

**Oak Ridge National Laboratory
Technology Logic Diagram**

**Volume 3
Technology Evaluation Data Sheets**

**Part A
Characterization • Decontamination**

**Prepared for the Office of Technology Development
U.S. Department of Energy**

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U.S. DEPARTMENT OF ENERGY
under contract DE-AC05-84OR21400**

MASTER

FOREWORD

The *Oak Ridge National Laboratory Technology Logic Diagram (TLD)* was developed to provide a decision support tool that relates environmental restoration (ER) and waste management (WM) problems at Oak Ridge National Laboratory (ORNL) to potential technologies that can remediate these problems. The TLD uses information from the *Strategic Road Map for the Oak Ridge Reservation* and a previous Hanford TLD.

The TLD identifies the research, development, demonstration, testing, and evaluation needed to develop these technologies to a state that allows technology transfer and application to decontamination and decommissioning (D&D), remedial action (RA), and WM activities. It is essential that follow-on engineering studies be conducted to build on the output of this project. These studies will begin by selecting the most promising technologies identified in the TLD and finding an optimum mix of technologies that will provide a socially acceptable balance between cost and risk.

The TLD consists of three fundamentally separate volumes: Vol. 1, *Technology Evaluation*; Vol. 2, *Technology Logic Diagram*; and Vol. 3, *Technology Evaluation Data Sheets*. Part A of Vols. 1 and 2 focuses on RA. Part B of Vols. 1 and 2 focuses on the D&D of contaminated facilities. Part C of Vols. 1 and 2 focuses on WM. Each part of Vol. 1 contains an overview of the TLD, an explanation of the problems facing the volume-specific program, a review of identified technologies, and rankings of technologies applicable to the site. Volume 2 (Pts. A, B, and C) contains the logic linkages among EM goals, environmental problems, and the various technologies that have the potential to solve these problems. Volume 3 (Pts. A, B, and C) contains the TLD data sheets.

This volume provides the technology evaluation data sheets (TEDS) for ER/WM activities (D&D, RA, and WM) that are referenced by a TEDS code number in Vol. 2 of the TLD. Each of these sheets represents a single logic trace across the TLD. These sheets contain more detail than is given for the technologies in Vol. 2. The data sheets are arranged alphanumerically by the TEDS code number in the upper right corner of each sheet.

Volume 3 can be used in two ways: (1) technologies that are identified from Vol. 2 can be referenced directly by using the TEDS codes, and (2) technologies and general technology areas (alternatives) can be located in the index at the end of this volume.

The technology evaluations contained in these volumes are based on the best information available during compilation of the TLD. New or more accurate information is solicited to improve the TLD data base. Please send comments to R. L. Fellows, Editor, *Oak Ridge National Laboratory Technology Logic Diagram*, Martin Marietta Energy Systems, Inc., P.O. Box 2003, Oak Ridge, TN 37831-7274. FAX (615-576-8558).

ACKNOWLEDGMENTS

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EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: Inorganic

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Laboratory methods

Technology: Electron spectroscopy for chemical analysis (ESCA). A surface technique that operates using the photoelectric effect. Electrons are ejected from the core of the atom with kinetic energies specific to the element. Chemical shifts in energy add information about the chemical state of the element.

Status: Accepted; commercially available

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Inorganic (U, Tc, CrO₄, Hg, Pb, ...)

Waste produced—About a 5-mg sample is required. Sample and sample holder become waste.

Overall cost—\$200–\$600/sample

Efficacy/strengths—Elemental and chemical state information from the outermost surface material (<10 nm) provide information about contaminant attachment and bonding mechanism. This is a mature technology.

Science/Technology Needs: Model studies are needed to identify binding energies for standard compounds of technetium and uranium for suspected matrices.

Implementation Needs: Instrumentation and personnel currently exist at ORNL, K-25 Site, and Y-12 Plant. Capital costs, >\$200K.

Author: D. P. Hoffmann/615-574-3896

References: F. J. Gruthaner, *MRS Bulletin* 12(6), 60–63 (1987).

