

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, New Mexico, 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.

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 2000

Subcontractor	Scope of Work
Battelle Memorial Institute, Pacific Northwest Division	Fabrication of lung sets for <i>in vivo</i> bioassay
^a Texas A&M Experiment Station	Collection of aerosol samples
^a Electronic Counter Corporation	Instrument design & engineering
^a Texas A&M Research Foundation	Measurements of organic nitrogen in aerosol samples
National Institute of Standards & Technology	Intercomparison services for radioanalyses
Oak Ridge National Laboratory, Intercomparison Studies Program	Intercomparison services for <i>in vivo</i> radiobioassay
^a University of Rhode Island/Urszula Tomza	Neutron activation analysis, gamma-ray spectroscopy

^aCollaborative work not funded through CEMRP

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

Member/Term of Service	Affiliation
Stanley I. Auerbach, Ph.D. (PRB) / 1998-2000	Director Emeritus, Environmental Sciences Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee
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, Ph.D. (PRB) / 2000-present	Consultant, Envair/Aerochem President (past), Desert Research Institute, Las Vegas, Nevada
Gary H. Kramer, Ph.D. (SAB) / 2000-present	Head, Human Monitoring Laboratory, Radiation Protection Bureau, Health Canada, Ottawa, Ontario, Canada
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) / 1998-2000	Director Emeritus and Professor, Savannah River Ecology Laboratory, University of Georgia, Aiken, South Carolina
Shawki A. Ibrahim, Ph.D. (SAB) / 2000-present	Professor, Department of Radiological Health Sciences, Colorado State University, Ft. Collins, Colorado

Appendix D. Professional Presentations and Publications during 2000

Author	Title	Publisher/Conference
Arimoto, R.	Sources and composition of aerosol particles	Handbook of Atmospheric Chemistry, submitted
Arimoto, R.	Eolian dust and climate: relationships to sources, transport, and deposition	Earth Science Reviews, submitted
Arimoto, R., J. Greenlee, S. Sage, R. Okrasinski, C. Schloesslin and W. Gutman	Fugitive dust sampling and source characterization	2000 Southwest Center for Environmental Research and Policy Border Conference, Juarez, Mexico
Arimoto, R., A.S. Nottingham, J. Webb, and C.A. Schloesslin	Non-sea salt sulfate and other aerosol constituents at the South Pole during ISCAT	Geophysical Research Letters, submitted
Arimoto, R., W. Balsam and C.A. Schloesslin	Visible spectroscopy of atmospheric dust collected on filters: iron-bearing minerals	American Geophysical Union, Fall Meeting, San Francisco, California
Burnett, W.C., J. Christoff, B. Stewart, T. Winters and P. Wilbur	Reliable gross alpha-/beta-particle analysis of environmental samples via liquid scintillation counting	Radioactivity & Radiochemistry 11:26-44
Conley, M., R. Arimoto, T.B. Kirchner, L. Litinsky, D. Schoep, M. Walthall, J.L. Webb and S. B. Webb	Public access to environmental monitoring at waste sites – an experiment in progress	Waste Management 2000, Tucson, Arizona
Davis, D., M. Buhn, 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 Letters, submitted
Guelle, W., Y. Balkanski, M. Schulz, B. Marticorena, G. Bergametti, C. Moulin, R. Arimoto and K.D. Perry	Modeling the atmospheric distribution of mineral aerosol: comparison with ground measurements and satellite observations for yearly and synoptic time scales over the North Atlantic	Journal of Geophysical Research 105:1997-2012
Huang, S.R., R. Arimoto, and K.A. Rahn	Sources and source variations for aerosol at Mace Head, Ireland	Atmospheric Environment, in press
Johnson, S.R., D.D. Breshears and T.B. Kirchner	Multi-pathway, multi-site contaminant transport: assessing vertical migration, wind erosion and water erosion at semiarid DOE sites	45 th Annual Meeting Health Physics Society, Denver, Colorado

Table continued on next page

Appendix D. Professional Presentations and Publications during 2000 (Cont.)

Author	Title	Publisher/Conference
Kirchner, T.B.	Multi-pathway, multi-site contaminant transport: assessing vertical migration, wind erosion and water erosion at semiarid DOE sites	45 th Annual Meeting Health Physics Society, Denver, Colorado
Kirchner, T.B.	Evolutionary consequences of skewed body distributions of body size	Ecological Society of America, 85 th Annual Meeting, Snowbird, Utah
Kirchner, T.B.	Multi-pathway, multi-site contaminant transport: assessing vertical migration, wind erosion and water erosion at semiarid DOE sites	45 th Annual Meeting Health Physics Society, Denver, Colorado
Kirchner, T.B., J.L. Webb, S.B. Webb, R. Arimoto, D.A. Schoep and B. 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.H., M.A. 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 photo energy using a realistic torso phantom	Radiation Protection Dosimetry 92:323-327
Litinsky, L.	Environmental quality system development within the university structure	U.S. Environmental Protection Agency 19 th Annual National Conference on Managing Environmental Quality Systems, Albuquerque, New Mexico
Malek, M., T.G. Hinton and S.B. Webb	Comparative uptake pathways of ¹³⁷ Cs and ⁹⁰ Sr in cabbage grown near Chernobyl	Journal of Environmental Radioactivity, in press
Maring, H., D.L. Savoie, M.A. Izaguirre, C. McCormick, R. Arimoto, J.M. Prospero and C. Pilinis	Aerosol physical and optical properties and their relationship to aerosol composition in the free troposphere at Izana, Canary Island during July 1995	Journal of Geophysical Research 105:14677-14700
Orcutt, K.M., F. Lipshultz, K. Gundersen, R. Arimoto, A.F. Michaels, A.H. Knap and J.R. Gallon	Seasonal pattern and significance of N ₂ fixation by <i>Trichodesmium</i> spp. at the Bermuda Atlantic Time-series Study (BATS) site	Deep Sea Research II Special Issue: Nitrogen Fixation by <i>Trichodesmium</i> in the Sargasso Sea, in press
Schoep, D.A., J.L. Webb, R. Arimoto, T.B. Kirchner, S.B. Webb, P.M. Walthall and M.R. Conley	Monitoring of radioactive and inorganic aerosols in exhaust air released from the Waste Isolation Pilot Plant	45 th Annual Meeting, Health Physics Society, Denver, Colorado

Table continued on next page

Appendix D. Professional Presentations and Publications during 2000 (Cont.)

Author	Title	Publisher/Conference
Stegman, P.M., R. Arimoto, and U. Tomza	Correspondence between SeaWiFS-derived aerosol optical thickness and aerosol concentrations determined at surface sites in the North Atlantic	Journal of Geophysical Research, submitted
Tomza, U., R. Arimoto and B.J. Ray	Filter color as an indicator of aerosol composition	Atmospheric Environment, in press
Uematsu, M. and R. Arimoto	The East Asian/North Pacific Regional Experiment (APARE)	IGACTivities Newsletter 20:2-3
Webb, J. 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, in press
Webb, J., R. Nelson and D. Schoep	The effect of a 657-meter cosmic ray shield on <i>in vivo</i> measurement sensitivity for radionuclides deposited in lungs	Lung Counting Workshop, Idaho Falls, Idaho
Webb, J. 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	Lung Counting Workshop, Idaho Falls, Idaho
Webb, J. and T.B. Kirchner	An evaluation of <i>in vivo</i> sensitivity via public monitoring	Radiation Protection Dosimetry 89:183-191
Webb, J., M. Gadd, F. Bronsen and O. Tench	An evaluation of recent lung counting technology	Radiation Protection Dosimetry 89:325-332
Webb, J. 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	45 th Annual Meeting Health Physics Society, Denver, Colorado
Webb, S.B., S.A. Ibrahim, F.W. Whicker	Inventory estimate of ²³⁹ Pu in soils east of Rocky Flats, Colorado	Technology 7:497-507
Whicker, J.J., D.D. Breshears, P.T. Wasiolek, R. Tavani, D. Schoep and T.B. Kirchner	Effects of episodic high-wind events and fire on resuspension rates: measurements near the Waste Isolation Pilot Plant	45 th Annual Meeting Health Physics Society, Denver, Colorado
Zhang, X.Y., R. Arimoto, Z.S. An, J.J. Cao and D. Wang	Atmospheric dust aerosol over the Tibetan Plateau	Journal of Geophysical Research-Atmospheres, in press

