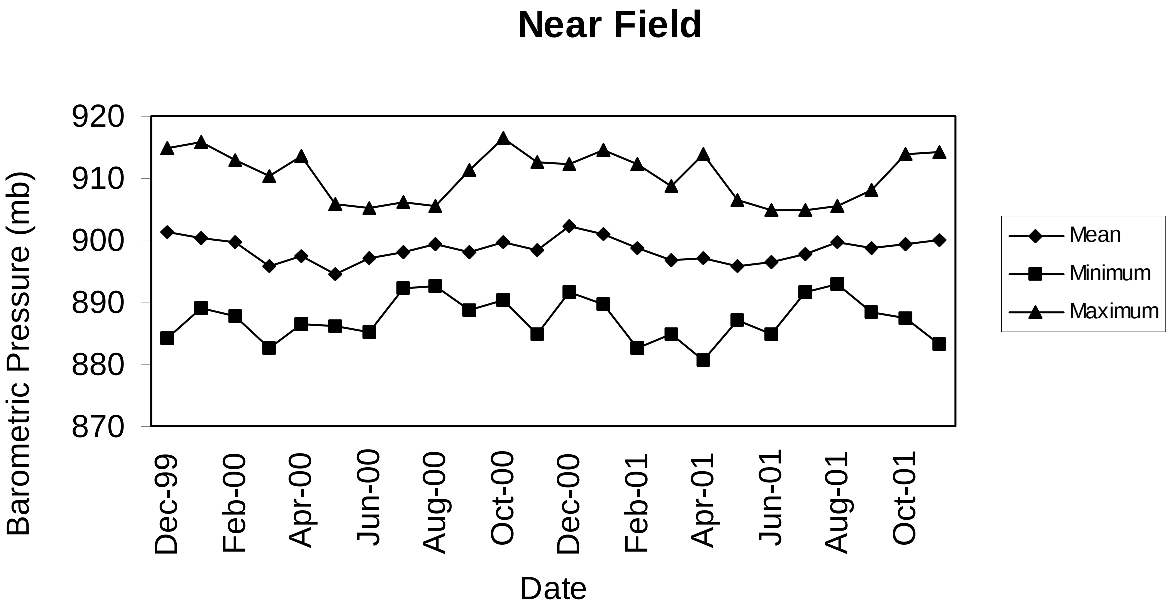


Figure 7. Monthly Mean, Minimum and Maximum Relative Humidity at Near Field and Cactus Flats during December 1999 - November 2001

Relative humidity sensor may have reduced accuracy at < 12% and > 94%.



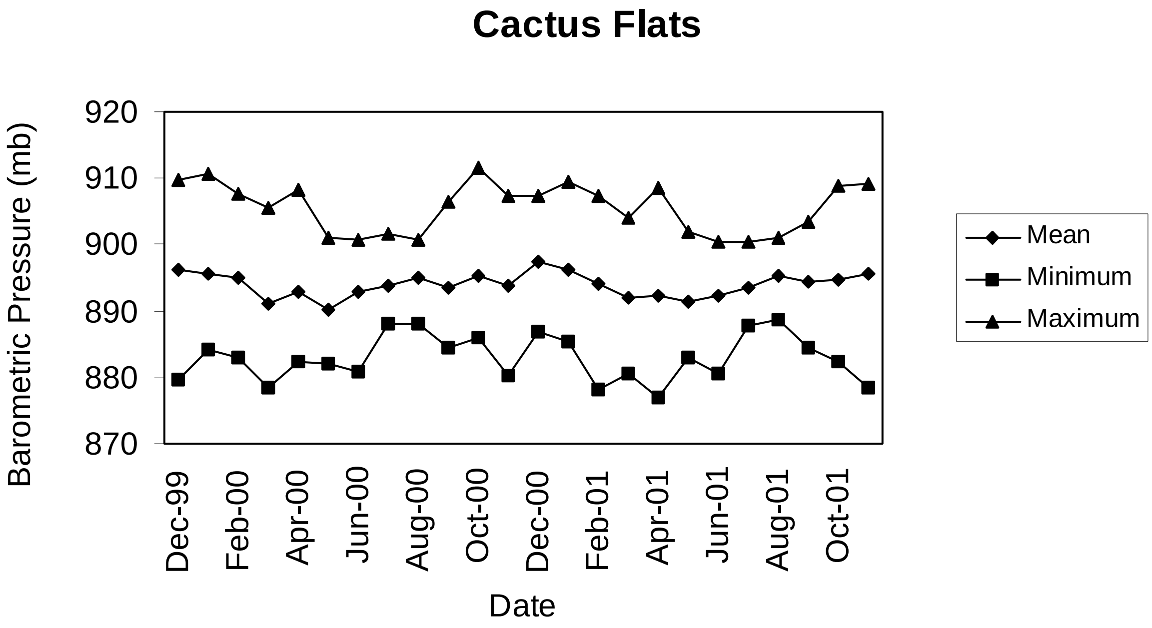


Figure 8. Monthly Mean, Minimum and Maximum Barometric Pressure at Near Field and Cactus Flats during December 1999 - November 2001

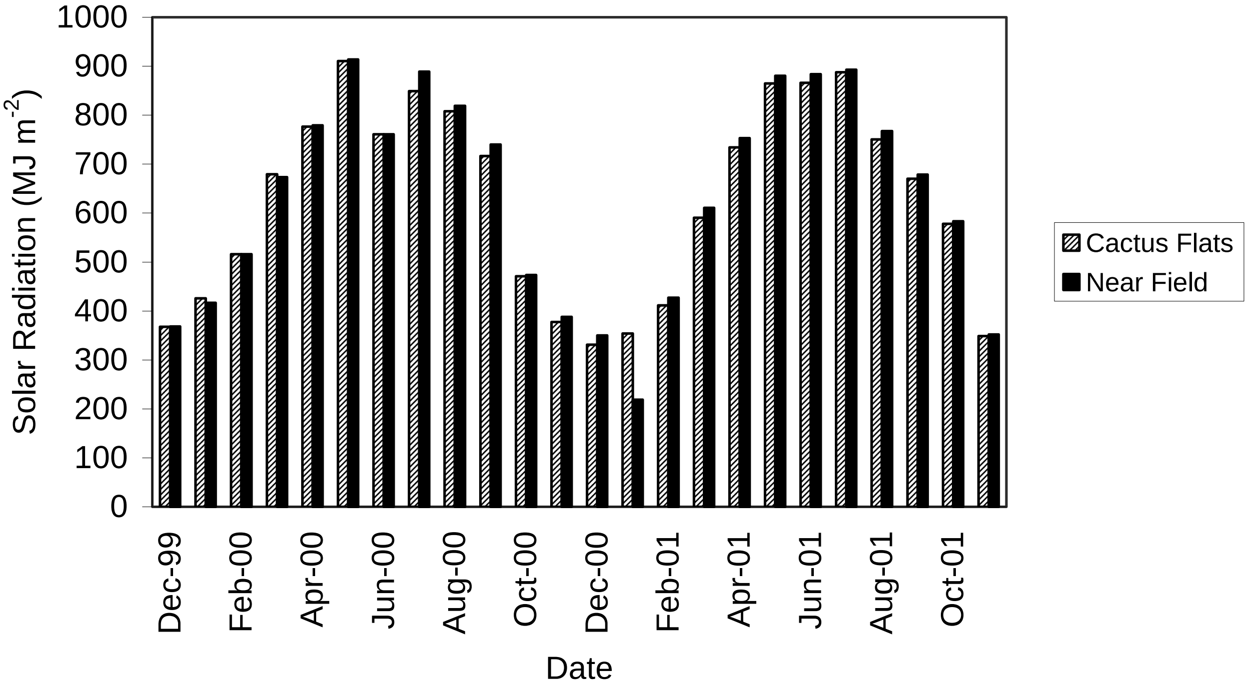


Figure 9. Monthly Total Solar Radiation at Near Field and Cactus Flats during December 1999 - November 2001

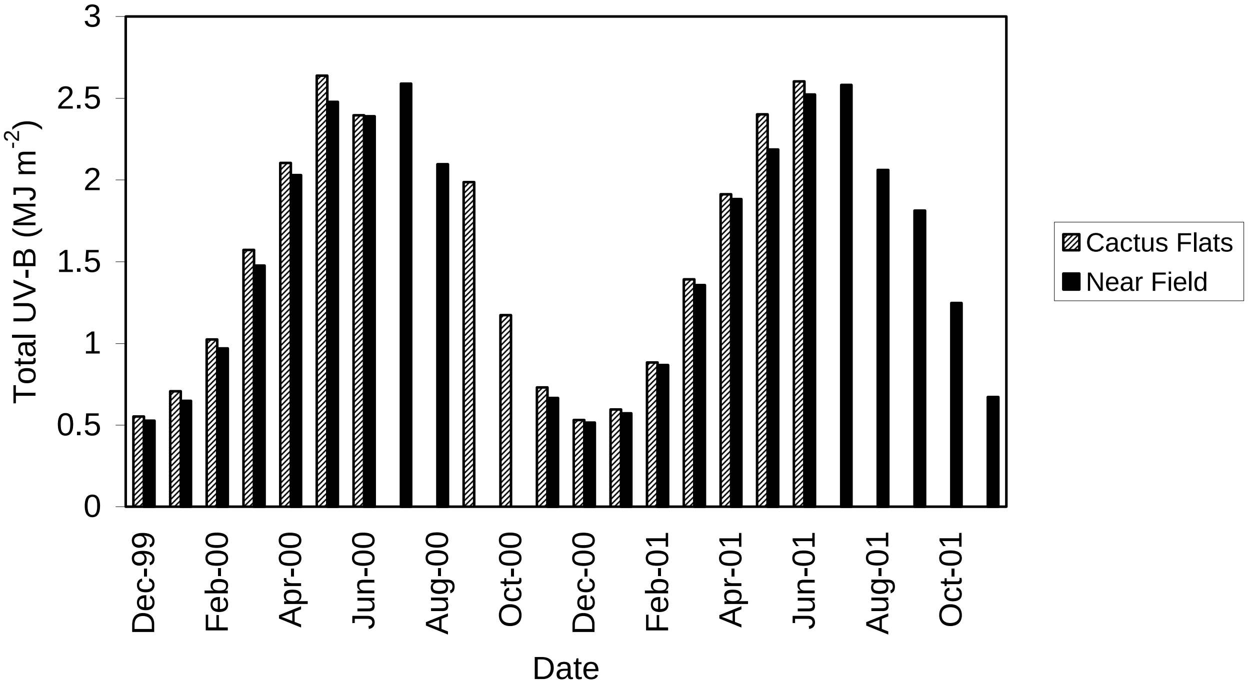


Figure 10. Monthly Total UV-B Radiation at Near Field and Cactus Flats during December 1999 - November 2001

Cactus Flats sensor inoperative June-July 2000 and July-November 2001;
Near Field sensor inoperative August-October 2000.

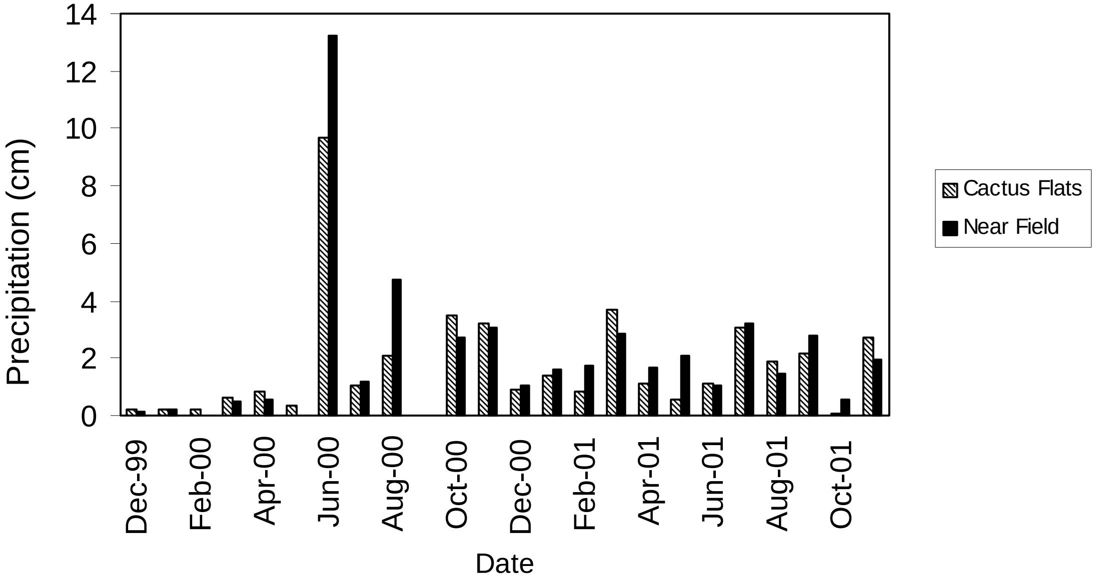


Figure 11. Monthly Total Precipitation at Near Field and Cactus Flats during December 1999 - November 2001

Radionuclides and Inorganics in Ambient Aerosols

Introduction

CEMRC collects and analyzes samples of airborne particulate matter ("aerosols") as part of its WIPP Environmental Monitoring (EM) project. Although the term “aerosol” technically applies to both the solid and liquid particles and the gases in which they are suspended, common usage allows “aerosol” to refer to the particles alone, a practice that will be followed here.

These studies of atmospheric aerosols are an important part of the Center’s monitoring efforts because if a situation arose in which radioactive or chemical contaminants were released from the WIPP, those materials could be rapidly dispersed through the atmosphere and spread throughout the environment. Furthermore, in the unlikely event of such a release, the inhalation of aerosol contaminants from the WIPP would represent a major route of exposure to radionuclides and other chemicals for the local citizenry.

Aerosol studies for the WIPP EM began prior to the receipt of the first shipment of radioactive waste at the WIPP, which was on March 26, 1999. Data for the samples collected before the receipt of that waste shipment have been used to characterize the baseline concentrations of selected radionuclides in the atmosphere of the WIPP environs. Baseline data for selected inorganic substances extend up to September 9, 2000, when the first shipments of mixed waste arrived at the site. The baseline aerosol data are being compared with results from the ongoing WIPP EM monitoring studies as a means of determining whether activities at the WIPP site have affected radionuclide activities in the atmosphere or the concentrations of nine elements of primary concern (As, Be, Ba, Cd, Cr, Pb, Hg, Se and Ag). These elements are listed as components of the Permitted TRU Mixed Wastes in the WIPP hazardous waste permit (*Waste Acceptance Criteria for the Waste Isolation Pilot Plant*, DOE/WIPP-069, November 8, 1999).

It bears mention at the outset of this section, that there is no evidence to date that operations at the WIPP have significantly impacted the activities of any radionuclides or concentrations of any trace elements of concern. In the discussion of the aerosol results that follows, we first present a condensed version of a manuscript reporting the results of a study of ^{239,240}Pu and inorganic substances in aerosols from the vicinity of the WIPP site (Arimoto et al., *Health Physics*, in press) and then conclude the discussion with a synopsis of the more recent monitoring data.

Methods

Detailed information regarding the sampling design for the WIPP EM ambient aerosol studies has been presented in the description of the WIPP Environmental Project above and in the CEMRC reports for 1998 to 2000. Briefly, for the aerosol studies, several different types of samples were collected from three sampling stations, On Site, Near Field and Cactus Flats (Fig. 2). For the radionuclide studies, high-volume samples were collected on 20 x 25 cm Gelman A/E™ glass fiber filters, which were changed when the flow rates dropped to 90% of their starting values. Therefore, the time intervals for the radionuclide sample collections were variable, but typically several weeks in length. At Cactus Flats and Near Field, high-volume samples for the radiochemistry studies were collected for both total suspended particles (TSP) and PM_{10} (particles less than 10 µm, aerodynamic equivalent diameter). At On Site, only TSP samples were collected for radionuclide analyses.

Gravimetric measurements were made to determine the amounts of aerosol mass collected on the high-volume filters. Prior to sampling, new filters were weighed without being desiccated, and after exposure and re-weighing, the total mass that accumulated on a filter was divided by the total air volume drawn through it to calculate the aerosol mass concentration. Gravimetric determinations were only made for the high-volume filters because static charging and other technical problems caused the weights of the other types of filters to vary erratically.

The high-volume samples were analyzed for selected radionuclides, including ^{238}Pu and ^{239,240}Pu, and for these analyses, entire filters were muffled for 4 hr at 500° C and then spiked with Pu tracers. The samples were dissolved using HF, HCl and $HClO_4$, and the resulting solutions processed by multiple precipitation, co-precipitation, and ion-exchange and/or extraction chromatography steps. The nuclides of interest were then precipitated with LaF_3, deposited onto filters, mounted on planchettes, and counted using an Oxford Oasis alpha spectroscopy system. The plutonium data are reported in the following two ways. First, ^{239,240}Pu *activity concentrations* were calculated as the ^{239,240}Pu activity per unit volume of air samples during each collection period (nBq m^{-3}). Uncertainties in the activity concentrations, not taking into account errors in the volumes of air sampled (which are estimated to be ~10%), ranged from 1.4 nBq m^{-3} for the PM_{10} samples from Near Field to 2.2 nBq m^{-3} for the TSP samples from Cactus Flats, with relatively small differences among sites. Second, *activity densities* were calculated as the activity of ^{239,240}Pu per unit mass of aerosol particles material collected (mBq g^{-1}). Uncertainties in the activity densities, again without propagating errors in the sampling volumes, ranged from 0.049 mBq g^{-1} for the On Site TSP samples to 0.080 mBq g^{-1} for the Cactus Flats PM_{10}.

For the trace element (TE) study, aerosol samples were collected from the same three stations used for the radionuclide studies. These TE samples, in contrast to the ones for the radionuclide studies, were collected using low-volume (~ 10 L min^{-1}) systems for TSP, PM_{10} and $PM_{2.5}$ (particulate matter less than 2.5 µm in diameter). From the beginning of the experiment through January 1998, all low-volume samples were collected daily using 2-µm pore-size, 47-mm diameter Teflo™ filters. Starting in February 1998, the TE sampling periods were changed to 2, 2, and 3 days per week (the filters were replaced on Monday, Wednesday, Friday). Beginning with the change in sampling intervals, the sampling substrate used for the TE study was switched from the Teflo™ filters to 0.8-µm pore-size, 47-mm diameter cellulose-ester filters. The PM_{10} and $PM_{2.5}$ sampling at Near Field and Cactus Flats was discontinued in March 2000.

Aerosol filters were prepared for elemental analyses using a mixture of HCl, HNO_3, HF, and H_2O_2, with heat and high pressure from a microwave digestion system. The concentrations of major and trace elements were determined in the aerosol samples by atomic absorption spectrometry (AAS) and inductively coupled plasma-emission spectrometry prior to January 1999 and by AAS and inductively coupled plasma-mass spectrometry (ICP-MS) afterwards.

The inorganic data are subject to uncertainties in (a) flow volumes; (b) sample collection and storage, and preparation; (c) analytical methods; and (d) blank corrections. The magnitudes of these uncertainty components, except flow volumes, vary among analytes, and representative values for each range from < 5% to 15%, resulting in combined uncertainties of 15% to 20%. Representative detection limits for the inorganic analytes are as follows: nitrate = 0.0045 µg m^{-3}, sulfate = 0.0119 µg m^{-3}, sodium = 0.02 µg m^{-3}, aluminum = 17 to 57 ng m^{-3}, and lead = 0.06 to 0.12 ng m^{-3}.

Results and Discussion

The results of the CEMRC aerosol studies drew our attention to the importance of re-suspension as a determinant of Pu activities in aerosols, and those results were thought to be of interest for others working on related topics. As a result, in FY 2001, a manuscript based on the WIPP-EM aerosol studies was prepared and submitted for publication in a peer-reviewed scientific journal. The sampling periods covered in the study were as follows: 2 February 1998 to 10 August 2000 for the radionuclides; 4 November 1997 to 17 August 2000 for the major ions; and 2 February 1998 to 7 September 2000 for the trace elements. Highlights of that study are presented in the next section.

Summary of: Arimoto, et. al, *^{239,240}Pu and inorganic substances in aerosols from the vicinity of the Waste Isolation Pilot Plant: The importance of resuspension* (Health Physics, in press)

^{239,240}Pu Activities

^{239,240}Pu was quantified in all but one of the 141 aerosol samples analyzed. The geometric mean, volume-based, activity concentrations for ^{239,240}Pu in the PM_{10} samples were 6.2 nBq m^{-3} at Near Field and 8.8 nBq m^{-3} at Cactus Flats while the means for the TSP samples collected over the same time periods were 12, 16, and 14 nBq m^{-3} at Near Field, Cactus Flats, and On Site respectively. The geometric mean PM_{10} ^{239,240}Pu mass-based activity densities were 0.39 mBq g^{-1} at Near Field and 0.47 mBq g^{-1} at Cactus Flats. The corresponding average TSP activity densities were 0.48 (Near Field), 0.54 (Cactus Flats), and 0.33 mBq g^{-1} (On Site).

The geometric mean ^{239,240}Pu activity concentrations in the TSP and PM_{10} samples from Near Field were roughly half of those presented in Lee et al., (*J. Radioanal Nucl Chem*, 1998) who analyzed a more limited set of samples collected from the same site during February-May 1996. While it is possible that the activities of ^{239,240}Pu changed over time, the differences between the two data sets can more simply be explained by the strong temporal variability in ^{239,240}Pu observed in the current study as discussed below.

Temporal Variability and Resuspension

Strong seasonal cycles and interannual differences in the aerosol mass loadings and ^{239,240}Pu activity concentrations are evident for both the TSP and PM_{10} samples (Fig. 12). The highest ^{239,240}Pu activities tend to occur in the first half of each calendar year, which is the when the samples analyzed by Lee et al., (*op cit.*) were collected, and this likely explains the high activities they observed compared with the average concentrations from the present study. Peaks in the ^{239,240}Pu activity concentrations generally were observed between March and May each year for both the TSP and PM_{10} samples, with especially strong springtime peaks evident in 1999. High plutonium activities also were observed at Cactus Flats and On Site in November-December 1999.

Atmospheric studies conducted prior to the end of above-ground nuclear weapons testing era showed that plutonium activities in the atmosphere varied with season, and those temporal patterns were thought to be driven by seasonal cycles in the exchange of material from stratosphere to the troposphere (Perkins and Thomas, U.S. Department of Energy: DOE/TIC-22800, 1980). While the current WIPP EM aerosol data and those collected during the time of above-ground weapons testing both show springtime peaks in aerosol ^{239,240}Pu, the causes for the cycles are likely quite different. This is because the contribution of bomb-derived ^{239,240}Pu from primary stratospheric sources to present day atmospheric loadings is likely to be small (Lee et al., *op cit.*). Atmospheric nuclear weapons testing ended in 1980 and the residence time of plutonium in the atmosphere is on the order of a year (Perkins and Thomas, *op cit.*), and therefore contemporary aerosol Pu activities are likely to be controlled by sources and processes other than weapons testing and stratosphere/troposphere exchange.

The most likely explanation for the present-day seasonal cycles is that they are a consequence of the re-suspension of previously deposited fallout nuclides. As shown in Fig. 12, the aerosol mass loadings followed a seasonal pattern similar to that of the ^{239,240}Pu activity concentrations. In addition, a scatterplot of ^{239,240}Pu activity concentrations versus aerosol masses (Fig. 13) shows a distinct linear trend between the variables, thus demonstrating that the Pu activities varied in proportion to aerosol mass concentrations.

It is apparent in Fig. 13 that the relationship between mass loadings and ^{239,240}Pu activities for the On Site TSP samples is clearly different compared with the other sets of samples. More specifically, the On Site samples generally showed lower ^{239,240}Pu to mass ratios (lower activity densities) than the other sets of samples. This result implies that activities or processes occurring at or near the WIPP site produced aerosols that contributed to the mass loadings but contained less ^{239,240}Pu than ambient aerosols. A second implication of this finding is that local sources of non-radioactive particulate matter can affect the mass-based plutonium activity densities. Therefore measurements of activity calculated with respect to both particulate mass and air volume are useful in understanding the factors controlling the dynamics of ^{239,240}Pu in the atmosphere. It is also worth noting that the volume-based activity concentrations likely encompass larger error terms (than activity density) in association with air-flow volume measurement uncertainty and possible losses of particulate mass from filters during handling.

Relationships between ^{239,240}Pu and Major Ions and Trace Elements: Further Evidence for Resuspension

The CEMRC WIPP-EM program also involves studies of local soils, and these studies are relevant to the present discussion of aerosols because the entrainment of soil particles into the atmosphere by strong winds would cause the re-suspension of previously deposited fallout nuclides. Studies by Kirchner et al. (*op cit.*) showed that all of the radionuclides quantified in soils for the WIPP EM (^{234}U, ^{235}U, ^{238}U, ^{230}Th, ^{232}Th, ^{228}Th and ^{239,240}Pu, ^{137}Cs, ^{208}Tl, ^{212}Pb, ^{212}Bi, ^{214}Pb, ^{228}Ac, ^{234m}Pa, ^{241}Am, ^{40}K, ^{60}Co and ^{7}Be) were significantly ($p < 0.01$) correlated with soil texture and with aluminum concentrations, that is, the nuclides showed an affinity for relatively small soil particles. In atmospheric studies, aluminum has been shown to be a good indicator of mineral dust (Rahn, Grad. Sch. of Oceanogr.: Univ. of Rhode Island, Kingston, 1976; Uematsu et al., *J. Geophys. Res.*, 1983), and the Earth's upper crust contains approximately 8.04 parts per million aluminum (Taylor and McLennan, *Rev. Geophys.*, 1995).

As mineral matter was expected to be a major component of the aerosol mass, and particle mass loadings were found to be related to ^{239,240}Pu activities, we next focused our attention on the relationship between mineral dust and aerosol ^{239,240}Pu. Mineral aerosol concentrations, as represented by Al, were highly variable over time, and the highest dust concentrations occurred in the spring (Fig. 14), which is when the winds in Carlsbad are often strong and the visibility in the area occasionally impaired by raised dust. As noted above, spring is also when the highest ^{239,240}Pu activities are observed and the implication is that there is an association between aerosol ^{239,240}Pu and soil-derived aerosols.

A simple test of this hypothesis was made by examining the aerosol data for a correlation between ^{239,240}Pu and Al. For this analysis, the aluminum data were averaged over the longer collection intervals used for the high-volume radionuclide sample collections. Even though the radionuclide and trace element samples were not precisely matched, a scatterplot of ^{239,240}Pu activity versus aluminum (Fig. 15) shows the two variables were weakly but significantly correlated ($r = 0.54$, $p < 0.0001$). Furthermore, there were no discernable differences in the relationships among sites as there were for ^{239,240}Pu versus mass loadings.

While the correlation between ^{239,240}Pu and mineral dust does not prove that the activities of ^{239,240}Pu are controlled by resuspension, it does establish a link between plutonium activities and the concentrations of mineral particles in the atmosphere, at least some of which must be mobilized by resuspension of local soils. A comparison of the aerosol and soil data show that the ^{239,240}Pu activity/aluminum concentration ratio for the aerosols (all data = 3.3×10^{-2} nBq ng^{-1}) was much higher than for soils (6.9×10^{-5} and 1.1×10^{-5} nBq ng^{-1} at Near Field and Cactus Flats, respectively), (Kirchner et al., *J. Environ. Radioactivity, op cit.*). The higher ^{239,240}Pu/aluminum ratio in aerosols relative to soils are likely due to the affinity of ^{239,240}Pu for small soil particles that have large surface area to mass (and volume) ratios. While these small particles contribute little to the soil mass, they tend to have higher aluminum contents than larger soil particles, which include a considerable amount of quartz. Even though small with respect to other soil particles, these Al-rich particles are large compared with most aerosols, and they would tend to remain suspended in the atmosphere much longer than the bulk of the soil-derived aerosol mass, which is quite rapidly re-deposited by gravitational settling (Sehmel, et al., *Washington, DC: Office of Science and Technical Information CONF-841142*, 1987).

The results of the WIPP-EM study demonstrate that processes affecting the resuspension of ^{239,240}Pu and possibly other substances of concern are of considerable importance in terms of material budgets and must be known and quantified if any impacts of WIPP operations are to be properly evaluated. This is an important consideration because any potential releases of radionuclides or other materials from the WIPP will be superimposed on the variability caused by the winds and other meteorological factors responsible for the resuspension and re-distribution of contaminants deposited independent of WIPP operations.

The inorganic results serve to highlight the dynamics of the aerosol system in the area around the WIPP. In particular, the aluminum data show that the loadings of mineral dust in the atmosphere were higher during the spring peaks in 1999 and 2000 compared with the baseline period (Fig. 14). Because dust concentrations and ^{239,240}Pu activities are correlated, one can infer that interannual differences in the amounts of resuspended mineral dust would directly translate into variability in the activities of resuspended ^{239,240}Pu, again with important implications for any programs designed to detect any potential releases from the WIPP. Such interannual variability in mineral dust concentrations is well documented in the atmospheric sciences literature, and differences of this type are influenced both by conditions in the dust source regions (Prospero and Nees, *Nature*, 1986) and variations in meteorology and transport pathways (Tegen and Miller, *J. Geophys. Res*., 1998).

Summary of Recent Aerosol Data

Early data from the trace element studies of aerosols (covering the period from 3 February 1998 to 29 July 1999 and summarized in the CEMRC 1999 report) suggested that that the sites differed in the percentages of samples with TE concentrations above detection (Fig. 16, upper panel). As a follow-up to that analysis, the data from the beginning of the program up until July 2001 were replotted for comparison against the earlier results (Fig. 16, lower panel). It is clear from this exercise that the patterns in TE concentrations above detection limits are now comparable at all stations, with most of the changes between the earlier and more recent data occurring at Cactus Flats. In particular, the percentage of samples with Ba and Pb at Cactus Flats have increased over the course of the WIPP-EM while the number of samples with detectable Ag, Cd, and Hg at Cactus Flats has decreased.

The similarity in the percentages of samples with TE concentrations above detection limits at the three stations reinforces the notion that there has been little if any perturbation to the trace elements of concern that can be tied to activities at the WIPP. More rigorous comparisons can be made by comparing the mean concentrations using statistical methods such as the analysis of variance (ANOVAs). Two examples of such tests are presented here, one for aerosol Ba and the other for Pb because these two elements are detected in far more samples than the other elements. For these tests (Tables 3 and 4), the logarithms of the Ba and Pb concentrations were used because the data tend to be more nearly log-normally distributed than normal.

The geometric mean Ba concentrations are 4.50, 3.88 and 5.12 ng m^{-3} for Cactus Flats, Near Field and On Site, respectively. The probability (p) for differences in means as large as these due to chance alone is $p = 0.033$, which we regard as marginally significant. While it is possible that some Ba has been released by the activities at the WIPP, the concentrations at the monitoring stations were not very different from those in the exhaust shaft (i.e., the FAS samples). For comparison, the mean Ba concentration for the FAS samples presented in the 2000 CEMRC report was 7.8 ng m^{-3}, and this only slightly higher than those at the three ambient aerosol stations. Thus it is unlikely that the WIPP is a significant source for Ba especially at Near Field and Cactus Flats.

The situation for Pb is quite different from Ba: first, the Pb concentration in the exhaust shaft FAS samples (6.8 ng m^{-3}, CEMRC 2000 report) is nearly ten times higher than in the ambient samples (0.768, 0.832 and 0.743 ng m^{-3} at Cactus Flats, Near Field, and On Site respectively). Second, and more revealing is the fact that the differences in the mean log (Pb) concentrations among stations were clearly not significant (the probability for chance occurrence from the ANOVA was $p = 0.544$). Therefore, in the case of Pb, for which there was nearly a ten-fold enrichment in the exhaust shaft aerosols, there is no evidence for a perturbation at the On Site station, which is only 0.1 km from the exhaust shaft.

As noted in the CEMRC report for 2000, other benchmarks used for interpreting the aerosol data were the maximum trace element concentrations observed during the baseline period. Table 5 presents the maximum concentrations for each trace element for the baseline and operational periods. For the elements of primary interest (As, Be, Ba, Cd, Cr, Pb, Hg, Se and Ag), there were several cases in which the operational maxima exceeded the baseline maxima, but in most of these cases, the percentage increases were considered to be small, less than 20%. The one notable exception was Pb for which the baseline maximum at On Site was 2.05 ng m^{-3} and the operational maximum there was 8.62 ng m^{-3}. Further analysis of the On Site Pb data showed that the operational maximum occurred in the first sample collected after the mixed waste was received and that the Pb concentrations in subsequent samples decreased. However, a second On Site sample (from late April 2001) had a Pb concentration of 4.36 ng m^{-3}, which was also higher than the baseline maximum. As a result of these observations, the concentrations of Pb will be given special scrutiny in future studies.

Tables presenting the aerosol data summarized herein are available on the CEMRC web site at http://www.cemrc.org.

Table 3. Means for One-way ANOVA (LogBa)

Station	[a]Number	Mean	Std Error
Cactus Flats	110	0.6531	0.0301
Near Field	96	0.5892	0.0322
On Site	95	0.7091	0.0324
		F-ratio = 3.45, p = 0.033	

[a] Number = number of samples.

Table 4. Means for One-way ANOVA (LogPb)

Station	[a]Number	Mean	Std Error
Cactus Flats	102	-0.1145	0.0301
Near Field	90	-0.0799	0.0320
On Site	87	-0.1287	0.0326
		F-ratio = 0.61, p = 0.544	

[a] Number = number of samples.

Table 5. Maximum Trace Element Concentration for Baseline and Operational Aerosol Samples

Element	Parameter	Cactus Flats	Near Field	On Site
Ag	[a]N [b]Baseline	19	19	12
	Baseline Max	4.14E-01	1.56E-01	6.23E-02
	N Operational	10	6	10
	Operational Max	3.96E-02	3.15E-02	5.24E-02
	Percent Increase	None	None	None
Al	N Baseline	82	70	66
	Baseline Max	1.86E+03	2.86E+03	1.44E+03
	N Operational	19	16	18
	Operational Max	8.04E+02	1.54E+03	1.53E+03
	Percent Increase	None	None	6.3
As	N Baseline	4	1	1
	Baseline Max	5.47E+00	3.77E+00	7.21E-01
	N Operational	0	0	0
	Operational Max	[c]NA	NA	NA
	Percent Increase	None	None	None
Ba	N Baseline	81	69	65
	Baseline Max	3.33E+01	2.30E+01	2.71E+01
	N Operational	19	16	18
	Operational Max	8.08E+00	1.50E+01	2.87E+01
	Percent Increase	None	None	5.9
Be	N Baseline	0	0	1
	Baseline Max	NA	NA	9.32E-02
	N Operational	0	0	1
	Operational Max	NA	NA	1.14E-01
	Percent Increase	None	None	22.3
Ca	N Baseline	75	68	65
	Baseline Max	2.23E+03	4.55E+03	5.30E+03
	N Operational	18	14	18
	Operational Max	8.35E+02	1.10E+03	2.66E+03
	Percent Increase	None	None	None
Cd	N Baseline	19	19	11
	Baseline Max	1.39E+00	2.21E+00	1.56E+00
	N Operational	9	6	9
	Operational Max	4.60E-01	2.15E-01	8.32E-01
	Percent Increase	None	None	None

Table continued on next page

Table 5. Maximum Trace Element Concentration for Baseline and Operational Aerosol Samples (Cont.)

Element	Parameter	Cactus Flats	Near Field	On Site
Ce	N Baseline	82	70	67
	Baseline Max	1.90E+00	3.99E+00	1.61E+00
	N Operational	19	16	18
	Operational Max	8.02E-01	1.50E+00	1.47E+00
	Percent Increase	None	None	None
Co	N Baseline	56	48	51
	Baseline Max	1.29E+01	3.10E+00	8.03E+01
	N Operational	10	7	14
	Operational Max	7.62E-01	1.10E+00	2.67E+00
	Percent Increase	None	None	None
Cr	N Baseline	10	11	10
	Baseline Max	53.7	60.1	40.9
	N Operational	6	4	5
	Operational Max	8.66	8.24	6.71
	Percent Increase	None	None	None
Cu	N Baseline	65	57	56
	Baseline Max	1.30E+01	4.89E+01	1.34E+01
	N Operational	13	12	17
	Operational Max	3.79E+00	3.45E+00	1.94E+01
	Percent Increase	None	None	44.8
Dy	N Baseline	79	61	56
	Baseline Max	1.41E-01	2.94E-01	1.15E-01
	N Operational	16	11	15
	Operational Max	5.63E-02	1.03E-01	8.74E-02
	Percent Increase	None	None	None
Er	N Baseline	66	47	46
	Baseline Max	8.81E-02	1.66E-01	7.40E-02
	N Operational	7	6	12
	Operational Max	2.97E-02	5.60E-02	6.00E-02
	Percent Increase	None	None	None
Eu	N Baseline	54	38	39
	Baseline Max	4.39E-02	7.06E-02	4.19E-02
	N Operational	4	2	8
	Operational Max	1.56E-02	2.59E-02	3.04E-02
	Percent Increase	None	None	None

Table continued on next page

Table 5. Maximum Trace Element Concentration for Baseline and Operational Aerosol Samples (Cont.)

Element	Parameter	Cactus Flats	Near Field	On Site
Fe	N Baseline	66	58	53
	Baseline Max	8.73E+02	1.52E+03	6.88E+02
	N Operational	16	12	17
	Operational Max	4.02E+02	7.54E+02	8.13E+02
	Percent Increase	None	None	18.2
Gd	N Baseline	79	64	60
	Baseline Max	2.60E-01	3.54E-01	2.34E-01
	N Operational	16	11	15
	Operational Max	8.42E-02	1.74E-01	1.49E-01
	Percent Increase	None	None	None
Hg	N Baseline	18	15	14
	Baseline Max	2.25E-01	2.10E-01	1.39E-01
	N Operational	4	3	2
	Operational Max	3.77E-02	5.32E-02	4.29E-02
	Percent Increase	None	None	None
K	N Baseline	77	68	63
	Baseline Max	6.30E+02	1.23E+03	1.14E+03
	N Operational	17	15	17
	Operational Max	2.17E+02	4.36E+02	6.09E+02
	Percent Increase	None	None	None
La	N Baseline	68	56	54
	Baseline Max	1.97E+00	7.61E+00	1.46E+00
	N Operational	8	7	9
	Operational Max	3.92E-01	7.39E-01	7.32E-01
	Percent Increase	None	None	None
Li	N Baseline	28	19	20
	Baseline Max	2.72E+00	1.16E+00	1.08E+00
	N Operational	6	6	10
	Operational Max	4.64E-01	1.11E+00	9.19E-01
	Percent Increase	None	None	None
Mg	N Baseline	79	69	67
	Baseline Max	3.64E+02	6.69E+02	6.10E+02
	N Operational	18	15	18
	Operational Max	1.82E+02	3.43E+02	4.56E+02
	Percent Increase	None	None	None

Table continued on next page

Table 5. Maximum Trace Element Concentration for Baseline and Operational Aerosol Samples (Cont.)