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: Inorganic

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Laboratory methods

Technology: Auger electron spectroscopy (AES). A surface characterization technique with high spatial resolution. An electron beam is used to eject primary electrons. The auger electrons are ejected by the cascade effect. An electron energy system is used to measure the kinetic energy of the electron, which is elementally specific.

Status: Accepted; commercially available

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Inorganic (U, CrO₄, Hg, Pb,...); Al₁Mg₁ alloys (Co-Ni)

Waste produced—About a 5-mg sample is required. Sample preparation varies from none to extensive. Sample and sample holder become waste.

Overall cost—\$300-\$800/sample

Efficacy/strengths—Elemental, spatial, and depth profiling information is obtained from the surface region (<10 nm) of the sample. It is applicable to monitoring contaminant interaction with the host matrix and identifying complexation, location, and binding sites of the contamination. This is a mature technology.

Science/Technology Needs: Mature model studies are needed to probe the host/contaminant effects for accurate depth profiling.

Implementation Needs: Instrumentation and personnel exist at ORNL, K-25 Site, and Y-12 Plant. Capital costs, >\$200K.

Author: D. P. Hoffmann/615-574-3896

References:

1. C. C. Chang, *MRS Bulletin* 12(6), 70-74 (1987).
2. N. H. Turner and J. A. Schreifels, *Anal. Chem.* 64(12), 302R (1992).

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: General

Reference Requirements: Refer to the regulatory compliance chapter of Vol. 1 (Part A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Laboratory methods

Technology: Secondary ion mass spectroscopy (SIMS). Ionized gas impinges on sample to eject secondary ions that are subsequently mass analyzed.

Status: Accepted; commercially available

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Organic (oil, polychlorinated biphenyls, volatile organic compounds, trichloroethylene, ...); inorganic (U, Tc, Cr, CrO₄, Hg, Pb, ...)

Waste produced—About a 5-mg sample is required. Minimal sample preparation is required.

Overall cost—~\$400/sample

Efficacy/strengths—Elemental and compound identification from the sample surface, spatially resolved information, and depth profiling are possible. Enrichment information is also possible. Nonconduction materials may present problems.

Science/Technology Needs: This is a mature technology. Model studies are needed to calibrate for depth-profiling studies.

Implementation Needs: Instrumentation and personnel exist at ORNL, K-25 Site, and Y-12 Plant. Capital costs, >\$200K.

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References:

1. W. Katz and J. G. Newman, *MRS Bulletin* **12**(6), 40-47 (1987).
2. D. W. Koppenaal, *Anal. Chem.* **62**(12), 303R (1990).

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: General

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Laboratory methods

Technology: Laser ionization mass spectrometry (LIMS, LAMMA, LIMMA). A technique for mass spectrometric analysis of solids that uses a pulsed, laser-energy source to vaporize and ionize the analyte.

Status: Accepted; commercially available

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Organic (oil, polychlorinated biphenyls, volatile organic compounds, trichloroethylene, ...); inorganic (U, Tc, Cr, Hg, Pb, metals, nonmetals, ...)

Waste produced—About a 1- to 5-mg sample is required. Minimum sample preparation is needed.

Overall cost—\$300–\$500 per sample

Efficacy/strengths—Mass spectroscopy identification of elements and compounds on a surface with high spatial resolution. Enrichment information is possible.

Science/Technology Needs: This is a mature technology. Model studies are needed to optimize interpretation of results.

Implementation Needs: Prototype and research instrumentation exist at ORNL, K-25 Site, and Y-12 Plant. More equipment would be required. Necessary personnel are available to train additional staff. Development costs are estimated at ~\$250K; capital costs, >\$200K.

Author: D. P. Hoffmann/615-574-3896

References: Hercules et al., *Anal. Chem.* **54**, 280A (1982).

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: Organic (gas phase only)

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Field methods

Technology: Portable volatile organic compound (VOC) detectors. A valuable, quick, and yet inexpensive method to screen for the contamination of soils based on flame ionization or photolionization of sample. Useful at a variety of sites including leaking underground tanks, pits, and drain spillage. Depending on the sophistication of the instruments used, quantitative and qualitative information can be provided.

Status: Accepted; commercially available

Temporal areas of evaluation: Pretreatment; treatment

Deployment evaluation: Manual, automated, and robotic applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Organic (oil, polychlorinated biphenyls, VOCs, trichloroethylene, ...)