Appendix E. Guest Colloquia

Topic	Presenter
Paleoclimatic interpretations of the Chinese loess sequence: evidence from changes in iron oxides	Bill Balsam, Professor, Geology, University of Texas at Arlington
Globalization and analytical needs for the 21 st century	Jon Broadway, Manager, International Corps on the Environment, Auburn University-Montgomery
Seeing the sun from deep underground (the physics of neutrinos from the nuclear reactions that power our sun and their detection)	Todd Haines, Los Alamos National Laboratory
Plutonium distribution and behavior in man and the environment: an overview	Shawki Ibrahim, Associate Professor, Radiological Health Sciences, Colorado State University
Easter red cedar expansion into native tallgrass prairie: patterns and processes	John Briggs, Associate Professor, Plant Biology, Arizona State University
Urban and regional air pollution: current research and future outlook	Judith Chow, Research Professor, Atmospheric Sciences Division, Desert Research Institute
Radiation resistance of concrete and of sodium chloride	Zbigniew Zagorski, Professor, Institute of Nuclear Chemistry and Technology, Warsaw, Poland
Distribution and effects of radioisotopes on small mammals at Chernobyl	Michael Smith, Director Emeritus and Professor, Savannah River Ecology Laboratory, University of Georgia,
Radiochemical procedures in use at IAEA Laboratories for anthropogenic alpha and beta-emitting radionuclides in environmental samples	Josue Moreno-Bermudez, Environmental Radiochemist, International Atomic Energy Agency, Seibersdorf, Austria
Aqueous diffusion in repository systems – the role of volumetric water	James Conca, Los Alamos National Laboratory/Carlsbad Operations
Monte Carlo simulations, how we can investigate the impossible	Gary Kramer, Head, Human Monitoring Laboratory, Radiation Protection Bureau, Health Canada
Chemical speciation of radionuclides in environmental samples from microspectroscopic techniques	Paul Bertsch, Director, Savannah River Ecology Laboratory, University of Georgia

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

Group/Activity
Next Generation U.S. Underground Science Facility Workshop participants - tour and presentation
National Central University, Chung-Li, Taiwan - invited lecture
NMSU Department of Fishery & Wildlife Sciences - invited seminars (2)
Carlsbad Altrusa Club - presentation and tour
Epsilon Sigma Alpha, Beta Rho Chapter - presentation and tour
Carlsbad Historical Society - presentation
Blodgett Street Baptist Adult Seniors program - presentation
American Association of University Women Senior Honors Luncheon - presentation
Winona State University (Winona, Minnesota) - invited seminar
16 th of September Celebration, Carlsbad - exhibit
Carlsbad Community Health and Safety Fair 2000 - exhibit
NMSU-Carlsbad Junior/Senior Day - presentation
NMSU-Carlsbad Career Expo 2000 - presentations
NMSU-Carlsbad Alliance for Minority Participation program - tour
Carlsbad Sportsman's Club - presentation and tour
Rotary Club of Carlsbad - presentation
Carlsbad Municipal Schools, Chihuahuan Desert Laboratory project - presentations and tours
Carlsbad Municipal Schools, Alta Vista Leyva Middle School, 6 th grade classes - tour and program
Carlsbad Municipal Schools, Sunset Elementary Science Fair - exhibit
Carlsbad Municipal Schools, Joe Stanley Smith Elementary Science Fair - exhibit
Carlsbad Municipal Schools, Pate Elementary Science Fair - exhibit
Universidad Autonoma de Juarez, Environmental Science students - presentation and tour
Nye County, Nevada city/county representatives - tour and presentation
American Association of University Women - presentation
Cochiti Pueblo Environmental Protection Office representatives - tour and presentation
Texas Wind Power Company (Austin, Texas) - provided wind measurement data from CEMRC
Japan Nuclear Fuel Ltd. and Japanese Aomori Prefectural Institute of Public Health and Environment representatives - tour and presentation
Border EcoWeb Internet site (www.borderecoweb.sdsu.edu) - section added featuring CEMRC

**Appendix G. Leadership Participation by CEMRC Staff
in Professional Functions**

Function	CEMRC Staff/Role
ACE-Asia	R. Arimoto, Member, Executive Committee
International Global Atmospheric Chemistry/Asia Pacific Regional Experiment, Tokyo, Japan	R. Arimoto, Member, Executive Committee and Technical Session Chair
American Geophysical Union, Journal of Geophysical Research-Atmospheres	R. Arimoto, Associate Editor
National Aeronautics and Space Administration, Transport and Chemical Evolution over the Pacific program, Washington, D.C.	R. Arimoto, Member, Review Panel
National Aeronautics and Space Administration	R. Arimoto, Recipient, Group Achievement Award as member of Global Tropospheric Experiment Pacific Exploratory Mission to the Western Pacific
Institute of Earth Environment, Xi'an, China	R. Arimoto, invited lecture "Atmospheric haze, dust fluxes and fine particle controls"
Korea Meteorological Administration, Seoul, Korea	R. Arimoto, invited lecture "ACE-Asia and aerosol characterization"
U.S. Geological Service Upper Midwest Environmental Sciences Center, LaCrosse, Wisconsin	M. Conley, invited lecture "Where environmental science and public information meet – an experiment in progress"
Applications of Probability and Statistics in Health Physics, Short Course, Ft. Collins, Colorado	T.B. Kirchner, invited lecture "Uncertainty analysis"
American National Standards Institute, HPS N13.25, Internal Dosimetry Programs for Plutonium Exposure – Minimum Requirements	J. Webb, Member, Standards Committee Working Group
45 th Annual Meeting Health Physics Society, Denver, Colorado	J. Webb, Chair, Technical Session
Health Canada, Environmental Health Directorate Radiation Protection Bureau	J. Webb, Technical Lead, Memorandum of Understanding for scientific cooperation
American Institute of Biological Sciences and U.S. Army Research and Materiel Command, Gulf War Related Illness research program, Toxicity of Militarily-Relevant Heavy Metals panel	S.B. Webb, Review Panel 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	Amended, in progress
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)	\$27,843, 1999-2001	Funded, in progress
Determination of Be and U in aqueous extracts of contaminated soils	R. Arimoto	NMSU Cooperative Fish and Wildlife Research Unit (with funding from DOE)	\$5,618, 1999-2000	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: multiphase chemical processing of Asian outflow air over the northwestern Pacific Ocean during spring	R. Arimoto (with Massachusetts Institute of Technology and others)	National Science Foundation	\$69,409, 2000-2002	Submitted, not funded
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	Submitted

Table continued on next page

Appendix H. New Project Development (Cont.)

Proposal/Bid Title	PI(s)	Sponsor	Funding/ Term	Status
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
Significance and suppression of air emissions from open-lot cattle-feeding facilities: a Great Plains research and technology-transfer partnership	R. Arimoto (with Texas Agricultural Extension Service and others)	U.S. Department of Agriculture	\$49,856, 2000-2002	Submitted, not funded
Determination of uranium content in human hair	R. Arimoto (with J. Webb)	Freeborn & Peters/Moye, Giles, O'Keefe, Vermire & Gorrell, LLP	\$8,500, 2000	Funded, in progress
Determination of nickel content in digested rodent lung tissue	R. Arimoto (with J. Webb)	Lovelace Respiratory Research Institute	\$4,600, 2000	Funded, in progress
Source identification for energy-related atmospheric pollution in the southwestern USA using a new technique-positive matrix factorization	R. Arimoto	New Mexico Institute of Mining and Technology (with proposed funding from DOE)	\$30,181, 2000-2001	Collaboration commitment submitted, not funded
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
Proposal to establish the U.S. Department of Energy Waste Isolation Pilot Plant Environmental Research Park	M. Conley	DOE/Carlsbad Area Office	No request for funding	Submitted
General Agreement to establish the National Cave & Karst Research Institute	M. Conley	U.S. Department of Interior National Park Service and NMSU	No funding	Adopted

Table continued on next page

Appendix H. New Project Development (Cont.)