Element	Parameter	Cactus Flats	Near Field	On Site
Mn	N Baseline	80	68	65
	Baseline Max	1.89E+01	3.70E+01	1.65E+01
	N Operational	18	16	18
	Operational Max	8.48E+00	1.60E+01	1.98E+01
	Percent Increase	None	None	20.0
Mo	N Baseline	10	6	9
	Baseline Max	8.79E-01	3.57E-01	4.75E-01
	N Operational	6	8	6
	Operational Max	2.03E-01	1.98E-01	9.75E-01
	Percent Increase	None	None	105.3
Na	N Baseline	50	53	50
	Baseline Max	3.23E+03	2.40E+03	7.34E+02
	N Operational	16	15	18
	Operational Max	3.44E+02	2.74E+02	4.11E+02
	Percent Increase	None	None	None
Nd	N Baseline	82	70	67
	Baseline Max	8.40E-01	1.75E+00	6.64E-01
	N Operational	19	16	18
	Operational Max	3.10E-01	5.95E-01	6.76E-01
	Percent Increase	None	None	1.8
Ni	N Baseline	34	29	34
	Baseline Max	4.07E+01	2.08E+01	5.93E+01
	N Operational	4	4	9
	Operational Max	3.62E+00	3.45E+00	2.08E+01
	Percent Increase	None	None	None
Pb	N Baseline	74	62	58
	Baseline Max	2.95E+00	4.91E+00	2.05E+00
	N Operational	18	16	17
	Operational Max	3.44E+00	2.12E+00	8.62E+00
	Percent Increase	16.6	None	320.5
Pr	N Baseline	81	69	65
	Baseline Max	2.29E-01	7.57E-01	1.89E-01
	N Operational	19	16	18
	Operational Max	9.54E-02	1.77E-01	1.67E-01
	Percent Increase	None	None	None

Table continued on next page

Table 5. Maximum Trace Element Concentration for Baseline and Operational Aerosol Samples (Cont.)

Element	Parameter	Cactus Flats	Near Field	On Site
Sb	N Baseline	28	26	25
	Baseline Max	1.38E+01	5.85E-01	7.65E-01
	N Operational	19	16	18
	Operational Max	6.05E-01	3.60E-01	3.02E-01
	Percent Increase	None	None	None
Sc	N Baseline	14	12	12
	Baseline Max	1.59E+00	1.19E+00	1.32E+00
	N Operational	8	6	10
	Operational Max	4.82E-01	8.74E-01	8.75E-01
	Percent Increase	None	None	None
Se	N Baseline	2	0	1
	Baseline Max	7.94E-01	NA	2.51E+00
	N Operational	2	2	2
	Operational Max	1.32E+00	1.55E+00	1.31E+00
	Percent Increase	66.2	None	None
Sm	N Baseline	76	63	56
	Baseline Max	1.90E-01	3.42E-01	1.44E-01
	N Operational	16	14	16
	Operational Max	8.26E-02	1.31E-01	1.13E-01
	Percent Increase	None	None	None
Sn	N Baseline	3	3	7
	Baseline Max	3.15E-01	1.01E+02	6.32E+01
	N Operational	0	0	0
	Operational Max	[d]ND	ND	ND
	Percent Increase	None	None	None
Sr	N Baseline	73	60	61
	Baseline Max	8.72E+00	2.07E+01	9.82E+00
	N Operational	19	16	18
	Operational Max	3.51E+00	6.36E+00	7.05E+00
	Percent Increase	None	None	None
Th	N Baseline	81	68	60
	Baseline Max	3.45E-01	6.28E-01	2.70E-01
	N Operational	17	13	16
	Operational Max	1.44E-01	2.69E-01	2.71E-01
	Percent Increase	None	None	0.4

Table continued on next page

Table 5. Maximum Trace Element Concentration for Baseline and Operational Aerosol Samples (Cont.)

Element	Parameter	Cactus Flats	Near Field	On Site
Ti	N Baseline	78	64	58
	Baseline Max	9.49E+01	1.71E+02	8.11E+01
	N Operational	15	12	16
	Operational Max	3.38E+01	6.36E+01	6.93E+01
	Percent Increase	None	None	None
Tl	N Baseline	10	8	11
	Baseline Max	9.04E-02	2.53E-01	6.20E-01
	N Operational	8	7	5
	Operational Max	7.41E-02	7.20E-02	5.23E-02
	Percent Increase	None	None	None
U	N Baseline	73	56	52
	Baseline Max	1.00E-01	1.28E-01	7.40E-02
	N Operational	16	11	16
	Operational Max	3.81E-02	6.66E-02	6.44E-02
	Percent Increase	None	None	None
V	N Baseline	26	21	24
	Baseline Max	3.08E+01	1.03E+01	2.14E+01
	N Operational	8	4	7
	Operational Max	2.69E+00	3.88E+00	4.46E+00
	Percent Increase	None	None	None
Zn	N Baseline	20	20	23
	Baseline Max	1.84E+02	7.19E+01	1.62E+02
	N Operational	12	12	15
	Operational Max	9.93E+00	1.22E+01	4.89E+01
	Percent Increase	None	None	None

[a] N = number of samples
[b] Baseline samples were collected prior to 9 September 2000; operational samples were collected through June 2001
[c] NA = not analyzed
[d] ND = no data

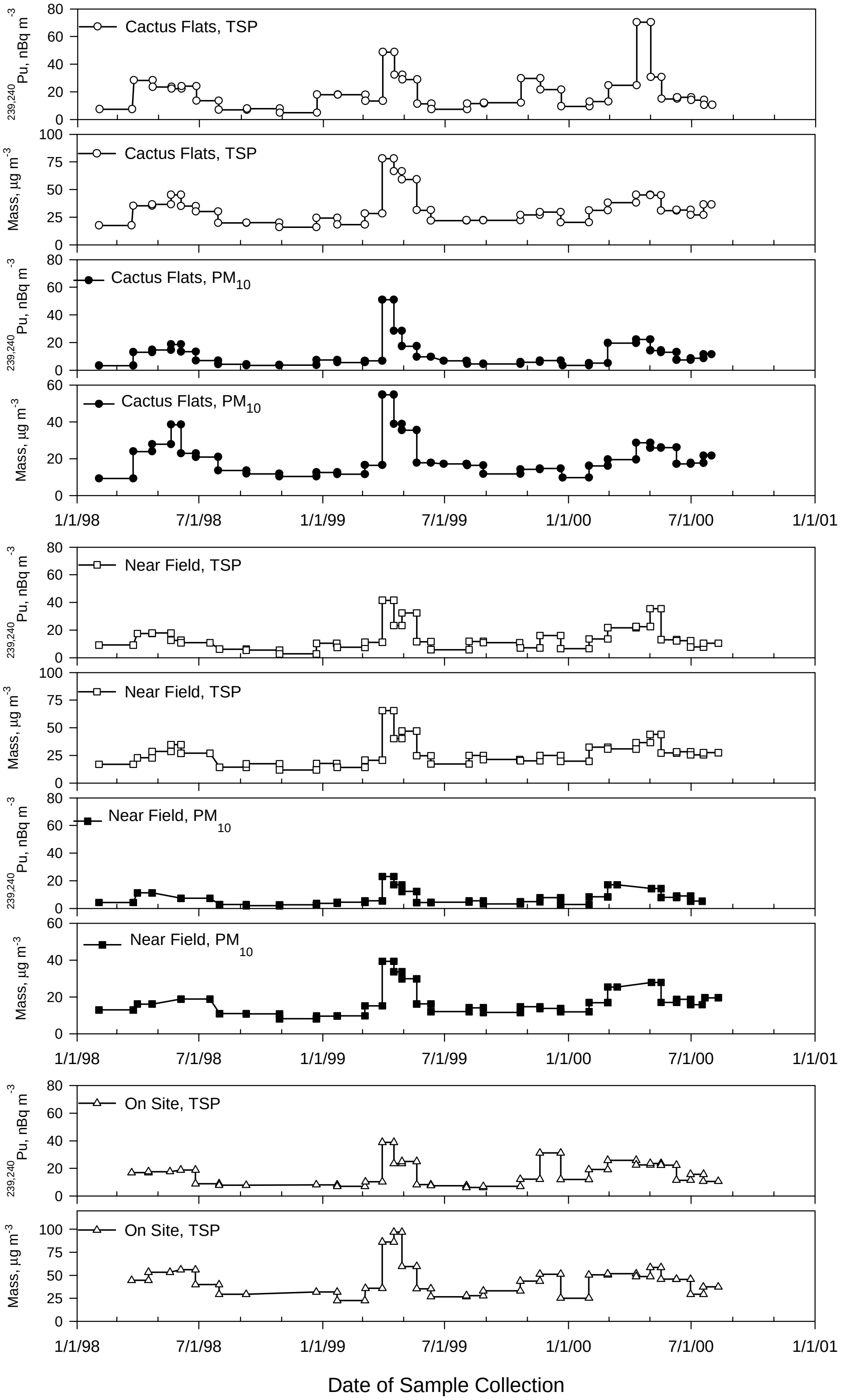


Figure 12. Mass and ^{239,240}Pu Activity Concentrations in Aerosol Samples Collected from February 1998 to August 2000.

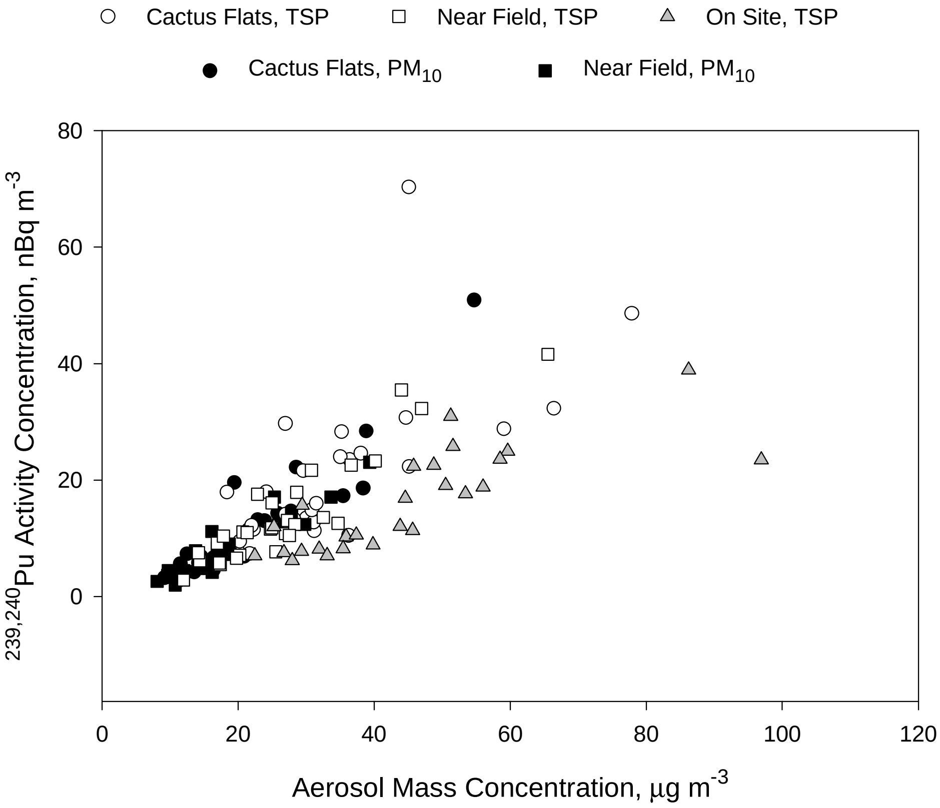


Figure 13. ^{239,240}Pu Activity Concentrations versus Aerosol Mass for High-Volume Samples.

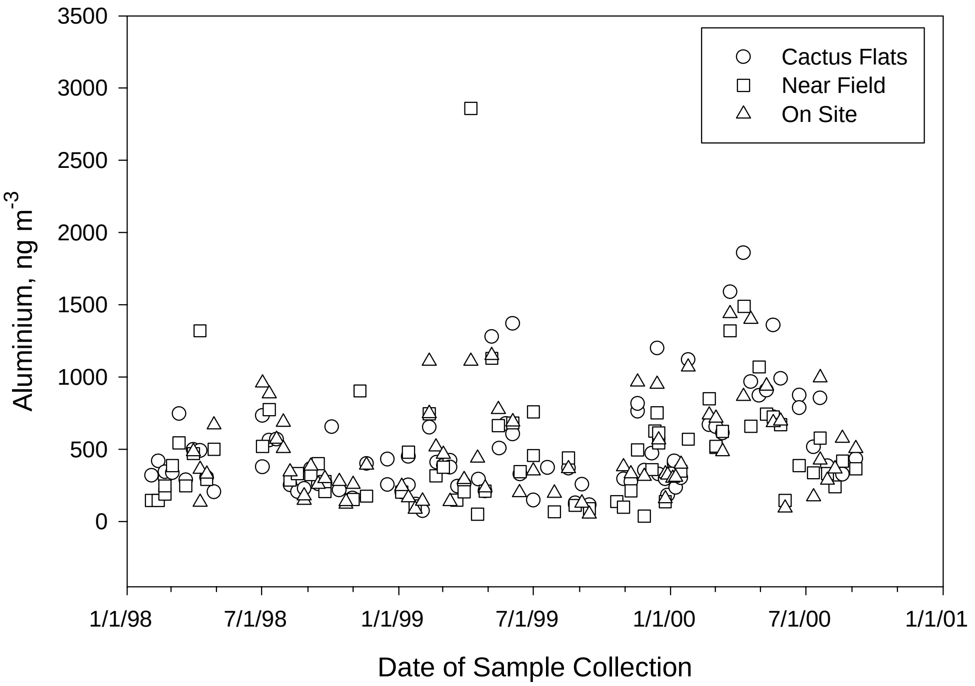


Figure 14. Temporal Variations in Aluminum Concentrations in Total Suspended Particle Samples Collected during February 1998 to July 2000.

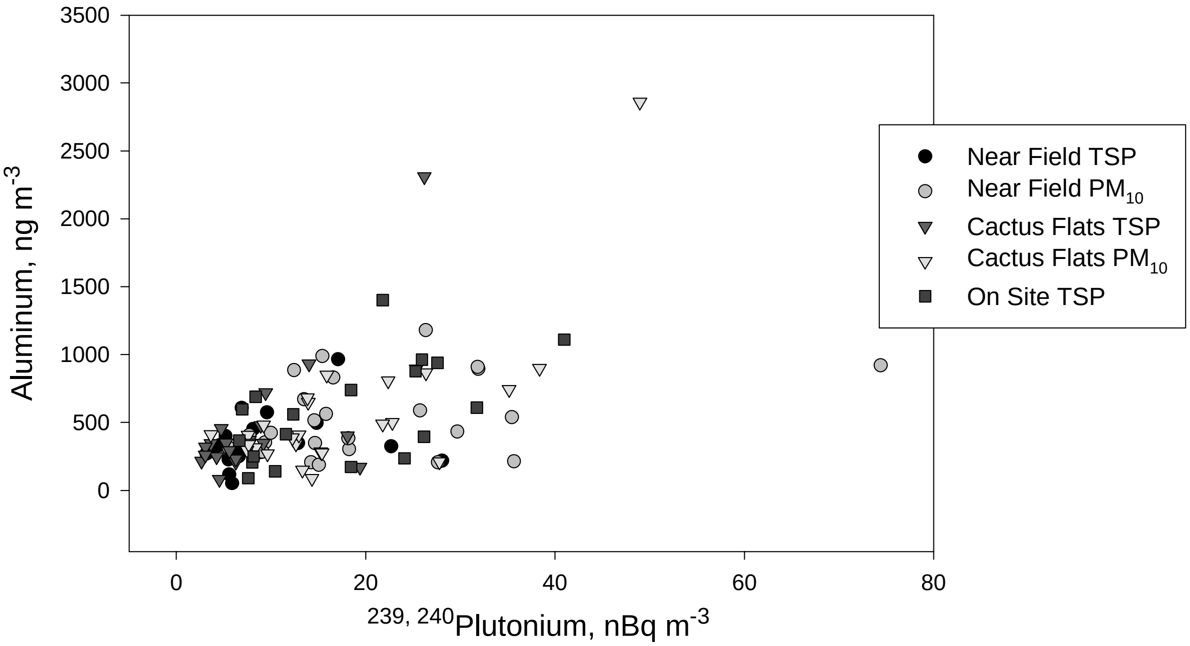


Figure 15. Relationship between ^{239,240}Pu vs. Aluminum Aerosol Samples from Cactus Flats, Near Field, and On Site Stations.

PM$_{10}$ stands for particles less than 10 μm aerodynamic diameter and TSP stands for total suspended particles.

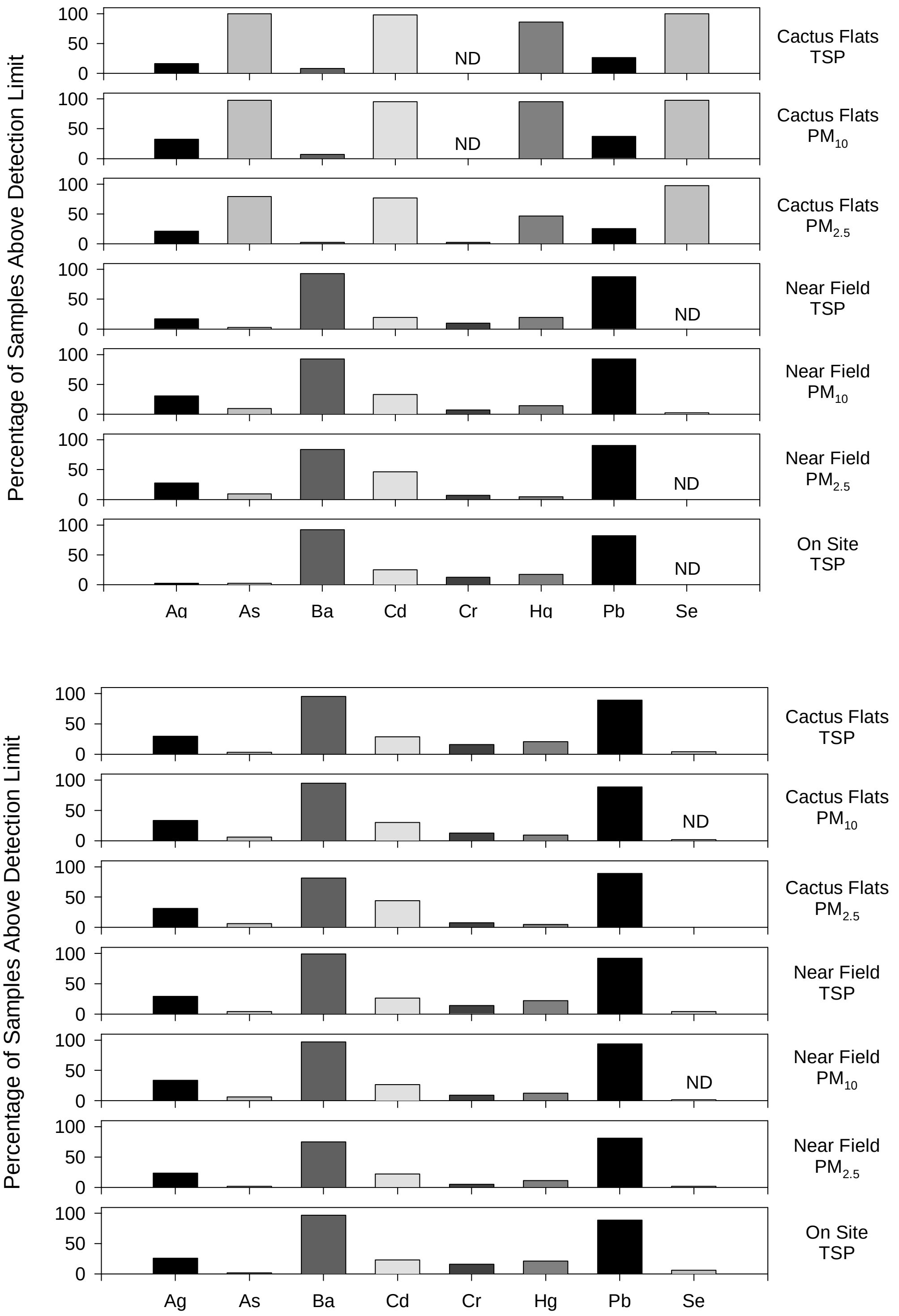


Figure 16. Percentages of Samples with Selected Elemental Concentrations above Detection Limits for Samples Collected from February 1998 to July 1999 (above) and February 1998 to July 2001 (below).
ND = not detected

Radionuclides and Inorganics in WIPP Exhaust Air

Introduction

The CEMRC aerosol sampling program for the WIPP EM is designed to study the pathway that is the most likely route by which contaminants from the WIPP site could become rapidly dispersed in the environment. One facet of this comprehensive program is the monitoring of aerosols in the WIPP exhaust shaft. These samples are collected at a location (Station A) that represents the release point of aerosol effluents from the underground to the environment. CEMRC is interested in obtaining information on air quality from Station A because it provides a means for characterizing a source-term that will be needed for the interpretation of future monitoring results from the WIPP EM. For example, if radioactive or hazardous material was released from the WIPP, we would expect to detect it at Station A before it is observed in the local population or environment. In addition, source-term data collected at Station A would be of critical importance for the determination of public or worker dose in the event of an accident at the WIPP.

Another objective of the sampling program at Station A is to provide a gross check of emissions on a short resolution time-scale (e.g. weeks). For example, many of the WIPP EM analyses require many months to complete once the samples are collected. Such time is needed because of the specificity and sensitivity of the analyses. At Station A, gross monitoring results (less specific and sensitive) are provided within three weeks of sample collection and are used to trigger more detailed investigations if necessary.

Methods

A detailed description of the sampling protocol, aerosol sampler, analytical methods and detection limits are provided in the CEMRC 1999 and 2000 Reports. These reports and continually updated results can be found at the CEMRC website (http://www.cemrc.org). In summary, the monitoring program consists of daily aerosol sampling, gravimetric and gross alpha/beta analyses of individual filters, elemental and gamma-ray analysis of weekly filter composites and actinide analysis of quarterly filter composites.

Some changes to effluent sampling and analytes measured were made during this reporting period. Specifically, changes were made to the sampling location within Station A and ^{241}Pu was added to the suite of actinides analyzed as part of the quarterly composite.

At Station A, there are three shrouded-probe aerosol samplers, located on three separate sampling skids (skids 1-3). On each skid, aerosols are split into three sampling legs such that three concurrent samples can be collected from a single skid. CEMRC had sampled on skid 3, leg 2. The Environmental Evaluation Group (EEG) and Westinghouse TRU Solutions (WTS) sample concurrently on the remaining legs of skid 3. In April 2001, the entire sampling apparatus from skid 3 was exchanged with that at skid 1. Sampling was moved to this location to reduce problems associated with water infiltration into the exhaust shaft, which was most prevalent at the previous skid location.

Results and Discussion

Routine Monitoring

Aerosol sampling has been conducted continuously at Station A by CEMRC since 12 December 1998. Monitoring results from 1 July 2000 through 1 July 2001 are discussed herein. Tables presenting aerosol data summarized herein are available on the CEMRC web site at http://www.cemrc.org. For measurements of radioactivity, data reported during the current period are considered operational monitoring, since radioactive waste was received in March 1998. For measurements of elemental constituents, data reported herein constitute baseline and operational monitoring since WIPP received mixed waste on September 9, 2000.

Values of gross alpha activity concentration and density ranged from < MDC (≈ 0.03) to 0.7 mBq m^{-3} and < MDC (≈ 0.4) to 4.5 Bq g^{-1}, respectively. Values of gross beta activity concentration and density ranged from < MDC (≈ 0.07) to 58 mBq m^{-3} and < MDC (≈ 1) to 92 Bq g^{-1}, respectively. In general, values of gross alpha and beta concentration and density are either unchanged or have decreased since the WIPP began receiving waste in March 1998. (Table 6, Figs 17 and 18).

In January 2001, the CEMRC monitoring program identified elevated gross beta radioactivity for filters collected on January 9, 2001 (Fig. 18). CEMRC notified the DOE, and the elevated measurements were later confirmed by EEG and WTS. While investigating these results, it was noted that on this day a fire retardant, trade name Purple K, was accidentally released in the WIPP underground. The primary constituent of Purple K is potassium bicarbonate, which includes the naturally occurring radioactive K isotope (^{40}K) that decays by beta emission 89% of the time. Follow-up measurements verified that the fire retardant containing ^{40}K was the cause of the elevated results and that WIPP waste had not been released. In addition, it is important to note that EEG confirmed the absence of beta emitting ^{90}Sr (WIPP waste constituent) on these filters.

The release of the fire retardant provided an excellent opportunity for the organizations sampling at Station A to intercompare analytical results and evaluate the efficacy of the sampling apparatus. For all three filters containing the fire retardant, results reported by CEMRC, EEG and WTS compared very well (Table 7) and demonstrates the quality of monitoring efforts at Station A.

WIPP received mixed waste on September 9, 2000. For elemental constituents, samples collected prior to this date represent a baseline and samples collected thereafter represent operational monitoring. Numerous elemental constituents were observed in weekly composites (Table 8) prior to and after the receipt of mixed waste. Greater than 85% of all of the 36 elements were observed in 75-100% of the weekly composites. Many of the hazardous elements (e.g. Pb, Be, Cd, etc.) expected to be contained in WIPP mixed waste were already present in WIPP aerosol effluents prior to the receipt of mixed waste. A high degree of variability in weekly concentrations was observed for most elements prior to and after receipt of mixed waste. For example, the ratio between the maximum and minimum Na concentration exceeded 200 and strong temporal peaks in concentration were observed (Fig 19). These peaks appeared during time periods when significant mining was occurring in the repository (e.g. panel excavation). This level of variability was an essential aspect of baseline characterization and should be considered when evaluating operational monitoring results.

With the exception of ^{7}Be, no detectable gamma-emitting radionuclides were observed during this monitoring period. ^{7}Be was detected in approximately 20% of samples, ranging in activity concentration and density from 4 to 18 mBq m^{-3} and 29 to 148 Bq g^{-1}, respectively. For detectable results, mean values (± SE) of activity concentration and density were 9.5 (± 0.4) mBq m^{-3} and 99 (± 8) Bq g^{-1}, respectively. ^{7}Be values during this monitoring period were consistent with those reported in the CEMRC 1999 and 2000 Reports. These results indicate that the aerosols entering through the WIPP air intake eventually reach the exhaust system and are released as exhaust effluents. The presence of ^{7}Be in the exhaust is an indicator of this mechanism because ^{7}Be is a short-lived radionuclide ($T_{1/2}$ = 53 days) that is produced in the stratosphere through spallation of atmospheric gases (not occurring naturally in the WIPP underground). This finding may be of importance because other aerosols containing radionuclides of concern (e.g. Pu, ^{137}Cs) may follow a similar process and be detected in the exhaust in the absence of a WIPP-related contamination event. Therefore, ^{7}Be may be a useful tracer for understanding aerosol residence times in the WIPP.

Isotopes of naturally occurring U and Th isotopes were detected in all quarterly composites reported for this monitoring period with the exception of the fourth quarter 2000 (Table 9). For this quarter, all U and Th analyses were invalidated due to concerns regarding weekly digestate preservation. Concentrations and activity densities of U and Th isotopes for all quarters reported here in were consistent with that reported in the CEMRC 1999 and 2000 Reports.

No detectable concentrations of ^{238}Pu, ^{239,240}Pu, ^{241}Pu, or ^{241}Am (Table 9) were observed in any operational quarter reported herein. These results are consistent with that reported in the CEMRC 1999 and 2000 Reports. The analysis for ^{241}Pu was first implemented in the first quarter of 2001, yielding MDCs of approximately 25 μBq m^{-3} and 80 mBq g^{-1}. The ^{241}Pu analysis failed for the second quarter of 2001 because of difficulties in preparing the alpha spectrometry source for liquid scintillation counting.

Table 6. Summary Statistics for Gross Alpha/Beta Analyses of Daily FAS Filters

Gross Emission	[a]N	% ≥ [b]MDC	Activity Concentration (Bq m^{-3})			Activity Density (Bq g^{-1})		
			[c]Mean	[d]SE	[e]Max	Mean	SE	Max
Pre-Operations Baseline								
Alpha	71	100	3.1E-04	3.1E-05	1.5E-03	3.6E+00	5.8E-01	3.7E+01
Beta	71	100	1.1E-03	9.1E-05	4.9E-03	1.4E+01	1.9E+00	1.2E+02
Operational Monitoring April 1999 – June 2000								
Alpha	427	60	9.8E-05	3.3E-06	3.9E-04	9.9E-01	1.5E-01	9.2E+00
Beta	427	97	9.6E-04	2.1E-05	3.3E-03	1.0E+01	1.0E+00	4.8E+01
Operational Monitoring June 2000 – June 2001								
Alpha	454	35	6.8E-05	2.8E-06	7.3E-04	6.1E-01	3.7E-02	4.5E+00
Beta	454	94	1.1E-03	1.4E-05	5.8E-02	9.5E+00	6.0E-01	9.1E+01

[a] N = number of samples
[b] MDC = minimum detectable concentration
[c] Mean = arithmetic mean
[d] SE = standard error
[e] Max = maximum

Table 7. An Intercomparison of Gross Beta Results following the Release of Fire Retardant Containing ^{40}K on January 9, 2001

Filter	Gross Beta Radioactivity (Bq) per Filter Mean ± 2 [a]SD			Gross Beta Radioactivity Concentration (mBq m^{-3}) Mean ± 2 SD		
	EEG	WTS	CEMRC	EEG	WID	CEMRC
1 (morning)	0.30 ± 0.04	0.37 ± 0.08	0.35 ± 0.02	44 ± 6	55 ± 13	58 ± 3
2 (afternoon)	0.46 ± 0.10	0.38 ± 0.09	0.38 ± 0.02	35 ± 8	27 ± 6	31 ± 1
3 (evening)	0.31 ± 0.08	0.32 ± 0.08	0.33 ± 0.02	5 ± 1	5 ± 1	5 ± 1

[a] SD = Standard deviation

Table 8. Summary Statistics for Elemental Constituents in Weekly FAS Composites

Analyte	**[a]Baseline Volume Concentration 12 December 1998 – 9 September 2000 (ng m^{-3})**				**[b]Operational Volume Concentration 9 September 2000 – 1 July 2001 (ng m^{-3})**			
	[c]FD (%)	**[d]Mean**	**[e]SE**	**[f]Max**	**FD (%)**	**Mean**	**SE**	**Max**
Ag	79	1.1E-01	2.2E-02	1.2E+00	48	5.9E-01	3.1E-01	5.5E+00
Al	99	7.2E+02	9.7E+01	7.8E+03	92	4.6E+02	4.3E+01	1.4E+03
As	70	1.3E+00	1.2E-01	4.7E+00	73	1.2E+00	1.6E-01	3.8E+00
Ba	100	7.6E+00	4.1E-01	2.0E+01	92	6.1E+00	5.6E-01	2.3E+01
Be	7	2.9E-01	1.4E-01	9.8E-01	0	[g]NA	NA	NA
Ca	100	4.1E+03	8.8E+02	7.0E+04	92	8.8E+03	3.1E+03	1.3E+05
Cd	82	9.4E-01	2.4E-01	1.5E+01	46	6.3E-01	1.4E-01	2.4E+00
Ce	99	7.4E-01	4.7E-02	2.1E+00	92	5.4E-01	6.5E-02	2.1E+00
Co	94	3.1E+00	4.5E-01	2.4E+01	88	9.4E+00	2.3E+00	8.5E+01
Cr	61	5.8E+01	1.3E+01	6.2E+02	75	5.2E+01	5.1E+00	1.7E+02
Cu	100	3.7E+01	2.0E+00	1.1E+02	88	4.6E+01	6.1E+00	2.7E+02
Dy	100	4.6E-02	3.4E-03	1.6E-01	33	4.9E-02	7.2E-03	1.2E-01
Er	96	2.8E-02	2.4E-03	1.5E-01	6	4.9E-02	6.5E-03	6.1E-02
Eu	93	1.5E-02	9.3E-04	3.7E-02	6	2.5E-02	2.4E-03	2.9E-02
Fe	100	8.0E+02	7.9E+01	5.8E+03	92	7.6E+02	1.1E+02	4.6E+03
Gd	99	7.2E-02	5.5E-03	2.8E-01	60	7.8E-02	9.8E-03	2.3E-01
Hg	30	1.6E-01	2.9E-02	5.7E-01	0	NA	NA	NA
K	99	1.3E+03	1.1E+02	5.4E+03	92	1.4E+03	2.2E+02	8.9E+03
La	100	4.5E-01	3.0E-02	1.3E+00	92	2.6E-01	2.5E-02	9.0E-01
Li	76	2.4E+00	2.7E-01	1.4E+01	90	2.2E+00	6.5E-01	2.7E+01
Mg	100	2.7E+03	6.4E+02	5.1E+04	92	4.1E+03	1.5E+03	6.1E+04
Mn	100	3.4E+01	3.5E+00	1.4E+02	92	3.5E+01	5.4E+00	2.2E+02
Mo	70	4.3E+00	1.3E+00	7.5E+01	81	4.4E+00	6.3E-01	2.3E+01
Na	99	6.7E+04	7.2E+03	2.9E+05	96	4.5E+04	6.4E+03	2.2E+05
Nd	100	3.1E-01	2.0E-02	9.2E-01	58	2.6E-01	3.0E-02	7.6E-01
Ni	91	1.8E+01	5.7E+00	4.2E+02	92	2.4E+01	4.1E+00	1.4E+02
Pb	100	7.0E+00	7.4E-01	4.6E+01	92	5.3E+00	5.0E-01	1.7E+01
Pr	100	8.9E-02	5.6E-03	2.7E-01	92	5.6E-02	5.9E-03	1.9E-01
Sb	100	3.1E+01	3.1E+00	2.2E+02	92	1.7E+01	1.2E+00	4.9E+01
Se	28	5.5E-01	4.7E-02	1.1E+00	10	7.7E-01	1.5E-01	1.3E+00
Sm	100	4.7E-01	2.0E-02	1.2E+00	67	4.7E-01	1.8E-02	6.8E-01
Sr	100	6.8E+01	1.8E+01	1.4E+03	92	1.8E+02	7.3E+01	3.1E+03
Th	94	1.1E-01	9.7E-03	4.8E-01	73	6.3E-02	9.3E-03	2.6E-01
Ti	99	4.4E+01	3.3E+00	2.1E+02	81	3.1E+01	4.6E+00	1.8E+02

Table continued on next page

Table 8. Summary Statistics for Elemental Constituents in Weekly FAS Composites (Cont.)

Analyte	[a]Baseline Volume Concentration 12 December 1998 – 9 September 2000 (ng m^{-3})				[b]Operational Volume Concentration 9 September 2000 – 1 July 2001 (ng m^{-3})			
	[c]FD (%)	[d]Mean	[e]SE	[f]Max	FD (%)	Mean	SE	Max
U	91	4.7E-02	4.5E-03	2.4E-01	88	3.4E-02	3.9E-03	1.5E-01
Zn	98	2.7E+02	8.0E+01	4.7E+03	92	1.3E+02	1.9E+01	5.4E+02

[a] A total of 88 weekly composites were analyzed during this interval
[b] A total of 59 weekly composites were analyzed during this interval
[c] FD = frequency of detection
[d] Mean = arithmetic mean
[e] SE = standard error
[f] Max = maximum
[g] NA = not applicable

Table 9. Results of Actinide Analyses for Quarterly FAS Composite Samples

Radionuclide	Activity Concentration (Bq m^{-3})			Activity Density (Bq g^{-1})		
	[a]C	[b]SE	[c]MDC	C	SD	MDC
Pre-Operational Baseline						
^{238}Pu	< MDC	[d]NA	2.4E-08	< MDC	NA	3.0E-04
$^{239, 240}$Pu	< MDC	NA	2.4E-08	< MDC	NA	2.9E-04
^{241}Am	< MDC	NA	5.5E-08	< MDC	NA	6.9E-04
^{228}Th	7.6E-07	5.2E-08	9.7E-08	8.1E-03	5.6E-04	1.2E-03
^{230}Th	7.0E-07	4.9E-08	6.8E-08	7.5E-03	5.3E-04	8.3E-04
^{232}Th	4.9E-07	3.7E-08	3.6E-08	5.2E-03	4.0E-04	4.3E-04
^{234}U	8.9E-07	4.9E-08	3.0E-08	9.5E-03	5.3E-04	3.8E-04
^{235}U	4.1E-08	1.5E-08	2.7E-08	4.4E-04	1.6E-04	3.2E-04
^{238}U	8.5E-07	4.9E-08	2.4E-08	9.1E-03	5.2E-04	3.0E-04
[d]Operational Monitoring April 1999 – June 2000						
^{238}Pu	<MDC	NA	1.1E-07	<MDC	NA	7.1E-04
$^{239, 240}$Pu	<MDC	NA	6.5E-08	<MDC	NA	2.3E-04
^{241}Am	<MDC	NA	5.4E-08	<MDC	NA	1.9E-04
^{228}Th	9.7E-07	1.8E-07	1.8E-07	7.3E-03	2.4E-03	1.1E-03
^{230}Th	5.9E-07	1.7E-07	1.4E-07	3.8E-03	1.0E-03	8.6E-04
^{232}Th	4.2E-07	1.0E-07	8.4E-08	3.0E-03	1.1E-03	5.3E-04
^{234}U	8.7E-07	1.9E-07	8.4E-08	5.8E-03	1.4E-03	6.0E-04
^{235}U	8.1E-08	5.1E-08	9.7E-08	3.6E-04	4.8E-05	6.1E-04
^{238}U	7.1E-07	1.7E-07	9.1E-08	4.6E-03	1.1E-03	6.9E-04
Operational Monitoring Third Quarter 2000						
^{238}Pu	<MDC	NA	8.6E-08	<MDC	NA	7.6E-04
$^{239, 240}$Pu	<MDC	NA	6.1E-08	<MDC	NA	5.4E-04
^{241}Am	<MDC	NA	7.0E-08	<MDC	NA	6.2E-04
^{228}Th	3.5E-07	5.9E-08	1.2E-07	3.1E-03	5.2E-04	1.1E-03
^{230}Th	2.3E-07	4.7E-08	1.0E-07	2.0E-03	4.2E-04	9.3E-04
^{232}Th	1.5E-07	3.1E-08	5.4E-08	1.4E-03	2.8E-04	4.8E-04
^{234}U	4.6E-07	5.0E-08	8.5E-08	4.0E-03	4.4E-04	7.5E-04
^{235}U	1.5E-07	3.6E-08	7.1E-08	1.4E-03	3.2E-04	6.3E-04
^{238}U	3.2E-07	4.3E-08	7.8E-08	2.9E-03	3.8E-04	6.9E-04
Operational Monitoring Fourth Quarter 2000						
^{238}Pu	<MDC	NA	1.4E-07	<MDC	NA	1.2E-03
$^{239, 240}$Pu	<MDC	NA	1.0E-07	<MDC	NA	8.4E-04
^{241}Am	<MDC	NA	7.1E-08	<MDC	NA	5.8E-04
^{228}Th	[e]NR	NR	NR	NR	NR	NR
^{230}Th	NR	NR	NR	NR	NR	NR
^{232}Th	NR	NR	NR	NR	NR	NR
^{234}U	NR	NR	NR	NR	NR	NR
^{235}U	NR	NR	NR	NR	NR	NR
^{238}U	NR	NR	NR	NR	NR	NR

Table continued on next page

Table 9. Results of Actinide Analyses for Quarterly FAS Composite Samples (Cont.)