Waste produced—None

Overall cost—~\$1/analysis

Efficacy/strengths—These portable units allow real-time field monitoring of organic vapors. Some units are specifically calibrated for certain gases. Others allow a wide range of gas detection. There are various sizes ranging from pocket to briefcase size, with a variety of data logging and sample collection options. Detection limits can range from screening quality (1%) to as low as the ppb range.

Science/Technology Needs: This is a mature technology

Implementation Needs: Instruments are available for quick screening and surveying. Interfacing the instruments with an ion mobility mass spectrometer would allow detection of individual compounds (~\$30K). Capital costs, ~\$500.

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References:

1. Vendor literature
MDA Scientific/800-344-4632
Sensidyne, Inc./813-530-3602
Graseby-Andersen Instruments, Inc./404-691-1910
Sentex Systems, Inc./201-945-3694
2. L. Clement, M. L. Langhost, and G. A. Elceman, "Environmental Analysis," *Anal. Chem.* **63**(12), (1991).

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: Inorganic

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: In situ characterization and monitoring

Technology: Portable X-ray Fluorescence (PXRF). Fluorescence from the decay of elements excited by X-rays is used to obtain quantitative and qualitative elemental analyses of samples.

Status: Accepted; commercially available

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual, automated, and robotic applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Inorganic (U, Tc, Cr, CrO₄, Hg, Pb, most metals, ...)

Waste produced—None

Overall cost—Just pennies/sample

Efficacy/strengths—It is portable, logs data, and has an elemental range from aluminum to uranium. For Level I site assessment, EPA accepts ppm levels. It is a quick procedure (~1-2 min/sample).

Science/Technology Needs: Routine procedure development

Technical Task Plan RL321113 (FY 1992); relevance: high

RL321114 (FY 1992); relevance: high

Implementation Needs: This technology is mature for manual applications. It is an excellent candidate technology for automated or robotic deployment systems. Requires knowledge of X-ray techniques for use. Capital costs, ~\$50K.

Author: D. P. Hoffmann/615-574-3896

References:

1. Vendor literature (Outokompu, HP).
2. S. B. Török, R. E. VanGrieken, *Anal. Chem.* **64**(12), 180R (1992).

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: Inorganic, organic

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Laboratory methods

Technology: Fourier transform infrared spectroscopy (FTIR). A spectroscopic technique used for identifying and quantitating multiple inorganic and organic materials by measuring the absorbance spectrum of the material in the infrared spectral region. Also measures photon absorption due to molecular vibrations.

Status: Accepted; commercially available. Demonstrated at the K-25 Site TSCA incinerator in July 1993.

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual and automated applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Organic (oil, polychlorinated biphenyls, volatile organic compounds, trichloroethylene); inorganic (U, Tc, Cr, CrO₄, Hg, transition metals,...)

Waste produced—None to a few milliliters per sample; sample becomes waste.

Overall cost—\$50–\$500/sample

Efficacy/strengths—A multitude of detector and sampling devices exist, allowing gas, liquid, solid, and microanalysis to be performed. Measurement time is typically 1 s. Detection limits typically submilligram. Applicability to specific compounds and matrices needs to be demonstrated. A fingerprint technique for pure compound mixtures will present data interpretation challenges.

Science/Technology Needs: A data base for rapid materials identification and model studies of materials interaction is needed.

Technical Task Plan RL421206 (FY 1992); relevance: high

Implementation Needs: Hardware costs, \$25K–\$500K; development costs, <\$200K; \$75K hardware cost projected for EPA—certified unit. Instrumentation is available at ORNL, K-25 Site, and Y-12 Plant.

Author: D. P. Hoffmann/615-574-3896

References: C. L. Putzig, et al., *Anal. Chem.* **64**(12), 270R (1992).

Note: See CHAR-18-OL for wavelength dispersive infrared.

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: Organic, inorganic

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Laboratory methods

Technology: Ultraviolet/visible spectroscopy (UV-VIS). Compounds are identified by wavelength of absorption and are quantified by their absorbance.

Status: Accepted; commercially available.