Proposal/Bid Title	PI(s)	Sponsor	Funding/ Term	Status
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
Long-term risk from actinides in the environment II: assessment tools for mobility thresholds	T. Kirchner (with Los Alamos National Laboratory and others)	DOE Office of Environmental Management	\$95,998, 2000-2003	Submitted, not funded
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
Limnological monitoring: Brantley Dam Reservoir	M. Walthall	U.S. Department of Interior, Bureau of Reclamation	\$83,363, 1997-2003	Amended, in progress
Quarterly collection of environmental samples	M. Walthall (with J. Webb)	Envirocare of Texas, Inc.	\$9,102, 2000-2001	Submitted, not funded
Lung & whole body <i>in vivo</i> radiobioassay measurements	J. Webb	Waste Control Specialists, Inc.	\$233,414, 1997-2001	Amended, in progress
<i>In vivo</i> radiobioassay measurements for WIPP personnel	J. Webb	Westinghouse Electric Company	\$299,000, 1998-2001	Amended, in progress
²¹⁰ Pb - A biomarker for exposure of people to radon in indoor environments	J. Webb	Lovelace Respiratory Research Institute	\$116,182, 2000-2002	Pre-proposal submitted, not funded
Human radon exposure estimate using an <i>in vivo</i> biomarker	J. Webb	Lovelace Respiratory Research Institute (with proposed funding from National Institutes of Health)	\$117,721, 2001-2004	Collaboration commitment submitted
Internal dose assessments from historical radiation worker records	J. Webb	MJW Corporation	\$10,000, 1999-2000	Amended, in progress

Table continued on next page

Appendix H. New Project Development (Cont.)

Proposal/Bid Title	PI(s)	Sponsor	Funding/ Term	Status
Radiobioassay measurements of New Mexico Environment Department Hazardous and Radioactive Materials Bureau employees	J. Webb	New Mexico Environment Department	\$10,000, 2000-2001	Submitted
The cow counter: technology for the measure of radio-contaminants and fat-free lean content in livestock	J. Webb (with NMSU Department of Animal and Range Sciences)	Waste-management Education and Research Consortium (with funding from DOE)	\$169,860, 1999-2000	First phase completed, proposal submitted for second phase, 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
Memorandum of Understanding	J. Webb	Health Canada and NMSU	No funding	Adopted
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	\$250,000, 2000-2001	Submitted
Actinide chemistry & repository science laboratory initiative	J. Webb (with M. Conley)	DOE	\$7,072,767, 2000-2008	Submitted
Analysis of quarterly environmental samples	S. Webb (with J. Webb)	Envirocare of Texas, Inc.	\$17,470, 2000-2001	Submitted, not funded
Radiochemical, chemical and physical characterization of radioactive particles in the environment	S. Webb	International Atomic Energy Agency	No funding	Submitted, not selected

Appendix I. Status of Completion of 2000 Key Performance Indicators

1. Concurrent high-volume and low-volume aerosol sampling at three locations through 2000. **[Completed]**
2. Collection of daily FAS samples in WIPP exhaust shaft through 2000. **[Completed]**
3. Collection of soil samples at current 32 locations during January-February 2000. **[Completed]**
4. Concurrent operation of meteorological sampling stations at two sites through 2000. **[Completed]**
5. Collection of drinking water samples at six sources during March-April 2000. **[Completed]**
6. Collection of sediment and surface water samples from three reservoirs during June-July 2000. **[Completed]**
7. Collection of vegetation samples from six locations during fall 2000. **[No collection due to failure to complete analyses of archived samples from 1997-1999]**
8. Completion of repeat counts for half of original volunteer cohort and initial counts for a minimum of 100 new volunteers. **[Through 1 October 2000, bioassays completed for 98 of original volunteer cohort and 133 new volunteers since first waste receipt at WIPP; 500 volunteer participants measured since project initiation]**
9. Radioanalyses of all pre-2000 aerosol, sediment, surface water, drinking water and vegetation samples by October 2000 **[Analyses of all pre-2000 aerosol, surface water, and drinking water samples completed; alpha spectroscopy analyses of pre-2000 sediment samples delayed to February 2001; analyses of pre-2000 vegetation samples delayed to August 2001]**
10. Radioanalyses of soil, aerosol, sediment, surface water and drinking water samples collected through June 2000 by October 2000 **[Analyses of all 2000 soil, aerosol, sediment, surface water and drinking water samples completed, except alpha spectroscopy of 2000 sediment samples, which is delayed to February 2001]**
11. Radioanalyses of FAS sample analyses to meet weekly and quarterly posting schedule. **[Completed]**
12. Non-radiological (trace element inorganic) analyses of representative subset of 2000 low-volume aerosol, soil, sediment, surface water and drinking water samples within three months after each sample collection. **[Completed]**
13. Non-radiological (trace element inorganic) analyses of FAS samples to meet weekly and quarterly posting schedule **[Completed]**
14. Post results of radioanalyses of 2000 and pre-2000 samples within two months after completion of analyses **[Postings of analytical results for 2000 and pre-2000 samples were delayed, averaging three months after completion of analyses]**
15. Post results of non-radiological analyses of 2000 samples within two months after completion of each set of samples. **[Postings of analytical results for 2000 samples were delayed, averaging three months after completion of analyses]**
16. Issue CEMRC 1999 Report and post report and background data to CEMRC web site by March 2000. **[Completed]**
17. Issue newsletters in March and September 2000. **[Spring newsletter issued in March 2000; Fall newsletter issued in October 2000]**
18. Submit manuscript for publication by February 2000 on baseline characteristics of soils. **[Delayed, submitted April 2000, accepted for publication in Journal of Environmental Radioactivity]**
19. Submit manuscript for publication by July 2000 on baseline characteristics of aerosols. **[Delayed due to delayed completion of radioanalyses of pre-2000 aerosol samples, rescheduled for February 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 aerosol samples, soils, and sediments. Configured differently, the same instrumentation was used to determine the concentrations of several cations (calcium, magnesium, sodium, ammonium and potassium). 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. The cations were determined using a CG12A guard column and a CS12A analytical column, with the same type of 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, especially for the hydride elements (As, Se and Hg), 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 as summarized below. 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 2000.

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. For previous reports, the MDLs for metals were determined by replicate analyses of prepared blanks, as outlined by the instrument manufacturers. In some cases, this change produced improved limits of detection (note the filter detection limits for V, Cr, Zn Sr, Sb, etc.)(Tables K1 and K2). In other cases, the change caused the limits to increase (e.g., drinking water for Cu and Ba).

The use of a closed microwave digestion system for the preparation of the surface water, soil and sediment also contributed to better method detection limits for some analytes (Zn, Na, K, Mg, Al, Fe, and Ca) in these matrices. It should be noted however, that the method used in 2000 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.

The environmental chemistry laboratory participated in the InterLaB WatR™ Pollution WP-58 Proficiency Testing Program sponsored by Environmental Resource Associates. Overall, the lab received a "Very Good" rating, with a laboratory score of 90.3% (Table K3). Calcium and orthophosphate results were flagged "Not Acceptable" and magnesium results were flagged "Check for Error". A comparison of ICP-MS calibration standards to other known standards indicated that the calibration standards were high for calcium and magnesium. New standards were purchased from another source and the problem was resolved. New IC calibration standards were also purchased. After calibration with the new standards, the phosphate test sample was rerun and found to be within acceptance limits.