Radionuclide	**Activity Concentration (Bq m^{-3})**			**Activity Density (Bq g^{-1})**		
	[a]C	**[b]SD**	**[c]MDC**	**C**	**SD**	**MDC**
Operational Monitoring First Quarter 2001						
^{238}Pu	<MDC	NA	1.2E-07	<MDC	NA	4.4E-04
$^{239, 240}$Pu	<MDC	NA	1.4E-07	<MDC	NA	4.9E-04
^{241}Pu	<MDC	NA	2.2E-05	<MDC	NA	7.9E-02
^{241}Am	<MDC	NA	8.4E-08	<MDC	NA	3.0E-04
^{228}Th	5.6E-07	7.9E-08	1.7E-07	2.0E-03	2.8E-04	5.9E-04
^{230}Th	5.5E-07	8.0E-08	1.6E-07	2.0E-03	2.9E-04	5.8E-04
^{232}Th	3.2E-07	5.0E-08	8.5E-08	1.1E-03	1.8E-04	3.1E-04
^{234}U	8.9E-07	9.3E-08	8.3E-08	3.2E-03	3.3E-04	3.0E-04
^{235}U	<MDC	NA	1.2E-07	<MDC	NA	4.3E-04
^{238}U	6.3E-07	8.1E-08	1.3E-07	2.2E-03	2.9E-04	4.7E-04
Operational Monitoring Second Quarter 2001						
^{238}Pu	<MDC	NA	1.0E-07	<MDC	NA	6.3E-04
$^{239, 240}$Pu	<MDC	NA	1.0E-07	<MDC	NA	6.2E-04
^{241}Pu	NR	NR	NR	NR	NR	NR
^{241}Am	<MDC	NA	8.0E-08	<MDC	NA	5.0E-04
^{228}Th	8.3E-07	8.5E-08	1.5E-07	5.1E-03	5.3E-04	9.2E-04
^{230}Th	8.5E-07	8.9E-08	1.3E-07	5.3E-03	5.5E-04	8.3E-04
^{232}Th	5.4E-07	6.2E-08	7.5E-08	3.3E-03	3.9E-04	4.7E-04
^{234}U	8.3E-07	7.1E-08	7.7E-08	5.2E-03	4.4E-04	4.8E-04
^{235}U	<MDC	NA	7.1E-08	<MDC	NA	4.4E-04
^{238}U	7.1E-07	6.5E-08	5.1E-08	4.4E-03	4.0E-04	3.1E-04

[a] C = concentration

[b] SE = standard error

[c] MDC = minimum detectable concentration

[d] NA = not applicable

[e] NR = data not reported ; analyses for U and Th isotopes were not reported for the fourth quarter of 2000 because of concern associated with digestate preservation; ^{241}Pu results were not reported for the second quarter of 2001 because of difficulties in preparing the alpha spectrometry source for liquid scintillation counting.

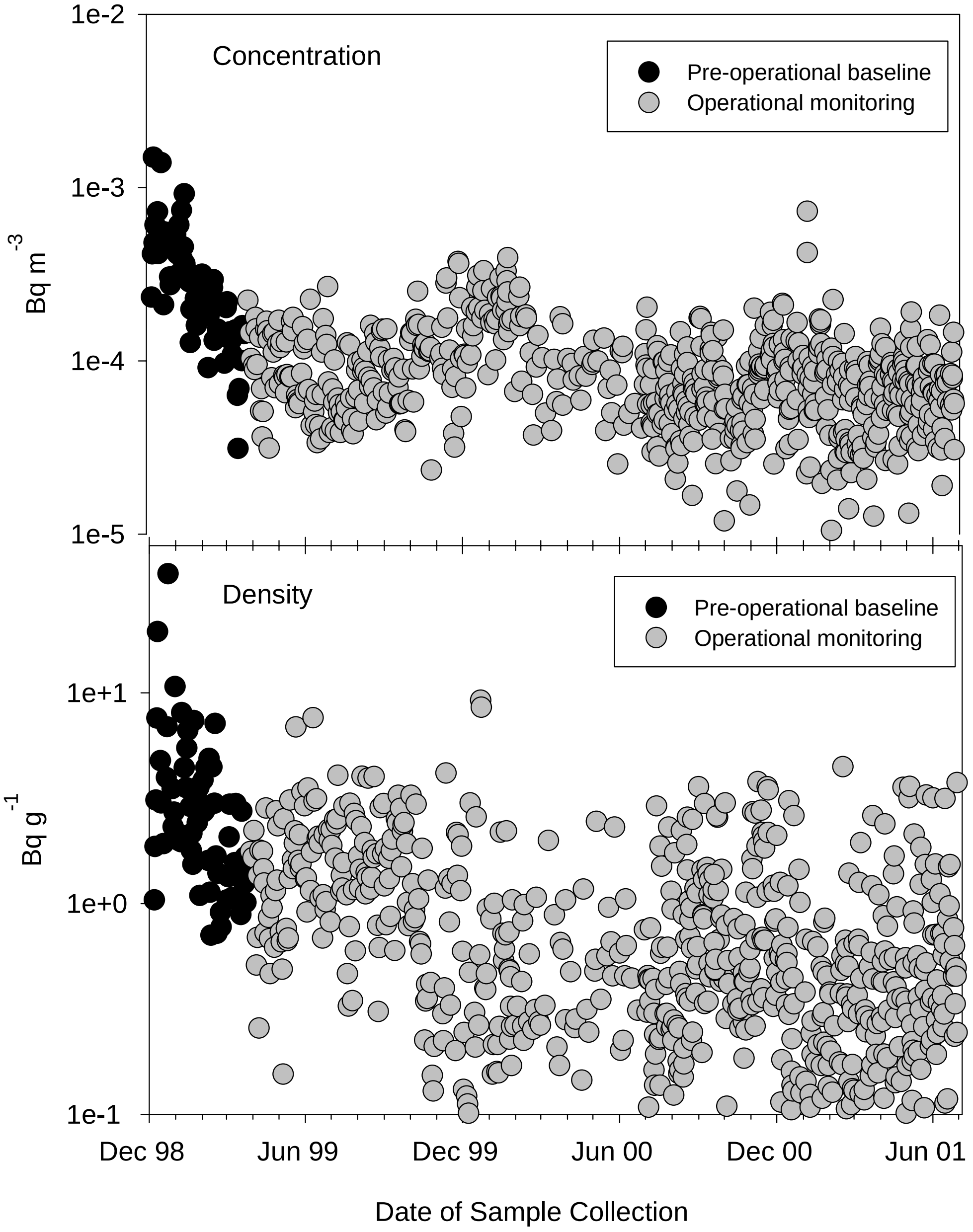


Figure 17. Alpha Emitting Radioactivity in FAS Samples Collected during December 1998 - July 2001

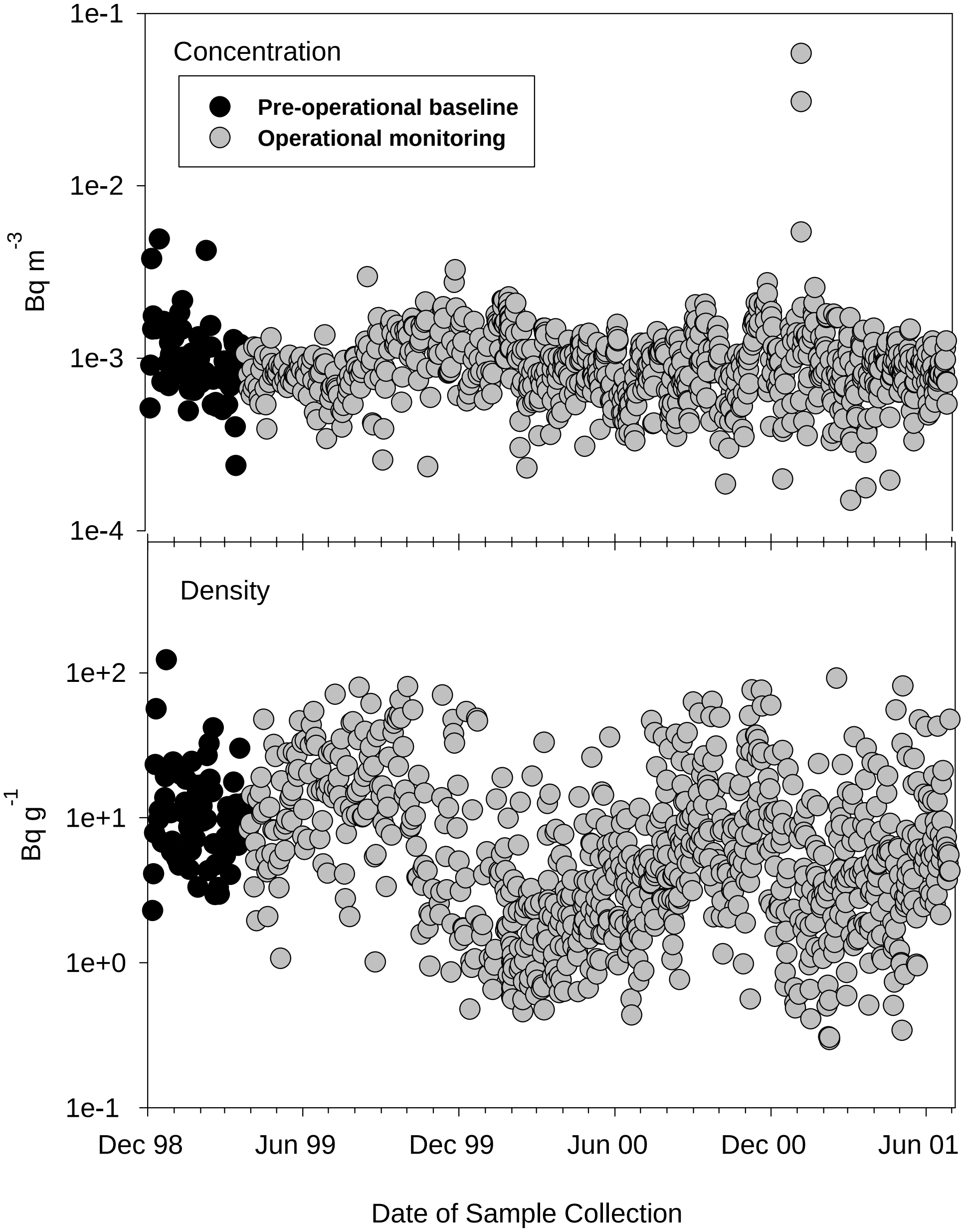


Figure 18. Beta Emitting Radioactivity in FAS Samples Collected during December 1998 - July 2001

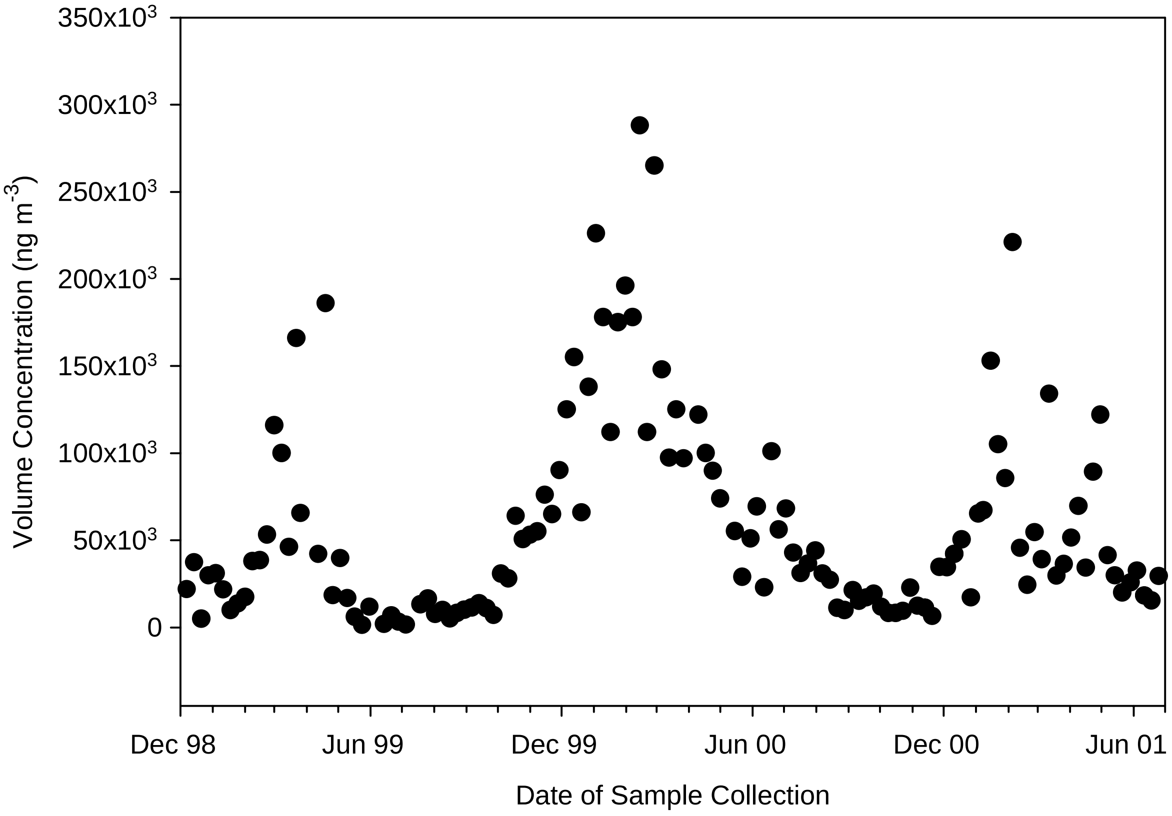


Figure 19. Sodium Released as Aerosols in the Exhaust from the WIPP

Surface Soil Radionuclides and Inorganic Chemicals

Introduction

Results reported herein are from soil samples collected during 2001 from a grid of 16 locations surrounding the WIPP site (the Near Field grid) and a grid of 16 locations approximately 12 miles southeast of the WIPP (the Cactus Flats grid, Fig. 2). The 2001 soil samples were collected after the arrival of the first mixed waste shipments at WIPP. Thus, the data for the radioactive and hazardous waste constituents are results from the monitoring phase. Measurements were made by CEMRC on the 2001 surface soil samples for ^{234}U, ^{235}U, ^{238}U, ^{230}Th, ^{232}Th, ^{228}Th, ^{239,240}Pu, ^{137}Cs, ^{208}Tl, ^{212}Pb, ^{212}Bi, ^{214}Pb, ^{228}Ac, ^{241}Am, and ^{40}K. The natural radionuclides ^{208}Tl, ^{212}Bi, ^{214}Pb and ^{212}Pb are measured after allowing for ingrowth to equilibrium and their concentrations do not represent natural levels in the environment. The activity of ^{214}Pb was used to estimate the original environmental concentration of ^{226}Ra. The activity of ^{208}Tl, ^{212}Bi and ^{212}Pb can be used to estimate activities of other members of the thorium series. Results are also presented for 43 non-radiological analytes measured using ICP-MS, AAS and IC.

One finding presented in the CEMRC 2000 Report was that there were significant differences in many analyte concentrations between the Near Field and Cactus Flats grids. In a subsequent publication differences in soil texture were identified as a likely cause for these observations (Kirchner et al., in press). The need for data on the vertical distribution of radionuclides in the soils was also identified in the CEMRC 2000 Report. In 2001 samples were taken from within the vertical soil profile to depths of 125 cm at four sampling locations.

Methods

The 16 sampling locations constituting each grid are distributed over approximately 16,580 hectares. In both 1998 and 1999 at each of the 32 locations (grid nodes), soil was collected from three randomly selected sites within a 50-m radius of the selected reference point. In 2000, one sample was collected at each of the 32 grid nodes. In 2001, two samples were collected at each of the 32 grid nodes. One of each pair of the 2001 samples was analyzed and the other was archived. Four additional field duplicates were collected at randomly selected reference points each year. Individual sampling sites were selected on the basis of relatively flat topography, minimum surface erosion and minimum surface disturbance by human or livestock activity. At each sampling site, approximately 20 g of soil were removed using a plastic trowel from near the center of each of two 25-cm x 25-cm areas and placed in a plastic bag for inorganic analyses. In addition, approximately 8 L of soil were collected from within the two sampling areas to a depth of approximately 2-cm for radionuclide analyses. Soil samples were excavated using a trowel and placed in plastic bags for transport and storage. Sampling equipment was cleaned between samples.

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

Gamma spectroscopy analysis was conducted using high purity Ge (HPGe) detector systems for 2-3 days. A set of soil matrix standards was prepared using NIST traceable solutions and used to establish matrix-specific calibration and counting efficiencies.

A 15-g and a 2-g aliquot of soil were used for actinide analyses. The 15-g aliquot of soil was used for the analysis of Am and Pu. The aliquots were heated in a muffle furnace at 500 °C to combust organic material and spiked with a radioactive tracer to allow determination of the efficiency of extraction.

The aliquots then underwent dissolution with HNO_3, HF and HCl followed by digestion with perchloric acid to remove silica. The samples were then dissolved in dilute HNO_3 and boric acid.

U and Th were determined by sequential analysis using the 2-g aliquot of soil. The aliquots were spiked with radioactive tracers and then underwent NaOH fusion. The fused sample was dissolved in HCl and treated with HF and perchloric acid to remove silica.

Multiple precipitation, co-precipitation and ion-exchange and/or extraction chromatography procedures were then used to separate and purify the desired elements from each of the aliquots. The elements of interest from each were then precipitated with NdF_3, deposited onto filters, mounted and counted on an alpha spectroscopy system. A summary of QA/QC for radioanalyses is presented in Appendix L.

Soil sample aliquots of 0.1 g were analyzed for the inorganic analytes using the soil collected from near the center of the sampling areas. These samples were neither sieved nor ground to prevent potential contamination by metals. EPA Method 3052 (microwave digestion) was used to prepare samples for both the AA and ICP-MS. ICP-MS was used to analyze samples for Ag, Al, Ba, Be, Ca, Cd, Ce, Co, Cr, Cu, Dy, Er, Eu, Fe, Gd, K, La, Li, Mg, Mn, Mo, Na, Ni, Pb, Pr, Sb, Si, Sm, Sr, Th, Ti, Tl, U, V and Zn using EPA Method 200.8. Hg was determined with flow injection hydride ICP-MS using EPA Method 1631 for digestion. As and Se were determined on the AA using the EPA 7000 series methods. The lower detection limits for both of these systems are in the low parts per billion range (Appendix K). Soil samples were analyzed by IC for chloride, fluoride, nitrate, phosphate and sulfate using EPA Method 300.0. A summary of QA/QC methods for inorganic analyses is presented in Appendix K. The mean concentrations of these analytes reported herein for soils include only those values that are above detection levels. Thus, some estimates of the mean may be biased toward larger values.

Reported concentrations are blank-corrected. Negative concentrations of analytes can result when both the sample and the blank have concentrations above the MDL, and are hence regarded as detectable quantities, with the blank concentration exceeding the sample concentration. Thus negative values are invariably small and represent values very near the blank concentrations.

Quality Control

Reproducibility of the measurements for the non-radiological analytes was determined from comparing five sets of laboratory duplicates. Relative Percent Differences (RPDs) were computed for all pairs for which the measurements were greater than the Minimum Detectable Concentration (MDC). The RPD is calculated as

$$RPD = 2\frac{|c_1 - c_2|}{c_1 + c_2} \times 100\%$$

where c_i is the concentration of the i^{th} duplicate. The RPD is the difference divided by the mean of two values expressed as a percent.

Reproducibility of the measurements of radionuclides was determined by comparing measurements from four sets of laboratory duplicates. Relative Error Ratios (RERs) were computed for all measurements for which concentrations were greater than the MDC. RER is computed as

$$RER = \frac{|c_1 - c_2|}{\sqrt{s_1^2 + s_2^2}}$$

where c_i is the concentration of the i^{th} duplicate and s_i is the estimated standard deviation of the i^{th} concentration. The standard deviation incorporates counting uncertainty and uncertainties associated with other aspects of the instrument measurements. Relative error ratios are used in addition to RDPs when comparing duplicate samples of radionuclides because they take into account counting and other uncertainties that are associated with activity measurements. RERs were computed for ^{228}Ac, ^{241}Am, ^{212}Bi, ^{214}Bi, ^{137}Cs, ^{40}K, ^{212}Pb, ^{214}Pb, ^{239}Pu, ^{228}Th, ^{230}Th, ^{232}Th, ^{208}Tl, ^{234}U, ^{235}U, and ^{238}U.

Results and Discussion

Reproducibility of Measurements

The average RPDs for the non-radiological analytes ranged from 5% to 27% with the exception of those analytes which had measurements below the Practical Quantitation Limit (PQL) of 5 × MDL (Table K3). The maximum RPD values ranged from 9% to 41%. The average RPD value is appropriate for estimating the reproducibility on the average of several samples, whereas the maximum RPD is a conservative estimate of the uncertainty in reproducibility that could be observed on any single measurement. The RPDs reflect the uncertainty in estimated concentrations due to variability in analysis and heterogeneity in the samples. Heterogeneity in the non-radiological samples was probably high because of the relatively small aliquots analyzed and because the samples were not ground. All of the duplicate comparisons were considered acceptable as defined under the Quality Assurance/Quality Control criteria defined for soils (Appendix K), meeting either a criteria of an RPD < 35% or sample measurements < 5 × MDL (the Practical Quantitative Limit).

The measurements of radionuclides in laboratory duplicates were generally in good agreement. RPDs ranged between 1% and 37%. RPDs hold meaning only when the RERs are relatively low, i.e. when the differences do not fall within the range of analytical uncertainty. The maximum RER was 2.19 for the radionuclides measured by gamma analysis (Table L5). The maximum RER for gamma analyses was incorrectly reported as 0.21 in the CEMRC 2000 Report. The correct maximum RER value for 2000 soil samples was 2.5. The RERs for the actinides measured by alpha spectroscopy ranged between 0.80 for ^{241}Am to 1.68 for ^{228}Th. These RERs are comparable to the RERs for soil radionuclide measurements reported in the DOE/WIPP Site Environmental Report (2001, *Waste Isolation Pilot Plant 2000 Site Environmental Report*, DOE/WIPP-01-2225, hereafter DOE/WIPP SER). The duplicate soil analyses reported in the DOE/WIPP SER were limited to ^{234}U, ^{238}U, ^{40}K and ^{137}Cs because ^{238}Pu, and ^{239,240}Pu were not detected in any soil samples, and the 2 measurements of ^{241}Am that were above detection levels were less than twice their total propagated uncertainty values and hence judged to be absent in the samples. The maximum RER reported in the DOE/WIPP SER was 2.42.

Comparison to Other Studies

The concentrations of the inorganic analytes (Figs. 20 and 21) and radionuclides (Figs. 22 and 23) are generally consistent between years. As was noted previously (CEMRC 2000 and Kirchner et al. In Press), there are notable differences between the mean concentrations of many of the analytes between the Near Field and Cactus Flats grids. The higher concentrations of many metals and radionuclides on the Cactus Flats grid as compared to the Near Field grid is probably due to a higher proportion of fine soil particles in the Cactus Flats samples (Tables 10 and 11).

The activity concentrations of ^{137}Cs, ^{234}U, ^{235}U, ^{238}U, and ^{40}K in CEMRC 2001 samples fell within the ranges reported in the DOE/WIPP SER (*op. cit.*). It should be noted, however, that the mean concentrations of ^{234}U, ^{235}U, and ^{238}U reported for 2001 are significantly higher ($p < 0.05$) than the mean values reported for 1998 and 2000 (Figs. 22 and 23). The 2001 mean values for the uranium isotopes showed an increase of 18% or more over the means from previous years. It was suspected that this increase resulted from the change in the sample preparation methodology for actinide analyses even though both methods were expected to result in complete dissolution of the samples. To evaluate this hypothesis 10 samples from 2000 were reanalyzed using the new methodology. Each of the new measurements exceeded the corresponding measurement made in 2000. The average RPDs between the 2000 and 2001 measurements for ^{234}U, ^{235}U and ^{238}U were 17%, 28% and 19%, respectively. Thus, the change in methodology does appear to be the cause of the increase.

The maximum ^{239,240}Pu concentration (0.40 mBq g^{-1}) was within the range reported by Kenney et al. (1995, *Radionuclide Baseline in Soil Near Project Gnome and the Waste*

Isolation Pilot Plant, EEG-58) at the WIPP (0-0.74 mBq g^{-1}) and was lower than background concentrations found at Hueston Woods and Urbana, Ohio (0.7-1.0 mBq g^{-1}) (Alberts et al., 1980, *J. Environ. Qual.* 9, 592) and at a series of 15 locations between Ft. Collins and Colorado Springs, Colorado (0.6-1.7 mBq g^{-1}) (Hodge et al., 1996, *Chemosphere* 32, 2067).

Tables presenting soil data summarized herein are available on the CEMRC web site at http://www.cemrc.org.

Table 10. Summary Statistics for Inorganic Analytes in Soil Samples Collected in 2001

Analyte		**Near Field**			**Cactus Flats**		
	Unit	**[a]N**	**[b]Mean**	**Range**	**N**	**Mean**	**Range**
Ag	mg kg^{-1}	21	8.8E-03	4.8E-03 - 1.2E-02	20	1.3E-02	7.0E-03 - 3.1E-02
Al	mg kg^{-1}	21	3.7E+03	2.3E+03 - 5.6E+03	19	3.7E+03	2.2E+03 - 6.9E+03
As	mg kg^{-1}	21	2.5E+00	1.8E+00 - 4.3E+00	20	3.2E+00	9.5E-01 - 5.6E+00
Ba	mg kg^{-1}	21	2.6E+01	1.6E+01 - 4.3E+01	19	3.0E+01	1.6E+01 - 5.9E+01
Be	mg kg^{-1}	21	1.5E-01	1.0E-01 - 2.1E-01	20	2.0E-01	1.1E-01 - 3.2E-01
Ca	mg kg^{-1}	21	7.0E+02	4.0E+02 - 2.3E+03	20	7.3E+02	4.0E+02 - 2.1E+03
Cd	mg kg^{-1}	20	3.9E-02	2.6E-02 - 6.0E-02	20	5.4E-02	2.4E-02 - 9.5E-02
Ce	mg kg^{-1}	21	7.7E+00	5.1E+00 - 1.2E+01	20	8.0E+00	4.9E+00 - 1.3E+01
Chloride	mg kg^{-1}	21	6.1E-01	8.4E-02 - 1.8E+00	20	6.9E-01	1.2E-01 - 5.2E+00
Co	mg kg^{-1}	21	9.1E-01	6.2E-01 - 1.2E+00	20	1.1E+00	6.9E-01 - 1.8E+00
Cr	mg kg^{-1}	21	4.9E+00	3.7E+00 - 6.3E+00	20	6.2E+00	3.9E+00 - 8.6E+00
Cu	mg kg^{-1}	21	2.0E+00	1.3E+00 - 2.7E+00	20	2.6E+00	1.7E+00 - 3.8E+00
Dy	mg kg^{-1}	21	3.0E-01	2.2E-01 - 4.1E-01	20	3.7E-01	2.4E-01 - 5.6E-01
Er	mg kg^{-1}	21	1.4E-01	1.0E-01 - 1.9E-01	20	1.8E-01	1.2E-01 - 2.8E-01
Eu	mg kg^{-1}	21	1.0E-01	6.9E-02 - 1.4E-01	20	1.2E-01	7.6E-02 - 1.7E-01
Fe	mg kg^{-1}	21	3.8E+03	2.7E+03 - 5.0E+03	19	4.3E+03	3.1E+03 - 6.1E+03
Fluoride	mg kg^{-1}	18	2.2E-01	3.0E-02 - 4.0E-01	14	4.4E-01	2.8E-01 - 6.1E-01
Gd	mg kg^{-1}	21	5.6E-01	3.9E-01 - 7.4E-01	20	6.8E-01	4.4E-01 - 9.9E-01
Hg	mg kg^{-1}	11	3.7E-03	2.3E-03 - 6.3E-03	20	5.0E-03	2.6E-03 - 1.3E-02
K	mg kg^{-1}	21	9.9E+02	7.1E+02 - 1.4E+03	20	1.1E+03	5.9E+02 - 2.0E+03
La	mg kg^{-1}	21	3.9E+00	2.8E+00 - 5.2E+00	20	4.5E+00	2.9E+00 - 6.7E+00
Li	mg kg^{-1}	21	3.1E+00	2.4E+00 - 4.2E+00	20	3.6E+00	2.2E+00 - 6.1E+00
Mg	mg kg^{-1}	21	5.8E+02	3.7E+02 - 8.9E+02	19	6.2E+02	3.8E+02 - 1.3E+03
Mn	mg kg^{-1}	21	4.9E+01	3.5E+01 - 6.4E+01	19	6.0E+01	4.1E+01 - 9.3E+01
Mo	mg kg^{-1}	21	1.1E-01	7.4E-02 - 1.7E-01	20	1.7E-01	1.0E-01 - 2.8E-01
Na	mg kg^{-1}	21	1.7E+01	1.1E+01 - 2.8E+01	20	1.7E+01	1.0E+01 - 3.8E+01
Ni	mg kg^{-1}	21	2.9E+00	2.0E+00 - 4.5E+00	20	1.1E+00	-3.7E+00 - 4.2E+00
Nitrate	mg kg^{-1}	12	8.8E+00	1.9E+00 - 4.1E+01	20	7.3E+00	2.5E+00 - 2.4E+01
Pb	mg kg^{-1}	21	2.9E+00	2.1E+00 - 4.2E+00	20	3.8E+00	2.7E+00 - 5.0E+00
Phosphate	mg kg^{-1}	2	4.6E+00	4.6E+00 - 4.6E+00	13	6.1E+00	3.0E+00 - 1.3E+01
Sb	mg kg^{-1}	21	7.4E-02	4.4E-02 - 1.4E-01	20	1.1E-01	5.8E-02 - 1.6E-01
Sc	mg kg^{-1}	21	7.1E-01	5.1E-01 - 9.9E-01	20	8.3E-01	5.0E-01 - 1.3E+00
Si	mg kg^{-1}	21	6.3E+02	9.0E+01 - 1.1E+03	20	1.9E+02	-9.2E+01 - 1.2E+03
Sm	mg kg^{-1}	21	6.1E-01	4.3E-01 - 8.3E-01	20	7.0E-01	4.7E-01 - 1.0E+00
Sr	mg kg^{-1}	21	4.5E+00	3.2E+00 - 6.5E+00	20	5.1E+00	3.3E+00 - 8.4E+00
Sulfate	mg kg^{-1}	2	2.8E+00	2.7E+00 - 2.9E+00	13	2.9E+00	1.6E+00 - 3.8E+00

Table continued on next page

Table 10. Summary Statistics for Inorganic Analytes in Soil Samples Collected in 2001 (Cont.)

Analyte		Near Field			Cactus Flats		
	Unit	[a]N	[b]Mean	Range	N	Mean	Range
Th	mg kg^{-1}	21	1.3E+00	8.3E-01 - 3.1E+00	20	1.4E+00	9.8E-01 - 2.1E+00
Ti	mg kg^{-1}	21	7.6E+01	3.5E+01 - 1.1E+02	19	6.3E+01	4.2E+01 - 1.1E+02
Tl	mg kg^{-1}	21	3.7E-02	2.3E-02 - 5.5E-02	20	5.1E-02	3.1E-02 - 7.8E-02
U	mg kg^{-1}	21	1.1E-01	7.4E-02 - 2.2E-01	20	1.2E-01	8.1E-02 - 1.8E-01
V	mg kg^{-1}	21	8.5E+00	3.9E+00 - 1.7E+01	20	6.2E+00	4.0E+00 - 1.6E+01
Zn	mg kg^{-1}	15	1.3E+01	1.1E+01 - 1.6E+01	20	1.4E+01	1.1E+01 - 2.1E+01

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

Table 11. Summary Statistics for Radionuclides in Soil Samples Collected in 2001

Analyte		Near Field			Cactus Flats		
	Unit	[a]N	[b]Mean	Range	N	Mean	Range
^{228}Ac	mBq g^{-1}	20	9.2E+00	6.3E+00 - 1.4E+01	20	1.1E+01	8.9E+00 - 1.6E+01
^{241}Am	mBq g^{-1}	18	4.4E-02	1.3E-02 - 1.0E-01	19	4.8E-02	3.0E-02 - 1.0E-01
^{212}Bi	mBq g^{-1}	20	8.9E+00	6.1E+00 - 1.4E+01	20	1.1E+01	7.8E+00 - 1.7E+01
^{214}Bi	mBq g^{-1}	20	8.3E+00	5.9E+00 - 1.2E+01	20	9.7E+00	7.6E+00 - 1.3E+01
^{137}Cs	mBq g^{-1}	20	4.0E+00	3.0E-01 - 8.8E+00	20	5.0E+00	2.6E+00 - 9.6E+00
^{40}K	mBq g^{-1}	20	2.2E+02	1.7E+02 - 3.2E+02	20	2.1E+02	1.7E+02 - 3.0E+02
^{212}Pb	mBq g^{-1}	20	8.6E+00	6.3E+00 - 1.3E+01	20	1.1E+01	8.1E+00 - 1.5E+01
^{214}Pb	mBq g^{-1}	20	8.8E+00	6.5E+00 - 1.3E+01	20	1.0E+01	8.2E+00 - 1.4E+01
^{239}Pu	mBq g^{-1}	17	1.4E-01	5.4E-02 - 3.1E-01	20	1.8E-01	8.8E-02 - 4.0E-01
[c] ^{226}Ra	mBq g^{-1}	20	8.8E+00	6.5E+00 - 1.3E+01	20	1.0E+01	8.2E+00 - 1.4E+01
^{228}Th	mBq g^{-1}	18	9.0E+00	6.8E+00 - 1.3E+01	20	1.1E+01	8.6E+00 - 1.6E+01
^{230}Th	mBq g^{-1}	18	1.0E+01	7.3E+00 - 1.4E+01	20	1.2E+01	9.2E+00 - 1.6E+01
^{232}Th	mBq g^{-1}	18	8.7E+00	6.4E+00 - 1.2E+01	20	1.1E+01	8.4E+00 - 1.5E+01
^{208}Tl	mBq g^{-1}	20	2.7E+00	1.9E+00 - 4.1E+00	20	3.3E+00	2.5E+00 - 4.8E+00
^{234}U	mBq g^{-1}	18	9.1E+00	6.5E+00 - 1.3E+01	20	1.0E+01	8.4E+00 - 1.3E+01
^{235}U	mBq g^{-1}	18	5.4E-01	3.3E-01 - 7.6E-01	20	6.3E-01	4.1E-01 - 8.6E-01
^{238}U	mBq g^{-1}	18	9.2E+00	6.8E+00 - 1.3E+01	20	1.1E+01	8.0E+00 - 1.3E+01

[a] N = number of samples > MDC
[b] Mean = arithmetic mean
[c] Based on ^{214}Pb at equilibrium

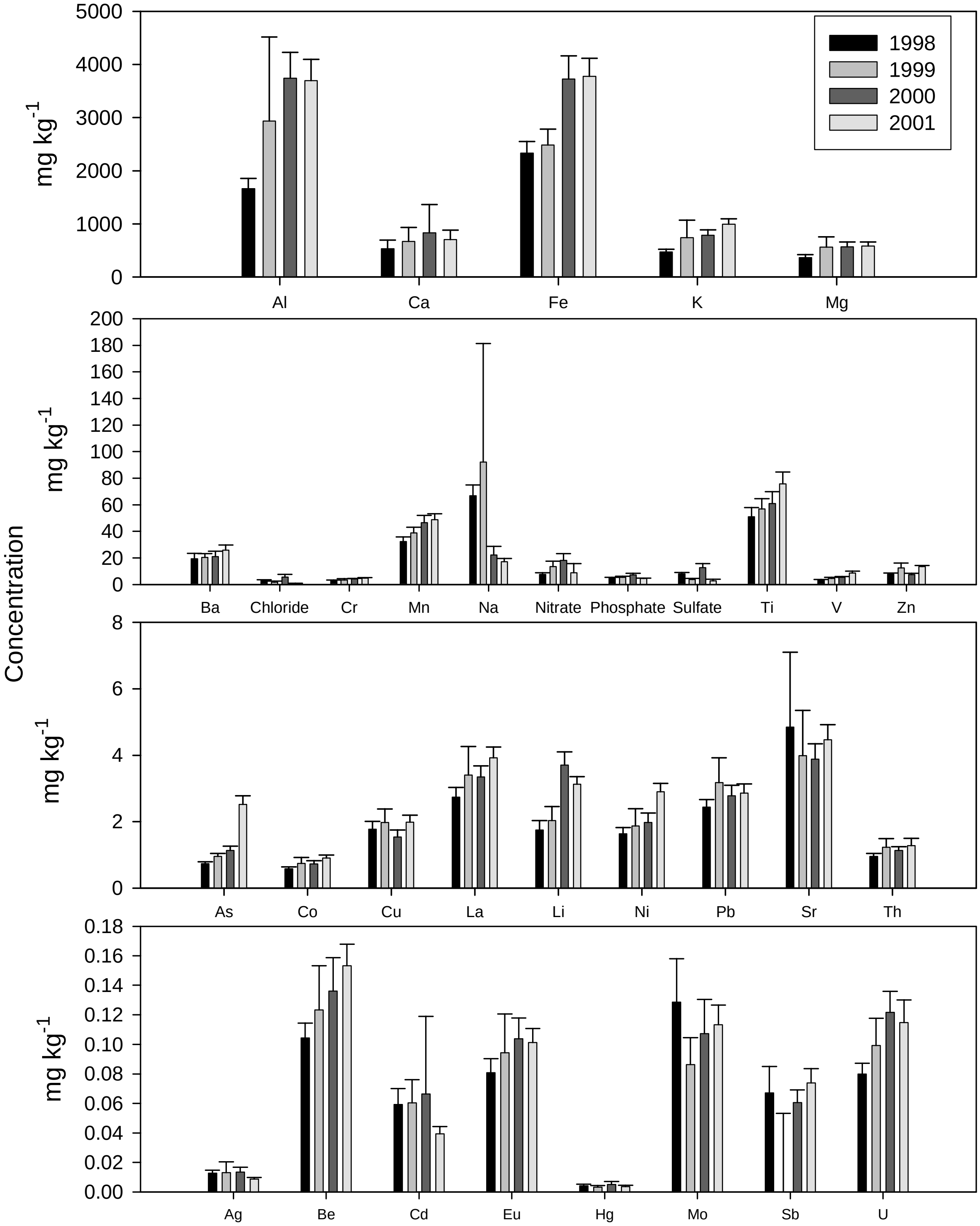


Figure 20. Mean Concentrations of Inorganic Analytes in Soil Samples from Near Field Grid Collected during 1998 – 2001

Error bars show upper 95% confidence intervals for concentrations.