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual, automated, and robotic applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Organic; inorganic (U, Tc, Cr, CrO₄, Hg, Pb, metals, anionic species...)

Waste produced—None to a few milliliters per sample

Overall cost—\$50–\$200/sample

Efficacy/strengths—This mature technology can be used in a variety of field and laboratory procedures for the identification of materials. It can provide rapid screening capabilities for sample selection. Not typically compound-specific. Poor "fingerprint" technique, typically.

Science/Technology Needs: Model studies and application design are needed.

Implementation Needs: Hardware costs, <\$200K; development costs, <\$100K; \$50–\$500/sample. Available at ORNL, K-25 Site, and Y-12 Plant.

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References:

1. MMES staff
2. L. G. Hargis and J. A. Howell, *Anal. Chem.* **64**(12), 66R (1992).

EM Problem: Decontamination and decommissioning

ORNL Problem: See Appendix A, list A

Problem Area/Constituents: General

Reference Requirements: Ref. [] Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potential applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Laboratory methods; field methods

Technology: Electrochemical methods (e.g., electrogravimetry, polarography, coulometry, voltametry). Oxidizable or reducible species, excited by a voltage or current function in an electrical circuit, yield quantitative and qualitative information about species of interest.

Status: Accepted; commercially available

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual and automated applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Organic (oil, polychlorinated biphenyls, volatile organic compounds, trichloroethylene, ...); inorganic (U, Tc, Cr, CrO₄, Hg, Pb, I, Pu, Cd, Ni, Cu, S, Zn, Eu, Tl, ...)

Waste produced—5–100 mL/sample

Overall cost—Widely variable (~\$1K–\$50K), minimum of \$100/sample

Efficacy/strengths—A wide variety of electrochemical techniques can provide chemical and materials interaction information. These are selective and sensitive in many situations, but applicability must be demonstrated for sample/matrix combinations. These techniques could be useful in waste treatment and interaction studies, as well as identifying species present in waste streams. **Detection limits:** submicrogram for electro-active species.

Science/Technology Needs: Adaptation and protocols for model studies to be performed on complex systems are needed.

Implementation Needs: Hardware costs, \$50K–\$250K; development costs, \$250K. Instruments exist at ORNL.

Author: D. P. Hoffmann/615-574-3896. Reviewed by R. D. Shelton/615-574-6829

References: M. D. Ryan and J. Q. Chambers, "Dynamic Electrochemistry: Methodology and Application," *Anal. Chem.* **64**(12), (June 15, 1992).

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: Organic

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Laboratory methods

Technology: Nuclear magnetic resonance (NMR). A method for identification and quantitation of molecules by detecting absorption of radio frequency power that excites nuclear spin resonances of various nuclei (^1H , ^{13}C) contained in the molecule. Typically used for organic samples although selected inorganic atoms are detectable.

Status: Accepted; commercially available

Temporal areas of evaluation: Pretreatment; posttreatment

Deployment evaluation: Manual applications

Driver Evaluation: Risk and technical assessments

Applicable contaminant evaluation: Organic (oil, polychlorinated biphenyls, volatile organic compounds, trichloroethylene, ...); inorganic [odd numbered elements (^1H , ^{13}C , ^{17}O , ^{19}F , ...)]

Waste produced—None to a few milliliters per sample

Overall cost—\$200–\$500/sample

Efficacy/strengths—This mature technology can be applied to both liquid and solid samples (MAS) and can provide imaging information. This technology is very useful for identifying materials, as well as for studying material interactions. An ex situ technique only. Detection limits, hundreds of micrograms range.

Science/Technology Needs: Routine analytical procedure development

Implementation Needs: Hardware costs, \$200K–\$2M; development costs, \$200K–\$500K. Instrumentation available at ORNL and Y-12 Plant.

Author: D. P. Hoffmann/615-574-3896

Reference: J. F. Haw, *Anal. Chem.* 64(12), 243R (1992).

EM Problem: Decontamination and decommissioning

ORNL Problem: See Appendix A, list A

Problem Area/Constituents: General

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: In situ characterization and monitoring

Technology: Laser photoacoustic spectroscopy (LPAS, PAS). The photoacoustic effect is based on the conversion of absorbed light energy into heat by means of radiationless deexcitation processes. On irradiation of a solid or liquid sample by intensity-modulated light, a heat wave of the same frequency is generated in the sample. The heat wave is transferred by diffusion to the surface of the sample, where oscillatory thermal effects are generated in the coupled gas. These can be detected as an acoustic signal.