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.

Fluoride was not determined in sediments due to co-eluting organic peaks; method development is in progress to determine whether it will be possible to correct for this. 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 (Tables K4 and K5). LRB results higher than MDL must be subtracted from sample results. For aerosol filter analyses, some LRB results indicated reagent blank contamination for nitrate. Sources of blank contamination were traced to some laboratory personal protective equipment and various containers. More rigorous cleaning methods were employed to reduce contamination on these items. 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. As prescribed 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 (Table K6).

One duplicate analysis was performed for each sample batch. When available, duplicate aliquots of some field samples were analyzed. In cases where duplicate aliquots from the original sample 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 \pm MDL for samples less than five times the MDL) considered acceptable (Table K7).

A Laboratory Fortified Blank (LFB) was prepared and analyzed with each sample batch, using a spiked ultrapure water sample for aerosol filters and water samples, and certified reference materials (CRM) for soils and sediments. Recoveries of 85-115% were considered acceptable for aerosol filters, and water samples (Table K8). 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. Recoveries for fluoride and phosphate were lower than desirable on CRM samples for soils (average recovery 73% and 67%, respectively), indicating a possible negative bias for fluoride and phosphate for this matrix. Fluoride and chloride recoveries for CRM samples from sediments were also low (average recovery 67% and 79%, respectively), indicating a negative bias for fluoride and chloride results from sediment samples. During 2000, matrix spikes were added to soil and sediment samples prior to extraction. This change resulted in lower recoveries for fluoride and phosphate than in previous years when the spikes were added after sample extraction. The standard procedure for future analyses will employ spiking after extraction.

Low-volume aerosol filters were also analyzed by IC for five cations with overall acceptable results (Table K9). Acceptance limits for each QC parameter were the same as previously described.

Quality Control for Elemental Analyses by ICP-MS and AAS

For elemental analyses, sets of quality control samples comparable to those previously described for the IC analyses were included with each sample batch. Detailed performance results for all QC measures are not presented here due to the number of elements that are determined by ICP-MS and AAS. 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 at 40 CFR 136, Appendix B. Digestion QC samples were analyzed at a frequency of 10% 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. Due to limitations in sample quantities, duplicate and post digestion spike analyses could not be performed for the ICP-MS and AAS analyses of aerosol samples.

The digestion QC parameters used for the evaluation of metals 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 Quantitation Limits (PQLs) which are used in the same manner as CRDLs for non-EPA projects. The PQL is obtained by multiplying the Method Detection Limit (MDL) by five. For drinking water, surface water, soils, and sediments, 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 $\pm 15\%$ of the manufacturer’s established true values for all analytes except Se. The average recovery for Se was 78%, and therefore a negative bias is assumed to be present in reported values for Se in aerosol samples.

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 $\pm 15\%$ of the manufacturer’s established true values, with the exception of Cu (77%). The filter fortified by High Purity Standards has a much lower Cu background than the Versapore filter and the Cu level contained in the Versapore filters is significant compared to the fortification level, therefore when blank subtraction is performed the CRM recovery is biased low.

Four standard QC measures were used in association with analyses of drinking water and surface water samples. Ultrapure water was used for LRB samples, and average concentrations were less than the MDLs for all analytes except Al, Cr, Fe, Li, Pb, Sb, Sn, Sr, Th, and Ti in drinking water samples and Be, La, Mn and Zn in surface water. All results were corrected for blank bias. 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.

LFM samples were also used for QC in analyses of water samples, with all recoveries within a 70%-130% acceptance window, with the exception of Ba in surface water (31%). In compliance with the EPA CLP, the results for Ba must be considered estimates and are possibly biased low. 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 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 \pm PQL control limit was used. If the sample result were greater than the PQL, a $\pm 20\%$ RPD control limit was used. All duplicate results were within these modified acceptance limits.

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 Al, Ba, Ca, Cd, Cr, Co, Cu, Fe, La, K, Mg, Mn, Na, Ni, Pb, Sb, Sn, Sr and Zn, which were above the MDL. The sample measurements were at least ten times higher than the LRB results for all analytes except Ca, Cd, Cr, Cu, Na, Ni, Sb, Sn and Zn. The contaminant effects on the measurements are considered negligible for analytes with sample concentrations greater than 10 times the blank level. Sample results were corrected for bias by reagent blank subtraction for all analytes with LRBs above the MDL, regardless of sample concentration.

Sediment LRB results were less than the MDL with the exception of Al, Ba, Ca, Co, Cu, Cr, Fe, Gd, Hg, K, La, Li, Mg, Mn, Nd, Ni, Pb, Sb, Sr, Ti and Zn. The elemental concentrations of all analytes in the sediment samples were 10 times the level in the blanks with the exception of Sb in all sediment samples and Hg in four of the sediment samples. Results for Sb and Hg in these samples may be biased high. For samples with results greater than ten 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. All analytes were recovered within the supplier's specified control limits for all digestions with the exception of Ag and Mn. Due to low recovery, Ag results may be biased low for all soils and sediments. Due to high recovery, Mn results may be biased high for all soils and sediments.

Duplicate digestions were performed 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 \pm PQL control limit was used. If the sample results were greater than the PQL a \pm 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 (\pm 2 times the PQL) control limit may be adopted for soils and sediments due to the relatively high level of inhomogeneity compared with other matrices. For soils and sediments, the average RPD over the duplicate digestions performed was within these broader usability acceptance limits for all analytes, except Na (95% RPD) in soils and Ag (67% RPD) and Sb (38% RPD) in sediments. One batch of soils had unacceptable duplicate results for several analytes (Be, Ce, Co, Cu, Mo, Na, and Ti) even when compared to the broader guidelines. It could not be determined whether a digestion error had occurred or if sample inhomogeneity was the cause. The results for the seven samples in this digestion batch must be considered estimated values according to the usability guidelines.

A LFM also was prepared for each batch of soils and sediments processed. The average recovery was within 70%-130% for all analytes with the exception of Na (145%) in the soils and Be (56%), Se (69%) and Sb (69%) in the sediments. In compliance with the EPA CLP usability guidelines, the sediment results for Be, Se and Sb must be considered estimates that are biased low. The Na results for the soils must also be considered estimates that are biased high.

Conclusions and Future Improvements

In IC analysis, development is in progress to improve the resolution of fluoride and its separation from co-eluting organic species in the sediments.

For metals analysis, the detection limits are dependent upon how clean the blank, reagents and preparation labware can be made. Although CEMRC's detection limits are already 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 initially quite pure. A closed vessel microwave digestion sample preparation system was employed for the 2000 sample preparation and an improvement in our detection limits was observed. At present we are investigating alternative filter materials for use in the soil and sediment preparations as the filters in use were found to be a source of contamination for many analytes. Investigations into preparation method modifications are also underway in an effort to increase reproducibility and reduce contamination introduced by preparation.