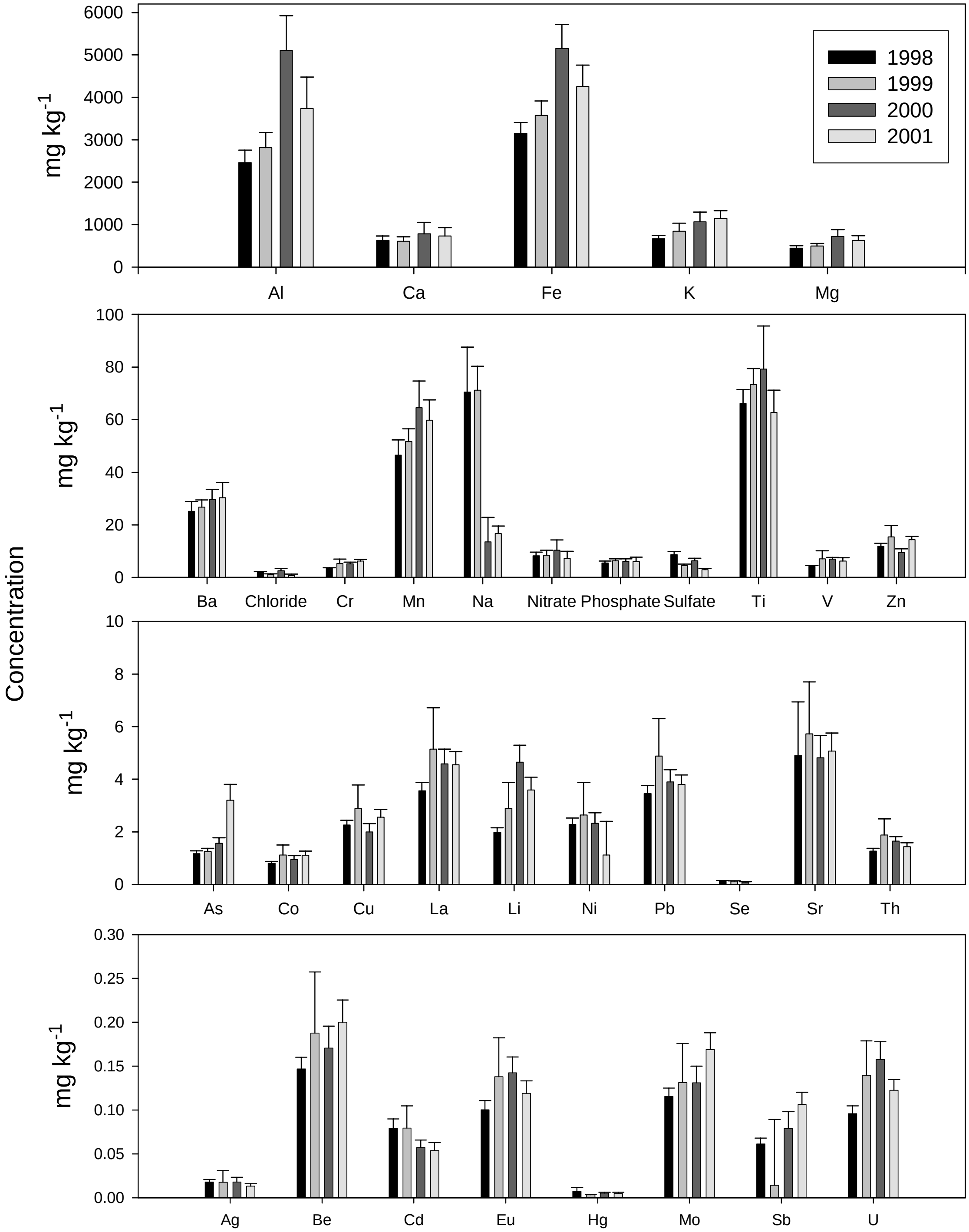


Figure 21. Mean Concentrations of Inorganic Analytes in Soil Samples from Cactus Flats Grid Collected during 1998 - 2001

Error bars show upper 95% confidence intervals for concentrations.

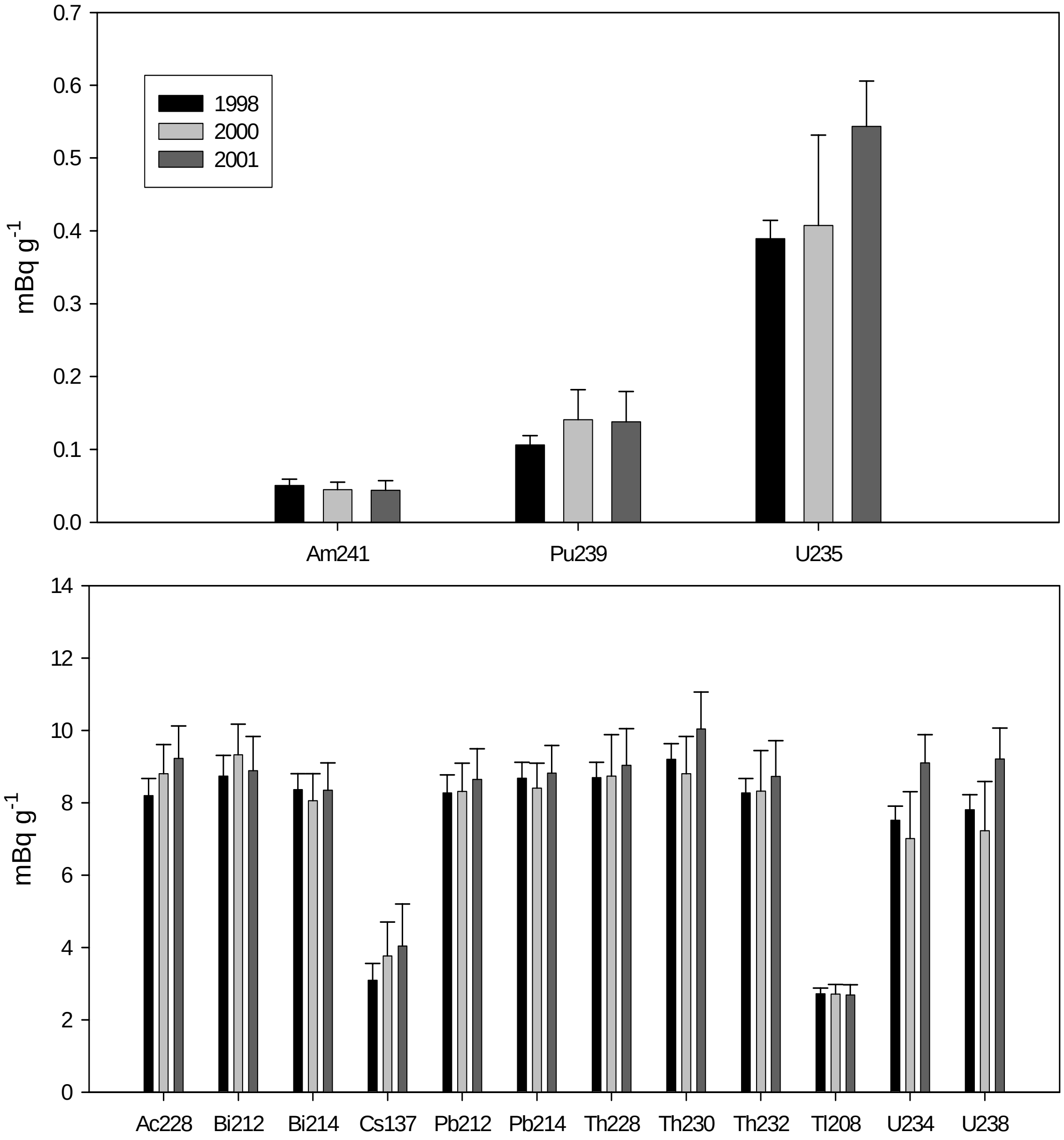


Figure 22. Mean Concentrations of Radionuclides in Soil Samples from Near Field Grid Collected during 1998 – 2001

Error bars show upper 95% confidence intervals for concentrations.

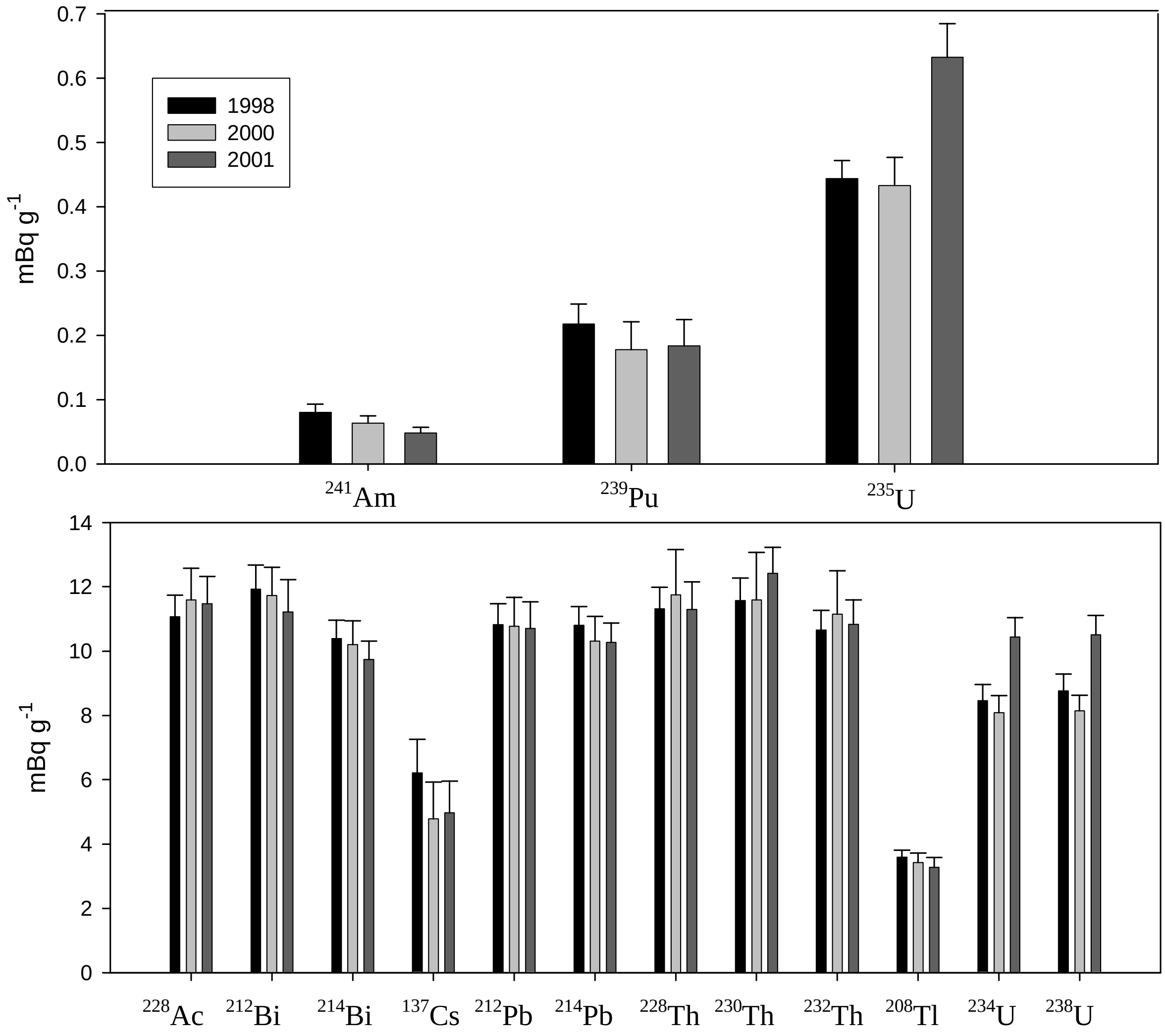


Figure 23. Mean Concentrations of Radionuclides in Soil Samples from Cactus Flats Grid Collected during 1998 – 2001

Error bars show upper 95% confidence intervals for concentrations.

Radionuclides and Inorganics in Surface Water and Sediments at Selected Reservoirs

Introduction

As part of the WIPP EM project, surface water and sediments are routinely sampled from three regional reservoirs situated on the Pecos River. Brantley Lake and Red Bluff Reservoir were selected for sampling because they are impoundments located "upstream" and "downstream", respectively, relative to surface and ground water flows from the area immediately surrounding the WIPP site (Figs. 24 and 25). Both reservoirs support a warm-water fishery and are used for irrigation, livestock watering, wildlife habitat and recreation. Lake Carlsbad is an impounded section of the Pecos River within the city of Carlsbad (Fig. 26) that is used extensively by the local population for recreational warm-water fishing, boating and swimming.

Analyses reported herein summarize the monitoring phase results for radiological and non-radiological elemental constituents in regional surface water and sediments (1999, 2000, and 2001). A summary of results from the first year of monitoring mixed wastes (2001) is contrasted with prior baseline data from 1999 and 2000.

Methods

Sediment and surface water samples were collected during May-June 2001 from previously selected sites within each reservoir. Four site locations at each lake were identified using sonar and a combination of triangulation to known shoreline locations and GPS coordinates established during the 1998 and 1999 sampling seasons. These locations fall within the deep basins of each reservoir (Figs. 24-26). Deep basins were chosen for sampling to minimize the disturbance and particle mixing effects of current and wave action that occur at shallower depths. Also, many of the analytes of interest tend to concentrate in the fine sediments that settle in the deep reservoir basins; thus, measurements from these areas would typically represent the highest levels that might be expected for a given reservoir.

Sediments were collected using an Eckman dredge. The thickness of the sediment collected ranged from 5 to 10 cm. Excess water was decanted from the sediment. Approximately 5 L of sediment was sealed in a pre-cleaned plastic bucket in the field and transported to CEMRC for preparation prior to analyses.

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

In the laboratory, sediment samples were air-dried, pulverized to pass a 2-mm sieve, homogenized and split into aliquots for radiochemical, and inorganic analyses. Samples destined for radiochemical analyses were dried at 105° for 24 hours and pulverized in a jar mill prior to analysis.

In the laboratory, surface water samples collected for radiological analyses were vacuum-filtered to 0.2 μm and acidified with HNO_3 to a pH < 2. A 3-L aliquot was removed for analysis of alpha and gamma-emitting radionuclides. Alpha-emitting radionuclides analyzed in surface water and sediment samples included ^{241}Am, ^{238}Pu, ^{239,240}Pu, ^{228}Th, ^{230}Th, ^{232}Th, ^{234}U, ^{235}U, and ^{238}U. Gamma-emitting radionuclides included ^{228}Ac, ^{241}Am, ^{7}Be, ^{212}Bi, ^{213}Bi, ^{214}Bi, ^{144}Ce, ^{249}Cf, ^{60}Co, ^{134}Cs, ^{137}Cs, ^{152}Eu, ^{154}Eu, ^{40}K, ^{233}Pa, ^{234m}Pa, ^{212}Pb, ^{214}Pb, ^{106}Rh, ^{125}Sb, and ^{208}Tl.

Surface water samples collected for elemental analyses (1-L each) were prepared according to the applicable EPA standard methods for the instrumentation used. Inorganic analyses were determined by IC, ICP-MS and AAS, with methods described elsewhere in this report. Minimum Detectable Concentrations (MDC) for 2001 surface water samples are elevated over MDCs reported in 1999 and 2000 for reasons described in the Quality Assurance Appendix of this report (Appendix K). Surface water aliquots and sediment sample digests 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. Inorganic analytes included Ag, Al, As, Ba, Be, Ca, Cd, Ce, Co, Cr, Cu, Dy, Er, Eu, Fe, Gd, Hg, K, La, Li, Mg, Mn, Mo, Na, Nd, Ni, Pb, Pr, Sb, Sc, Se, Sm, Sn, Sr, Th, Ti, Tl, U, V, Zn, chloride, fluoride, nitrate, phosphate and sulfate.

Results and Discussion

Comparison of Radionuclides in Baseline and Operational Phase Surface Water Samples

Activity concentrations measured for ^{241}Am, ^{238}Pu, and $^{239,\ 240}$Pu were below the respective MDCs for each analyte in all filtered surface water samples collected in 1999, 2000 and 2001 from all three reservoirs. MDC ranges for CEMRC analyses were 0.049-0.105 mBq L^{-1} for ^{241}Am, 0.047-0.239 mBq L^{-1} for ^{238}Pu, and 0.030-0.168 mBq L^{-1} for ^{239,240}Pu.

Maximum activity concentrations for ^{234}U, ^{235}U and ^{238}U (Table 12) increased slightly in the monitoring phase relative to the baseline phase for samples collected from all three reservoirs. The activity concentration ranges for these isotopes across lakes, by year, showed no significant difference between baseline and monitoring phases, considering the 95% confidence intervals of the radioanalytical uncertainty. The lower activity concentrations (minimum values) measured for the baseline data may be the result of random sampling error and possibly prolonged holding times for the baseline samples prior to analyses, during which adsorption of analytes to container walls may have occurred.

^{228}Th was detected in all surface water samples collected from 1998-2001. However, a positive bias is present in the reported ^{228}Th activity concentrations that results from the addition of a ^{232}U tracer during analyses. ^{232}Th was detected only in samples from Red Bluff Reservoir during the baseline phase and in samples from Brantley Lake and Red Bluff Reservoir during the monitoring phase.

For surface water samples collected during May and June of 2000, ^{40}K was the only gamma-emitting radionuclide determined at activity concentrations above MDC, and it was only detected in samples from Red Bluff Reservoir (1.22–1.26 Bq L^{-1}). These activities were only slightly above MDC activities, which ranged between 0.8 and 0.9 Bq L^{-1}. No ^{40}K was detected in any surface water samples collected by CEMRC during 2001.

Comparison of Radionuclides in Baseline and Operational Phase Sediment Samples

Analytes in sediment samples having activity concentrations < MDC in all samples included: ^{241}Am, ^{213}Bi, ^{144}Ce, ^{249}Cf, ^{60}Co, ^{134}Cs, ^{152}Eu, ^{154}Eu, ^{233}Pa, ^{106}Rh, and ^{125}Sb.

Comparison of minimum and maximum activity concentrations of gamma-emitting radionuclides determined for sediment samples collected during the baseline and monitoring phase (1998 to 2001) indicated no increase in any of the analytes with the possible exception of ^{7}Be (Table 13). ^{7}Be was not detected in Red Bluff Reservoir in 2001, but was detected in two samples from Lake Carlsbad and one sample from Brantley Lake. ^{7}Be activities were only slightly above the MDC in all samples. As mentioned earlier for the surface water samples in regards to the isotopes of U, the lower activity concentrations (minimum values) measured for the baseline data may be the result of random sampling error or possibly prolonged holding times for the baseline samples prior to analyses.

In most cases there were no significant differences between baseline and monitoring phases for ^{137}Cs (maximum 11.1 mBq/g) and ^{40}K (maximum 476 mBq/g) for a given lake. However, activity concentrations for both analytes were substantially lower in Lake Carlsbad relative to Brantley Lake and Red Bluff Reservoir. Activity concentrations of ^{137}Cs for samples collected from Brantley Lake in 2001 were significantly lower than in samples collected in the two sampling periods of 1998. Activities of ^{137}Cs and ^{40}K reported herein are consistent with activities reported by WTS for sediment samples collected from smaller catchments in closer proximity to the WIPP site. The maximum ^{137}Cs activity reported by WTS for sediment samples collected in 2000 was 18.6 mBq/g; the maximum ^{40}K activity reported by WTS was 1,029 mBq/g (WTS DOE/WIPP 01-2225 ESRF-045). No analyses of sediment samples for ^{137}Cs or ^{40}K have been reported by EEG.

^{239,240}Pu activities are highest in the sediment collected from Red Bluff Reservoir. Maxima range from 0.435 mBq/g observed in the baseline phase compared to 0.454 mBq/g in the monitoring phase. Maxima ^{239,240}Pu activities from Lake Carlsbad are lower ranging from 0.163 mBq/g in the baseline phase compared to 0.283 mBq/g in the monitoring phase. ^{239,240}Pu activities in samples from Brantley Lake are intermediate between Red Bluff Reservoir and Lake Carlsbad. ^{241}Am activities in sediment samples from the three reservoirs are lower than ^{239,240}Pu activities, but follow the same trend in maxima.

^{239,240}Pu activities were not detected by WTS in sediment samples collected in catchments surrounding the WIPP site in 2000. ^{241}Am activities were detected in two samples, but were less than the calculated total probability of uncertainty, and were considered non-detects (WTS DOE/WIPP 01-2225 ESRF-045).

Operational Comparison of Constituents in Surface Water and Sediments

Deposition of mixed waste (hazardous + radioactive) was initiated at the WIPP September 9, 2000. The data presented herein for inorganics represent a comparison of baseline characterization studies (1999 and 2000) to the first year of monitoring (2001).

To date, 24 surface water samples (eight from each reservoir) have been analyzed for a suite of inorganic compounds. The majority of analytes were detected in each of the samples collected from each sampling period with the exceptions of Ag, Be, Cd, Hg, Sn, Tl, nitrate, and phosphate (Table 14). Be was not detected in any samples during 2001. Be was detected in samples collected from Red Bluff Reservoir in 2000. No nitrates were detected in any of the lakes sampled. Hg was not detected in any of the surface water samples, although it was detected in previous years in Brantley Lake and Red Bluff Reservoir.

To date, 48 sediment samples (12 from each reservoir) have been analyzed for the same suite of inorganic constituents as surface water samples. Most of the analytes were detected in all of the sediment samples from the three reservoirs (Table 15) with the exceptions of fluoride, nitrate and phosphate. Analyses of fluoride failed because of interference of soluble organics extracted from the sediments. As was the case with surface water, neither nitrate nor phosphate was detected in any of the sediments.

Summary

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

Tables presenting the surface water and sediment data summarized herein are available on the CEMRC web site at http://www.cemrc.org.

Table 12. Range of Activity Concentrations for Uranium Isotopes in Surface Water Samples Collected from Three Regional Lakes during 1998 – 2001

The baseline sampling period is represented by two sampling events in 1998. The monitoring sampling period is represented by individual events in 1999, 2000, and 2001.

Analyte	Baseline [a]N	Baseline Minimum (Bq L^{-1})	Baseline Maximum (Bq L^{-1})	Monitoring N	Monitoring Minimum (Bq L^{-1})	Monitoring Maximum (Bq L^{-1})
Brantley Lake						
^{234}U	2	6.99E-02	7.54E-02	9	4.24E-04	1.68E-01
^{235}U	4	[b]<MDC	8.43E-02	18	<MDC	7.55E-02
^{238}U	2	3.80E-02	3.89E-02	9	3.59E-04	7.86E-02
Lake Carlsbad						
^{234}U	2	1.13E-01	1.16E-01	6	1.19E-01	1.88E-01
^{235}U	4	<MDC	2.74E-03	13	<MDC	5.15E-02
^{238}U	2	5.66E-02	5.71E-02	6	5.55E-02	9.10E-02
Red Bluff						
^{234}U	2	2.13E-01	2.14E-01	7	1.37E-01	2.50E-01
^{235}U	4	<MDC	5.78E-03	14	<MDC	1.20E-01
^{238}U	2	1.06E-01	1.06E-01	7	6.79E-02	1.23E-01

[a] N = number of samples

[b] <MDC = less than minimum detectable concentration

Table 13. Range of Activity Concentrations for Selected Radionuclides in Sediment Samples Collected from Three Regional Reservoirs during 1998 – 2001

The baseline sampling period is represented by two sampling events in 1998. The monitoring sampling period is represented by individual events in 1999, 2000, and 2001.

Radionuclide	Baseline [a]N	Baseline Minimum (Bq g^{-1})	Baseline Maximum (Bq g^{-1})	Baseline N	Monitoring Minimum (Bq g^{-1})	Monitoring Maximum (Bq g^{-1})
Brantley Lake						
^{228}Ac	8	3.21E-02	4.76E-02	17	2.73E-02	4.63E-02
^{241}Am	9	6.93E-05	1.00E-04	15	3.94E-05	1.26E-04
^{7}Be	0	[b]<MDC	<MDC	3	6.50E-03	1.54E-02
^{212}Bi	8	3.32E-02	4.97E-02	17	2.92E-02	5.01E-02
^{214}Bi	8	2.70E-02	4.20E-02	17	1.92E-02	2.86E-02
^{137}Cs	8	7.33E-03	9.00E-03	17	3.14E-03	9.00E-03
^{40}K	8	4.72E-01	6.21E-01	17	3.90E-01	6.96E-01
^{234m}Pa	3	4.20E-02	4.44E-02	3	4.09E-02	7.62E-02
^{212}Pb	8	3.19E-02	4.56E-02	17	2.84E-02	4.53E-02
^{214}Pb	8	2.82E-02	4.40E-02	17	2.04E-02	2.95E-02
^{239,240}Pu	9	2.06E-04	2.87E-04	15	9.00E-05	3.23E-04
^{208}Tl	8	1.01E-02	1.42E-02	17	8.77E-03	1.46E-02
^{234}U	9	4.34E-02	6.82E-02	15	3.41E-02	6.61E-02
^{235}U	9	2.20E-03	3.16E-03	16	1.63E-03	3.25E-03
^{238}U	9	3.64E-02	4.55E-02	15	3.17E-02	4.27E-02
Lake Carlsbad						
^{228}Ac	8	1.70E-02	2.76E-02	13	1.68E-02	2.51E-02
^{241}Am	8	3.17E-05	5.47E-05	13	2.74E-05	8.28E-05
^{7}Be	0	<MDC	<MDC	5	6.97E-03	2.46E-02
^{212}Bi	8	1.52E-02	2.92E-02	13	1.61E-02	2.86E-02
^{214}Bi	8	1.94E-02	2.87E-02	13	1.85E-02	2.76E-02
^{137}Cs	8	2.48E-03	5.19E-03	13	2.86E-03	5.00E-03
^{40}K	8	2.75E-01	4.51E-01	13	2.85E-01	4.29E-01
^{234m}Pa	2	2.68E-02	3.99E-02	1	5.29E-02	5.29E-02
^{212}Pb	8	1.63E-02	2.58E-02	13	1.59E-02	2.48E-02
^{214}Pb	8	1.93E-02	2.80E-02	13	1.93E-02	2.76E-02
^{239,240}Pu	8	8.97E-05	1.63E-04	13	8.94E-05	2.83E-04
^{208}Tl	8	5.04E-03	8.28E-03	13	4.80E-03	7.99E-03
^{234}U	8	3.51E-02	5.23E-02	13	3.99E-02	5.94E-02
^{235}U	8	1.40E-03	2.44E-03	14	1.54E-03	2.87E-03
^{238}U	8	2.56E-02	3.76E-02	13	2.84E-02	4.06E-02

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Table 13. Range of Activity Concentrations for Selected Radionuclides in Sediment Samples Collected from Three Regional Reservoirs during 1998 – 2001 (Cont.)

The baseline sampling period is represented by two sampling events in 1998. The monitoring sampling period is represented by individual events in 1999, 2000, and 2001.

Radionuclide	Baseline [a]N	Baseline Minimum (Bq g^{-1})	Baseline Maximum (Bq g^{-1})	Baseline N	Monitoring Minimum (Bq g^{-1})	Monitoring Maximum (Bq g^{-1})
Red Bluff						
^{228}Ac	8	2.33E-02	3.38E-02	18	1.94E-02	3.48E-02
^{241}Am	8	5.28E-05	1.81E-04	18	1.32E-05	1.54E-04
^{7}Be	0	<MDC	<MDC	1	1.01E-02	1.01E-02
^{212}Bi	8	2.54E-02	3.91E-02	18	1.78E-02	4.22E-02
^{214}Bi	8	2.48E-02	3.46E-02	18	1.95E-02	3.50E-02
^{137}Cs	8	4.88E-03	1.11E-02	18	9.66E-04	9.78E-03
^{40}K	8	4.08E-01	4.55E-01	18	4.05E-01	4.76E-01
^{234m}Pa	5	5.04E-02	1.00E-01	10	4.41E-02	7.21E-02
^{212}Pb	8	1.99E-02	3.50E-02	18	1.85E-02	3.38E-02
^{214}Pb	8	2.56E-02	3.59E-02	18	2.09E-02	3.55E-02
^{239,240}Pu	8	1.49E-04	4.35E-04	17	3.90E-05	4.54E-04
^{208}Tl	8	6.96E-03	1.07E-02	18	5.73E-03	1.12E-02
^{234}U	8	4.35E-02	1.02E-01	18	2.80E-02	1.06E-01
^{235}U	11	1.97E-03	4.44E-03	22	1.21E-03	4.86E-03
^{238}U	8	2.99E-02	6.15E-02	18	2.35E-02	6.27E-02

[a] N = number of samples > MDC

[b] <MDC = less than minimum detectable concentration

Table 14. Range of Concentrations for Baseline Inorganic Constituents in Surface Water Samples Collected during 1999 – 2001 from Three Regional Reservoirs

The baseline period is represented by two sampling events in 1999 and 2000. The monitoring period is represented by a single sampling event in 2001.

Analyte	Baseline [a]N	Baseline Minimum (µg L^{-1})	Baseline Maximum (µg L^{-1})	Monitoring N	Monitoring Minimum (µg L^{-1})	Monitoring maximum (µg L^{-1})
Brantley Lake						
Ag	4	[b]<MDC	1.03E-02	[c]ND	<MDC	<MDC
Al	6	4.25E+01	1.20E+03	2	1.15E+02	4.14E+02
As	6	1.13E+00	5.21E+00	ND	<MDC	<MDC
Ba	6	4.41E+01	7.45E+01	3	4.71E+01	6.36E+01
Be	5	1.78E-02	6.61E-02	ND	<MDC	<MDC
Ca	6	3.46E+05	6.95E+05	3	4.54E+05	5.15E+05
Cd	0	[d]NA	NA	1	1.51E-01	1.51E-01
Ce	6	8.07E-02	1.15E+00	3	9.73E-02	3.46E-01
Chloride	6	5.25E+05	2.20E+06	3	5.10E+05	1.26E+06
Co	6	1.81E+00	8.01E+00	3	9.72E-01	2.32E+00
Cr	6	3.17E-01	2.41E+00	ND	<MDC	<MDC
Cu	6	4.69E+00	8.07E+00	ND	<MDC	<MDC
Dy	6	5.79E-03	9.01E-02	2	2.88E-02	2.97E-02
Er	4	3.52E-03	4.66E-02	ND	<MDC	<MDC
Eu	6	1.55E-02	4.79E-02	1	3.16E-02	3.16E-02
Fe	6	5.30E+01	8.56E+02	3	2.75E+02	4.20E+02
Fluoride	5	1.54E+03	3.13E+03	3	5.30E+02	5.48E+02
Gd	6	7.34E-03	1.37E-01	ND	<MDC	<MDC
Hg	ND	<MDC	<MDC	1	1.77E-01	1.77E-01
K	6	6.61E+03	1.63E+04	3	4.59E+03	6.87E+03
La	6	<MDC	4.80E-01	ND	<MDC	<MDC
Li	6	3.89E+01	8.88E+01	3	4.21E+01	6.34E+01
Mg	6	9.31E+04	2.26E+05	3	9.23E+04	1.46E+05
Mn	5	8.98E+00	9.45E+02	3	1.80E+01	6.97E+02
Mo	6	2.41E+00	3.83E+00	3	2.98E+00	3.94E+00
Na	6	3.68E+05	1.21E+06	3	3.50E+05	7.34E+05
Nd	6	3.73E-02	5.69E-01	ND	<MDC	<MDC
Ni	6	3.65E+00	3.28E+01	3	1.59E+01	1.93E+01
Nitrate	ND	<MDC	<MDC	ND	<MDC	<MDC
Pb	4	2.88E-01	9.14E-01	1	7.04E-01	7.04E-01
Phosphate	ND	<MDC	<MDC	ND	<MDC	<MDC
Pr	4	1.08E-02	1.39E-01	ND	<MDC	<MDC
Sb	6	<MDC	3.01E-01	1	1.27E-01	1.27E-01

Table continued on next page

Table 14. Range of Concentrations for Baseline Inorganic Constituents in Surface Water Samples Collected during 1999 – 2001 from Three Regional Reservoirs (Cont.)

The baseline period is represented by two sampling events in 1999 and 2000. The monitoring period is represented by a single sampling event in 2001.

Analyte	Baseline [a]N	Baseline Minimum (μg L^{-1})	Baseline Maximum (μg L^{-1})	Monitoring N	Monitoring Minimum (μg L^{-1})	Monitoring maximum (μg L^{-1})
Sc	0	NA	NA	3	9.33E-01	1.56E+00
Se	ND	<MDC	<MDC	1	1.35E+00	1.35E+00
Sm	3	2.93E-02	1.69E-01	ND	<MDC	<MDC
Sn	0	NA	NA	ND	<MDC	<MDC
Sr	6	5.00E+03	1.15E+04	3	6.12E+03	7.55E+03
Sulfate	6	1.35E+06	2.61E+06	3	1.25E+06	1.45E+06
Th	6	2.58E-03	1.91E-01	ND	<MDC	<MDC
Ti	0	NA	NA	ND	<MDC	<MDC
Tl	1	4.81E-02	4.81E-02	ND	<MDC	<MDC
U	6	3.42E+00	8.46E+00	3	3.61E+00	4.28E+00
V	6	5.13E+00	7.33E+00	3	3.47E+00	5.31E+00
Zn	6	5.03E+00	1.71E+01	ND	<MDC	<MDC
Lake Carlsbad						
Ag	1	3.10E-03	3.10E-03	ND	<MDC	<MDC
Al	4	5.70E+01	2.15E+02	2	2.66E+02	5.03E+02
As	4	1.23E+00	2.37E+00	ND	<MDC	<MDC
Ba	4	1.86E+01	3.30E+01	2	2.76E+01	3.00E+01
Be	4	<MDC	3.15E-02	ND	<MDC	<MDC
Ca	4	3.03E+05	4.19E+05	2	3.29E+05	3.32E+05
Cd	1	9.00E-02	9.00E-02	ND	<MDC	<MDC
Ce	4	8.08E-02	4.16E-01	2	2.21E-01	4.87E-01
Chloride	4	6.31E+05	1.06E+06	2	6.31E+05	6.38E+05
Co	4	1.67E+00	5.22E+00	2	9.28E-01	1.00E+00
Cr	4	3.02E-01	2.19E+00	ND	<MDC	<MDC
Cu	4	3.88E+00	1.13E+01	ND	<MDC	<MDC
Dy	3	6.67E-03	3.51E-02	1	3.28E-02	3.28E-02
Er	4	1.17E-03	1.51E-02	ND	<MDC	<MDC
Eu	4	6.54E-03	1.81E-02	ND	<MDC	<MDC
Fe	4	7.60E+01	3.96E+03	2	4.07E+02	4.73E+02
Fluoride	4	9.53E+02	1.36E+03	2	5.48E+02	5.50E+02
Gd	4	9.10E-03	4.84E-02	ND	<MDC	<MDC
Hg	ND	<MDC	<MDC	1	2.82E-02	2.82E-02
K	4	5.26E+03	1.24E+04	2	5.51E+03	5.82E+03
La	4	<MDC	2.21E-01	ND	<MDC	<MDC

Table continued on next page

Table 14. Range of Concentrations for Baseline Inorganic Constituents in Surface Water Samples Collected during 1999 – 2001 from Three Regional Reservoirs (Cont.)

The baseline period is represented by two sampling events in 1999 and 2000. The monitoring period is represented by a single sampling event in 2001.

Analyte	Baseline ^{a}N	Baseline Minimum (µg L^{-1})	Baseline Maximum (µg L^{-1})	Monitoring N	Monitoring Minimum (µg L^{-1})	Monitoring maximum (µg L^{-1})
Li	4	4.33E+01	7.75E+01	2	5.01E+01	5.03E+01
Mg	4	1.09E+05	1.51E+05	2	1.10E+05	1.13E+05
Mn	3	1.92E+01	6.65E+01	2	2.64E+01	2.97E+01
Mo	4	2.65E+00	3.37E+00	2	3.46E+00	3.64E+00
Na	4	3.38E+05	5.06E+05	2	3.58E+05	3.67E+05
Nd	4	3.79E-02	2.31E-01	ND	<MDC	<MDC
Ni	4	2.33E+00	2.29E+01	2	1.28E+01	1.37E+01
Nitrate	4	3.16E+03	6.28E+03	ND	<MDC	<MDC
Pb	3	6.38E-01	2.65E+00	2	1.08E+00	2.42E+00
Phosphate	ND	<MDC	<MDC	ND	<MDC	<MDC
Pr	2	1.11E-02	5.66E-02	1	5.29E-02	5.29E-02
Sb	2	<MDC	<MDC	ND	<MDC	<MDC
Sc	0	NA	NA	2	4.42E+00	4.72E+00
Se	1	5.54E-01	5.54E-01	ND	<MDC	<MDC
Sm	2	1.51E-02	5.94E-02	ND	<MDC	<MDC
Sn	0	NA	NA	ND	<MDC	<MDC
Sr	4	4.16E+03	6.15E+03	2	4.36E+03	4.47E+03
Sulfate	4	1.15E+06	2.01E+06	2	1.02E+06	1.03E+06
Th	4	9.10E-03	5.40E-02	1	5.79E-02	5.79E-02
Ti	0	NA	NA	1	1.40E+01	1.40E+01
Tl	2	1.20E-01	1.36E-01	ND	<MDC	<MDC
U	4	3.78E+00	9.17E+00	2	4.40E+00	4.57E+00
V	4	6.13E+00	9.31E+00	2	8.10E+00	8.68E+00
Zn	4	5.93E+00	2.08E+01	ND	<MDC	<MDC
Red Bluff Reservoir						
Ag	2	7.34E-04	7.56E-04	ND	<MDC	<MDC
Al	3	1.65E+01	6.54E+01	2	1.78E+02	3.96E+02
As	4	1.96E+00	4.97E+00	ND	<MDC	<MDC
Ba	4	6.43E+01	9.58E+01	2	6.83E+01	7.23E+01
Be	4	1.83E-02	5.14E-02	ND	<MDC	<MDC
Ca	4	4.20E+05	6.18E+05	2	6.37E+05	6.64E+05
Cd	0	NA	NA	2	4.11E-01	1.04E+00
Ce	4	3.93E-02	9.78E-02	2	2.71E-01	5.71E-01
Chloride	4	1.52E+06	2.20E+06	2	2.31E+06	2.32E+06

Table continued on next page

Table 14. Range of Concentrations for Baseline Inorganic Constituents in Surface Water Samples Collected during 1999 – 2001 from Three Regional Reservoirs (Cont.)

The baseline period is represented by two sampling events in 1999 and 2000. The monitoring period is represented by a single sampling event in 2001.