Status: Accepted

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Organic (oil, polychlorinated biphenyls, volatile organic compounds, trichloroethylene, ...); inorganic (U, Tc, Cr, CrO₄, Hg, Pb, ...)

Waste produced—Little to none

Overall cost—Moderate capital costs; cost per sample is low, \$50-\$100K.

Efficacy/strengths—The technology has high sensitivity, large dynamic range, simple experimental procedures, and can be used on gases or solids. It can be portable and allows in situ measurements. Levels of ppb detection are possible for select components..

Science/Technology Needs: Laser detection combinations (wavelength wise element) that apply to specific decontamination and decommissioning waste or monitoring scenarios are needed.

Implementation Needs: Development or enhancement of portable and in situ capabilities is needed. Development costs are estimated at ~\$400K.

Author: D. P. Hoffmann/615-574-3896

Reference: P. L. Meyer and M. W. Sigrist, *Rev. Sci. Instrum.* **61**(7), 1779 (1990).

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: Physical

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Laboratory methods

Technology: Particle-induced X-ray emission (PIXE). Protons, photons, and other particles in the 2-4MeV range, impinging upon a solid sample which, when detected with an energy dispersive detector, will yield multielement, elemental analysis quantitation, and spatial distribution in the sample.

Status: Accepted; not commercially available

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Inorganic (U, Tc, Cr, CrO₄, Hg, Pb, ...)

Waste produced—None

Overall cost—This is a high-capital item (>\$200K) and takes about 0.5 h/sample.

Efficacy/strengths—It enables trace elemental analysis over a wide elemental range.

Detection limits in ppm range. It has micro and mapping capabilities and high performance.

Science/Technology Needs: This is not a mature technology. A photon source is under development.

Implementation Needs: The instrumentation is available at ORNL. Analysis is available at outside laboratories. Sampling scenarios could be designed to identify and use the strengths of the technique.

Author: D. P. Hoffmann/615-574-3896

References:

1. W. Maenhaut, *Nucl. Instrum. Meth. Phys. Res. B* **49**, 518 (1990).
2. S. B. Török, R. E. VanGrieken, *Anal. Chem.* **64**(12), 180R (1992).

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: Organic, inorganic

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Field methods

Technology: Infrared spectroscopy (wavelength dispersion) (IR). This method includes long-path diffuse reflectance (LP) and attenuated total reflectance (ATR) for determination of compounds found in the air and water and on surfaces. Measures photon absorption due to molecular vibrations. Photon wavelength is scanned sequentially across detection range.

Status: Accepted; commercially available

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual and automated applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Organic (oil, polychlorinated biphenyls, volatile organic compounds, trichloroethylene); inorganic (anions, select dissolved gases, gases)

Waste produced—Ranges from none to a few milliliters

Overall cost—\$100/sample for liquids not needing special preparation; \$50/sample for noncorrosive gases.

Efficacy/strengths—Both LP and ATR methods have a long path range that allows averaging of emissions over a large area. Remote sensing is easily performed, with real-time results and simultaneous multiple species identification.

Science/Technology Needs: Software development would enhance site-specific applications.

Implementation Needs: Centralized mounting areas with a robotically controlled unit would allow multiple site areas to be monitored with one unit. Available at ORNL, K-25 Site, and Y-12 Plant. Capital costs, >\$5K.

Author: D. P. Hoffmann/615-574-3896

References:

1. R. H. Kagann, O. A. DeSimone, and W. F. Herget, *Proc. EPA/A & WMA Int. Symposium on Toxic and Related Air Pollutants*, 1989.
2. C. L. Puttjg, et al., *Anal. Chem.* **64**(120, 270R (1992).
3. See CHAR-8-OL for Fourier transform infrared.

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: General

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Sample preparation

Technology: Microwave digestion. Radiation in the microwave region is used to excite polar molecules to speed sample dissolution in closed systems. This is very useful in preparing soil and other environmental samples.