Table K1. Comparison of 1999 and 2000 Method Detection Limits for Analyses by AAS

Instrument	Analyte	^a Units	1999 Method Detection Limit			Accuracy	Precision	
			Air Filter	Water	Soil: Acid Extract			
AAS (^b CV)	Hg	ppt	^c NA	6	6	± 30%	± 20%	
AAS (^c FIH)	As	ppt	NA	30	150	± 30%	± 20%	
	Se	ppt	NA	120	600	± 30%	± 20%	
AAS (^d GF)	As	ppb	1.3	NA	1.4	± 30%	± 20%	
	Se	ppb	1.1	NA	1.2	± 30%	± 20%	
	Fe	ppb	28	11	NA	± 30%	± 20%	
Instrument	Analyte	Units	2000 Method Detection Limit			Accuracy	Precision	
			Air Filter	Water				Soil: Acid Extract
				Drinking	Surface			
AAS (CV)	Hg	ppt	NA	12	0.2	NA	± 30%	± 20%
AAS (FIH)	As	ppt	NA	80	44	NA	± 30%	± 20%
	Se	ppt	NA	90	69	NA	± 30%	± 20%
AAS (GF)	As	ppb	1.4	NA	NA	1.4	± 30%	± 20%
	Se	ppb	1.2	NA	NA	0.92	± 30%	± 20%
	Fe	ppb	29	NA	NA	NA	± 30%	± 20%

^aUnits: ppt = parts per trillion; ppb = parts per billion

^bCV = cold vapor (Surface waters by cold vapor purge and trap hydride)

^cFIH = flow injection hydride

^dGF = graphite furnace

^eNA = not analyzed

Table K2. Comparison of 1999 and 2000 Method Detection Limits for Analyses by ICP-MS

Analyte	Air Filters ($\mu\text{g L}^{-1}$)		Drinking Water ($\mu\text{g L}^{-1}$)		Surface Water ($\mu\text{g L}^{-1}$)		Soil/Sediment (mg L^{-1})	
	1999	2000	1999	2000	1999	2000	1999	2000
Ag	0.01	0.01	0.00	0.01	0.08	0.01	0.05	0.10
Al	38	11	1.8	6.0	17	46	45	34
Ba	0.65	0.34	0.007	0.09	0.45	0.03	2.2	0.21
Be	0.06	0.07	0.04	0.09	0.03	0.05	0.02	0.15
Ca	97	28	6.1	18	150	77	440	154
Cd	0.06	0.04	0.01	0.03	0.46	0.05	0.30	0.10
Ce	0.008	0.007	0.0007	0.01	0.03	0.05	0.03	0.13
Co	0.29	0.07	0.01	0.06	0.03	0.04	0.23	0.16
Cr	7.1	2.6	0.12	0.07	0.38	0.26	3.1	0.47
Cu	0.33	0.45	0.09	0.30	1.6	0.65	5.8	0.15
Dy	0.002	0.005	0.002	0.01	0.004	0.007	0.006	0.10
Er	0.003	0.008	0.002	0.01	0.001	0.005	0.004	0.11
Eu	0.002	0.006	0.001	0.01	0.002	0.009	0.005	0.13
Fe	50	29	1.1	5.4	34	15	120	28
Gd	0.002	0.008	0.002	0.01	0.004	0.007	0.007	0.11
Hg	0.02	0.02	NA	NA	NA	NA	NA	0.05
K	53	21	13	17	59	23	390	36
La	0.006	0.15	0.0004	0.01	0.02	0.07	0.02	0.09
Li	0.43	0.13	0.11	0.06	0.53	0.16	0.31	0.13
Mg	9.7	12	1.7	1.3	19	10	120	15
Mn	0.35	0.38	0.01	0.05	0.57	0.11	0.88	0.37
Mo	0.72	0.11	0.05	0.10	0.02	0.10	0.32	0.12
Na	150	48	3.7	3.7	190	38	580	23
Nd	0.006	0.007	0.002	0.01	0.01	0.05	0.01	0.10
Ni	1.6	0.63	0.02	0.01	1.7	0.65	1.3	0.32
Pb	0.08	0.04	0.04	0.07	1.9	0.17	2.2	0.07
Pr	0.003	0.004	0.0007	0.01	0.005	0.05	0.007	0.09
Sb	0.67	0.04	0.006	0.01	0.24	0.14	0.17	0.09
Sm	0.003	0.007	0.003	0.01	0.002	0.09	0.007	0.07
Sn	35	10	0.12	1.5	20	7.5	74	NA
Sr	0.60	0.07	0.21	0.01	0.53	0.51	1.2	0.51
Th	0.004	0.003	0.00	0.01	0.006	0.006	0.007	0.08
Ti	4.7	4.0	0.12	0.04	0.39	0.24	1.5	3.4
Tl	12	0.004	0.04	0.01	7.9	0.03	1.4	0.14
U	0.003	0.005	0.00	0.01	0.002	0.003	0.008	0.07
V	4.7	0.90	0.37	0.06	0.51	0.13	5.5	1.7
Zn	19	2.6	0.27	0.12	21	1.3	27	1.4

Table K3. Summary of Participation in Environmental Chemistry Performance Evaluation Testing^a

Analyte	Percent Bias	^b Method Description	^c Performance Evaluation
Ag	-2.7	200.8	Acceptable
Al	0.7	200.8	Acceptable
Ammonia as N	12.7	300.0	Acceptable
As	7.0	7060	Acceptable
Ba	-5.2	200.8	Acceptable
Be	-3.8	200.8	Acceptable
Ca	-13.1	200.8	Not Acceptable
Cd	-5.4	200.8	Acceptable
Chloride	-3.6	300.0	Acceptable
Co	1.9	200.8	Acceptable
Cr	-2.6	200.8	Acceptable
Cu	4.7	200.8	Acceptable
Fe	5.6	200.8	Acceptable
Fluoride	-7.0	300.0	Acceptable
K	3.3	200.8	Acceptable
Mg	-10.6	200.8	Check for Error
Mn	-0.5	200.8	Acceptable
Mo	2.9	200.8	Acceptable
Na	-1.8	200.8	Acceptable
Ni	4.0	200.8	Acceptable
Nitrate as N	9.6	300.0	Acceptable
Ortho-phosphate as P	-18.4	300.0	Not Acceptable
Pb	-5.8	200.8	Acceptable
Sb	1.6	200.8	Acceptable
Se	-7.4	7740	Acceptable
Sr	-3.5	200.8	Acceptable
Sulfate	-11.7	300.0	Acceptable
Tl	-3.7	200.8	Acceptable
V	-0.4	200.8	Acceptable
Zn	-3.7	200.8	Acceptable

^aThe testing program used was the Environmental Resource Associates InterLaB WatR™ Pollution WP-58 Proficiency Testing Program.

^bThe method description number corresponds to the EPA standard testing method used.

^cDefinitions:

Acceptable: reported value falls within the acceptance limits.

Not Acceptable: reported value falls outside acceptance limits.

Check for Error: reported value falls within acceptance limits and outside of warning limits.

Table K4. Method Detection Limits for Analyses by Ion Chromatography

Sample Matrix	Units	Unit Type	Fluoride	Chloride	Nitrite	Nitrate	Phosphate	Sulfate
Low volume aerosol filter	$\mu\text{g L}^{-1}$	General	25.5	29.9	21.4	82.9	20.8	30.1
Drinking water and surface water	$\mu\text{g L}^{-1}$	General	68	80	^a NR	45	36	35
Soil	$\mu\text{g L}^{-1}$	General	68.1	79.2	39.0	44.9	34.6	36.1
Sediment	$\mu\text{g L}^{-1}$	General	16	22	NA	59	250	140
^b Low volume aerosol filter	$\mu\text{g m}^{-3}$	Matrix specific	0.7286	0.8571	0.0229	0.0482	0.0375	0.0386
^c Drinking water and surface water	$\mu\text{g L}^{-1}$	Matrix specific	68	80	NR	45	36	35
^d Soil	mg kg^{-1}	Matrix specific	0.68	0.80	0.39	0.45	0.35	0.36
^d Sediment	mg kg^{-1}	Matrix specific	0.016	0.022	NR	0.059	0.250	0.140

^aNR = not reported^bTeflo® 0.2 micron 45 mm diameter filter extracted into 30 mL ultrapure water; nominal flow volume of 28 L³ of air per filter^cWater samples are analyzed by direct injection^d1 g of solid material extracted into 10 mL ultrapure water**Table K5. Mean Laboratory Reagent Blank Results for Ion Chromatography**