Analyte	Baseline [a]N	Baseline Minimum (µg L^{-1})	Baseline Maximum (µg L^{-1})	Monitoring N	Monitoring Minimum (µg L^{-1})	Monitoring maximum (µg L^{-1})
Co	4	1.42E+00	6.01E+00	2	1.33E+00	2.05E+00
Cr	4	6.12E-02	2.24E+00	ND	<MDC	<MDC
Cu	4	6.73E+00	8.70E+00	ND	<MDC	<MDC
Dy	2	2.99E-03	3.50E-03	2	3.66E-02	4.24E-02
Er	3	2.08E-03	8.34E-03	ND	<MDC	<MDC
Eu	4	<MDC	3.43E-02	2	4.68E-02	6.86E-02
Fe	4	3.38E+01	8.24E+01	2	3.31E+02	3.75E+02
Fluoride	2	3.01E+03	3.77E+03	2	6.67E+02	6.70E+02
Gd	4	<MDC	1.51E-02	1	8.33E-02	8.33E-02
Hg	ND	<MDC	<MDC	ND	<MDC	<MDC
K	4	1.92E+04	3.63E+04	2	3.19E+04	3.34E+04
La	4	2.30E-02	6.00E-02	1	4.47E-01	4.47E-01
Li	3	6.77E+01	9.48E+01	2	1.16E+02	1.23E+02
Mg	4	1.24E+05	2.25E+05	2	2.47E+05	2.49E+05
Mn	4	3.85E+01	2.97E+02	2	9.20E+01	9.84E+01
Mo	4	3.00E+00	4.92E+00	2	5.69E+00	5.82E+00
Na	4	7.21E+05	1.36E+06	2	1.32E+06	1.34E+06
Nd	2	2.06E-02	3.12E-02	ND	<MDC	<MDC
Ni	4	1.35E+01	2.84E+01	2	2.21E+01	2.23E+01
Nitrate	1	2.38E+03	2.38E+03	ND	<MDC	<MDC
Pb	3	7.76E-01	1.28E+00	ND	<MDC	<MDC
Phosphate	1	5.68E+03	5.68E+03	ND	<MDC	<MDC
Pr	2	7.11E-03	8.10E-03	1	7.55E-02	7.55E-02
Sb	4	2.47E-01	4.83E-01	2	3.35E-01	3.39E-01
Sc	0	NA	NA	2	3.42E-01	5.93E-01
Se	ND	<MDC	<MDC	ND	<MDC	<MDC
Sm	2	3.11E-02	3.80E-02	ND	<MDC	<MDC
Sn	0	NA	NA	ND	<MDC	<MDC
Sr	4	5.76E+03	9.49E+03	2	9.71E+03	9.83E+03
Sulfate	4	1.77E+06	2.35E+06	2	2.04E+06	2.07E+06

Table continued on next page

Table 14. Range of Concentrations for Baseline Inorganic Constituents in Surface Water Samples Collected during 1999 – 2001 from Three Regional Reservoirs (Cont.)

The baseline period is represented by two sampling events in 1999 and 2000. The monitoring period is represented by a single sampling event in 2001.

Analyte	Baseline [a]N	Baseline Minimum (µg L^{-1})	Baseline Maximum (µg L^{-1})	Monitoring N	Monitoring Minimum (µg L^{-1})	Monitoring maximum (µg L^{-1})
Th	4	4.68E-03	1.72E-02	1	3.31E-02	3.31E-02
Ti	0	NA	NA	1	1.30E+01	1.30E+01
Tl	ND	<MDC	<MDC	ND	<MDC	<MDC
U	4	4.70E+00	9.51E+00	2	8.04E+00	8.17E+00
V	4	2.48E+00	4.91E+00	2	5.03E+00	5.27E+00
Zn	3	6.21E+00	1.09E+01	ND	<MDC	<MDC

[a] N = number of samples above minimum detectable concentration
[b] <MDC = less than minimum detectable concentration
[c] ND = no concentration > MDC detected
[d] NA = not analyzed for

Table 15. Range of Concentrations for Inorganic Constituents in Sediment Samples Collected during 1999 – 2001 from Three Regional Reservoirs

The baseline period is represented by two sampling events in 1999 and 2000. The monitoring period is represented by a single sampling event in 2001.

Analyte	Baseline [a]N	Baseline Minimum ($mg\ kg^{-1}$)	Baseline Maximum ($mg\ kg^{-1}$)	Monitoring N	Monitoring Minimum ($mg\ kg^{-1}$)	Monitoring Maximum ($mg\ kg^{-1}$)
Brantley Lake						
Ag	10	5.89E-02	8.52E+00	5	2.30E-02	7.74E-02
Al	10	1.89E+02	3.88E+04	5	6.37E+03	4.79E+04
As	10	-8.52E-02	5.76E+00	5	2.71E+00	9.73E+00
Ba	10	2.02E+00	2.70E+02	5	1.16E+02	3.70E+02
Be	10	4.62E-01	8.09E+01	5	3.06E-01	1.77E+00
Ca	10	1.06E+03	1.70E+05	5	4.83E+04	1.33E+05
Cd	10	2.52E-01	3.43E+01	5	1.43E-01	2.66E-01
Ce	10	2.55E+01	2.78E+03	5	1.64E+01	4.71E+01
Chloride	10	2.10E+03	1.18E+04	5	1.81E+03	2.61E+03
Co	10	7.60E+00	7.37E+02	5	4.21E+00	1.52E+01
Cr	10	1.66E+01	1.93E+03	5	8.85E+00	4.76E+01
Cu	10	1.29E+01	1.55E+03	5	4.44E+00	2.00E+01
Dy	10	1.32E+00	1.44E+02	5	9.37E-01	3.40E+00
Er	10	6.30E-01	6.66E+01	5	4.81E-01	1.70E+00
Eu	10	5.26E-01	6.28E+01	5	3.27E-01	1.35E+00
Fe	8	1.83E+04	2.56E+04	5	7.68E+03	3.64E+04
Gd	10	2.36E+00	2.66E+02	5	1.78E+00	6.83E+00
Hg	6	1.61E-02	2.47E-02	5	1.96E-02	2.63E-02
K	10	3.94E+01	8.71E+03	5	1.85E+03	1.19E+04
La	8	1.24E+01	1.96E+01	5	8.01E+00	2.00E+01
Li	10	1.79E+01	2.28E+03	5	6.79E+00	3.40E+01
Mg	10	1.44E+02	2.34E+04	5	5.06E+03	1.86E+04
Mn	10	4.73E+00	6.97E+02	5	2.26E+02	6.04E+02
Mo	10	9.50E-01	1.19E+02	5	3.23E-01	1.33E+00
Na	10	5.12E+01	5.29E+03	5	6.97E+02	2.68E+03
Nd	10	1.25E+01	1.45E+03	5	7.79E+00	2.38E+01
Ni	10	2.07E+01	2.26E+03	5	9.91E+00	3.20E+01
Nitrate	[b]ND	[c]<MDC	<MDC	ND	<MDC	<MDC
Pb	10	9.94E+00	1.06E+03	5	4.20E+00	2.00E+01
Phosphate	ND	<MDC	<MDC	ND	<MDC	<MDC
Pr	10	3.35E+00	3.75E+02	5	2.13E+00	6.16E+00
Sb	10	4.42E-02	1.05E+01	5	1.26E-01	3.29E-01
Se	10	-2.64E-01	7.64E+00	5	7.44E-01	2.31E+00

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Table 15. Range of Concentrations for Inorganic Constituents in Sediment Samples Collected during 1999 – 2001 from Three Regional Reservoirs (Cont.)

The baseline period is represented by two sampling events in 1999 and 2000. The monitoring period is represented by a single sampling event in 2001.

Analyte	Baseline [a]N	Baseline Minimum (mg kg^{-1})	Baseline Maximum (mg kg^{-1})	Monitoring N	Monitoring Minimum (mg kg^{-1})	Monitoring Maximum (mg kg^{-1})
Sm	10	2.56E+00	2.92E+02	5	1.55E+00	5.60E+00
Sn	10	1.01E+00	1.26E+02	5	3.87E-01	1.62E+00
Sr	10	4.96E+00	7.76E+02	5	1.45E+02	5.69E+02
Sulfate	10	5.70E+03	1.13E+04	5	1.11E+03	4.30E+03
Th	10	2.34E+00	3.00E+02	5	2.17E+00	7.62E+00
Ti	10	2.07E+00	3.90E+02	5	5.12E+01	3.74E+02
Tl	10	1.26E-01	1.42E+01	5	1.21E-01	5.28E-01
U	10	1.29E+00	1.37E+02	5	7.34E-01	2.52E+00
V	10	3.08E+01	3.26E+03	5	1.19E+01	5.77E+01
Zn	9	4.84E+01	4.85E+03	5	2.34E+01	7.61E+01
Lake Carlsbad						
Ag	8	5.83E-02	1.17E-01	4	5.71E-02	9.65E-02
Al	8	8.02E+03	1.95E+04	4	9.41E+03	1.40E+04
As	8	2.36E+00	1.11E+01	4	4.55E+00	6.25E+00
Ba	8	1.13E+02	1.77E+02	4	1.27E+02	1.89E+02
Be	8	3.28E-01	5.74E-01	4	4.79E-01	7.45E-01
Ca	8	1.24E+05	2.30E+05	4	1.69E+05	2.50E+05
Cd	8	3.09E-01	6.93E-01	4	3.34E-01	6.58E-01
Ce	8	1.30E+01	2.60E+01	4	2.20E+01	3.16E+01
Chloride	8	7.20E+02	1.07E+04	4	7.97E+02	1.15E+03
Co	8	3.00E+00	6.43E+00	4	3.22E+00	4.64E+00
Cr	8	9.62E+00	2.39E+01	4	1.06E+01	1.68E+01
Cu	8	9.72E+00	2.28E+01	4	8.89E+00	1.58E+01
Dy	8	8.07E-01	1.92E+00	4	1.76E+00	2.51E+00
Er	8	3.96E-01	9.74E-01	4	8.90E-01	1.28E+00
Eu	8	2.86E-01	7.66E-01	4	5.46E-01	7.91E-01
Fe	7	8.22E+03	1.57E+04	4	8.96E+03	1.24E+04
Gd	8	1.32E+00	3.96E+00	4	3.26E+00	4.56E+00
Hg	4	3.28E-02	6.02E-02	4	3.07E-02	4.80E-02
K	8	1.80E+03	4.70E+03	4	2.55E+03	3.77E+03
La	8	6.90E+00	1.33E+01	4	1.08E+01	1.48E+01
Li	8	8.05E+00	2.29E+01	4	1.08E+01	1.70E+01
Mg	8	1.13E+04	1.95E+04	4	9.94E+03	1.56E+04
Mn	8	2.62E+02	4.81E+02	4	2.77E+02	3.02E+02
Mo	8	4.43E-01	1.08E+00	4	4.86E-01	9.80E-01

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Table 15. Range of Concentrations for Inorganic Constituents in Sediment Samples Collected during 1999 – 2001 from Three Regional Reservoirs (Cont.)

The baseline period is represented by two sampling events in 1999 and 2000. The monitoring period is represented by a single sampling event in 2001.

Analyte	**Baseline [a]N**	**Baseline Minimum (mg kg^{-1})**	**Baseline Maximum (mg kg^{-1})**	**Monitoring N**	**Monitoring Minimum (mg kg^{-1})**	**Monitoring Maximum (mg kg^{-1})**
Na	8	1.07E+03	8.33E+03	4	9.61E+02	1.54E+03
Nd	8	6.86E+00	1.42E+01	4	1.12E+01	1.58E+01
Ni	8	1.15E+01	3.86E+01	4	1.46E+01	2.06E+01
Nitrate	2	2.07E+01	2.37E+01	0	<MDC	<MDC
Pb	8	9.53E+00	3.99E+01	4	1.49E+01	5.48E+01
Phosphate	ND	<MDC	<MDC	1	7.99E+00	7.99E+00
Pr	8	1.78E+00	3.82E+00	4	3.01E+00	4.19E+00
Sb	8	3.78E-02	2.34E-01	4	1.53E-01	3.09E-01
Se	8	1.72E+00	8.60E+00	4	2.04E+00	3.81E+00
Sm	8	1.41E+00	3.09E+00	4	2.66E+00	3.68E+00
Sn	8	1.05E+00	3.75E+00	4	9.01E-01	2.53E+00
Sr	8	3.83E+02	9.00E+02	4	5.65E+02	1.06E+03
Sulfate	8	3.95E+03	2.45E+04	4	3.50E+03	4.80E+03
Th	8	1.31E+00	4.70E+00	4	3.23E+00	4.29E+00
Ti	8	2.27E+02	4.20E+02	4	1.32E+02	3.37E+02
Tl	8	3.31E-01	1.35E+00	4	9.52E-01	1.23E+00
U	8	9.16E-01	2.99E+00	4	1.47E+00	2.45E+00
V	8	1.57E+01	3.23E+01	4	2.04E+01	2.76E+01
Zn	8	6.40E+01	1.28E+02	4	5.38E+01	9.88E+01
Red Bluff						
Ag	10	6.96E-02	1.11E+01	7	1.89E-02	7.52E-02
Al	10	1.20E+02	2.67E+04	7	5.60E+03	3.37E+04
As	10	-8.47E-02	5.54E+00	7	2.12E+00	8.22E+00
Ba	10	2.33E+00	3.46E+02	7	1.04E+02	3.77E+02
Be	10	4.12E-01	6.11E+01	7	2.69E-01	1.34E+00
Ca	10	1.03E+03	1.79E+05	7	3.42E+04	1.84E+05
Cd	10	3.80E-01	4.15E+01	7	1.12E-01	4.55E-01
Ce	10	2.67E+01	2.33E+03	7	1.56E+01	4.22E+01
Chloride	10	3.76E+02	1.80E+04	7	6.24E+02	6.13E+03
Co	10	7.68E+00	6.50E+02	7	3.03E+00	1.32E+01
Cr	10	1.06E+01	1.34E+03	7	7.48E+00	3.71E+01
Cu	10	1.36E+01	1.44E+03	7	3.12E+00	1.85E+01
Dy	10	2.31E+00	1.30E+02	7	1.01E+00	2.79E+00
Er	10	1.17E+00	6.38E+01	7	5.18E-01	1.39E+00
Eu	10	9.51E-01	5.13E+01	7	3.52E-01	1.08E+00

Table continued on next page

Table 15. Range of Concentrations for Inorganic Constituents in Sediment Samples Collected during 1999 – 2001 from Three Regional Reservoirs (Cont.)

The baseline period is represented by two sampling events in 1999 and 2000. The monitoring period is represented by a single sampling event in 2001.

Analyte	Baseline [a]N	Baseline Minimum (mg kg^{-1})	Baseline Maximum (mg kg^{-1})	Monitoring N	Monitoring Minimum (mg kg^{-1})	Monitoring Maximum (mg kg^{-1})
Fe	6	1.29E+04	1.94E+04	7	6.44E+03	3.03E+04
Gd	10	4.77E+00	2.27E+02	7	2.07E+00	5.16E+00
Hg	6	3.12E-02	3.54E-02	7	5.97E-03	4.66E-02
K	10	3.59E+01	7.95E+03	7	1.52E+03	8.09E+03
La	6	1.44E+01	1.65E+01	7	7.81E+00	1.85E+01
Li	10	1.12E+01	1.27E+03	7	6.78E+00	2.69E+01
Mg	10	1.01E+02	1.24E+04	7	4.18E+03	1.58E+04
Mn	10	4.65E+00	5.33E+02	7	1.83E+02	5.51E+02
Mo	10	2.12E+00	2.18E+02	7	2.46E-01	3.07E+00
Na	10	7.52E+01	4.34E+03	7	6.00E+02	4.20E+03
Nd	10	1.58E+01	1.24E+03	7	8.15E+00	2.17E+01
Ni	10	3.28E+01	2.22E+03	7	8.54E+00	2.85E+01
Nitrate	6	1.93E+00	1.25E+02	6	4.90E+00	2.38E+01
Pb	10	1.35E+01	1.04E+03	7	3.84E+00	1.76E+01
Phosphate	ND	<MDC	<MDC	ND	<MDC	<MDC
Pr	10	4.27E+00	3.15E+02	7	2.05E+00	5.60E+00
Sb	10	1.48E-01	1.25E+01	7	4.46E-02	2.68E-01
Se	10	-4.86E-01	7.50E+00	7	7.60E-01	3.31E+00
Sm	10	3.71E+00	2.47E+02	7	1.68E+00	4.78E+00
Sn	10	7.60E-01	9.84E+01	7	4.66E-01	1.31E+00
Sr	10	5.43E+00	7.34E+02	7	1.06E+02	8.32E+02
Sulfate	10	7.98E+02	1.29E+04	7	1.48E+03	7.24E+03
Th	10	5.50E+00	2.36E+02	7	2.31E+00	6.58E+00
Ti	10	2.91E+00	5.51E+02	7	3.50E+01	2.80E+02
Tl	10	1.91E-01	1.16E+01	7	7.68E-02	2.93E-01
U	10	3.06E+00	2.51E+02	7	7.12E-01	4.30E+00
V	10	2.63E+01	3.12E+03	7	1.12E+01	4.48E+01
Zn	9	4.15E+01	5.28E+03	7	1.63E+01	6.25E+01

[a] N = number of samples above minimum detectable concentration

[b] ND = no concentration > MDC detected

[c] <MDC = less than minimum detectable concentration

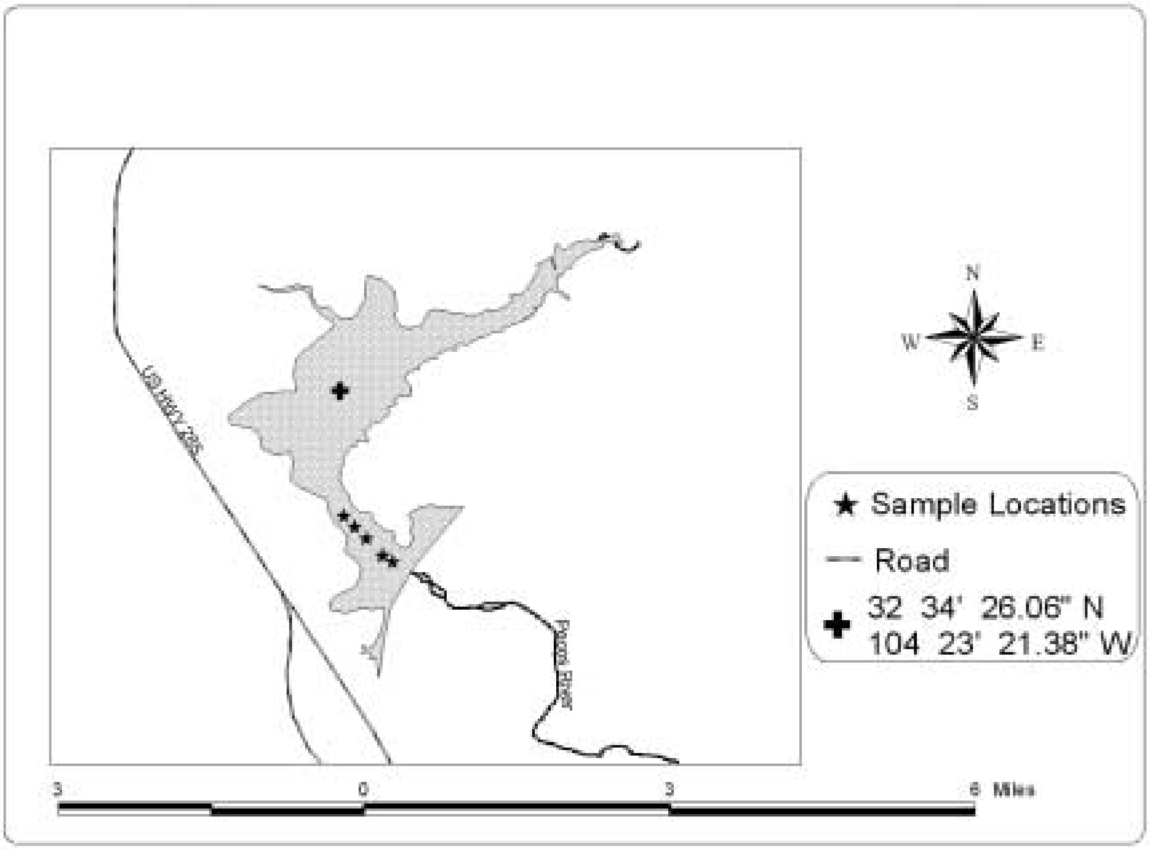

Figure 24. Surface Water and Sediment Sampling Locations at Brantley Lake

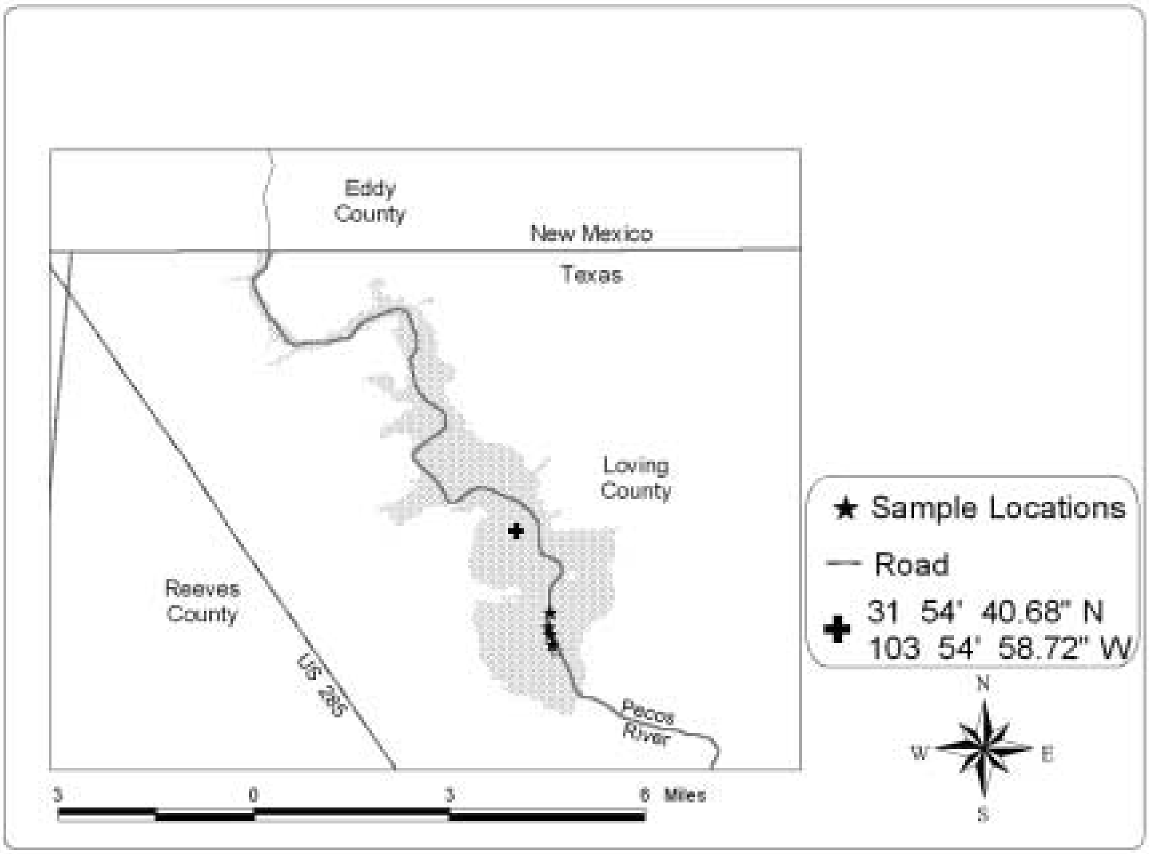

Figure 25. Surface Water and Sediment Sampling Locations at Red Bluff Reservoir

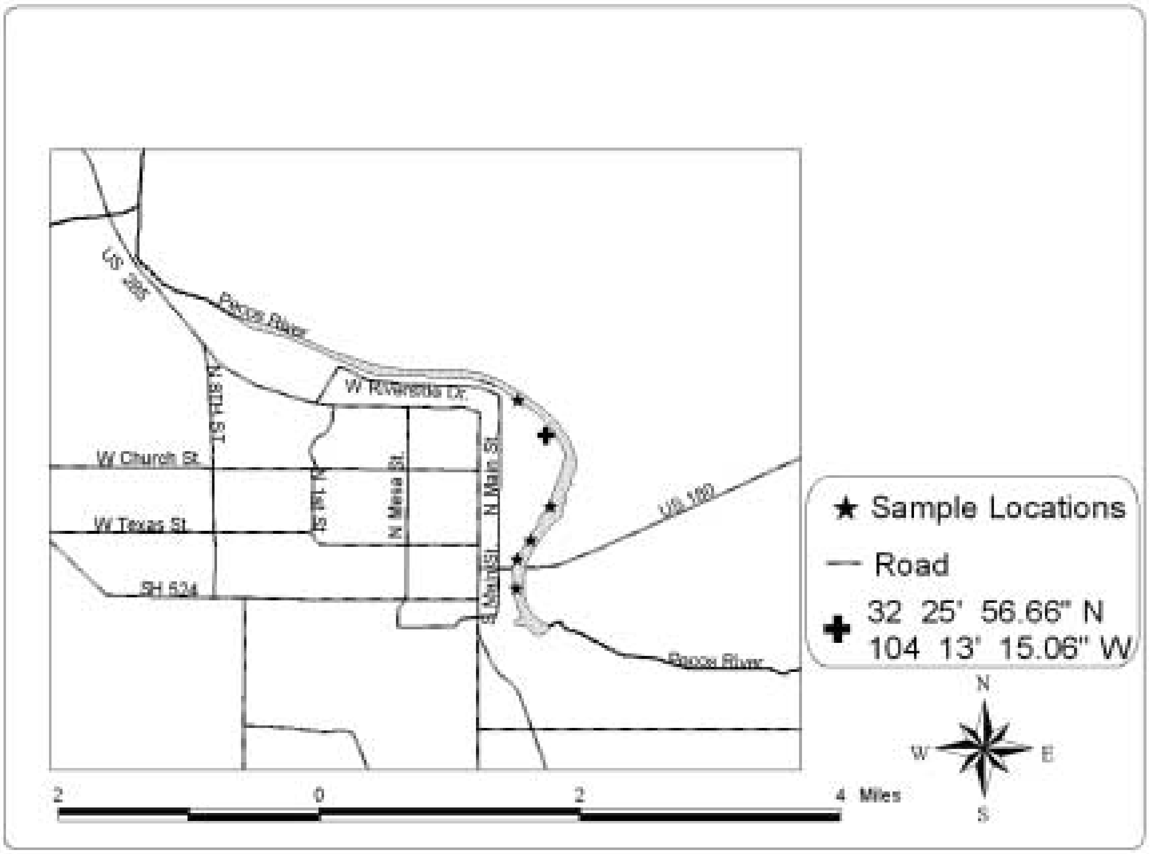

Figure 26. Surface Water and Sediment Sampling Locations at Lake Carlsbad

Radionuclides and Inorganics in Selected Drinking Water Sources

Introduction

The water wells in the immediate 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. In May and July 2001, water samples were collected for CEMRC environmental monitoring studies from five sources in the region of the WIPP. The sources included the community water supplies of Carlsbad, Loving, Otis, and Hobbs; and the water supply for the WIPP site (Double Eagle). In past years a sixth source, a private well (Private Well #2), was sampled; however, during the 2001 sampling period that well was dry, and thus no sample was obtained.

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 2001 drinking water samples were collected after WIPP began receiving both radioactive waste (March 1999) and mixed waste (September 2000). Therefore, this summary represents monitoring phase data for both radionuclides and non-radiological constituents in drinking water.

CEMRC began collecting drinking water samples in 1997, and summaries of methods, data and results from previous sampling were reported in the CEMRC 1997, 1998, 1999 and 2000 reports (available at http://www.cemrc.org). The results of previous analyses of drinking water were generally 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.

Methods

All 2001 samples were collected according to EPA protocols for the collection, handling and preservation of drinking water as follows: (1) 4 L for radiological analyses, (2) 1 L for elemental analyses and (3) 1 L for anion tests. 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 gamma spectroscopy analyses. The 2001 samples were collected at the same locations as the 2000 samples except for Private Well #2.

CEMRC performed non-radiological analyses of drinking water samples using IC, ICP-MS and AAS. Instrumentation, general methods and QA/QC results are presented in Appendix K. CEMRC did not test the 2001 drinking water samples for organic constituents because of low concentrations and consistent results in prior analyses performed by an external laboratory.

Radiological analyses were carried out at CEMRC by first counting the samples in Marinelli beakers using a coaxial, high purity Ge detector system to determine gamma-emitting radionuclide activity concentrations. 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. Radioanalytical QA/QC data are presented in Appendix L.

Results and Discussion

Radiological

The only radionuclides measured above MDC in 2001 samples as determined by gamma spectroscopy targeting 11 naturally occurring and 12 anthropogenic gamma-emitters, were ^{214}Bi and ^{214}Pb (in samples from Double Eagle, Hobbs, Loving and Otis). These two nuclides were produced through the decay of ^{222}Rn present in the water. The source of ^{222}Rn was decay of ^{226}Ra contained in materials (soils, sediments, etc.) with which the water had been in contact prior to sampling. Neither ^{214}Pb nor ^{214}Bi could be used to quantify the ^{222}Rn activity in the water since the Marinelli beakers used in the counting of the samples did not provide an adequate seal to prevent the loss of ^{222}Rn gas, thus preventing the establishment of secular equilibrium. In previous years a longer period of time had elapsed between sample collections and counting, which allowed these two radionuclides to decay below detection. Thus, the activities for these two radionuclides were not previously reported.

Three naturally occurring actinides (^{234}U, ^{235}U and^{238}U) were detected via alpha spectroscopy in all of the samples from each location. The uranium isotope activity concentrations in 2001 water samples were quite similar to the 2000, 1999 and 1998 samples, with the greatest variations appearing in ^{235}U measurements. Measured values for samples collected during 2001 were 31-162 mBq L^{-1} for ^{234}U, 0.95-3.3 mBq L^{-1} for ^{235}U, and 12-60 mBq L^{-1} for ^{238}U. The highest levels of all three uranium isotopes for each year studied were in samples from Otis (Fig. 27-29). Across all years, ^{234}U concentrations were 3.2-3.4 times greater than ^{238}U in samples from Loving, and 2.3-2.8 times greater in samples from the other four drinking water sources. Enrichment of ^{234}U compared to ^{238}U at these levels is common in drinking water produced from underground sources (Eisenbud, M. and T. Gesell, 1997, *Environmental Radioactivity*, Academic Press, San Diego).

For ^{235}U, the levels measured in 2001 were higher than in 1998, 1999 and 2000 (5 to 32% RPD) for samples from Carlsbad, Hobbs and Otis. A similar or lower level of ^{235}U (-0.8 to –7% RPD) was measured in the 2001 sample from Loving as compared to samples from 1998, 1999 and 2000. The ^{235}U level in the 2001 sample for Double Eagle is lower compared to samples from 1998, 1999 and 2000 (-13 to -39% RPD). For ^{234}U, the 2001 sample from Otis was higher than levels measured in 1998, 1999 and 2000 (8 to 23% RPD). For Double Eagle, Hobbs and Loving, the ^{234}U levels measured in 2001 samples were lower (-1 to -42% RPD) than in 1998, 1999 and 2000 samples. The ^{234}U activity in the 2001 sample from Carlsbad was higher compared to samples from 1999 and 2000 (6 to 7% RPD) but lower than in 1998 (-6% RPD). For ^{238}U, the 2001 samples from Double Eagle and Hobbs were lower (-14 to -31% RPD) than 1998, 1999 and 2000, while Otis was higher than in the previous three years (13 to 25% RPD). The value for Carlsbad was lower (-11% RPD) in 2001 compared to 1998, while the value for Loving was higher (3% RPD) compared to 1998.

The ranges and ratios of all three uranium isotopes measured in CEMRC samples during 1998-2001 were similar to values from 1992 samples from Carlsbad, Double Eagle and Loving reported by EEG (Kenney, J.W., 1994, *Preoperational Radiation Surveillance of the WIPP Project by EEG during 1992*, EEG-54). No comparable data for community drinking water sources have been generated in recent years by Westinghouse Waste Isolation Division (WID), the WIPP management and operating contractor.

The levels and ratios measured by CEMRC for these naturally occurring radionuclides are typical of natural variations in ground water (Cothern, C.R. and W.L. Lappenbusch, 1983, *Health Physics* 45, 89; Luo et al., 2000, *Geochim. Cosmochim*. 64, 867), and agree well with the few directly comparable values reported from studies in the region. Overall the CEMRC measurements are more consistent through time for each source than the cited annual measurements reported by WID. It is important to note that the quantification of ^{235}U by alpha spectroscopy may be impacted by tailing from the ^{234}U spectral region. As previously noted, values for samples collected in 1998 are believed to have been affected by storage of the samples for > 12 months prior to analyses. Despite acidification, such prolonged storage may have allowed U adsorption to the containers, producing a low bias in measured U.

Of the 15 uranium isotope measurements in 2001 samples, only 6 were higher than in 1998 samples (compared with 11 measurements in 2000 that were higher than the 1998 levels). Of these, five values (^{235}U for Carlsbad, Hobbs and Otis and ^{234}U and ^{238}U for Otis) were above 2 SD (counting error) of the matching 1998 value. Based on the comparisons as summarized, other relevant scientific information and results of analyses of other media reported herein, CEMRC concludes that the higher levels of some uranium isotopes in the 2001 drinking water samples from some sources represent a combination of natural variation and analytical artifact, and are not the result of releases from the WIPP.

Pu was not detected in any 2001 drinking water samples. Results of previous tests using thermal ionization mass spectrometry revealed no Pu in samples from the same six drinking water sources (reported in the CEMRC 1999 Report).

Non-Radiological Results

Measurements of inorganic analytes produced by CEMRC from the five drinking water sources showed little variation between years for each source. Differences of > 100% between the results for samples from 2001 and previous monitoring years have been recorded for Ca, Ce, Cu, La, Mg, Nd and fluoride at a single sampling location. For Co, Na, Sr, Zn and chloride, differences > 100% have been recorded in samples from two sources, while for Al, Fe and Mn, differences >100% were recorded in samples from three sources.

With the exception of these instances, the 1998-2001 measurements exhibit a high level of consistency that provides a useful characterization of each source (Table 16-18). In past years (1998-2000) samples from Otis exhibited higher levels of Sr, Na, Mg, K, Co, Cu and Ca compared to the other sampling sources (except for Private Well #2). This trend continued for 2001 with the exception of Cu. The level of Cu was higher in the sample from Carlsbad (6.9 $\mu g\ L^{-1}$) in 2001 compared to the other sites. Otis had the highest levels of Zn (16 $\mu g\ L^{-1}$) and total U (5.3 $\mu g\ L^{-1}$ measured by ICP-MS), while measured levels of Ba (14 $\mu g\ L^{-1}$) were lowest in this source. Total nitrates (not reduced to N) were highest in samples from Otis (9.6-22 mg L^{-1}) and Loving (17-23 mg L^{-1}) for all sampling years. Across all years, samples from Loving were highest in measured Pb levels (1.0-1.7 $\mu g\ L^{-1}$), while Hg was detected only in samples from Hobbs (0.011-0.014 $\mu g\ L^{-1}$). Measured As levels were highest in samples from Hobbs (4.9-7.45 $\mu g\ L^{-1}$) and Double Eagle (5.2-7.4 $\mu g\ L^{-1}$), and these measurements suggest that these drinking water sources would exceed any As standard $\leq 5\ \mu g\ L^{-1}$ as has been recently considered for adoption by EPA.

As in previous years, measured levels of chloride and sulfate exceeded reference levels (secondary maximum contaminant levels) in the 2001 samples from Otis.

These results are not appropriate for use in assessing regulatory compliance, due to sample collection locations and other methodological details. However, it is noteworthy that the CEMRC results for Carlsbad and Double Eagle drinking water collected during 1998-2001 generally agreed well with measurements published by the City of Carlsbad Municipal Water System (*2000 Annual Consumer Report on the Quality of Your Drinking Water*, *1999 Annual Consumer Report on the Quality of Tap Water; 1998 Annual Consumer Report on the Quality of Tap Water)* and with measurements published by the Otis Water User Co-Op (*Annual Water Quality Report*, 1999). As noted in the CEMRC 1999 Report, CEMRC values for nitrates are higher than those reported by Carlsbad and Loving, because the city-reported values are actually total N, rather than total nitrates. Based on these comparisons and the results of the analyses of the other media reported in this document, CEMRC concludes the higher levels of some inorganic analytes in the 2001 drinking water sources are not the result of releases from the WIPP.

It should be noted that concentrations for inorganic analytes reported in the CEMRC 2000 Report were not blank-corrected. The values reported in Table 16-18 in this document have been corrected for blank contributions, and therefore concentrations may not be directly comparable to those previously reported.