Status: Accepted; commercially available

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Inorganic (U, Tc, Cr, CrO₄, Hg, Pb, ...); Radioactive (α, β, γ)

Waste produced—Ranges from 0–20 mL of aqueous RCRA waste per sample, depending on the solvents used in protocol

Overall cost—\$50/sample for labor and materials

Efficacy/strengths—It has the ability to digest soil samples completely and cause extraction of trace elements from soils and complex matrices before analysis.

Science/Technology Needs: This technology shows much promise in reducing the amount of waste produced in analyzing samples, as well as increasing the quality of the data obtained.

Implementation Needs: Protocols are needed to optimize the digestion of environmental samples in preparation for subsequent analytical techniques. Development costs are estimated at ~\$200K. Equipment costs, ~\$15K for microwave digester and hood.

Authors: C. S. Dudney/615-576-2712, D. P. Hoffmann/615-574-3896

References:

1. U.S. Patents 4,835,354 and 4,877,624.
2. S. A. Malthes, R. F. Farrell, and A. J. Mackle, "A Microwave System for the Acid Dissolution of Metal and Mineral Samples," *Bureau of Mines Technical Progress Report* **120**, April 1983.
3. S. Kokot et al., "Microwave Digestion: An Analysis of Procedures," *Analytica Clinica Acta* **259**, 1992.

EM Problem: Decontamination and decommissioning; waste management

ORNL Problem: See Appendix A, lists A and C

Problem Area/Constituents: General

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Sample collection

Technology: Ultrasonic extraction. Solvent is pumped across and into a porous material surface in the presence of intense ultrasonic irradiation, which produces good solvent contact with and penetration of the sample surface, resulting in a faster and more efficient extraction of the sample for analysis.

Status: Predemonstration; technology not yet demonstrated

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Radioactive (α , β , γ); inorganic (U, Tc, Cr, CrO_4 , Hg, Pb, ...); organic (oil, polychlorinated biphenyls, volatile organic compounds, trichloroethylene, ...)

Waste produced—>5 mL, dependent on the sampling scenario, plus solvent

Overall cost—\$400/sample

Efficacy/strengths—It utilizes low-temperature, high-energy solvent extraction for removal of materials from porous media; can be conducted on-site without removing specimen from surface.

Science/Technology Needs: Testing to establish the enhancement of material retrieval from porous media using various solvents, acids, and bases is needed.

Implementation Needs: Hardware costs, \$2K–\$5K; development costs, \$200K. Inverse heads need to be designed for sampling from the floors and other horizontal (top side) applications.

Author: D. P. Hoffmann/615-574-3896

References:

1. Personal experience.
2. Interaction with various vendors for possible applications.
3. EPA SW-846 method 3550.

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: Organic, inorganic

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Field methods; laboratory methods

Technology: Immunoassay detection. Immunoassay detectors, which are very selective, sensitive, and easy to use, are used to determine environmentally important analytes. Sample wipes are used to collect smear samples of suspected contaminated areas. Wipes are extracted in the field and subjected to test kit screening using immunoassay-based methodology.

Status: Accepted

Predemonstration; immunoassay-based screening kits are commercially available for screening of polychlorinated biphenyls (PCBs) in soil. Applications to sample wipe for oils must be developed and validated.

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual, automated, and robotic applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Organic (oil, PCBs, volatile organic compounds, trichloroethylene, ...); inorganic (Hg, Pb)

Waste produced—Low, ~5 mL/sample; from PCB test—~20 cc of methanol sample extract, plus two disposable plastic tubes per analysis.

Overall cost—\$10–\$40/sample (PCB includes \$35/kit, 25–30 tests/person day)

Efficacy/strengths—It is field portable; test kits are specifically designed for target contaminants and are easy to use; detection limits are in ppb range, PCB (5 ppm). PCB tests were thoroughly evaluated in DOE Site Restoration to minimize false negatives with commercially available test kit. Samples can be acquired and screened in the field much faster than by conventional gas chromatographic analysis. Field screening of the samples can be used to identify hot spots and direct more detailed sampling efforts.