Sample Matrix	Fluoride	Chloride	Nitrite	Nitrate	Phosphate	Sulfate
Low volume aerosol filter ($\mu\text{g L}^{-1}$)	5.47	15.5	4.9	51.7	1.7	16.4
Drinking water and surface water (mg L^{-1})	0.6744	-0.0838	NR	0.1566	0.0002	0.0060
Soil (mg kg^{-1})	-0.0563	-0.0324	-0.1241	1.1341	0.1817	0.1481
Sediment (mg kg^{-1})	0	0	^a NR	0.0009	0	0

^aNR = not reported

Table K6. Mean Laboratory Fortified Matrix Recovery Results for Ion Chromatography

Sample Matrix	Fluoride	Chloride	Nitrate	Phosphate	Sulfate	% Recovery Limit
Low volume aerosol filter	97%	91%	100%	98%	107%	70-130%
Drinking water & surface water	77%	93%	79%	72%	102%	70-130%
Soil	73%	^a NA	84%	72%	NA	70-130%
Sediment	Not Reported	NA	95%	74%	NA	70-130%

^aNA = not applicable; concentration of analyte in sample is more than 4 times spike concentration

Table K7. Mean Relative Percent Difference Results for Duplicate Analyses using Ion Chromatography

Sample Matrix	Fluoride	Chloride	Nitrite	Nitrate	Phosphate	Sulfate	% Recovery Limit
Low volume aerosol filter	^a NA	NA	NA	4	NA	0.8%	± 20
Drinking water/ surface water	1%	3%	^b NR	1%	3%	9%	± 20
Soil	NA	14%	NR	-7%	5%	4%	± 20
Sediment	-2.6%	2%	NR	4.9%	NA	-1%	± 20

^aNA = not applicable; concentration present in samples was < 5 times MDL therefore ± MDL control limit used

^bNR = not reported

Table K8. Mean Laboratory Fortified Blank (LFB) or Certified Reference Material (CRM) Recovery Results for Ion Chromatography

Sample Matrix	Fluoride (%)	Chloride (%)	Nitrate (%)	Phosphate (%)	Sulfate (%)	Recovery Limit (%)
Low volume aerosol filter (LFB)	99	98	102	99	100	85-115
Drinking water and surface water (LFB)	95	102	91	93	102	85-115
Soil (CRM)	73	92	81	67	80	80-120
Sediment (CRM)	67	79	90	101	117	80-120

Table K9. QC Results for Cations in Aerosol Filters Analyzed by Ion Chromatography

Parameter	Sodium	Ammonium	Potassium	Magnesium	Calcium
MDL ($\mu\text{g L}^{-1}$)	10	13	20	7	8
MDL ($\mu\text{g m}^{-3}$)	0.0107	0.0139	0.0214	0.0075	0.0086
Average LRB ($\mu\text{g L}^{-1}$)	53	14	12	15	48
Average LFM recovery (%)	114	112	106	105	108
Average RPD (%)	1.7	0.6	0.8	^a NA	1.8
Average LFB recovery (%)	107	103	98	95	99

^aNA = not applicable; concentration present in samples was < 5 times MDL therefore \pm MDL control limit used

Appendix L. Quality Assurance/Quality Control for Radioanalyses

The CEMRC radioanalytical program continued method development throughout 2000, resulting in standard methodologies for determining background levels of alpha- and gamma-emitting radionuclides in sediment, and for Am and Pu in high volume air filters. QA activities in 2000 were essentially the same as they were for 1999, but included an increase in the number of analytes for performance evaluation samples and in the use of matrix spiked samples.

During 2000, the CEMRC radioanalytical program participated in two rounds of the DOE Environmental Measurement Laboratory Quality Assurance Program (EML QAP), resulting in “acceptable” ratings for 56 individual determinations of eighteen analytes in glass fiber filters, soil, vegetation and water samples (Table L1). One “warning” rating was received for $^{239,240}\text{Pu}$ in soil in the September 1999 distribution. An “acceptable” rating for $^{239,240}\text{Pu}$ in soil was received in the March 2000 distribution. Two “warning” ratings were received for U in soil samples from the March 2000 distribution. The radioanalytical program also participated in five rounds of the National Institute of Standards and Technology (NIST) Radiochemistry Intercomparison Program (NRIP). Reports of traceability were received for measurements of four analytes in glass fiber filters, three analytes in two separate sets of soil samples, four analytes in water and four analytes in synthetic urine (Table L2). CEMRC reported Am results for one set of soil samples that were within 5% of the NIST values, but not within the traceability limits. However, traceability was achieved for Am on the following set of soil performance tests. Methods to calculate the reported uncertainty for NRIP samples were revised during 2000 to better reflect potential systematic biases.

Routine activities conducted for radioanalyses included (1) tracking and verification of analytical instrument performance, (2) use of American Chemical Society certified reagents, (3) use of American Society for Testing and Materials (ASTM) Type II water for reagent preparations, (4) use of NIST traceable radionuclide solutions and (5) verification testing of radionuclide concentrations for tracers not purchased directly from NIST. In addition to analyte-surrogate isotopic tracers used in samples, ^{148}Gd was added to samples where no alpha emitters were expected (e.g. thorium blanks) to provide a monitor that spectral shifting had not taken place. For high volume air filters, ^{209}Po was added to the Am portion of the sample after chemical separation of Am, but before purification of Am. The ^{209}Po was used as a monitor 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 was used) performance checks were done on the gas-flow, α/β proportional counter used for the FAS program. These checks included counting ^{239}Pu and ^{90}Sr standards for efficiency control charting and ensuring that α/β cross-talk were within limits. Sixty-minute background counts were also recorded daily. Standards made with ^{152}Eu were counted daily or before system use on the high purity Ge (HPGe) coaxial and well detector systems used for drinking water, surface water, soil, and FAS samples. Efficiency, centroid, and resolution measurements were made and tracked using the detector system software. Routine background determinations were made on the HPGe detector systems by counting blank samples, and the data were used to blank correct the sample concentrations. Pulser checks were performed on the alpha spectrometer before each sample was counted to ensure acceptable detector resolution and centroid. Also, control charting of alpha detector response, resolution, and centroid was implemented using ^{148}Gd sources.

Standard procedures included use of blanks to identify contamination or interference carried through the analytical process, but blank measurements were not used to correct measurements made by alpha spectroscopy. Blanks constituted approximately 10% of the sample load for WIPP EM analyses, 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. A laboratory reagent blank was used when no suitable matrix blank was available, and consisted of major inorganic constituents known to compose the sample matrix. Results for blank measurements (Table L3) indicated that Pu and Am contamination (considered to result from sample cross contamination, especially with analysis of higher activity performance samples) was detected infrequently, but the practice of analyzing blanks at least 10% of the time will

be continued to monitor for contamination. ^{241}Am contamination appeared in blanks for one batch of performance assessment water samples but the blank activity was a small fraction of the actual sample activity. Detectable activity of ^{228}Th 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. In addition, some small amount of ^{228}Th impurity may be present in the ^{232}U tracer due to incomplete tracer purification. Mathematical corrections for ^{228}Th ingrowth have been implemented for future analyses. The most common source of detectable ^{234}U in blanks is spectral tailing of ^{232}U tracer into the ^{234}U region of interest, but another possible source is incomplete removal of ^{234}U by water purification systems. The magnitude of contributions to activity measurements for ^{234}U from these sources will be investigated further in the coming year.

Isotopic tracers were used to determine the analytical system's effectiveness in extracting, purifying, and quantifying the isotopes of interest. Although some samples had tracer recoveries < 20% for Am, U and Th (Table L4), they were still adequate to meet minimum detectable concentration requirements for reporting under the study plan. In general, Am yields for analyses during 2000 were improved over those recorded in 1999, and Am yields were greater for filter samples than other environmental media. In high volume air filters, a few Am yields were greater than 100% which is attributed to ^{210}Po spectral interferences with the ^{243}Am tracer in samples that were analyzed before initiation of the use of ^{209}Po as a purity monitor. However, these samples had ^{241}Am activity well below MDC, so reported results were not affected. Compared to 1999, Pu yields were somewhat lower for analyses conducted during 2000 for water and soil samples. Relative variance in tracer yields (as indicated by coefficients of variation) was highest for Pu in water samples (45%), Am in soil samples (44%) and U in soil samples (43%). Overall, relative variance in yields decreased in 2000, indicating better control of the analytical process.