Table 16. Range of Concentrations of Selected Inorganic Analytes in Drinking Water Samples Collected from Carlsbad and Double Eagle during 1998-2001

Analyte	Unit	Carlsbad				Double Eagle			
		1998-2000			Concentration 2001	1998-2000			Concentration 2001
		[a]N	[b]Min	[c]Max		N	Min	Max	
Ag	$\mu g\ L^{-1}$	1	1.75E-02	1.75E-02	[d]NA	0	NA	NA	NA
Al	$\mu g\ L^{-1}$	2	2.34E+00	3.17E+01	3.68E+00	3	6.76E-01	7.22E+01	6.08E+00
As	$\mu g\ L^{-1}$	3	5.67E-01	6.82E-01	NA	3	5.21E+00	7.42E+00	5.60E+00
Ba	$\mu g\ L^{-1}$	3	6.83E+01	6.96E+01	6.64E+01	2	7.97E+01	8.96E+01	1.25E+02
Be	$\mu g\ L^{-1}$	0	NA	NA	NA	1	3.63E-02	3.63E-02	NA
Ca	$\mu g\ L^{-1}$	3	7.26E+04	7.98E+04	8.06E+04	3	5.08E+03	5.83E+04	5.11E+04
Cd	$\mu g\ L^{-1}$	0	NA	NA	NA	0	NA	NA	NA
Ce	$\mu g\ L^{-1}$	0	NA	NA	NA	0	NA	NA	3.63E-03
Co	$\mu g\ L^{-1}$	2	1.83E-01	3.41E-01	8.80E-02	2	9.31E-02	1.37E-01	NA
Cr	$\mu g\ L^{-1}$	2	2.68E+00	4.01E+00	3.81E+00	2	2.94E+00	3.20E+00	1.29E+00
Cu	$\mu g\ L^{-1}$	2	1.81E+00	4.29E+00	6.90E+00	2	1.19E+00	4.84E+00	2.54E+00
Dy	$\mu g\ L^{-1}$	0	NA	NA	NA	0	NA	NA	NA
Eu	$\mu g\ L^{-1}$	2	1.80E-02	2.42E-02	1.35E-02	2	1.88E-02	2.58E-02	2.70E-02
Fe	$\mu g\ L^{-1}$	1	2.07E+00	2.07E+00	NA	2	1.98E+00	7.93E+01	1.48E+02
Gd	$\mu g\ L^{-1}$	0	NA	NA	NA	0	NA	NA	NA
Hg	$\mu g\ L^{-1}$	0	NA	NA	NA	0	NA	NA	NA
K	$\mu g\ L^{-1}$	3	1.27E+03	2.91E+03	3.56E+03	3	2.66E+03	2.94E+04	2.62E+03
La	$\mu g\ L^{-1}$	2	1.35E-02	4.42E-02	NA	2	1.59E-02	6.26E-02	1.19E-02
Li	$\mu g\ L^{-1}$	2	7.25E+00	7.87E+00	7.41E+00	3	1.81E+01	1.90E+01	1.37E+01
Mg	$\mu g\ L^{-1}$	2	3.14E+04	3.40E+04	3.43E+04	2	1.09E+03	1.07E+04	9.21E+03
Mn	$\mu g\ L^{-1}$	3	5.50E-02	3.37E-01	9.40E-01	2	2.30E-01	3.52E-01	8.73E-01
Mo	$\mu g\ L^{-1}$	3	7.03E-01	1.20E+00	8.93E-01	2	1.42E+00	1.66E+00	1.48E+00
Na	$\mu g\ L^{-1}$	3	1.97E+04	9.94E+04	4.55E+04	3	3.84E+03	3.25E+04	2.35E+04
Nd	$\mu g\ L^{-1}$	0	NA	NA	NA	0	NA	NA	NA
Ni	$\mu g\ L^{-1}$	2	2.13E+00	2.84E+00	1.46E+00	2	1.44E+00	1.72E+00	1.66E+00
Pb	$\mu g\ L^{-1}$	2	3.76E-01	1.44E+00	6.32E-01	2	3.16E-01	1.38E+00	6.92E-01
Pr	$\mu g\ L^{-1}$	0	NA	NA	NA	0	NA	NA	NA
Sb	$\mu g\ L^{-1}$	1	1.99E-01	1.99E-01	NA	3	2.41E-02	1.39E-01	NA
Sc	$\mu g\ L^{-1}$	1	1.82E+00	1.82E+00	1.57E+00	1	5.27E+00	5.27E+00	4.61E+00
Se	$\mu g\ L^{-1}$	0	NA	NA	NA	0	NA	NA	3.41E+00
Sm	$\mu g\ L^{-1}$	2	2.34E-02	2.57E-02	3.39E-02	2	2.83E-02	3.70E-02	3.31E-02
Sn	$\mu g\ L^{-1}$	0	NA	NA	5.97E-02	1	3.36E-01	3.36E-01	NA
Sr	$\mu g\ L^{-1}$	3	3.53E+02	4.59E+02	3.59E+02	3	5.06E+01	5.28E+02	5.53E+02

Table continued on next page

Table 16. Range of Concentrations of Selected Inorganic Analytes in Drinking Water Samples Collected from Carlsbad and Double Eagle during 1998-2001 (Cont.)

Analyte	Unit	Carlsbad				Double Eagle			
		1998-2000			Concentration 2001	1998-2000			Concentration 2001
		[a]N	[b]Min	[c]Max		N	Min	Max	
Th	µg L^{-1}	1	1.76E-02	1.76E-02	NA	1	2.07E-03	2.07E-03	NA
Ti	µg L^{-1}	0	NA	NA	1.60E+00	0	NA	NA	2.87E+00
Tl	µg L^{-1}	2	1.11E-01	1.20E-01	1.54E-01	0	NA	NA	NA
U	µg L^{-1}	2	8.21E-01	8.42E-01	8.43E-01	2	1.75E+00	1.77E+00	1.48E+00
V	µg L^{-1}	3	3.82E+00	4.69E+00	4.59E+00	2	2.65E+01	2.70E+01	2.80E+01
Zn	µg L^{-1}	3	4.52E+00	1.52E+01	7.11E+00	2	1.46E+00	5.19E+00	1.25E+01
Chloride	µg L^{-1}	3	1.53E+04	1.88E+05	6.65E+04	3	2.58E+04	3.69E+04	2.43E+04
Fluoride	µg L^{-1}	3	2.18E+02	7.81E+02	5.36E+02	3	5.01E+02	9.71E+02	7.86E+02
Nitrate	µg L^{-1}	3	3.52E+03	5.91E+03	4.06E+03	3	1.07E+04	1.36E+04	1.20E+04
Sulfate	µg L^{-1}	3	8.07E+04	1.17E+05	9.96E+04	3	4.12E+04	5.69E+04	4.09E+04

[a]N = number of samples > MDL (1998-2000)
[b]Min = minimum measured concentration in annual samples from 1998-2000
[c]Max = maximum measured concentration in annual samples from 1998-2000
[d]NA = all samples below MDL for analyte

Table 17. Range of Concentrations of Selected Inorganic Analytes in Drinking Water Samples Collected from Hobbs and Loving during 1998-2001

Analyte	Unit	Hobbs				Loving			
		1998-2000			Concentration 2001	1998-2000			Concentration 2001
		[a]N	[b]Min	[c]Max		N	Min	Max	
Ag	$\mu g\ L^{-1}$	1	3.86E-03	3.86E-03	[d]NA	2	2.55E-03	3.28E-03	NA
Al	$\mu g\ L^{-1}$	3	3.03E+00	1.14E+02	8.62E+00	2	1.30E+00	1.56E+00	3.76E+00
As	$\mu g\ L^{-1}$	3	5.71E+00	7.37E+00	4.91E+00	3	1.48E+00	1.85E+00	1.67E+00
Ba	$\mu g\ L^{-1}$	3	5.65E+01	5.99E+01	5.98E+01	3	2.90E+01	3.03E+01	3.01E+01
Be	$\mu g\ L^{-1}$	1	5.39E-02	5.39E-02	NA	1	9.35E-02	9.35E-02	NA
Ca	$\mu g\ L^{-1}$	3	7.99E+03	9.06E+04	7.79E+04	3	9.04E+03	1.04E+05	9.02E+04
Cd	$\mu g\ L^{-1}$	1	4.34E-03	4.34E-03	NA	0	NA	NA	NA
Ce	$\mu g\ L^{-1}$	3	5.87E-03	2.23E-02	5.10E-03	1	9.74E-04	9.74E-04	NA
Co	$\mu g\ L^{-1}$	3	2.01E-01	3.61E-01	9.78E-02	3	1.48E-01	2.48E-01	1.02E-01
Cr	$\mu g\ L^{-1}$	3	2.28E+00	3.10E+00	1.18E+00	3	2.51E+00	4.28E+00	1.91E+00
Cu	$\mu g\ L^{-1}$	3	1.87E+00	2.70E+00	1.06E+00	3	2.35E+00	5.59E+00	2.11E+00
Dy	$\mu g\ L^{-1}$	0	NA	NA	4.18E-03	0	NA	NA	NA
Eu	$\mu g\ L^{-1}$	3	1.37E-02	1.97E-02	1.31E-02	3	7.00E-03	1.01E-02	7.92E-03
Fe	$\mu g\ L^{-1}$	3	2.10E+00	6.70E+01	1.74E+02	0	NA	NA	2.24E+02
Gd	$\mu g\ L^{-1}$	0	NA	NA	NA	1	2.15E-03	2.15E-03	NA
Hg	$\mu g\ L^{-1}$	2	1.06E-02	1.42E-02	NA	0	NA	NA	NA
K	$\mu g\ L^{-1}$	3	2.44E+03	2.52E+04	2.59E+03	2	1.95E+03	2.45E+03	2.13E+03
La	$\mu g\ L^{-1}$	3	1.45E-02	5.01E-02	NA	3	6.66E-03	2.22E-02	NA
Li	$\mu g\ L^{-1}$	3	2.92E+01	3.18E+01	2.65E+01	3	1.85E+01	1.96E+01	1.72E+01
Mg	$\mu g\ L^{-1}$	2	2.11E+03	2.00E+04	1.92E+04	2	4.04E+03	3.83E+04	3.88E+04
Mn	$\mu g\ L^{-1}$	3	3.79E-01	6.69E-01	6.73E-01	3	1.43E-02	8.59E-02	6.24E-02
Mo	$\mu g\ L^{-1}$	3	2.46E+00	2.72E+00	3.07E+00	3	1.28E+00	1.57E+00	1.58E+00
Na	$\mu g\ L^{-1}$	3	4.97E+03	4.75E+04	4.24E+04	3	2.33E+03	2.11E+04	1.96E+04
Nd	$\mu g\ L^{-1}$	3	3.01E-03	1.28E-02	NA	1	3.37E-03	3.37E-03	NA
Ni	$\mu g\ L^{-1}$	3	2.22E+00	2.64E+00	1.67E+00	3	2.71E+00	3.38E+00	2.03E+00
Pb	$\mu g\ L^{-1}$	3	9.82E-02	1.70E-01	9.44E-02	3	1.03E+00	1.67E+00	1.01E+00
Pr	$\mu g\ L^{-1}$	1	1.57E-03	1.57E-03	NA	0	NA	NA	NA
Sb	$\mu g\ L^{-1}$	2	3.88E-02	7.02E-02	6.15E-02	2	6.78E-02	1.84E-01	NA
Sc	$\mu g\ L^{-1}$	1	8.58E+00	8.58E+00	7.17E+00	1	3.22E+00	3.22E+00	3.40E+00
Se	$\mu g\ L^{-1}$	0	NA	NA	3.50E+00	0	NA	NA	NA
Sm	$\mu g\ L^{-1}$	3	2.20E-02	3.02E-02	1.93E-02	3	8.43E-03	1.30E-02	NA
Sn	$\mu g\ L^{-1}$	0	NA	NA	NA	1	4.45E-01	4.45E-01	NA
Sr	$\mu g\ L^{-1}$	3	7.89E+01	9.23E+02	8.86E+02	3	7.60E+01	8.32E+02	8.55E+02

Table continued on next page

Table 17. Range of Concentrations of Selected Inorganic Analytes in Drinking Water Samples Collected from Hobbs and Loving during 1998-2001 (Cont.)

Analyte	Unit	Hobbs				Loving			
		1998-2000			Concentration 2001	1998-2000			Concentration 2001
		[a]N	[b]Min	[c]Max		N	Min	Max	
Th	µg L^{-1}	2	2.29E-03	4.56E-03	NA	2	5.69E-03	7.38E-03	NA
Ti	µg L^{-1}	0	NA	NA	4.64E+00	0	NA	NA	2.68E+00
Tl	µg L^{-1}	0	NA	NA	2.24E-02	0	NA	NA	4.32E-02
U	µg L^{-1}	3	2.90E+00	3.39E+00	3.23E+00	3	1.98E+00	2.11E+00	2.26E+00
V	µg L^{-1}	4	3.24E+01	3.56E+01	3.63E+01	3	1.22E+01	1.27E+01	1.20E+01
Zn	µg L^{-1}	3	8.44E-01	4.37E+00	2.06E+00	3	4.79E+00	9.03E+00	9.01E+00
Chloride	µg L^{-1}	3	6.32E+04	9.36E+04	7.40E+04	3	1.59E+04	2.94E+04	2.50E+04
Fluoride	µg L^{-1}	3	6.19E+02	1.33E+03	1.15E+03	3	2.45E+02	6.45E+02	6.10E+02
Nitrate	µg L^{-1}	3	1.70E+04	2.01E+04	1.58E+04	3	1.72E+04	2.32E+04	1.66E+04
Sulfate	µg L^{-1}	3	1.04E+05	1.42E+05	9.60E+04	3	1.45E+05	2.05E+05	1.56E+05

[a] N = number of samples > MDL (1998-2000)
[b] Min = minimum measured concentration in annual samples from 1998-2000
[c] Max = maximum measured concentration in annual samples from 1998-2000
[d] NA = all samples below MDL for analyte

Table 18. Range of Concentrations of Selected Inorganic Analytes in Drinking Water Samples Collected Otis during 1998-2001

Analyte	Unit	Otis			
		1998-2000			Concentration 2001
		[a]N	[b]Min	[c]Max	
Ag	μg L^{-1}	1	2.63E-02	2.63E-02	[d]NA
Al	μg L^{-1}	1	1.42E+00	1.42E+00	NA
As	μg L^{-1}	3	1.30E+00	1.56E+00	NA
Ba	μg L^{-1}	3	1.39E+01	1.70E+01	1.38E+01
Be	μg L^{-1}	0	NA	NA	NA
Ca	μg L^{-1}	3	2.14E+05	3.17E+05	3.83E+05
Cd	μg L^{-1}	0	NA	NA	NA
Ce	μg L^{-1}	0	NA	NA	NA
Co	μg L^{-1}	2	3.92E-01	6.82E-01	3.21E-01
Cr	μg L^{-1}	3	1.11E+00	4.08E+00	1.41E+00
Cu	μg L^{-1}	2	5.51E+00	6.02E+00	3.42E+00
Dy	μg L^{-1}	0	NA	NA	3.39E-03
Eu	μg L^{-1}	1	3.42E-03	3.42E-03	4.73E-03
Fe	μg L^{-1}	3	2.87E+00	2.99E+01	8.53E+02
Gd	μg L^{-1}	0	NA	NA	NA
Hg	μg L^{-1}	0	NA	NA	NA
K	μg L^{-1}	3	2.74E+03	3.93E+03	4.01E+03
La	μg L^{-1}	1	3.36E-03	3.36E-03	NA
Li	μg L^{-1}	2	4.70E+01	4.85E+01	4.51E+01
Mg	μg L^{-1}	2	7.95E+04	8.83E+04	1.08E+05
Mn	μg L^{-1}	2	2.00E-01	2.53E-01	1.78E-01
Mo	μg L^{-1}	2	2.25E+00	2.75E+00	2.49E+00
Na	μg L^{-1}	3	7.83E+04	1.14E+05	1.62E+05
Nd	μg L^{-1}	1	4.80E-03	4.80E-03	3.97E-02
Ni	μg L^{-1}	2	7.17E+00	1.06E+01	6.23E+00
Pb	μg L^{-1}	2	1.08E-01	1.91E-01	1.19E-01
Pr	μg L^{-1}	0	NA	NA	NA
Sb	μg L^{-1}	2	5.03E-02	4.10E-01	NA
Sc	μg L^{-1}	1	3.53E+00	3.53E+00	4.68E+00
Se	μg L^{-1}	0	NA	NA	NA
Sm	μg L^{-1}	1	3.56E-03	3.56E-03	NA
Sn	μg L^{-1}	0	NA	NA	NA
Sr	μg L^{-1}	3	2.38E+03	2.86E+03	3.61E+03

Table continued on next page

Table 18. Range of Concentrations of Selected Inorganic Analytes in Drinking Water Samples Collected from Otis during 1998-2001 (Cont.)

Analyte	**Unit**	**Otis**			
		1998-2000			**Concentration 2001**
		[a]N	**[b]Min**	**[c]Max**	
Th	µg L^{-1}	2	1.19E-03	2.67E-02	NA
Ti	µg L^{-1}	0	NA	NA	5.68E+00
Tl	µg L^{-1}	0	NA	NA	NA
U	µg L^{-1}	2	3.95E+00	4.20E+00	5.34E+00
V	µg L^{-1}	3	1.10E+01	1.17E+01	1.14E+01
Zn	µg L^{-1}	3	4.39E+00	1.16E+01	1.64E+01
Chloride	µg L^{-1}	3	1.36E+05	3.86E+05	4.21E+05
Fluoride	µg L^{-1}	3	1.29E+02	5.52E+02	7.53E+02
Nitrate	µg L^{-1}	3	9.59E+03	2.20E+04	1.90E+04
Sulfate	µg L^{-1}	3	3.27E+05	7.55E+05	7.56E+05

[a] N = number of samples > MDL (1998-2000)
[b] Min = minimum measured concentration in annual samples from 1998-2000
[c] Max = maximum measured concentration in annual samples from 1998-2000
[d] NA = all samples below MDL for analyte

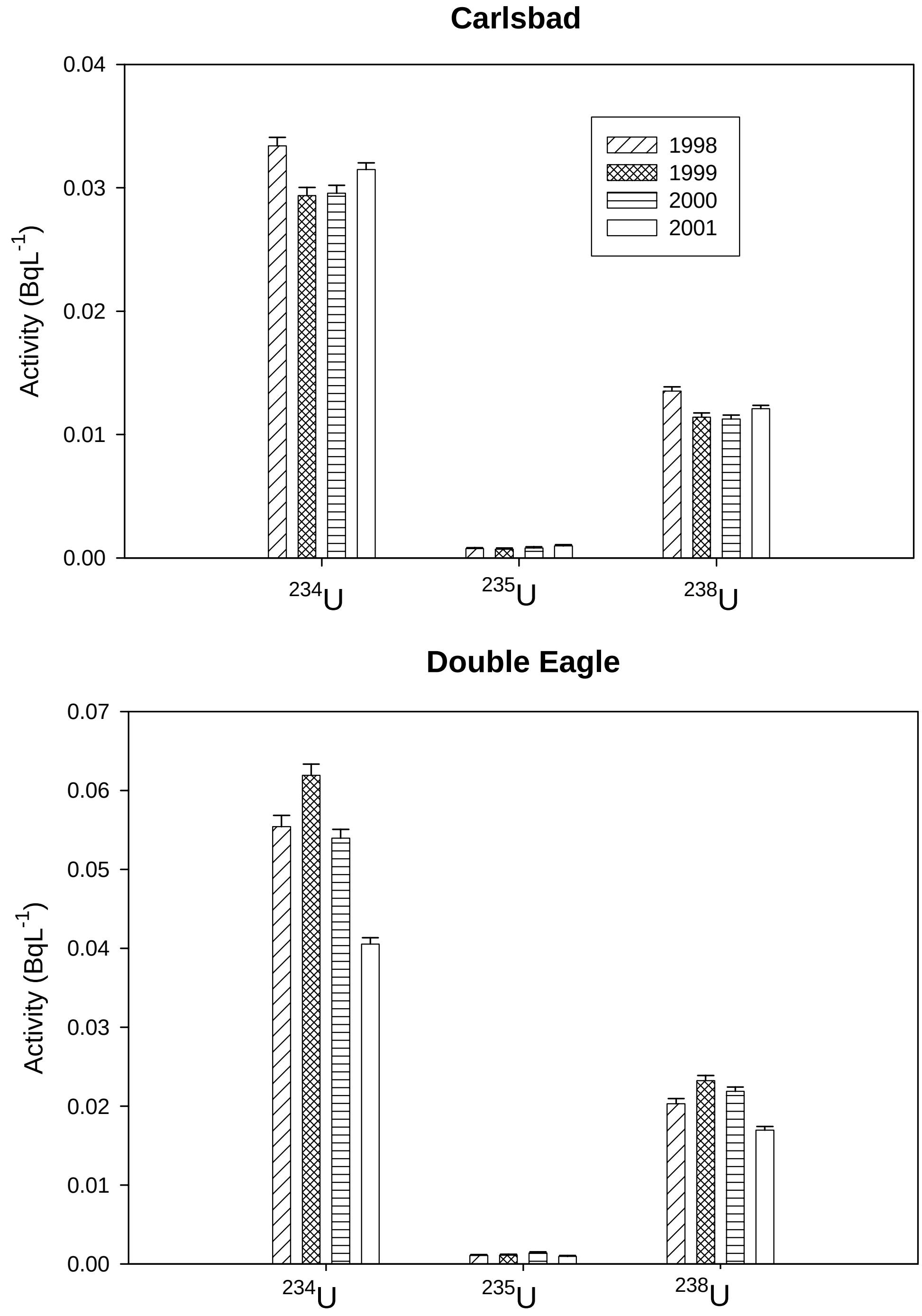

Figure 27. Activity Concentrations of Uranium Isotopes in Drinking Water Samples Collected at Carlsbad and Double Eagle during 1998-2001

Error bars represent the total radioanalytical uncertainty at 1 sigma.

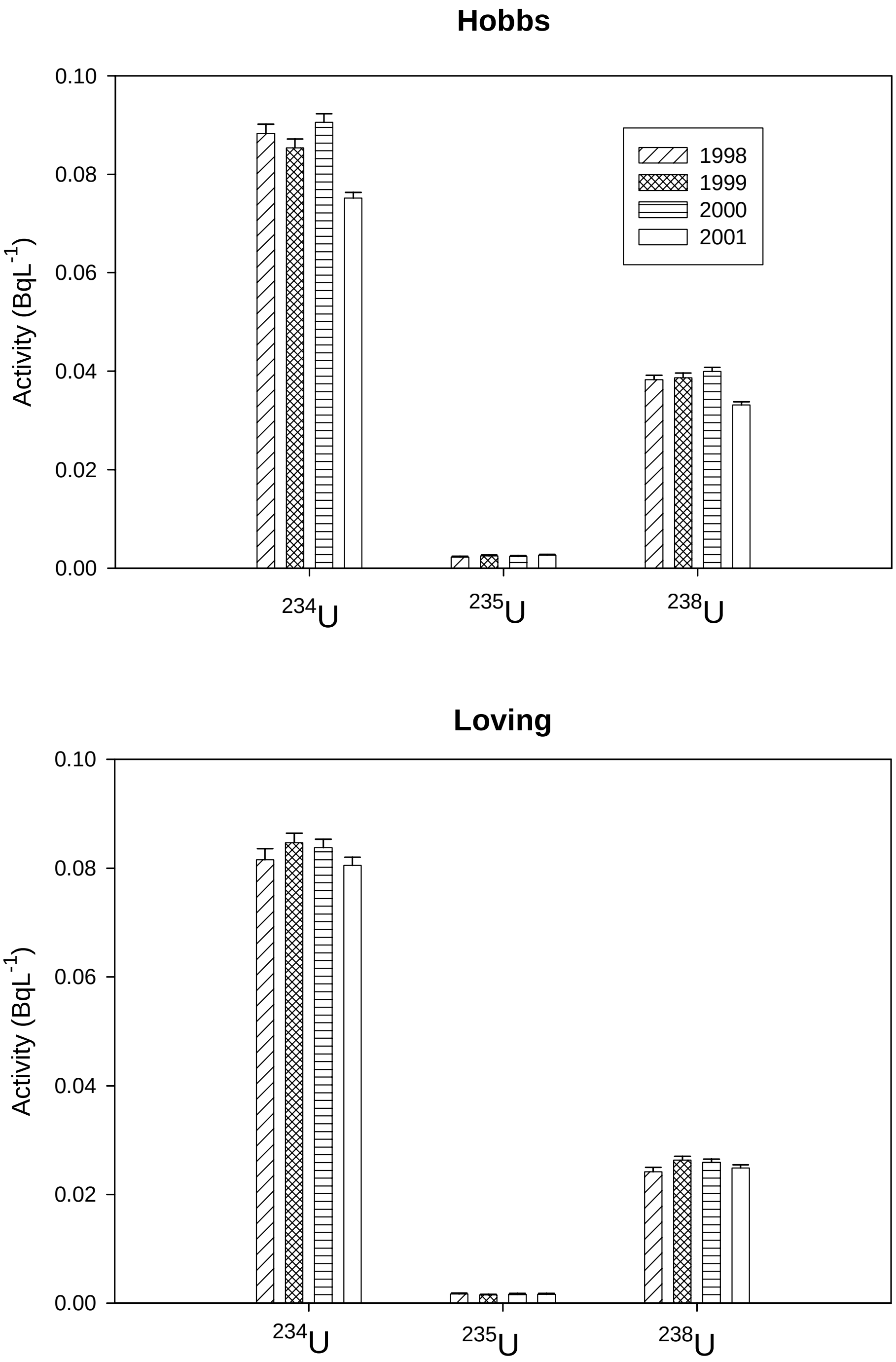

Figure 28. Activity Concentrations of Uranium Isotopes in Drinking Water Samples Collected at Hobbs and Loving during 1998-2001

Error bars represent the total radioanalytical uncertainty at 1 sigma.

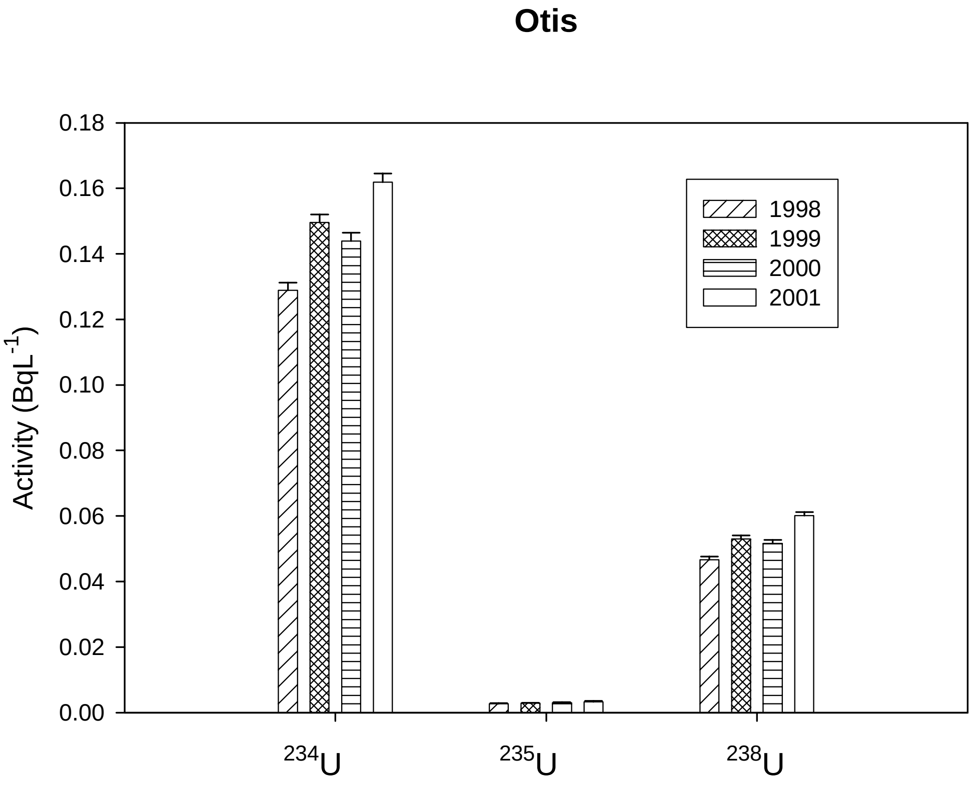

Figure 29. Activity Concentrations of Uranium Isotopes in Drinking Water Samples Collected at Otis during 1998-2001

Error bars represent the total radioanalytical uncertainty at 1 sigma.

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 to support education about naturally occurring and man-made radioactivity present in people 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 35-year operational phase of the WIPP. It is important to note that these data represent an interim summary (through 1 October 2001) of an ongoing study.

Participating in the LDBC consists of a lung and whole body count every two years. 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 updated quarterly on the CEMRC website (http://www.cemrc.org) and reported semi-annually through a newsletter distributed throughout the local community.

Results

As of 1 October 2001, 571 individuals had participated in the LDBC project. At the time the WIPP opened, 367 individuals had been measured using the *in vivo* protocol. This group of 367 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 of the original cohort began in July 1999, and 158 recounts had been performed through 1 October 2001. In addition, 71 new volunteers have participated in the program since 1 October 2000. These new volunteers form an additional baseline cohort for future comparisons.

Demographic characteristics (Table 19) of the current LDBC cohort are statistically unchanged from those reported in previous CEMRC reports, and are generally consistent with those reported in the 1990 census for citizens living in Carlsbad. The largest deviations reported in the 1999 report between the LDBC cohort and 1990 census were the over-sampling of males and under-sampling of Hispanics. Since that time, slight improvements have been made with respect to the percent of females and Hispanics represented. As soon as the data become available, demographic characteristics of the LDBC project will be compared to results of the 2000 census, which will provide a more accurate representation of the current population. In addition, it is important to note that if the presence of a radionuclide is dependent on a subclass of interest (gender, ethnicity, etc.), valid population estimates can still be made by correcting for the proportion of under- or over-sampling for the particular subclass.

As discussed in detail in the CEMRC 1998 Report and elsewhere (Webb et al., 2000, *Radiat. Prot. Dosim.* 89, 183), 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). For the baseline measurements (N = 367), 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 ^{212}Pb, ^{235}U / ^{226}Ra, ^{60}Co, ^{137}Cs, ^{40}K, ^{54}Mn, ^{232}Th via ^{228}Ac and ^{65}Zn (Table 20). 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 later).

For the operational monitoring counts (Table 20, N = 357), 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 years), and the content within the shield has decreased via decay by approximately 28% since the baseline phase of monitoring. The ^{232}Th (via ^{228}Ac) results were unexpected and are likely due to the replacement of aluminum (tends to contain Th and U) components with those manufactured from low radiation background steel.

It is important to note that 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.

^{40}K results were positive for all participants (n = 571), ranging from 1026 to 5558 Bq per person with an overall mean (± SE) of 2676 (± 33) 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 3252 (± 37) Bq per person, which was significantly greater ($p < 0.0001$) than that of females, which was 2011 (± 28) 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 26 ± 4% (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, J. L. et al., 2000, loc. cit.). Detectable ^{137}Cs body burdens ranged from 4.9 to 62.9 Bq per person with an overall mean (± SE) of 10.2 (± 0.5) Bq per person. The mean ^{137}Cs body burden for males (± SE), was 10.9 (± 0.6) Bq per person, which was significantly greater ($p = 0.02$) than that of females, which was 8.9 (± 0.4) Bq per person. As previously reported (CERMC Reports; Webb, J. L. et al., 2000, loc. cit.) the presence of ^{137}Cs was independent of ethnicity, age, radiation work history, consumption of wild game, nuclear medical treatments and European travel. Occurrence of detectable ^{137}Cs was associated with gender where males had higher prevalence of ^{137}Cs relative to females. Presence of ^{137}Cs was associated with smoking (where smokers had a higher prevalence relative to non-smokers). 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. Further study is warranted, but no additional investigations into this observation were conducted during this reporting period.

As reported in previous CEMRC reports, the percentage of results greater than L_C for ^{235}U / ^{226}Ra (10%) are significantly (although slightly) higher than the distribution-free confidence interval for a 5% random false-positive error rate (1 to 9%). 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. However, further study is needed; but no additional investigations into this observation were conducted during this reporting period.

Table 19. Demographic Characteristics of the "Lie Down and Be Counted" Population Sample through 1 October 2001

Characteristic		2001 Sample Group ([a]margin of error)	[b]Census, 1990
Gender	Male	53.4% (48.0 to 58.8%)	48.0%
	Female	46.6% (41.2 to 52.0%)	52.0%
Ethnicity	Hispanic	14.1% (10.3 to 18.0%)	33.4%
	Non-Hispanic	83.1% (79.0 to 87.4%)	63.0%
	Other	2.8% (0.9 to 4.7%)	3.6%
Age 60 or older		29.9% (24.9 to 35.0%)	33.7%
Currently or previously classified as a radiation worker		5.4% (3.0 to 7.9%)	[c]NA
Consumption of wild game within last 3 months		18.1% (13.8 to 22.2%)	NA
Medical treatment, other than x-rays, using radionuclides		8.0% (5.1 to 11.0%)	NA
European travel within the last 2 years		4.4% (2.1 to 6.7%)	NA
Current smoker		14.8% (11.0 to 18.7%)	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] United States Department of Commerce, Economics and Statistics Administration, Bureau of the Census. *1990 Census of Population*. Washington, DC: US Government Printing Office

[c] NA = not available

Table 20. "Lie Down and Be Counted" Results through 1 October 2001

Radionuclide	***In Vivo* Count Type**	**Baseline Counts (prior to 27 March 1999) [a]N = 367**	**Operational Monitoring Counts (27 March 1999 – 1 October 2001) N = 357**	
		% of Results ≥ [b]L_C	**% of Results ≥ L_C**	**[c]Margin of Error (%)**
^{241}Am	Lung	5	4	1 to 7
^{144}Ce	Lung	5	3	0 to 6
^{252}Cf	Lung	4	6	3 to 9
^{244}Cm	Lung	6	5	2 to 8
^{155}Eu	Lung	7	4	1 to 7
^{237}Np	Lung	4	3	0 to 6
^{210}Pb	Lung	4	7	4 to 10
Plutonium Isotope	Lung	6	4	1 to 7
[d] ^{232}Th via ^{212}Pb	Lung	34	35	28 to 42
^{232}Th	Lung	5	5	2 to 8
^{232}Th via ^{228}Th	Lung	4	5	2 to 8
^{233}U	Lung	6	9	5 to 13
^{235}U / ^{226}Ra	Lung	11	10	6 to 14
Natural Uranium via ^{234}Th	Lung	5	6	3 to 9
^{133}Ba	Whole Body	4	3	0 to 6
^{140}Ba	Whole Body	5	4	1 to 7
^{141}Ce	Whole Body	4	5	2 to 8
^{58}Co	Whole Body	4	4	1 to 7
[d] ^{60}Co	Whole Body	55	34	27 to 41
^{51}Cr	Whole Body	6	4	1 to 7
^{134}Cs	Whole Body	2	3	0 to 6
^{137}Cs	Whole Body	28	23	17 to 29
^{152}Eu	Whole Body	7	5	2 to 8
^{154}Eu	Whole Body	4	3	0 to 6
^{155}Eu	Whole Body	4	3	0 to 6
^{59}Fe	Whole Body	4	7	4 to 10
^{131}I	Whole Body	5	2	0 to 5
^{133}I	Whole Body	3	4	1 to 7
^{192}Ir	Whole Body	4	4	1 to 7
^{40}K	Whole Body	100	100	[e]NC
[d] ^{54}Mn	Whole Body	12	10	6 to 14
^{103}Ru	Whole Body	2	1	0 to 5
^{106}Ru	Whole Body	4	3	0 to 6

Table continued on next page

Table 20. "Lie Down and Be Counted" Results through 1 October 2001 (Cont.)

Radionuclide	***In Vivo* Count Type**	**Baseline Counts (prior to 27 March 1999) [a]N = 367**	**Operational Monitoring Counts (27 March 1999 – 1 October 2001) N = 357**	
		% of Results ≥ [b]L_C	**% of Results ≥ L_C**	**[c]Margin of Error (%)**
^{125}Sb	Whole Body	5	4	1 to 7
^{232}Th via ^{228}Ac	Whole Body	35	25	19 to 31
^{88}Y	Whole Body	8	6	3 to 9
^{95}Zr	Whole Body	7	4	1 to 7

[a] N = number of individuals

[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 complete replication of this experiment, one would expect the confidence interval to include the true population percentage 95% of the time, if the sample was representative of the true population

[d] These radionuclides are present in the shield background, so they are expected to be detected periodically

[e] NC = not calculated; the margin of error cannot be calculated for the observed percentage because the sample size for operational monitoring counts is as yet too small; when sufficient counts are performed, the margin of error will be calculated; the margin of error for ^{40}K cannot be calculated since this radionuclide is present in all individuals

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. Fingleton was named Director of Laboratory Development, and Dr. Marsha Conley became Director of Operations. Dr. Fingleton was transferred to a position with WERC in 1997, and Dr. Conley became Director. Mr. Joel Webb was named Manager of Program Development in 1998. Dr. Conley was named CEMRP Project Director in 1999. In July 2001, Dr. Conley retired. In February 2002, Mr. Joel Webb was appointed Director of CEMRC and CEMRP Project Director. Dr. George Hidy acted as an interim director during the search for the new permanent director.

Temporary office accommodations for the CEMRC initially were provided at NMSU-Carlsbad. 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 (to be referred to as 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. An application for a Radioactive Material License was prepared and submitted to the New Mexico Environment Department, and the license was issued in 1996.

In 1999, CEMRC was separated from WERC and is now a division reporting directly to the Dean of Engineering at NMSU. However, CEMRC continues to conduct various collaborative activities with WERC.

Appendix B. Subcontracts for Technical Assistance during 2001

Subcontractor	Scope of Work
Battelle Memorial Institute, Pacific Northwest Division	Fabrication of lung sets for *in vivo* bioassay
[a]Texas A&M Agricultural Experiment Station	Collection of aerosol samples
[a]Texas A&M Research Foundation	Measurements of organic nitrogen in aerosol samples
National Institute of Standards & Technology	Intercomparison services for radioanalyses

[a] Collaborative work not funded through CEMRP

Appendix C. Members of Scientific Advisory Board (SAB) and Program Review Board (PRB)

Member/Term of Service	Affiliation
John M. Briggs, Ph.D. (SAB) / 2000-present	Associate Professor, Department of Plant Biology, Arizona State University, Tempe, Arizona
Paul M. Bertsch, Ph.D. (SAB) / 2000-present	Director, Savannah River Ecology Laboratory, University of Georgia, Aiken, South Carolina
Judith Chow, Ph.D. (SAB) / 2000-present	Research Professor, Desert Research Institute, Reno, Nevada
George M. Hidy, D.Eng. (PRB) / 2000-present	Consultant, Envair/Aerochem President (past), Desert Research Institute, Reno, Nevada
Shawki A. Ibrahim, Ph.D. (SAB) / 2000-present	Professor, Department of Radiological Health Sciences, Colorado State University, Ft. Collins, Colorado
Gary H. Kramer, Ph.D. (SAB) / 2000-present	Head, Human Monitoring Laboratory, Radiation Protection Bureau, Health Canada, Ottawa, Ontario, Canada
Roger McClellan, Ph.D. (PRB)/2001-present	Consultant; President Emeritus, Chemical Industry Institute of Toxicology, Albuquerque, New Mexico
David E. Reichle, Ph.D. (PRB) / 2000-present	Associate Director Emeritus, Life Sciences and Environmental Technologies, Oak Ridge National Laboratory, Oak Ridge, Tennessee
Michael H. Smith, Ph.D. (PRB) / 1998-2001	Director Emeritus and Professor, Savannah River Ecology Laboratory, University of Georgia, Aiken, South Carolina

Appendix D. Professional Presentations and Publications during 2001

Author	Title	Publisher/Conference
Arimoto, R.	Aerosols—their relationship to past and present climates	Presentation to Department of Fishery and Wildlife Sciences, New Mexico State University, Las Cruces, NM, November, 2000
Arimoto, R.	Visible spectroscopy of atmospheric dust collected on filters: Iron-bearing minerals	Poster at American Geophysical Union Fall Meeting, San Francisco, CA, December, 2000
Arimoto, R.	Paso del Norte Air Research Program (PdNARP): Summary of Elemental Analyses for Fugitive Dust Sampling and Source Characterization	Texas Department of Health, El Paso, TX, March, 2001
Arimoto, R.	Aerosol studies at Cheju: PEM-West (1991 to 1994) and plans for ACE-Asia	International Workshop on ACE-Asia Surface Measurement, Kosan, Cheju, Korea, March 2001
Arimoto, R.	Aerosols in the anthropocene	Human Dimensions and Natural Processes in Environmental Change, Xi'an, People's Republic of China, May 2001
Arimoto, R.	Overview and preliminary results of ACE-Asia	APARE Executive Committee Meeting, Xining, People's Republic of China, August 2001
Arimoto, R.	Inorganic chemistry of aerosols from the anthropocene: Some case studies	Chemistry Symposium, New Mexico Institute of Mining and Technology, Socorro, NM, October 2001
Arimoto, R.	Sources and composition of aerosol particles	Handbook of Atmospheric Chemistry, J. Fishman, editor (In Press)
Arimoto, R.	Eolian dust and climate: Relationships to sources, transport, and deposition	Earth Science Reviews 54:29-42
Arimoto, R., A.S. Nottingham, J. Webb, C.A. Schloesslin, and D. Davis	Non-sea salt sulfate and other aerosol constituents at the South Pole during ISCAT	Geophysical Research Letters 28:3645-3648
Arimoto, R., T. Kirchner, J. Webb, M. Conley, B. Stewart, D. Schoep, and M. Walthall	^{239,240}Pu and inorganic substances in aerosols from the vicinity of the Waste Isolation Pilot Plant: The importance of resuspension	Health Physics (In Press); presented at Radiochemical Measurements Conference, Honolulu, Hawaii
Arimoto, R., W. Balsam, and C. Schloesslin	Visible Spectroscopy of Aerosol Particles Collected on Filters: Iron-oxide Minerals	Atmospheric Environment 36:89-96, 2001
Arimoto,R., R.A. Duce, B.J. Ray, and U. Tomza	Dry deposition of trace elements to the Western North Atlantic	Global Biogeochemical Cycles (Submitted)
Chen, G., D. Davis, J. Crawford, J.B. Nowak, F. Eisele, R.L. Mauldin III, D. Tanner, M. Buhr, R. Shetter, B. Lefer, R. Arimoto, A. Hogan, D. Blake	An investigation of South Pole HO_x chemistry: Comparison of model results with ISCAT observations	Geophysical Research Letters 28:3633-3637
Crawford, J.H., D.D. Davis, G. Chen, M. Buhr, R. Shetter, B. Lefer, A. Hogan, R. Arimoto, S. Oltmans, and R. Weller	Evidence for photochemical production of ozone at the South Pole surface	Geophysical Research Letters 28:3645-3648

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Appendix D. Professional Presentations and Publications during 2001 (Cont.)

Author	Title	Publisher/Conference
Davis, D., M. Buhr, J. Nowak, G. Chen, R. Arimoto, A. Hogan, F. Eisele, L. Mauldin, D. Tanner, R. Shetter, B. Lefer and P. McMurry	Unexpected high levels of NO observed at the South Pole	Geophysical Research Letter 28:3625-3628
Zhang, X., R. Arimoto, J. Cao, Z. An, and D. Wang	Atmospheric dust aerosol over the Tibetan Plateau	Journal of Geophysical Research 106:18,471-18,476
Hidy, G.	(Contributions to) Assessment of North American policy relevant tropospheric science of airborne particles	NARSTO, c/o NARSTO Coordination Office, Kennewick, WA published by Environment Canada (In Review)
Hidy, G.	N.A. Fuchs and the rise of theoretical aerosol dynamics	Presented at 2nd Symposium on the History of Aerosols, Portland, Oregon
Hidy, G., D. Eatough and G. Klouda	Radio-isotopic estimation of the biogenic component of airborne particles	Presented at American Association for Aerosol Research Annual Meeting, Portland, Oregon
Huang, S., R. Arimoto, and K.A. Rahn	Sources and source variations for aerosol at Mace Head, Ireland	Atmospheric Environment 35:1421-1437
Kirchner, T.B., J.L. Webb, S.B. Webb, R. Arimoto, D.A. Schoep, and B.D. Stewart	Variability in background levels of surface soil radionuclides in the vicinity of the Waste Isolation Pilot Plant	Journal of Environmental Radioactivity (In Press)
Kramer, G., M. Lopez, and J. Webb	A joint HML-CIEMAT-CEMRC project: testing a function to fit counting efficiency of a lung counting germanium detector array to muscle-equivalent chest wall thickness and photon energy using a realistic torso phantom over an extended energy range	Radiation Protection Dosimetry, 92, 4:323-327
Orcutt, K.M., F. Lipschultz, K. Gundersen, R. Arimoto, A.F. Michaels, A.H. Knap, and J.R. Gallon	Seasonal pattern and significance of N_2 fixation by *Trichodesmium* spp. at the Bermuda Atlantic Time-series Study (BATS) site	Deep-Sea Research II, 48:1683-1708
Popp, C.J., R.S. Martin, S. Huang, and R. Arimoto	Atmospheric effects of large fires: Spring 2000 Cerro Grande, NM (Los Alamos) fire	A Millennium Symposium on Atmospheric Chemistry: Past, Present, and Future of Atmospheric Chemistry, American Meteorological Society, Albuquerque, NM
Savoie, D.L., R. Arimoto, W.C. Keene, J.M. Prospero, R.A. Duce, and J. N. Galloway	Marine biogenic and anthropogenic contributions to nonsea-salt sulfate in the marine boundary layer over the North Atlantic Ocean	Journal of Geophysical Research (in press)
Stewart, Barry	How Rigorous is Rare Earth Fluoride Micro-Coprecipitation?	Presented at 47th Annual Conference on Bioassay, Analytical, and Environmental Radiochemistry
Tomza, U., R. Arimoto, and B. J. Ray	Filter color as an indicator of aerosol composition	Atmospheric Environment 35:1703-1709
Webb, J.L. and G. H. Kramer	An evaluation of germanium detectors employed for the measurement of radionuclides deposited in lungs using an experimental and Monte Carlo approach	Health Physics 81,6:711
Zhang, X.Y., R. Arimoto, Z.S. An, J.J. Cao and D. Wang	Atmospheric dust aerosol over the Tibetian Plateau	Journal of Geophysical Research 106:18,471-18,476

Appendix E. Guest Colloquia

Topic	Presenter
Methods of precision calculation and data validation for air quality measurements.	Dr. Judith Chow, Research Professor, Desert Research Institute
Central Arizona-Phoenix LTER:Land-Use Change and Ecological Processes in an Urban Ecosystem of the Sonoran Desert	Dr. John Briggs, Associate Professor of Plant Biology, Arizona State University
The Causes of the Accident at Chornobyl	Dr. George Anastas, Environmental Evaluation Group
Plutonium Behavior and Solution Chemistry in Synthetic Brines and Chloride Solutions (Preliminary Results)	Dr. Ningping Lu, Los Alamos National Laboratory-Carlsbad Operations
Corrosion of Calcium-Silicate-Hydrates in Acidic Solutions as a Model for C-S-H Carbonation Investigation of Surface Reactions on Xonotlite Using ESEM/EDX and EBSD	Dr. Guenther Beuchle, Research Center of Karlsruhe, Germany, Institute of Technical Chemistry Water and Geotechnology

Appendix F. Major Tours, Public Presentations, Exhibits and Other Outreach

Group/Activity
NMSU Department of Fishery & Wildlife Sciences - invited seminar
Southeastern New Mexico Educational Resource Center Virtual Internet Partnership - presentation
National Geographic - interviews and photography access
KENW-TV - interview and photography access
Cavern City Rotary Club - presentation
Eddy County Family Council - presentation
Society for Mining and Engineering - presentation
Autonomous Universidad de Ciudad Juarez students and faculty - tour and presentation
Joint National Science Foundation/DOE Committee on Underground Laboratories - tour and presentation
Los Alamos National Laboratory Physics Division - tour and presentation
Sunset Elementary School student science fair - exhibit and learning activities
Joe Stanley Smith Elementary School student science fair - exhibit and learning activities
Carlsbad Caverns National Park - support of student projects through water analysis
Lovington High School - support of student projects through water analysis
Earth Day - exhibit and learning activities
Heights Lions Club – presentation
Carlsbad Community Health and Safety Fair 2001 - exhibit
Downtown Lions Club – presentation
New Mexico Retirement Association - presentation

Appendix G. Leadership Participation by CEMRC Staff in Professional Functions

Function	CEMRC Staff/Role
Environmental Protection Agency's Environmental Monitoring for Public Access and Community Tracking (EMPACT) Program, September 2001	R. Arimoto, Review Panel
Human Dimensions and Natural Processes in Environmental Change, Xi'an, People's Republic of China, May 2001	R. Arimoto, Session Chair
APARE Executive Committee Meeting, Xining, People's Republic of China	R. Arimoto, Member
Analysis and Assessment Team for NARSTO.	G. Hidy, Co-Chairman
NARSTO	G. Hidy, Member, Executive Steering Committee (1995-present)
National Research Council Committee to Evaluate the Fossil Energy and Energy Efficiency R and D of the U. S. Department of Energy	G. Hidy, Member (2000-2001)
Rocky Flats Health Advisory Panel	T. Kirchner, Member

Appendix H. New Project Development

Proposal/Bid Title	PI(s)	Sponsor	Funding/ Term	Status
An investigation of sulfur chemistry in the Antarctic troposphere	R. Arimoto (with Georgia Institute of Technology and others)	National Science Foundation	$160,000, 1998-2002	Funded, in progress
Mineral dust and radionuclides over the North Atlantic	R. Arimoto (with Texas A&M University)	National Science Foundation	$270,428, 1997-2001	Completed
Characterization of ambient particulate matter in the Paso del Norte region	R. Arimoto (with NMSU Physical Science Laboratory and others)	Southwest Center for Environmental Research and Policy (with funding from U.S. Environmental Protection Agency)	$55,086, 1999-2001	Completed
Ambient air quality issues related to confined animal operations	R. Arimoto (with Texas Agricultural Extension Service and others)	U.S. Department of Agriculture, National Research Initiative Competitive Grants Program	$49,976, 1999-2001	Funded, in progress
Collaborative research: aerosol characterization experiment (ACE)-Asia surface network implementation, operations, and coordination	R. Arimoto (with University of Virginia and others)	National Science Foundation	$139,968, 2000-2004	Funded, in progress
Collaborative research: integrated studies of morphological, chemical optical, and radiative properties of multi-component aerosols containing mineral dust in the ACE-Asia region	R. Arimoto (with University of Hawaii and others)	National Science Foundation	$148,923, 2000-2004	Funded
Air deposition of mercury and other airborne pollutants in an arid environment	R. Arimoto (with NMSU Cooperative Fish and Wildlife Research Unit and others)	Southwest Center for Environmental Research and Policy (with funding from U.S. Environmental Protection Agency)	$12,537, 2000-2002	Funded, in progress
Effects of depleted uranium on amphibian health	R. Arimoto	NMSU Cooperative Fish and Wildlife Research Unit (with funding from DOE)	$8,000, 2000-2001	Funded, in progress

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Appendix H. New Project Development (Cont.)

Proposal/Bid Title	PI(s)	Sponsor	Funding/ Term	Status
Collaborative research: on Iron-oxide Minerals in Asian Dust	R. Arimoto	National Science Foundation	$64,207	Submitted
Infrastructure support for atmospheric science in NM-Atmospheric chemistry/climate change/climate dynamics	R. Arimoto, T. Kirchner	Experimental Program to Stimulate Competitive Research (EPSCoR), a joint program of the National Science Foundation (NSF) and several U.S. States and Territories.	$75,083	Submitted, not funded
Investigation of the Low-Wind Particulate Matter Spikes at the NMED Sunland Park City Yard Monitoring Site	R. Arimoto	SCERP	$81,657	Submitted
Developing a model for contaminate transport involving irrigation water	T. Kirchner	Los Alamos National Laboratory	$33,400 2001	Funded
Evolution of trends and gradients in body size	T. Kirchner	National Science Foundation	$97,307, 2001-2003	Submitted, not funded
Long-term risk from actinides in the environment: modes of mobility	T. Kirchner (with Los Alamos National Laboratory and others)	DOE Office of Environmental Management	$89,900, 1997-2001	Funded, in progress
Component based construction and testing of ecological models	T. Kirchner (with NMSU Department of Computer Science and others)	National Science Foundation	$240,607, 2000-2003	Submitted, not funded
Limnological monitoring: Brantley Dam Reservoir	M. Walthall	U.S. Department of Interior, Bureau of Reclamation	$83,363, 1997-2003	Amended, in progress
Groundwater Investigation on Non point Source Nitrate Contamination of the Pecos River Alluvial Aquifer	M. Walthall	Water Resources Research	$30,830	Submitted, not funded

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Appendix H. New Project Development (Cont.)

Proposal/Bid Title	PI(s)	Sponsor	Funding/ Term	Status
Lung & whole body *in vivo* radiobioassay measurements	J. Webb	Waste Control Specialists, Inc.	$233,414, 1997-2001	Amended, in progress
In vivo radiobioassay measurements for WIPP personnel	J. Webb	Westinghouse Electric Company	$299,000, 1998-2001	Amended, in progress
Human radon exposure estimate using an *in vivo* biomarker	J. Webb	Lovelace Respiratory Research Institute (with proposed funding from National Institutes of Health)	$117,721, 2001-2004	Submitted, not funded
Center for nuclear, neutrino and astroparticle physics	J. Webb (with Ohio State University and others)	National Science Foundation	$229,344, 2001-2006	Collaboration commitment submitted
Analytical scientific support for the Los Alamos National Laboratory, Carlsbad Office, actinide chemistry and repository science program	J. Webb (with B. Stewart, R. Arimoto and M. Walthall)	Los Alamos National Laboratory	$810,080, 2001-2002	Funded, in progress
Actinide chemistry & repository science laboratory initiative	J. Webb (with M. Conley)	DOE	$7,072,767, 2000-2008	Submitted

Appendix I. Status of Completion of 2001 Key Performance Indicators

1. Concurrent high-volume and low-volume aerosol sampling at four locations through 2001. **[Completed]**
2. Collection of daily FAS samples in WIPP exhaust shaft through 2001. **[Completed]**
3. Collection of soil samples at current 32 locations during January-February 2001. **[Completed]**
4. Concurrent operation of meteorological sampling stations at two sites through 2001. **[Completed]**
5. Collection of drinking water samples at six sources during April-May 2001. **[Completed]**
6. Collection of sediment and surface water samples from three reservoirs during June-July 2001. **[Completed]**
7. Completion of repeat counts for half of original volunteer cohort and initial counts for a minimum of 100 new volunteers. **[Completed but delayed by two months.]**
8. Radioanalyses of subset of pre-2000 vegetation and arthropod samples by October 2001. **[Vegetation and arthropods not completed due to higher priorities for other media and projects]**
9. Radioanalyses of soil, aerosol, sediment, surface water and drinking water samples collected through June 2001 by October 2001. **[Completed]**
10. Radioanalyses of FAS sample analyses to meet weekly and quarterly posting schedule. **[Completed]**
11. Non-radiological (trace element inorganic) analyses of representative subset of 2001 low-volume aerosol, soil, sediment, surface water and drinking water samples within three months after each sample collection. **[Completed within three months with exception of sediment and surface water which were delayed by approximately two months.]**
12. Non-radiological (trace element inorganic) analyses of FAS samples to meet weekly and quarterly posting schedule **[Completed]**
13. Post results of radioanalyses of 2001 and pre-2001 samples within two months after completion of analyses of each set of samples. **[Completed]**
14. Post results of non-radiological analyses of 2001 samples within two months after completion of each set of samples. **[Completed]**
15. Issue CEMRC 2000 Report and post report and background data to CEMRC web site by March 2001. **[Completed]**
16. Issue newsletters in March and September 2001. **[Spring newsletter issued in March 2001; fall newsletter was delayed.]**
17. Submit manuscript for publication by March 2001 on baseline characteristics of aerosols. **[Submitted September 2001]**

Appendix J. CEMRC Quality Assurance Policy

The Carlsbad Environmental Monitoring & Research Center (Center) is a division of the College of Engineering, New Mexico State University (NMSU). The Center 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. Subject to limitations specified by state law, NMSU is legally responsible for the operations and products of the Center. In addition to the general goals, mission and standards of NMSU, the Center adheres to the following principles:

- A quality system will be maintained to ensure that sponsor requirements are consistently met and carried out in accordance with recognized standards as identified and adopted by each programmatic area. The goal of the quality system will be continuous improvement in the processes composing the Center's activities in research and service.

- Standards of quality assurance and quality control incorporating standard scientific methods will be developed and implemented that are appropriate to the objectives and functions of specific projects and programmatic areas.

- Methods for performance assessment and quality improvement will be used throughout the Center in keeping with policies and procedures of NMSU, and with protocols adopted for specific projects and programmatic areas to ensure that all applicable quality objectives are met and maintained.

- Personnel, equipment and facilities will be provided to achieve adopted project objectives and quality standards, subject to the limitations of fiscal and other applicable constraints.

- Personnel will be provided access to written and verbal guidance, training and other professional development to support continuous improvement within all programmatic areas, subject to the limitations of fiscal and other applicable constraints.

- Personnel will be held accountable for their actions related to protection of employees, the public, and the environment, in carrying out projects and other activities, in compliance with all applicable laws and regulations.

- Employees are responsible for personal compliance with policies, procedures and other guidance adopted for purposes of quality control, fiscal accounting, and other management objectives.

Appendix K. Quality Assurance/Quality Control for Inorganic Analyses

As noted elsewhere in this report, the analytical methods employed for inorganic analyses in the environmental chemistry program at CEMRC are based, when applicable, on various standard procedures (EPA, 1983, *Methods for Chemical Analysis of Water and Wastes*, EPA/600/4-79-020; EPA, 1997, *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods*, EPA/SW-846; American Public Health Association, 1981, *Standard Methods for the Examination of Water and Wastewater, 15th Edition*). 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

A DIONEX 500 ion chromatography (IC) system was used to determine the concentrations of a suite of anions, including nitrate, nitrite, sulfate, chloride, fluoride, and phosphate in water samples and aqueous extracts of air filters, soils, and sediments. The anion analyses were performed with the use of AS11 and AS14 anion exchange columns and AG11 and AG14 guard columns, with chemical suppression and conductivity detection.

Elemental analyses employed an atomic absorption spectrometer (AAS) with a computer-controlled Perkin-Elmer 5100PC atomic absorption unit with Zeeman background correction. Samples are introduced into the AAS by aspiration through an air/acetylene flame, by vaporization in a heated graphite furnace, by flow-injection via a heated quartz cell, or through an unheated quartz cell (for Hg). Additional inorganic analyses were performed using a Perkin-Elmer Elan 6000 inductively-coupled plasma mass spectrometer (ICP-MS). The two instruments used for the elemental analyses are complementary; AAS is more sensitive than the ICP-MS for some elements, but compared with the ICP-MS, the AAS has a narrower linear range, requires more operator effort for calibration and operation, and has a much lower sample throughput.

General Quality Control

Several analytes are readily determined by more than one of the three instruments used at CEMRC, and this facilitates intra-laboratory comparisons, which are performed periodically. Results of these studies are not included in this report due to the extensive amount of data. Quality control summary tables for each matrix are provided below in tables K1-K5. Some of these internal QC comparisons are also summarized in other sections of this report that deal with specific media.

Independent quality assurance samples are obtained and analyzed to verify the performance of the instrumentation and the proficiency of the analyst. Both blind samples (obtained from an outside source, with true values not known at the time of analysis) and reference samples (obtained from an outside source or prepared internally, with true values known at the time of analysis) are used to perform this function. Regular QC verifications and batch QC provide records of sample performance data. Copies of the analytical data and performance results are maintained in the environmental chemistry instrument laboratory. The laboratory also carried out several informal inter-laboratory comparisons, and participated in two formal intercomparison studies in 2001

Calibrations are verified with a standard obtained from a source different from that used for the procurement of the primary calibration standards. The calibration standards and the verification standards used at CEMRC are, where possible, traceable to NIST. A calibration blank is analyzed at the beginning of each workday when samples will be run, after every ten samples, and at the end of the day. To pass the calibration verification, blank results must be less than the minimum detectable level or ± 3 standard deviations (SD) of control limits. Analysis of a blank and a standard are performed at a frequency of 10% during analytical runs, and these are repeated at the close of each analytical run to verify continued calibration validity. Batch quality control samples are counted as samples in determining the 10% frequency, but the continuing check samples are not counted as samples in determining the 10% frequency.

Various types of field blanks, check solutions and laboratory fortified (spiked) samples are analyzed along with the samples as part of the QA/QC procedures. These vary somewhat among matrices and analyses as described in more detail below. In addition, when feasible, duplicate samples (both field and laboratory duplicates) are processed to evaluate reproducibility and sample homogeneity. Control charts for each matrix have been established, and ± 3 SD limits have been determined for future reference. Control charts are used to track the performance of the instrument and the sample preparation procedures. Similarly, spike recoveries are calculated, tracked, and reported along with the analytical data.

Beginning in January 2000, Method Detection Limits (MDLs) were determined using a procedure outlined in 40 CFR 136, Appendix B. Briefly, this involves processing and analyzing seven replicates of a low level standard as though they were samples. The standard deviations of the replicate analyses are multiplied by 3.14 to obtain the MDLs. It should be noted however, that the method used for determining detection level does not address the problem of a systematic bias (such as background filter contamination). Therefore, it is possible to have a high level of precision without an accompanying high level of accuracy. In situations where this happens, the MDL obtained by this method may not accurately represent the true limit of detection. Method detection limits are presented in Tables K6-K8.

The environmental chemistry laboratory participated in the InterLaB WatR^{TM} Pollution WP-71 Proficiency Testing Program sponsored by Environmental Resource Associates. Results are presented in Table K-9. Calcium, magnesium, fluoride, selenium and ortho-phosphate results were flagged "Check for error", however all results were within the acceptance limits.

The laboratory also participated in the InterLaB WatR® Supply WS-58 Proficiency Testing Program sponsored by Environmental Resource Associates. Results are presented in Table K-9. Results for fluoride, sodium and calcium were outside the acceptance limits. Investigation revealed a contamination problem with the calibration standards. The standards were replaced and acceptable results were attained upon reanalysis.

Quality Control for Analyses by IC

For IC 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.

QC samples included Laboratory Reagent Blanks (LRB), with one LRB prepared for each sample batch (normally a set of ten samples). LRB results below MDL are considered acceptable. LRB results higher than MDL must be subtracted from sample results. Laboratory Fortified Matrix (LFM) samples were also used for QC, with one LFM analysis per batch. Results from analyses of LFMs are used to calculate matrix spike recoveries, with recoveries of 70-130% considered acceptable.

One duplicate analysis was performed for each sample batch. When possible, duplicates of selected field samples were analyzed. In cases where duplicates were not feasible (such as aerosol filters), separate aliquots of the sample extract were analyzed. The relative percent difference (RPD) between the sample and the duplicate was calculated, with a difference of < 20% (or an absolute difference of ± PQL for samples less than five times the MDL) considered acceptable.

A Laboratory Fortified Blank (LFB) was prepared and analyzed with each sample batch, using a spiked ultrapure water sample for water samples, and certified reference materials (CRM) for soils and sediments. Recoveries of 85-115% were considered acceptable for water samples. The CRM for soils and sediments was “Anions in Soils” from Environmental Research Associates (ERA) in Arvada, Colorado. Because there is no existing standard reference method for extracting soils or sediments for anion analysis, the results obtained by different methods may not be directly comparable. As proscribed by EPA Method 300.0, chloride and sulfate LFM values for surface water samples and chloride and sulfate LFM values in sediments were not reported because the concentration of the fortification was less than 25% of the background concentration. Fluoride was not determined in sediments due to co-eluting organic peaks.

Quality Control for Elemental Analyses by ICP-MS and AAS

For elemental analyses, sets of quality control samples comparable to those described above for the IC analyses were included with each sample batch. For all media (aerosol filters, water, soils, and sediments) ICP-MS and AAS values were reported relative to the method detection limit as determined by the method outlined in 40 CFR 136, Appendix B. Digestion QC samples were analyzed at a frequency of 10% or more relative to samples. The digestion QC control parameters used for the evaluation of metals in aerosol filters included laboratory reagent blank (LRB) filters and vendor-supplied certified reference filters. Post digestion duplicate and post digestion spike analyses were performed for the ICP-MS and AAS analyses of aerosol samples.

The digestion QC parameters used for the evaluation of elements in water, soils, and sediments were based on EPA Contract Laboratory Program (1994, U.S. EPA Contract Laboratory Program (CLP) National Functional Guidelines for Inorganic Data Review, EPA 540/R-94013) and SW-846 methods (EPA, 1997, *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods*, EPA/SW-846). No comparable control parameters presently exist for aerosol samples. The EPA CLP sets a required detection limit for metals referred to as the CRDL (Contract Required Detection Limit). The CRDL is used in determining acceptance criteria for blanks and duplicates. Due to the limited scope of analytes monitored in the CLP program, and the relatively high detection limit requirements, it is common practice in commercial laboratories to establish Practical Quantitative Limits (PQLs) which are used in the same manner as CRDLs for non-EPA projects. A PQL of 5 times the MDL was used in 2001. For all matrices PQLs were calculated to evaluate precision based on the analysis of duplicate samples.

For aerosol samples, unused cellulose ester filters were used as LRB samples. LRB results above the MDL were subtracted from each associated batch of sample results because the LRB results were greater than the MDL for many of the analytes studied. Analysis of reagent digests have shown inherent contamination in the cellulose ester filters for some analytes (Ca, Cr, Cu, Mg, Ni, and Pb), while others (Al, Ba, Co, Hg, and La) are introduced in trace amounts by the reagents used for digestion. A cellulose ester CRM (“Trace Metals on Filter Media” from High Purity Standards in Charleston, South Carolina) was also used for QC of aerosol sample analysis. Mean recoveries for all analytes were within ± 15% of the manufacturer’s established true values for all analytes.

For FAS samples, unused Versapore® filters were used as laboratory reagent blank samples. LRB results above the MDL were subtracted from each associated batch of sample results because they were greater than the MDL for several of the analytes studied. Analysis of reagent digests showed inherent contamination in the Versapore® filters for Cr, Cu, K, La, Mg, Na, Nd, Ni, Pb, Sm and V, while Be, Cd, Dy, Gd were introduced in trace amounts by the reagents during digestion. A cellulose ester CRM (“Trace Metals on Filter Media” from High Purity Standards in Charleston, South Carolina) was used for QC of the FAS samples. Mean recoveries for all analytes were within ± 15% of the manufacturer’s established true values.

Four standard QC measures were used in association with analyses of drinking water and surface water samples. Ultrapure water, prepared using a Barnstead Nanopure® system, was used for LRB samples, and average concentrations were less than the MDLs for all analytes except Cr in drinking water samples and Ba, Cd, Fe, Pb, Sb, Sc, and Zn in surface water. All results were corrected for blank bias. The drinking water samples were initially analyzed undiluted and at a two fold dilution. For both of these analyses the internal standard recovery was outside the acceptance limits, therefore a five-fold dilution was performed for all samples (with the exception of the trip blank). This dilution resulted in a five-fold increase in the MDCs as compared to previous years. A LFB was prepared by adding a known quantity of each analyte of interest to ultrapure water. All analytes for drinking water and surface water preparation were recovered within the 85-115% limits as specified by EPA methods with the exception of Ti (121%) and Zn (71%).

LFM samples were also used for QC in analyses of water samples, with all recoveries within a 70%-130% acceptance window. When evaluating LFM results, the concentration of the analyte in the sample must also be considered. If the concentration of the fortification is less than 25% of the background sample concentration, the recovery of the LFM is not reported. A duplicate digestion analysis of water samples was also performed to demonstrate reproducibility, but a slight modification of the EPA CLP program was used for acceptance determination. If the sample result were less than the PQL, a ± PQL control limit was used. If the sample result were greater than the PQL, a ± 20% RPD control limit was used. All duplicate results were within these modified acceptance limits with the exception of the zinc result for the Double Eagle well. Reanalysis was not performed as zinc is not an analyte of concern for WIPP monitoring.

For soils and sediments, LRB samples of prepared ultrapure water were compared to MDLs to determine if contamination was introduced during sample preparation. LRB results were within acceptance limits for soils with the exception of Cr in one batch. The sample measurements were at least ten times higher than the LRB results for all samples in the affected batch. The contaminant effects on the measurements are considered negligible for analytes with sample concentrations greater than 10 times the blank level. Sample results associated with the LRB above the MDL were corrected for bias by reagent blank subtraction.

For elemental analysis, the detection limits are dependent upon how clean the blank, reagents and preparation labware can be made. Although CEMRC's detections limits are arguably low, the MDLs can be improved for some analytes. Reagent grade acid is double distilled in-house, using a quartz distillation apparatus, and this produces ultrapure acid that is quite pure. For the soil and sediment preparations a Gelman Acrodisc® was used for final filtration in place of the Whatman 41® filter paper used previously and an improvement in our detection limits was observed for many analytes. The disc did, however increase the background level and method detection limit for nickel and zinc significantly.

Sediment LRB results were greater than the MDL for several analytes; however, the elemental concentrations of all analytes in the sediment samples were at least 10 times greater than the level in the blanks. For samples with results greater than 10 times the blank levels, the contaminant effects on measurements in sediments are considered negligible. Sample results were corrected for bias by reagent blank subtraction for all analytes with LRBs above the MDL, regardless of sample concentration.

A CRM (“Priority Pollutant T/CLP Soil” from ERA) was obtained and prepared with the soil and sediment samples to demonstrate matrix-specific performance of digestion and analysis procedures. Different lot numbers were used for the soil and sediment digests. All analytes were recovered within the supplier’s specified control limits for all digestions with the exception of Ag, which recovered high for all of the soil digests. The sediment control samples were all acceptable, and the same digestion procedure was used for both sets of digestions. The matrix spike recoveries were all within control limits for silver. Based on these results it is believed there is a problem with the silver level in our CRM sample, not a problem with the digestion or analysis. Results for silver in the soils were therefore reported as acceptable, pending further investigation.

Duplicate digestions were preformed for soil and sediment using a modification of the EPA CLP program for acceptance determination. If the sample results were less than the PQL, a ± PQL control limit was used. If the sample results were greater than the PQL, a ± 20% RPD control limit was used. The EPA Inorganic Usability Criteria (1994, U.S. EPA Contract Laboratory Program National Functional Guidelines for Inorganic Data Review, *EPA 540/R-94013*) indicate that a 35% RPD control limit may be adopted for soils and sediments due to the relatively high level of inhomogeneity compared with other matrices. For sample results less than the PQL, a ± 2*PQL control limit may be used. For soils, the RPD for the duplicate digestions performed was within these broader usability acceptance limits for all analytes. For sediments, one batch had unacceptable duplicate precision for Al, K, Tl and V. Two sediment batches had unacceptable duplicate precision for Ti. Redigest and re-analysis was not performed as these are not WIPP regulated analytes. The poor replicate precision is likely due to sample inhomogeneity with respect to these analytes.

A LFM also was prepared for each batch of soils and sediments processed. The recoveries were within 70%-130% for all analytes with the exception of Ba in one soil batch. The digestion for this batch was performed three times with unacceptable barium spike recoveries in all three digests. The recoveries varied (2.8%, 144% and 207%). This indicates an inhomogeneous barium concentration in this sample. The results for the three digestions were compared and good agreement for barium was found between all the samples in this batch. Therefore the results associated with the 144% spike recovery were reported.

Table K1. Summary of Batch Quality Control Results for Drinking Water

Analyte	**Certified Reference Material Recovery (%Recovery)**	**Average Matrix Spike Recovery (%Recovery)**	**Maximum Duplicate Precision (%Relative Percent Difference)**	**Average Duplicate Precision (%Relative Percent Difference)**
Ag	97.5	99.3	[a]<PQL	<PQL
Al	101.8	98.8	<PQL	<PQL
As	101.5	94.0	<PQL	<PQL
Ba	101.3	99.6	3.5	1.5
Be	95.6	116.8	<PQL	<PQL
Ca	93.8	96.6	3.7	1.3
Cd	96.0	113.9	<PQL	<PQL
Ce	101.3	105.6	<PQL	<PQL
Co	98.7	96.0	<PQL	<PQL
Cr	94.1	98.9	<PQL	<PQL
Cu	98.6	94.8	<PQL	<PQL
Dy	100.8	107.9	<PQL	<PQL
Er	100.7	108.4	<PQL	<PQL
Eu	99.9	104.4	<PQL	<PQL
Fe	98.5	93.4	<PQL	<PQL
Gd	102.2	106.1	<PQL	<PQL
Hg	105.0	91.0	<PQL	<PQL
K	103.8	110.7	<PQL	<PQL
La	101.4	106.6	<PQL	<PQL
Li	95.7	90.4	0.2	0.2
Mg	97.0	92.4	2.6	1.6
Mn	98.4	95.3	<PQL	<PQL
Mo	99.7	101.3	<PQL	<PQL
Na	94.5	88.4	4.9	2.3
Nd	100.7	102.8	<PQL	<PQL
Ni	99.4	95.6	<PQL	<PQL
Pb	103.0	104.6	13.6	10.5
Pr	100.4	103.1	<PQL	<PQL
Sb	101.4	119.0	<PQL	<PQL
Sc	98.7	100.7	<PQL	<PQL
Se	103.1	85.2	<PQL	<PQL
Si	98.6	88.9	6.2	4.8
Sm	100.2	104.5	<PQL	<PQL
Sn	100.8	102.3	<PQL	<PQL

Table continued on next page

Table K1. Summary of Batch Quality Control Results for Drinking Water (Cont.)

Analyte	Certified Reference Material Recovery (%Recovery)	Average Matrix Spike Recovery (%Recovery)	Maximum Duplicate Precision (%Relative Percent Difference)	Average Duplicate Precision (%Relative Percent Difference)
Sr	100.9	96.8	3.9	2.6
Th	103.5	120.5	<PQL	<PQL
Ti	95.0	104.7	<PQL	<PQL
Tl	101.8	104.3	<PQL	<PQL
U	101.1	112.9	7.2	2.8
V	99.4	100.8	5.1	3.1
Zn	101.9	124.9	86.6	86.6
Fluoride	92.0	88.0	1.7	0.7
Chloride	96.2	94.7	2.5	1.2
Nitrate	108.1	99.9	5.8	2.0
Phosphate	99.1	96.1	<PQL	<PQL
Sulfate	90.6	95.2	1.8	1.1

[a] <PQL = All sample results were less than the PQL therefore a +/- PQL control limit is used in place of the 20% RPD limit.

Table K2. Summary of Batch Quality Control Results for Air Filters

Analyte	Average Certified Reference Material Recovery (%Recovery)	Average Matrix Spike Recovery (%Recovery)	Maximum Duplicate Precision (%Relative Percent Difference)	Average Duplicate Precision (%Relative Percent Difference)
Ag	98.6	76.3	[a]<PQL	<PQL
Al	[b]NA	96.0	2.6	1.8
As	97.0	106.1	<PQL	<PQL
Ba	102.9	100.6	14.2	8.9
Be	99.6	97.6	<PQL	<PQL
Ca	NA	96.4	12.3	6.1
Cd	100.3	101.7	20.7	20.7
Ce	NA	103.8	18.7	6.3
Co	101.0	102.7	-3.3	-3.3
Cr	99.8	103.9	<PQL	<PQL
Cu	102.4	101.3	6.5	6.5
Dy	NA	103.5	6.4	6.4
Er	NA	100.2	<PQL	<PQL
Eu	NA	100.2	<PQL	<PQL
Fe	99.2	125.5	1.6	1.6
Gd	NA	103.7	11.4	9.8
Hg	NA	100.7	<PQL	<PQL
K	NA	131.2	6.7	2.6
La	NA	104.4	<PQL	<PQL
Li	NA	100.2	<PQL	<PQL
Mg	NA	100.4	2.0	1.8
Mn	102.2	109.9	4.6	0.7
Mo	NA	105.8	<PQL	<PQL
Na	NA	96.5	1.7	1.7
Nd	NA	101.5	20.8	13.3
Ni	102.8	101.2	<PQL	<PQL
Pb	101.0	100.8	19.1	5.8
Pr	NA	104.7	6.9	4.8
Sb	NA	102.0	13.5	7.4
Sc	NA	101.2	6.7	6.7
Se	84.4	99.5	<PQL	<PQL
Si	NA	99.1	5.4	2.8
Sm	NA	103.6	7.9	7.9
Sn	NA	101.7	<PQL	<PQL

Table continued on next page

Table K2. Summary of Batch Quality Control Results for Air Filters (Cont.)

Analyte	Average Certified Reference Material Recovery (%Recovery)	Average Matrix Spike Recovery (%Recovery)	Maximum Duplicate Precision (%Relative Percent Difference)	Average Duplicate Precision (%Relative Percent Difference)
Sr	NA	101.4	6.3	2.7
Th	NA	109.3	7.5	4.0
Ti	NA	95.0	0.2	0.2
Tl	100.6	101.1	<PQL	<PQL
U	NA	102.1	4.6	4.6
V	104.5	101.1	<PQL	<PQL
Zn	98.8	100.5	22.6	22.6

[a] <PQL = All sample results were less than the PQL therefore a +/- PQL control limit is used in place of the 20% RPD limit.
[b] NA = Certified value not available.

Table K3. Summary of Batch Quality Control Results for Soils

Analyte	Average Certified Reference Material Recovery (%Recovery)	Average Matrix Spike Recovery (%Recovery)	Maximum Duplicate Precision (%Relative Percent Difference)	Average Duplicate Precision (%Relative Percent Difference)
Ag	157.7	105.5	[a]<PQL	<PQL
Al	117.2	[b]NR	16.8	6.7
As	101.3	94.8	29.4	7.9
Ba	124.3	88.1	16.5	9.2
Be	118.4	109.3	22.4	12.6
Ca	101.8	NR	35.0	13.5
Cd	98.9	100.4	<PQL	<PQL
Ce	[c]NA	97.8	19.8	9.5
Co	97.9	105.0	13.9	8.5
Cr	110.5	101.0	18.3	6.8
Cu	112.9	103.2	15.8	7.5
Dy	NA	103.5	22.6	11.0
Er	NA	104.7	15.2	7.9
Eu	NA	102.9	14.9	8.2
Fe	103.4	NR	9.3	6.2
Gd	NA	104.3	15.3	7.9
Hg	101.0	115.8	<PQL	<PQL
K	129.9	NR	14.3	4.7
La	NA	102.2	12.6	7.4
Li	NA	98.8	22.0	8.6
Mg	98.6	NR	13.8	5.0
Mn	111.0	88.0	12.9	8.0
Mo	107.5	103.0	31.9	19.5
Na	111.6	82.0	<PQL	<PQL
Nd	NA	102.6	19.1	9.9
Ni	116.2	102.1	<PQL	<PQL
Pb	99.8	103.8	16.2	7.0
Pr	NA	104.4	18.0	9.4
Sb	119.0	88.3	24.5	9.1
Sc	NA	NR	9.7	5.0
Se	107.5	96.8	<PQL	<PQL
Si	NA	NR	33.9	14.3
Sm	NA	104.7	16.1	8.7
Sn	84.0	NR	<PQL	<PQL

Table continued on next page

Table K3. Summary of Batch Quality Control Results for Soils (Cont.)

Analyte	Average Certified Reference Material Recovery (%Recovery)	Average Matrix Spike Recovery (%Recovery)	Maximum Duplicate Precision (%Relative Percent Difference)	Average Duplicate Precision (%Relative Percent Difference)
Sr	120.6	103.8	26.6	13.1
Th	NA	102.7	14.0	7.5
Ti	95.9	NR	24.3	9.3
Tl	116.5	100.8	25.7	15.1
U	NA	103.0	19.8	11.4
V	102.0	94.2	15.3	8.2
Zn	105.8	103.8	<PQL	<PQL
Fluoride	83.1	98.8	7.0	4.4
Chloride	82.7	103.9	33.9	14.4
Nitrate	106.7	111.2	22.8	10.2
Phosphate	90.4	112.7	11.8	4.5
Sulfate	86.5	111.3	9.0	6.3

[a] <PQL = All sample results were less than the PQL therefore a +/- PQL control limit is used in place of the 20% RPD limit.
[b] NR = Sample result greater than 4 times the spike added, therefore spike recovery not reported.
[c] NA = Certified value not available.