Analyses of laboratory duplicates (aliquots of the same sample analyzed separately) were used to estimate precision, which is analyte- and matrix-specific (Table L5). Approximately 10% of the sample load during WIPP EM soil analyses was laboratory duplicate samples. The mean relative percent difference (RPD) between isotope activity concentrations in laboratory duplicate WIPP EM soil samples was greatest for $^{239,240}\text{Pu}$, ^{241}Am and ^{235}U . High RPD values can be associated with both variations introduced in the analytical process and background heterogeneity in the distribution of the analytes within the original sample. However, RPDs should be interpreted in comparison to relative error ratios (RER). For example, for ^{241}Am , although the RPD is high (34.2%), the RER is low (1.01), reflecting the relatively high counting uncertainty resulting from the extremely low activity concentrations of ^{241}Am in the samples. By comparison, the mean RPD for ^{228}Th was relatively low, while the mean RER was the highest of the nine analytes, reflecting the smaller counting uncertainties resulting from relatively higher ^{228}Th activity concentrations in the samples. The relative contributions of analytical error and background heterogeneity can thus not be determined from these results. For five of eight analytes, the RPDs for WIPP EM soil analyses in 2000 were lower than those reported for analyses during 1999.

Analyses of matrix spike samples were used to test the effectiveness of the analytical procedure to accurately quantify the analyte of interest (Table L6). Approximately 10% of the non-FAS sample load during WIPP EM analyses were matrix spikes. For water analyses, NIST traceable ^{239}Pu , ^{241}Am , ^{238}U and ^{230}Th standards were spiked into 3 L of ASTM Type II water. For air filter analyses, NIST traceable ^{239}Pu and ^{241}Am were spiked onto blank air filters. For soil analyses, EML QAP-50 soil was used as the matrix spike. A surface water matrix spike was prepared and used with sample batches of both surface water and drinking water. One surface water matrix spike yielded a positive 22% bias for $^{239,240}\text{Pu}$, which may be attributed to a low chemical yield that produced overestimation of the Pu activity concentration. Despite this, all values for $^{239,240}\text{Pu}$ measured in the surface water and drinking water samples were < MDC, eliminating any effect of the bias. ANSI N42.22 criteria were met for all other matrix spikes during WIPP EM analyses.

Table L1. Summary of Participation in Environmental Monitoring Laboratory Quality Assurance Program

Media	Radionuclide	^a Percent Bias QAP-51	^b Results QAP-51	Percent Bias QAP-52	Results QAP-52
Air Filters	²⁴¹ Am	-7.1	Acceptable	-2.3	Acceptable
	⁵⁷ Co	-3.2	Acceptable	-0.2	Acceptable
	⁶⁰ Co	-0.5	Acceptable	2.6	Acceptable
	¹³⁷ Cs	-5.6	Acceptable	6.6	Acceptable
	²³⁸ Pu	-4.2	Acceptable	12.5	Acceptable
	^{239,240} Pu	-1.5	Acceptable	9.0	Acceptable
	⁵⁴ Mn	4.0	Acceptable	5.5	Acceptable
	²³⁴ U	-0.8	Acceptable	4.8	Acceptable
	²³⁸ U	5.7	Acceptable	4.8	Acceptable
Soil	²²⁸ Ac	NA	NA	2.5	Acceptable
	²¹² Bi	NA	NA	5.7	Acceptable
	²¹⁴ Bi	NA	NA	7.3	Acceptable
	¹³⁷ Cs	NA	NA	0.3	Acceptable
	⁴⁰ K	NA	NA	-1.9	Acceptable
	²¹² Pb	NA	NA	1.8	Acceptable
	²¹⁴ Pb	NA	NA	7.5	Acceptable
	^{239,240} Pu	-10.9	Warning	22.9	Acceptable
	²³⁴ U	7.4	Acceptable	18.9	Warning
²³⁸ U	4.5	Acceptable	18.4	Warning	
Vegetation	²⁴¹ Am	1.0	Acceptable	-6.7	Acceptable
	²⁴⁴ Cm	15.5	Acceptable	10.0	Acceptable
	⁶⁰ Co	10.8	Acceptable	10.4	Acceptable
	¹³⁷ Cs	9.1	Acceptable	10.1	Acceptable
	⁴⁰ K	12.7	Acceptable	3.8	Acceptable
	^{239,240} Pu	3.7	Acceptable	-3.2	Acceptable
Water	²⁴¹ Am	11.3	Acceptable	3.6	Acceptable
	⁶⁰ Co	1.4	Acceptable	6.3	Acceptable
	¹³⁷ Cs	0.5	Acceptable	2.9	Acceptable
	Gross Alpha	NA	NA	1.8	Acceptable
	Gross Beta	NA	NA	-2.9	Acceptable
	²³⁸ Pu	3.8	Acceptable	10.2	Acceptable
	^{239,240} Pu	2.9	Acceptable	13.3	Acceptable
	²³⁴ U	6.8	Acceptable	7.9	Acceptable
²³⁸ U	12.2	Acceptable	1.6	Acceptable	

^aPercent bias is calculated as the mean of measurements by CEMRC minus the sponsor's known value, expressed as a percentage relative to the known value.

^bResults for EML QAP "acceptable" are defined in Report EML-605, December 1999 for QAP-51 and in Report EML-608, June 2000 for QAP-52; NA = not applicable, nuclide was not analyzed

Table L2. Summary of Participation in NIST Radiochemistry Intercomparison Program

Media	Radionuclide	^a Percent Bias	^b Results
Air Filter	²⁴¹ Am	3.7	NIST Traceable, 6.4%
	²³⁸ Pu	1.2	NIST Traceable, 7.1%
	²⁴⁰ Pu	3.5	NIST Traceable, 8.6%
	²³⁸ U	3.4	NIST Traceable, 9.7%
Soil (SO-3)	²⁴¹ Am	-4.5	Not Traceable
	²³⁸ Pu	-0.7	NIST Traceable, 2.5%
	²³⁸ U	-1.2	NIST Traceable, 5.9%
Soil (SO-11)	²⁴¹ Am	-2.3	NIST Traceable, 4.2%
	²³⁸ Pu	1.5	NIST Traceable, 4.1%
	²³⁸ U	2.7	NIST Traceable, 4.0%
Water	²⁴¹ Am	2.5	NIST Traceable, 12%
	²³⁸ Pu	1.0	NIST Traceable, 10%
	²⁴⁰ Pu	2.0	NIST Traceable, 9%
	²³⁸ U	-2.2	NIST Traceable, 8%
Synthetic Urine	²⁴¹ Am	-0.6	NIST Traceable, 13%
	²³⁸ Pu	-4.0	NIST Traceable, 13%
	²³⁹ Pu	-3.1	NIST Traceable, 8.5%
	²³⁸ U	4.3	NIST Traceable, 7.4%

^aPercent bias is the difference between sponsor's known value for a sample, and the mean of measurements by CEMRC for the sample, expressed as a percent relative to the sponsor's value

^bResults for NIST Traceability are defined under ANSI 42.22 standards at the stated limit