Table K4. Summary of Batch Quality Control Results for Sediments

Analyte	Average Certified Reference Material Recovery (%Recovery)	Average Matrix Spike Recovery (%Recovery)	Maximum Duplicate Precision (%Relative Percent Difference)	Average Duplicate Precision (%Relative Percent Difference)
Ag	104.8	89.6	9.8	4.0
Al	109.2	[a]NR	53.5	25.8
As	82.9	96.1	23.6	15.8
Ba	112.4	NR	11.2	10.5
Be	99.1	84.7	26.8	19.3
Ca	116.5	NR	12.3	6.9
Cd	105.6	95.8	13.4	8.5
Ce	[b]NA	100.6	18.8	8.1
Co	105.5	92.5	15.3	8.6
Cr	109.2	96.5	30.0	18.7
Cu	105.1	91.6	18.3	9.3
Dy	NA	95.3	17.3	7.0
Er	NA	98.8	14.2	7.3
Eu	NA	107.5	11.2	6.1
Fe	126.3	NR	25.8	15.2
Gd	NA	98.7	17.3	10.0
Hg	75.8	101.9	10.5	7.0
K	110.9	NR	54.4	27.0
La	NA	99.4	15.0	8.1
Li	NA	77.8	24.2	15.1
Mg	109.7	NR	22.5	12.2
Mn	114.7	NR	11.4	5.9
Mo	107.1	101.3	12.9	5.9
Na	96.8	NR	10.5	6.0
Nd	NA	99.2	17.2	8.9
Ni	105.5	99.3	15.4	7.5
Pb	113.2	90.3	8.9	4.0
Pr	NA	104.2	15.3	6.8
Sb	226.3	85.1	26.3	12.4
Sc	NA	85.4	28.4	15.5
Se	113.7	76.0	28.9	12.0
Si	NA		[c]<PQL	<PQL
Sm	NA	102.4	11.5	6.9
Sn	NA	98.9	5.0	5.0

Table continued on next page

Table K4. Summary of Batch Quality Control Results for Sediments (Cont.)

Analyte	Average Certified Reference Material Recovery (%Recovery)	Average Matrix Spike Recovery (%Recovery)	Maximum Duplicate Precision (%Relative Percent Difference)	Average Duplicate Precision (%Relative Percent Difference)
Sr	114.8	NR	10.3	6.7
Th	NA	91.4	15.0	7.7
Ti	111.4	NR	149	80.3
Tl	126.0	98.0	60.4	21.5
U	NA	96.9	8.6	6.7
V	109.3	97.3	53.3	26.4
Zn	106.4	143.0	17.7	10.3
Fluoride	NR	NR	11.3	NR
Chloride	NA	97.8	1.3	0.5
Nitrate	95.1	99.9	<PQL	<PQL
Phosphate	95.3	97.2	<PQL	<PQL
Sulfate	85.4	97.2	7.3	4.1

[a] NR = Sample result greater than 4 times the spike added, therefore spike recovery not reported.
[b] NA = Certified value not available. For chloride the certified value is less than the detection limit.
[c] <PQL = All sample results were less than the PQL therefore a +/- PQL control limit is used in place of the 20% RPD limit.

Table K5. Summary of Batch Quality Control Results for Surface Waters

Analyte	Average Certified Reference Material Recovery (%Recovery)	Average Matrix Spike Recovery (%Recovery)	Maximum Duplicate Precision (%Relative Percent Difference)	Average Duplicate Precision (%Relative Percent Difference)
Ag	114.1	99.1	[a]<PQL	<PQL
Al	97.7	101.2	<PQL	<PQL
As	89.6	96.7	<PQL	<PQL
Ba	93.7	101.0	15.0	4.1
Be	95.8	106.3	<PQL	<PQL
Ca	82.0	90.0	5.0	2.2
Cd	97.7	99.7	<PQL	<PQL
Ce	101.2	106.2	<PQL	<PQL
Co	100.8	89.1	<PQL	<PQL
Cr	101.7	84.8	<PQL	<PQL
Cu	97.4	84.1	<PQL	<PQL
Dy	98.1	111.3	<PQL	<PQL
Er	101.0	112.6	<PQL	<PQL
Eu	97.6	107.2	<PQL	<PQL
Fe	96.8	89.1	<PQL	<PQL
Gd	101.2	107.2	<PQL	<PQL
Hg	98.0	106.6	13.2	13.2
K	99.0	97.7	16.6	3.6
La	101.2	105.1	<PQL	<PQL
Li	99.2	116.0	13.7	3.5
Mg	98.0	97.7	3.6	2.0
Mn	101.1	93.4	16.0	4.5
Mo	105.7	106.9	24.3	7.5
Na	90.7	93.3	4.0	2.0
Nd	98.6	105.2	<PQL	<PQL
Ni	102.2	83.3	<PQL	<PQL
Pb	98.8	87.4	<PQL	<PQL
Pr	104.0	109.0	<PQL	<PQL
Sb	100.7	100.3	<PQL	<PQL
Sc	88.5	85.6	5.6	3.2
Se	105.4	100.6	<PQL	<PQL
Si	[b]NA	NA	<PQL	<PQL
Sm	99.9	106.9	<PQL	<PQL
Sn	97.5	96.3	<PQL	<PQL

Table continued on next page

Table K5. Summary of Batch Quality Control Results for Surface Waters (Cont.)

Analyte	Average Certified Reference Material Recovery (%Recovery)	Average Matrix Spike Recovery (%Recovery)	Maximum Duplicate Precision (%Relative Percent Difference)	Average Duplicate Precision (%Relative Percent Difference)
Sr	95.5	94.8	6.1	2.6
Th	99.6	92.2	<PQL	<PQL
Ti	121.1	112.9	<PQL	<PQL
Tl	98.2	89.0	<PQL	<PQL
U	99.3	88.5	18.0	4.1
V	102.4	92.5	6.6	5.8
Zn	71.2	89.3	<PQL	<PQL
Fluoride	98.5	100.3	21.9	8.3
Chloride	93.0	91.1	2.8	1.9
Nitrate	95.5	98.2	<PQL	<PQL
Phosphate	97.0	98.7	<PQL	<PQL
Sulfate	90.2	90.2	2.9	2.0

[a] <PQL = All sample results were less than the PQL therefore a +/- PQL control limit is used in place of the 20% RPD limit.
[b] NA = Certified value not available.

Table K6. 2001 Method Detection Limits for Analyses by AAS

Instrument	Analyte	[a]Units	2001 Method Detection Limit		
			Air Filter	Water	Soil: Acid Extract
AAS ([b]GF)	As	ppb	1.3	1.0	0.45
	Se	ppb	1.1	1.0	0.94

[a] Units: ppb = parts per billion

[b] GF = graphite furnace

Table K7. Method Detection Limits for Analyses by Ion Chromatography

Sample Matrix	Units	Unit Type	Fluoride	Chloride	Nitrite	Nitrate	Phosphate	Sulfate
[a]Drinking water and surface water	$\mu g\ L^{-1}$	General	68	80	[b]NR	45	36	35
[c]Soil and Sediment	$\mu g\ L^{-1}$	General	68	80	39.0	45	36	35

[a] Water samples are analyzed by direct injection

[b] NR = not reported

[c] 1 g of solid material extracted into 10 mL ultrapure water

Table K8. 2001 Method Detection Limits for Analyses by ICP-MS

Analyte	**[a] Drinking Water (µg L^{-1})**	**[b] Surface Water (µg L^{-1})**	**[c] Air Filter (µg L^{-1})**	**[d] Soil/Sediment (µg L^{-1})**
Ag	1.40E-02	3.20E-02	1.33E-02	2.24E-02
Al	1.00E+00	1.90E+01	1.15E+01	2.12E+02
Ba	5.90E-02	1.70E-01	3.36E-01	3.15E+00
Be	9.80E-02	2.10E-01	7.37E-02	1.19E-01
Ca	2.00E+01	9.30E+01	2.77E+01	4.91E+02
Cd	1.00E-01	3.10E-02	4.13E-02	2.15E-01
Ce	3.00E-03	2.30E-02	6.99E-03	1.65E-01
Co	7.30E-02	9.00E-02	7.05E-02	2.02E-02
Cr	1.10E-01	2.00E+00	2.63E+00	7.62E-01
Cu	5.00E-02	2.00E+00	4.47E-01	2.45E+00
Dy	3.00E-03	5.00E-03	4.60E-03	1.09E-02
Er	7.00E-03	5.00E-03	8.01E-03	1.36E-02
Eu	4.00E-03	5.00E-03	6.61E-03	6.52E-03
Fe	1.00E+01	1.80E+01	2.90E+01	3.53E+01
Gd	1.10E-02	5.00E-03	8.31E-03	1.22E-02
Hg	1.00E-02	1.00E-02	2.45E-02	1.00E-02
K	1.00E+02	1.10E+01	2.08E+01	2.36E+01
La	1.00E-02	5.40E-02	1.50E-01	3.45E+00
Li	2.60E-01	1.60E-01	1.26E-01	1.42E-01
Mg	2.00E+00	2.30E+00	1.23E+01	9.64E+00
Mn	2.00E-02	1.90E-01	3.78E-01	4.45E-01
Mo	2.00E-01	6.70E-02	1.07E-01	1.10E-01
Na	1.00E+00	1.60E+01	4.77E+01	9.19E+01
Nd	5.00E-03	5.20E-02	6.67E-03	1.19E-01
Ni	1.20E-01	2.00E+00	6.28E-01	1.28E+01
Pb	1.50E-02	2.00E-01	4.27E-02	3.00E-01
Pr	3.00E-03	5.00E-03	4.02E-03	1.57E-02
Sb	6.10E-02	2.50E-02	3.83E-02	1.33E-01
Sc	6.30E-02	1.00E-01	7.64E-02	1.81E-01
Si	1.00E+02	5.00E+02	9.60E+01	2.92E+02
Sm	1.20E-02	2.40E-02	7.54E-03	5.82E-02
Sn	3.80E-02	2.00E+00	1.00E+01	5.11E+00
Sr	8.00E-03	9.30E-01	6.82E-02	3.25E+00
Th	1.00E-02	5.00E-03	3.23E-03	3.98E-02
Ti	2.00E-01	2.00E+00	4.02E+00	2.02E+00
Tl	2.00E-02	1.10E-02	3.67E-03	2.96E-02
U	2.00E-03	5.00E-03	5.08E-03	2.27E-02
V	6.60E-02	2.60E-01	9.04E-01	1.49E+00
Zn	2.60E-01	5.00E+00	2.57E+00	1.03E+02

[a] Drinking Water samples are analyzed by direct injection.
[b] Surface Water samples are microwave digested using 45ml of sample and 5 ml of ultrapure nitric acid.
[c] Air Filter samples are extracted with nitric, hydrochloric and hydrofluoric acid and brought to 50 ml.
[d] 0.5 g of solid material extracted with nitric and hydrochloric acid and brought to 50 mL.

Table K9. Summary of Participation in Environmental Chemistry Performance Evaluation Testing

Analyte	[a]Method Description	[b]WP-71 % Bias	[c]Performance Evaluation	[d]WS-58 % Bias	[c]Performance Evaluation
Aluminum	200.8	6.7	Acceptable	-6.3	Acceptable
Antimony	200.8	-0.8	Acceptable	-2.0	Acceptable
Arsenic	7060	8.3	Acceptable	3.2	Acceptable
Barium	200.8	-5.7	Acceptable	-1.3	Acceptable
Beryllium	200.8	-2.7	Acceptable	2.2	Acceptable
Cadmium	200.8	1.7	Acceptable	-0.4	Acceptable
Chromium	200.8	-3.5	Acceptable	-2.2	Acceptable
Cobalt	200.8	1.5	Acceptable	[e]NA	
Copper	300.0	-0.5	Acceptable	1.9	Acceptable
Iron	200.8	-4.9	Acceptable	0.0	Acceptable
Lead	200.8	3.3	Acceptable	1.0	Acceptable
Manganese	200.8	-3.9	Acceptable	-1.6	Acceptable
Molybdenum	200.8	-1.2	Acceptable	-0.1	Acceptable
Nickel	200.8	-0.9	Acceptable	-1.7	Acceptable
Selenium	7740	15.0	Acceptable	-3.9	Acceptable
Silver	200.8	1.6	Acceptable	7.8	Acceptable
Strontium	200.8	0.0	Acceptable	NA	
Thallium	200.8	6.5	Acceptable	2.6	Acceptable
Vanadium	200.8	-5.7	Acceptable	-2.3	Acceptable
Zinc	200.8	0.5	Acceptable	-1.8	Acceptable
Mercury	245.2	-16.2	Acceptable	-13.9	Acceptable
Potassium	300.0	-6.4	Acceptable	5.0	Acceptable
Sodium	200.8	-5.5	Acceptable	-10.6	Not Acceptable
Calcium	200.8	-10.7	Warning	-13.3	Not Acceptable
Magnesium	200.8	-11.0	Warning	-6.9	Acceptable
Chloride	300.0	-3.2	Acceptable	-6.3	Acceptable
Fluoride	300.0	-10.6	Warning	-12.6	Not Acceptable
Nitrate-N	300.0	-5.1	Acceptable	6.7	Acceptable
Phosphate	300.0	15.2	Warning	3.1	Acceptable
Sulfate	300.0	4.4	Acceptable	-11.4	Acceptable

[a] The method description number corresponds to the EPA standard testing method used.

[b] The testing program used was the Environmental Resource Associates InterLaB WatR™ Pollution WP-71 Proficiency Testing Program.

[c] Definitions:

Acceptable: reported value falls within the acceptance limits.
Not Acceptable: reported value falls outside acceptance limits.
Warning (Check for Error): reported value falls within acceptance limits and outside of warning limits.

[d] The testing program used was the Environmental Resource Associates InterLaB WatR™ Supply WS-58 Proficiency Testing Program.

[e] NA = Certified value not available.

Appendix L. Quality Assurance/Quality Control for Radioanalyses

The CEMRC radioanalytical program continued to improve existing methodologies throughout 2001. Column chemistry modifications were implemented to improve consistency of chemical recoveries. For soil, thorium and uranium analysis was performed separately from americium and plutonium, resulting in a Pu/Am sample aliquot increase from 10 grams to 15 grams. For high-volume air filters, improvements were made to more efficiently remove interfering ^{210}Po from the sample. For high-volume air filters and the FAS quarterly composites, ^{241}Pu analysis was implemented. A revised methodology for synthetic urine was implemented that increased plutonium chemical yields. QA activities in 2001 were essentially the same as they were for 2000.

Routine activities conducted for radioanalyses include tracking and verification of analytical instrument performance, use of American Chemical Society certified reagents, use of American Society for Testing and Materials (ASTM) Type II water for reagent preparations, 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 Analytics. During methodology improvements for high-volume air filters, ^{209}Po was added to the Am portion of the sample after chemical separation, but before purification. The ^{209}Po was used to ensure that ^{210}Po, a naturally occurring radionuclide that can interfere with the ^{243}Am tracer, was chemically removed from the sample.

Daily (or each time the system is was used) control checks were performed on all nuclear counting instrumentation. The type of instrument and methods used for performance checks were as follows. For the Tennelec LB4100 gas-flow, α/β proportional counter used for the FAS program, efficiency control charting was performed using ^{239}Pu and ^{90}Sr check standards 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. For the Protean IPC-9025 gas-flow, α/β proportional counter used for other measurements, including ^{234}Th tracer recoveries for isotopic thorium analysis, efficiency control charting was performed using ^{239}Pu and ^{99}Tc check standards along with ensuring that α/β cross-talk was within limits. Sixty-minute background counts were recorded daily. For the Wallac Guardian 1414 liquid scintillation counter used for ^{241}Pu measurements, efficiency and centroid control charting was performed using ^{3}H and ^{14}C check standards. Fifty-minute background counts were recorded daily. Blanks counted for 12 hours were used as a background history for calculating results. Efficiency, resolution and centroid control charting were performed using ^{152}Eu check standards for the Canberra high purity germanium (HPGe) gamma detectors used for drinking water, surface water, soil, sediment and FAS samples. 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 used for all media, efficiency, resolution and centroid control charting was performed using ^{148}Gd check standards 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 the fall of 2000 and the spring of 2001, the CEMRC radioanalytical program participated in two rounds of the DOE Environmental Measurements Laboratory Quality Assurance Program (EML QAP), resulting in "acceptable" ratings for 67 individual determinations of 19 analytes in glass fiber filters, soil, vegetation and water samples (Table L1). Four "not acceptable" ratings in the fall of 2000 for uranium in the air filter and water were due to sample switching during the final sample mounting process. When recalculated with the correct tracer amount and sample aliquot, the uranium results would have passed criteria. The "warning" ratings in the spring of 2001 received for ^{212}Pb, ^{214}Pb and ^{214}Bi in soil were due to negative bias whose results overlap EML's results at the 95% confidence interval. The "warning" ratings in the spring of 2001 received for ^{238}Pu and ^{239,240}Pu in water were due to a positive bias whose results do not overlap at the 95% confidence interval but do overlap at the 99.9% confidence interval.

The radioanalytical program also participated in four rounds of the NIST Radiochemistry Intercomparison Program (NRIP). The four analytes typically measured by CEMRC in this program were ^{241}Am, ^{238}Pu, ^{239,240}Pu, and ^{238}U in soil, glass fiber filters, water and synthetic urine. For soil, CEMRC did not submit ^{241}Am data due to chemistry difficulties and therefore was not issued a traceability report. Also, for ^{239,240}Pu in water a traceability report was not received as CEMRC did not submit data for this nuclide due to the low concentration detected. For all other analytes of soil, filters, water and synthetic urine CEMRC received traceability (Table L2).

Blanks are assigned to sample batches to identify possible contamination or interference carried through the analytical process. Blanks constituted at least 10% of the sample load and consisted of laboratory reagent blanks and matrix blanks. Matrix blanks employed a medium as close as possible to that of the sample matrix that had been verified free of the radioanalytes of interest. Laboratory reagent blanks were used when no suitable matrix blank was available, and they consisted of major inorganic constituents known to compose the sample matrix. Results for blank measurements (Table L3) showed three Am/Pu blanks above MDC. Two of these blanks were slightly affected by cross contamination from higher activity performance samples but this was a small fraction of the sample activity. The third blank was from a FAS quarterly composite batch where an additional blank analyzed at the same time and the composite sample itself all had concentrations below MDC.

The most common source of detectable ^{234}U activity in blanks when ^{238}U was not detected is the spectral tailing of ^{232}U into the ^{234}U region of interest. When ^{238}U was also detected, uranium contamination had most likely occurred. Uranium contamination in blanks for soil, sediment, water and low volume air filters was a small fraction of the sample activities and was most likely due to slight cross contamination. Detectable ^{228}Th activity in blanks can be attributed to the addition of ^{232}U tracer to the sample. Due to the amount of time required for U to be chemically separated from Th during sample preparation, ^{228}Th ingrowth produces a small amount of ^{228}Th impurity in the sample. The ^{228}Th results are mathematically corrected for this ingrowth. In addition, some small amount of ^{228}Th impurity may be present in the ^{232}U tracer due to incomplete tracer purification. A correction is not made for this impurity which was usually the cause of ^{228}Th blank contamination when ^{230}Th and ^{232}Th were not detected. When ^{230}Th and/or ^{232}Th were also detected, Th contamination had most likely occurred. Thorium contamination in blanks for soil and sediment was at most 3% of the sample activities and was most likely due to slight cross contamination.

Isotopic tracers were used to determine the analytical system's effectiveness in extracting, purifying, and quantifying the isotopes of interest. For all media, Pu average tracer yields ranged from 66% to 95% (Table L4). The 80% average Pu yield for water was an improvement from last year's 47%. Average Pu yields for the other media remained similar to 2000 values. For all media, Am average tracer yields ranged from 65% to 89%. The 88% average Am yield for soil/sediment was an improvement from last year's 66%. There was a decrease in average Am yields for the FAS quarterly composite and high-volume air filters analysis. Average Am yields for the other media remained similar to 2000 values. For all media, U average tracer yields ranged from 41% to 85%. The 85% average U yield for soil/sediment was an improvement from last year's 58%. There was a decrease in average U yields for low volume air filters, and similar average yields for remaining media. For all media, Th average tracer yields ranged from 73% to 91%. The 91% average Th yield for soil/sediment was an improvement from last year's 69%. Average Th yields for the other media remained similar to 2000 values. For 2001, only 1 reported chemical yield is was less than 20%, compared to 27 yields less than 20% reported in 2000.

Analyses of laboratory duplicates (aliquots of the same sample analyzed separately) were used to estimate precision, which is analyte- and matrix-specific (Table L5). Duplicates constituted approximately 5% of the sample load for WIPP EM soil analyses. The mean relative percent difference (RPD) between radionuclide concentrations in laboratory duplicate WIPP EM soil samples was greatest for $^{239, 240}$Pu, ^{241}Am and ^{235}U. This was because the RPD does not reflect total uncertainty, which was greatest for these analytes due to larger counting uncertainty from low sample concentration. For these analytes, RPD should be interpreted in comparison to the relative error ratio (RER), which incorporates total uncertainty. For example, although the maximum RPD for ^{241}Am was somewhat elevated at 19%, the maximum RER was low (0.8), reflecting the relatively high counting uncertainty resulting from the low activity concentrations of ^{241}Am in the samples. All replicate concentrations overlapped at the 95% confidence interval. For six of eight analytes, the maximum RPDs and RERs for WIPP EM soil analyses in 2001 were lower than those reported for analyses during 2000.

Analyses of matrix spike samples were used to test the effectiveness of the analytical procedure to accurately quantify the analyte of interest (Table L6). Matrix spikes constituted approximately 5% of the sample load. For water analyses, NIST traceable ^{238}Pu, ^{239}Pu, ^{241}Am, ^{238}U and ^{230}Th liquid standards were spiked into 3 L of ASTM Type II water. For air filter analyses, NIST traceable ^{238}Pu, ^{239}Pu and ^{241}Am was spiked onto blank air filters. For soil/sediment analyses, EML QAP soil was used as the matrix spike. One water matrix spike had a negative bias for ^{238}Pu, ^{239}Pu and ^{230}Th and did not meet ANSI N42.22 criteria. Despite this, all values for ^{238}Pu, ^{239,240}Pu and ^{230}Th measured in the surface water and drinking water samples were well below MDC, eliminating any effect of the bias. ANSI N42.22 criteria were met for all other matrix spikes during WIPP EM analyses.

Table L1. Participation in Environmental Measurements Laboratory Quality Assurance Program

Media	Radionuclide	[a]Percent Bias QAP-53	[b] Results QAP-53	Percent Bias QAP-54	Results QAP-54
Air Filter	^{241}Am	-6.3	Acceptable	0.8	Acceptable
	^{57}Co	6.5	Acceptable	[c]NA	NA
	^{60}Co	7.9	Acceptable	-1.7	Acceptable
	^{134}Cs	NA	NA	1.8	Acceptable
	^{137}Cs	10.7	Acceptable	-0.7	Acceptable
	^{54}Mn	8.8	Acceptable	-1.8	Acceptable
	^{238}Pu	-11.1	Acceptable	2.3	Acceptable
	^{239,240}Pu	-5.4	Acceptable	5.1	Acceptable
	^{234}U	217	Not Acceptable	0.0	Acceptable
	^{238}U	120	Not Acceptable	0.0	Acceptable
Soil	^{228}Ac	4.7	Acceptable	-4.0	Acceptable
	^{241}Am	10.0	Acceptable	-1.4	Acceptable
	^{212}Bi	4.3	Acceptable	-16.7	Acceptable
	^{214}Bi	0.8	Acceptable	-14.1	Warning
	^{137}Cs	-2.0	Acceptable	-8.1	Acceptable
	^{40}K	-2.4	Acceptable	-8.1	Acceptable
	^{212}Pb	0.9	Acceptable	-10.8	Warning
	^{214}Pb	-1.5	Acceptable	-15.5	Warning
	^{238}Pu	1.0	Acceptable	9.9	Acceptable
	^{239,240}Pu	0.0	Acceptable	-3.5	Acceptable
	^{234}U	-7.0	Acceptable	-5.0	Acceptable
	^{238}U	-6.7	Acceptable	-6.5	Acceptable
Vegetation	^{241}Am	14.3	Acceptable	19.9	Acceptable
	^{244}Cm	0.0	Acceptable	0.3	Acceptable
	^{60}Co	0.6	Acceptable	5.3	Acceptable
	^{137}Cs	0.5	Acceptable	1.4	Acceptable
	^{40}K	-4.5	Acceptable	1.7	Acceptable
	^{238}Pu	2.9	Acceptable	-10.6	Acceptable
	^{239,240}Pu	-10.4	Acceptable	-14.4	Acceptable
Water	^{241}Am	2.5	Acceptable	21.0	Acceptable
	^{60}Co	-2.3	Acceptable	2.9	Acceptable
	^{137}Cs	-3.0	Acceptable	2.7	Acceptable
	Gross Alpha	3.0	Acceptable	2.5	Acceptable
	Gross Beta	-9.6	Acceptable	-5.6	Acceptable
	^{238}Pu	-3.3	Acceptable	17.1	Warning
	^{239,240}Pu	-0.2	Acceptable	17.7	Warning
	^{234}U	-66.7	Not Acceptable	12.5	Acceptable
	^{238}U	-56.5	Not Acceptable	11.5	Acceptable

[a] Percent bias is calculated as the CEMRC measured value minus the EML known value, expressed as a percentage relative to the known value

[b] Results for EML QAP “acceptable” are defined in Report EML-611, December 2000 for QAP-53 and in Report EML-613, June 2001 for QAP-54

[c] NA = not applicable, radionuclide was not present in sample

Table L2. Participation in NIST Radiochemistry Intercomparison Program

Media	Radionuclide	[a]Percent Bias	[b]Results
Soil 2000	^{241}Am	[c]NR	NR
	^{238}Pu	1.8	[d]NIST Traceable, 15%
	^{239,240}Pu	3.9	NIST Traceable, 11%
	^{238}U	-0.1	NIST Traceable, 30%
Air Filter 2001	^{241}Am	5.5	NIST Traceable, 10%
	^{238}Pu	0.5	NIST Traceable, 7%
	^{239,240}Pu	-0.3	NIST Traceable, 11%
	^{238}U	1.5	NIST Traceable, 10%
Water 2001	^{241}Am	1.1	NIST Traceable, 9%
	^{238}Pu	-0.2	NIST Traceable, 11%
	^{239,240}Pu	NR	NR
	^{238}U	-0.9	NIST Traceable, 9%
Synthetic Urine 2001	^{241}Am	2.2	NIST Traceable, 6%
	^{238}Pu	1.6	NIST Traceable, 5%
	^{239,240}Pu	0.5	NIST Traceable, 4%
	^{238}U	2.7	NIST Traceable, 3%

[a] Percent bias is calculated as the CEMRC measured value minus the NIST known value, expressed as a percentage relative to the known value

[b] Results and traceability limit (expressed in percent) for NIST Traceablity are defined under ANSI 42.22

[c] NR = not reported, nuclide was part of program but not reported

[d] ANSI N42.22 defines the acceptance criteria for traceability to NIST for performance testing as:

$$\left| V_C - V_N \right| < \overbrace{3 \times \sqrt{\sigma_C{}^2 + \sigma_N{}^2}}^{\text{Traceability Limit}}$$

V_C = CEMRC Value
V_N = NIST Value
σ_C = 1 sigma total uncertainty of V_C
σ_N= 1 sigma total uncertainty of V_N

Table L3. Results for Radioanalyses of Actinides in Blank Samples

Parameter	Analyte and Media								
	^{238}Pu	^{239,240}Pu	^{241}Am	^{234}U	^{235}U	^{238}U	^{228}Th	^{230}Th	^{232}Th
Soil/Sediment (WIPP EM 2001, NRIP-2000, EML QAP 53 & 54)									
[a]N	11	11	9	10	10	10	7	7	7
[b]N >[c] MDC	0	1	0	8	3	6	5	1	2
[d]Minimum (mBq kg^{-1})	[e]NA	47	NA	160	116	215	228	200	119
[f]Maximum (mBq kg^{-1})	NA	NA	NA	1269	303	446	418	NA	144
Water (WIPP EM 2001 Drinking & Surface, NRIP-2001, EML QAP 53 & 54)									
N	7	7	7	7	7	7	5	5	5
N > MDC	0	0	0	4	1	2	4	0	0
Minimum (µBq L^{-1})	NA	NA	NA	102	696	129	124	NA	NA
Maximum (µBq L^{-1})	NA	NA	NA	6970	NA	1207	507	NA	NA
FAS Quarterly Composite Filters (September 2000 to June 2001)									
N	8	8	8	8	8	8	7	7	7
N > MDC	1	0	0	2	0	0	0	0	0
Minimum (µBq)	633	NA	NA	365	NA	NA	NA	NA	NA
Maximum (µBq)	NA	NA	NA	588	NA	NA	NA	NA	NA
Low-Volume Air Filters (2001 FAS Incident Filters, NRIP-2001, EML QAP 53 & 54)									
N	5	5	5	3	3	3	0	0	0
N > MDC	0	1	0	2	1	2	0	0	0
Minimum (µBq)	NA	253	NA	841	374	753	NA	NA	NA
Maximum (µBq)	NA	NA	NA	2013	NA	2370	NA	NA	NA
High-Volume Air Filters (WIPP EM September 2000 to June 2001)									
N	7	7	7	0	0	0	0	0	0
N > MDC	0	0	0	NA	NA	NA	NA	NA	NA
Minimum (µBq)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Maximum (µBq)	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table continued on next page

Table L3. Results for Radioanalyses of Actinides in Blank Samples (Cont.)

Parameter	Analyte and Media								
	^{238}Pu	^{239,240}Pu	^{241}Am	^{234}U	^{235}U	^{238}U	^{228}Th	^{230}Th	^{232}Th
Vegetation (EML QAP 53 & 54)									
N	2	2	2	0	0	0	0	0	0
N > MDC	0	0	0	NA	NA	NA	NA	NA	NA
Lovelace Pu Determination in Dissolved Filters									
N	11	11	0	0	0	0	0	0	0
N > MDC	0	0	NA	NA	NA	NA	NA	NA	NA

[a] Number of blanks analyzed

[b] Number of blank samples with values greater than MDC (minimum detectable concentration)

[e] MDC in < 2 blanks

[d] Minimum activity/activity concentration observed in blanks > MDC

[e] NA = not applicable, the analysis of the analyte is not required for this media or not applicable for isotopes measured above

[f] Maximum activity/activity concentration observed in blanks > MDC

Table L4. Laboratory Tracer Recovery Results for Radioanalyses of Actinides

Media Group (includes internal QA)	Parameter	[a]Tracer Recovery by Analyte			
		Pu	Am	U	Th
Soil/Sediment WIPP EM 2001 NRIP 2000 EML QAP 53 & 54	[b]N	84	75	83	70
	[c]Mean (%)	67	88	85	91
	[d]Minimum (%)	31	56	32	35
	[e]Maximum (%)	92	98	102	101
Water WIPP EM 2001 NRIP 2001 EML QAP 53 & 54	N	48	48	48	34
	Mean (%)	80	89	67	93
	Minimum (%)	24	60	31	81
	Maximum (%)	97	99	88	102
FAS Quarterly Composite Filters September 2000 to June 2001	N	16	16	15	14
	Mean (%)	75	65	65	73
	Minimum (%)	51	24	40	56
	Maximum (%)	96	91	82	92
Low-Volume Air Filters FAS Incident 2001 NRIP 2001 EML QAP 53 & 54	N	19	19	12	[f]NA
	Mean (%)	74	87	41	NA
	Minimum (%)	64	65	19	NA
	Maximum (%)	96	100	87	NA
High-Volume Air Filters WIPP EM September 2000 to June 2001	N	48	49	NA	NA
	Mean (%)	66	74	NA	NA
	Minimum (%)	41	33	NA	NA
	Maximum (%)	87	101	NA	NA
Vegetation EML QAP 53 & 54	N	6	6	NA	NA
	Mean (%)	76	80	NA	NA
	Minimum (%)	71	65	NA	NA
	Maximum (%)	92	95	NA	NA
Dissolved Filters Lovelace 2001 project	N	109	NA	NA	NA
	Mean (%)	95	NA	NA	NA
	Minimum (%)	88	NA	NA	NA
	Maximum (%)	102	NA	NA	NA

[a] Tracer = an isotope of the radionuclide of interest, that is distinguishable from the analyte of interest, but assumed to behave the same in radiochemical processes

[b] N = number of samples included in each analysis

[c] Mean tracer percent yield

[d] Minimum observed tracer percent yield from all analyses

[e] Maximum observed tracer percent yield from all analyses

[f] NA = not applicable, the analysis of the analyte is not required for this media

Table L5. Results of Radioanalyses of Actinides in Replicate Soil Samples

Parameter	**Replicate Results by Analyte**								
	^{238}Pu	**^{239,240}Pu**	**^{241}Am**	**^{234}U**	**^{235}U**	**^{238}U**	**^{228}Th**	**^{230}Th**	**^{232}Th**
[a]N > MDC	0	2	2	2	2	2	2	2	2
[b]Mean RPD (%)	[c]NA	18.4	9.7	3.6	23.6	4.1	4.0	3.7	2.5
[d]Maximum RPD (%)	NA	20.2	19.0	4.1	34.4	5.0	6.7	4.8	4.3
[e]Mean RER	NA	1.49	0.41	0.88	1.22	0.99	1.03	0.99	0.69
[f]Maximum RER	NA	1.50	0.80	0.94	1.68	1.15	1.68	1.25	1.22

[a]Number of replicate sample pairs > MDC for subject analyte

[b]Mean relative percent difference (RPD); RPD defined as the absolute value of the difference between the analyte concentration in the first sample (a) and the concentration in the second sample (b), divided by the average of the two concentrations ($\bar{x}$) and expressed as a percent

[c]NA = not applicable; no measurements were > MDC

[d]Maximum relative percent difference (RPD)

[e]Mean relative error ratio (RER); RER defined as the absolute value of the difference between the analyte concentration in the first sample (a) and the concentration in the second sample (b), divided by the quadratic sum of the total uncertainty of the first sample (σ_a) and the second sample (σ_b)

[f]Maximum relative error ratio (RER)

$$RPD = \frac{|a-b|}{\bar{x}} \times 100\,\% \qquad RER = \frac{|a-b|}{\sqrt{\sigma_a{}^2 + \sigma_b{}^2}}$$

Table L6. Ranges of Bias as Measured by Matrix Spikes in Radioanalyses of Actinides

Media Group	**Parameter**	**[a]Percent Bias between Measured and Known Values by Analyte**								
		^{238}Pu	**^{239,240}Pu**	**^{241}Am**	**^{234}U**	**^{235}U**	**^{238}U**	**^{228}Th**	**^{230}Th**	**^{232}Th**
Soil/ Sediment WIPP EM 2001	[b]N	6	6	5	5	[c]NA	5	3	NA	2
	[d]Minimum	-18.8	-4.5	3.7	-6.3	NA	-6.4	-0.3	NA	-2.1
	[e]Maximum	4.7	0.5	11.4	-1.5	NA	-1.6	2.9	NA	-1.8
	[f] % Meeting ANSI N42.22	100	100	100	100	NA	100	100	NA	100
Water WIPP EM 2001	N	3	3	3	NA	NA	3	NA	3	NA
	Minimum	-13.2	-11.1	-6.7	NA	NA	-1.1	NA	-38.4	NA
	Maximum	1.6	0.0	-1.3	NA	NA	0.9	NA	-2.4	NA
	% Meeting ANSI N42.22	67	67	100	NA	NA	100	NA	67	NA
FAS Quarterly Composite Filters September 2000 to June 2001	N	1	4	4	NA	NA	4	NA	4	NA
	Minimum	2.4	-3.5	-2.9	NA	NA	-0.7	NA	-3.0	NA
	Maximum	NA	-2.0	3.9	NA	NA	5.8	NA	2.7	NA
	% Meeting ANSI N42.22	100	100	100	NA	NA	100	NA	100	NA
High-Volume Air Filters WIPP EM September 2000 to June 2001	N	2	5	6	NA	NA	NA	NA	NA	NA
	Minimum	0	-6.8	-3.1	NA	NA	NA	NA	NA	NA
	Maximum	3.8	-0.1	6.8	NA	NA	NA	NA	NA	NA
	% Meeting ANSI N42.22 Criteria	100	100	100	NA	NA	NA	NA	NA	NA
Dissolved Filters Lovelace 2001 project	N	NA	5	NA	NA	NA	NA	NA	NA	NA
	Minimum	NA	-9.6	NA	NA	NA	NA	NA	NA	NA
	Maximum	NA	3.5	NA	NA	NA	NA	NA	NA	NA
	% Meeting ANSI N42.22 Criteria	NA	100	NA	NA	NA	NA	NA	NA	NA

[a] Percent bias is the difference between the measured value and the known value for a matrix spike, expressed as a percent relative to the known value

[b] N = number of matrix spikes for each analytical group

[c] NA = not applicable; no matrix spike used for the subject radionuclide

[d] Minimum observed bias

[e] Maximum observed bias

[f] ANSI N42.22 criteria for the acceptance of testing results where the absolute value of the bias between the measured value (Vm) and the known value (Vn) shall be less than or equal to three times the propagated uncertainty of the measured value (σ_m) and the uncertainty of the known value (σ_n):

$$|Vm - Vn| \le 3 \times \sqrt{\sigma_m^{2} + \sigma_n^{2}}$$

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GLOSSARY

Aerosol - particles dispersed in a gas

Aliquot - a subsample drawn from a larger sample

alpha-emitting - producing ionizing radiation in the form of alpha particles

anthropogenic - referring to environmental alterations resulting from the presence or activities of humans

actinides - the series of radioactive elements that starts with actinium and ends with lawrencium

baseline (non-rad) - non-radioactive analyte conditions

baseline (rad) - radioactive analyte conditions

coefficient of variation - a statistical parameter that expresses standard deviation as a percentage of the mean, calculated as standard deviation divided by the mean, multiplied by 100

dosimetry - the measurement of radiation doses

gamma-emitting - producing ionizing radiation in the form of gamma rays

gross alpha - measurement of total number of alpha decays without specification of individual energies

in vivo - taking place within a living cell or organism

informatics - information management systems

monitoring (non-rad) - non-radioactive component monitoring

monitoring (rad) - radioactive component monitoring

photon - a massless particle, the quantum of the electromagnetic field, carrying energy, momentum and angular momentum

pyranometer – solar radiation sensor

radionuclide - a type of atom that loses particles and energy through decay or transformation into other elements

shield - cast iron or steel enclosure often used in conjunction with gamma detectors to reduce the influence of background radiation on measurements

spallation - a nuclear reaction in which several nucleons are released from the nucleus of an atom

standard deviation - a statistical parameter, calculated as the positive square root of the expected value of the square of the difference between a random variable and its mean

standard error - the standard deviation of the probability function or probability density function of a random variable and of a statistic; typically the standard deviation of the mean