Table L3. Results for Radioanalyses of Actinides in Blank Samples

Parameter	Analyte and Matrix Group								
	²³⁸ Pu	^{239,240} Pu	²⁴¹ Am	²³⁴ U	²³⁵ U	²³⁸ U	²²⁸ Th	²³⁰ Th	²³² Th
Soil (WIPP EM 2000, NRIP, EML QAP 51 & QAP 52)									
^a N	7	7	6	4	2	5	5	5	5
^b N > MDC	0	0	1	2	0	2	3	2	1
^c Minimum (mBq kg ⁻¹)	^d NA	NA	21	148	NA	183	216	76	112
^e Maximum (mBq kg ⁻¹)	NA	NA	NA	185	NA	203	682	427	NA
Water (WIPP EM 2000 Drinking Water & Surface Water, NRIP, EML QAP 51 & QAP 52)									
N	7	7	5	7	7	7	2	2	2
N > MDC	0	0	2	7	2	3	1	0	0
Minimum (μBq L ⁻¹)	NA	NA	4290	200	112	157	490	NA	NA
Maximum (μBq L ⁻¹)	NA	NA	12770	5258	2732	2796	NA	NA	NA
FAS Quarterly Composite Filters (April 1999 - June 2000)									
N	8	8	8	8	8	8	8	8	8
N > MDC	0	0	0	4	1	1	4	0	0
Minimum (μBq)	NA	NA	NA	344	33	573	484	NA	NA
Maximum (μBq)	NA	NA	NA	789	NA	NA	814	NA	NA
Low Volume Air Filters (2000 FAS Incident Filters, NRIP, EML QAP 51 & QAP 52)									
N	20	20	20	17	17	17	14	14	14
N > MDC	0	2	2	9	2	4	10	0	0
Minimum (μBq)	NA	176	425	283	229	500	700	NA	NA
Maximum (μBq)	NA	257	912	833	264	733	1350	NA	NA
High Volume Air Filters (WIPP EM February 1998 - June 2000)									
N	18	18	18	0	0	0	0	0	0
N > MDC	0	1	1	NA	NA	NA	NA	NA	NA
Minimum (μBq)	NA	78	186	NA	NA	NA	NA	NA	NA
Maximum (μBq)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Vegetation (EML QAP 51 & QAP 52)									
N	2	2	2	0	0	0	0	0	0
N > MDC	0	0	0	NA	NA	NA	NA	NA	NA

^aNumber of blanks analyzed^bNumber of blank samples with values greater than MDC (minimum detectable concentration)^cNot applicable for isotopes measured above MDC in < 2 blanks^dMinimum activity/activity concentration observed in blanks > MDC^eMaximum activity/activity concentration observed in blanks > MDC

Table L4. Laboratory Tracer Recovery Results for Radioanalyses of Actinides

^a Matrix Group	Parameter	^b Tracer Recovery by Analyte			
		Pu	Am	U	Th
Soil WIPP EM 2000 NRIP EML QAP 51 EML QAP 52	^c N	73	64	50	46
	^d Mean (%)	64	66	58	69
	^e CV (%)	28	44	43	39
	^f Minimum (%)	15	6	17	12
	^g Maximum (%)	94	97	94	97
	^h N < 20%	1	9	2	4
Water WIPP EM 2000 NRIP EML QAP 51 EML QAP 52	N	33	29	33	20
	Mean (%)	47	81	72	88
	CV (%)	45	23	18	15
	Minimum (%)	13	34	50	45
	Maximum (%)	80	97	96	98
	N < 20%	3	0	0	0
FAS Quarterly Composite Filters April 1999 – June 2000	N	12	12	15	12
	Mean (%)	76	82	59	76
	CV (%)	21	18	39	30
	Minimum (%)	37	52	5	11
	Maximum (%)	92	94	93	99
	N < 20%	0	0	2	1
Low Volume Air Filters FAS Incident NRIP EML QAP 51 EML QAP 52	N	35	36	32	18
	Mean (%)	79	83	66	78
	CV (%)	27	25	35	27
	Minimum (%)	1	2	24	8
	Maximum (%)	98	105	101	93
	N < 20%	1	2	0	1
High Volume Air Filters WIPP EM February 1998 - June 2000	N	165	165	ⁱ NA	NA
	Mean (%)	75	92	NA	NA
	CV (%)	17	11	NA	NA
	Minimum (%)	11	62	NA	NA
	Maximum (%)	95	155	NA	NA
	N < 20%	1	0	NA	NA
Vegetation EML QAP 51 EML QAP 52	N	7	7	NA	NA
	Mean (%)	75	76	NA	NA
	CV (%)	35	24	NA	NA
	Minimum (%)	26	46	NA	NA
	Maximum (%)	95	92	NA	NA
	N < 20%	0	0	NA	NA

^aEach group includes samples, blanks, and quality assurance samples of the various types of environmental media; types within each group are described in text

^bTracer = an isotope of the radionuclide of interest, that is distinguishable from the analyte of interest, but assumed to behave the same in radiochemical processes

^cN = number of samples included in each analysis; EML and NRIP analyses did not require the determination of Th

^dMean tracer percent yield

^eCV = coefficient of variation for tracer percent yield; standard deviation expressed as percentage of mean

^fMinimum observed tracer percent yield from all analyses

^gMaximum observed tracer percent yield from all analyses

^hNumber of samples with tracer percent yields less than 20%; samples having Pu yields < 20% were reanalyzed (except high volume air filters)

ⁱNA = not applicable; not included in analyses

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

Parameter	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	5	5	2	2	2	5	5	5
^b Mean RPD (%)	^f NA	13.6	34.2	6.9	12.9	1.1	8.2	5.4	7.6
^c Maximum RPD (%)	NA	47.3	126	7.7	14.5	1.3	19.8	10.2	13.2
^d Mean RER	NA	0.81	1.01	1.19	0.64	0.20	2.39	1.55	2.11
^e Maximum RER	NA	2.74	2.95	1.29	0.65	0.23	5.16	2.71	3.40

^aNumber of replicate sample pairs > MDC for subject analyte

^bMean 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: $RPD = \frac{|a - b|}{\bar{x}} \times 100 \%$

^cMaximum relative percent difference (RPD)

^dRelative error ratio (RER); RER defined as the absolute value of the difference between the analyte concentration in the first sample (c_1) and the concentration in the second sample (c_2), divided by the quadratic sum of the count standard

deviation (uncertainty) of the first sample (s_1) and the second sample (s_2): $RER = \frac{|c_1 - c_2|}{\sqrt{s_1^2 + s_2^2}}$

^eMaximum relative error ratio (RER)

^fNA = not applicable; no measurements were > MDC

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

Matrix 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 WIPP EM 2000	^b N	4	4	2	1	^c NA	1	NA	NA	NA
	^d Minimum	-5.9	3.6	0.4	-3.0	NA	-3.5	NA	NA	NA
	^e Maximum	16.8	14.2	7.9	-3.0	NA	-3.5	NA	NA	NA
	^f % Meeting ANSI N42.22 Criteria	100	100	100	100	NA	100	NA	NA	NA
Surface Water WIPP EM 2000	N	NA	1	1	NA	NA	1	NA	1	NA
	Minimum	NA	22.3	0.0	NA	NA	0.0	NA	2.5	NA
	Maximum	NA	22.3	0.0	NA	NA	0.0	NA	2.5	NA
	% Meeting ANSI N42.22 Criteria	NA	0	100	NA	NA	100	NA	100	NA
High Volume Air Filters WIPP EM February 1998-June 2000	N	NA	8	8	NA	NA	NA	NA	NA	NA
	Minimum	NA	0	0	NA	NA	NA	NA	NA	NA
	Maximum	NA	-5.9	-5.4	NA	NA	NA	NA	NA	NA
	% Meeting ANSI N42.22 Criteria	NA	100	100	NA	NA	NA	NA	NA	NA

^aPercent 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

^bN = number of matrix spikes for each analytical group

^cNA = not applicable; no matrix spike used for the subject nuclide

^dMinimum observed bias

^eMaximum observed bias

^fANSI N42.22 criteria for the acceptance of testing results where the absolute value of the bias between the reported value, V_r , and the or known value, V_n , shall be less than or equal to three times the total propagated reported uncertainty, σ_r , and the uncertainty of the known value, σ_n : $|V_r - V_n| \leq 3 \times \sqrt{\sigma_r^2 + \sigma_n^2}$