Science/Technology Needs: This is a mature and emerging technology as more become available. Kits are designed to perform in specialized waste streams. DOE has calibrated PCB

kits in the Analytical Field Screening Program. Field screening kits for PCBs in soil are commercially available. Methods for the acquisition and extraction of the wipe samples must be developed and validated.

Implementation Needs: Hardware costs, \$5K; development costs, \$100K. Automated sampling and reading systems for quick on-line testing of ground water and waste stream contamination.

Authors: W. G. Fisher/615-574-5042, D. P. Hoffmann/615-574-3896,
R. B. Gammage/615-574-6256, R. A. Jenkins/615-576-8594

References:

1. Vendor information (J.T. Baker, 1-800-JTBAKER)
2. K. R. Carter, *Environ. Protection* 3(5), 1992.
3. Roger Jenkins and Larry Waters, ACD-ORNL (PCB kit).
4. L. C. Waters, R. R. Smith, R. Counts, J. H. Stewart, and R. A. Jenkins, "Evaluation of Field Test Kits Including Immunoassays for the Detection of Contaminants in Soil and Water," presented at the Third International Symposium on Field Screening Methods, Las Vegas, February 24-26, 1993.

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: Inorganic (Hg)

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: Field and laboratory methods

Technology: Cold vapor (mercury) analysis. Based on the atomic ultraviolet and visible light absorption and phosphorescence spectroscopy of mercury. The technology is very sensitive and highly selective.

Status: Accepted; commercially available

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual and automated applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Inorganic [(Hg) Se, As]

Waste produced—About 5 mL/sample

Overall cost—Sample preparation comprises most of the sample cost.

Efficacy/strengths—It is automated; a mature technology; EPA approved; and detection is possible at ppt levels.

Science/Technology Needs: Routine procedure development.

Implementation Needs: Can be part of a mobile laboratory. Capital costs, ~\$15K.

Author: D. P. Hoffmann/615-574-3896. Reviewed by J. M. Storey/615-576-7607

References:

1. Vendor information (LDC Analytical, 1-800-532-4752)
2. K. W. Jackson and H. Qiao, *Anal. Chem.* **64**(12), 50R (1992).

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: Organic, inorganic

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Field methods

Technology: Fiber-optic chemical sensors. Remote detection using a variety of methods, including optical absorption, Raman scattering, and luminescence spectroscopy. The fiber-optic waveguide is used to deliver and/or collect the sample light. This technique allows remote sensing in hazardous environments.

Status: Accepted

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual, automated, and robotic applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Inorganic; organic (oils, polychlorinated biphenyls, volatile organic compounds, trichloroethylene, ...)

Waste produced—None

Overall cost—The cost is variable (~\$1K and up) for the fiber-optic probe. For luminescence detection (e.g., fluorescence, phosphorescence, chemiluminescence) method costs, see CHAR-92-OL. For Raman spectral detection method costs, see CHAR-84-OL. For optical absorption (e.g., UV-VIS, NIR), see CHAR-27-OL.

Efficacy/strengths—The waveguides allow a variety of spectroscopic probes to be located in remote regions and limited access areas. This technology allows remote sensing in hazardous environments and can be robotically placed within remote locations. Although this can be a "sampling" attachment for many spectroscopies, it can also be used in conjunction with a variety of physical measurements. Absorption and Raman detection limits, hundreds to thousands ppm. Luminescence detection limit to ppm for select compounds.

Science/Technology Needs: A combination of waveguides and spectroscopic techniques that have been matched not only for each other but also for specific monitoring scenarios are needed.

Technical Task Plan SF211203 (FY 1992); relevance: high
SF221104 (FY 1992); relevance: high

Implementation Needs: Waveguides that can withstand the harsh chemical environment that may be present in some of the sampling locations are needed.

Author: D. P. Hoffmann/615-574-3896. Reviewed by E. A. Wachter/615-574-6248

References:

1. R. E. Dessey, *Anal. Chem.* **61**(19), 1079R (1989).
2. J. Janata, "Chemical Sensors," *Anal. Chem.* **64**(19), June 15, 1992.

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: Dust, particulates

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: In situ characterization and monitoring

Technology: Particle size analysis. Photographic, photometric, and electrometric techniques produce size measurement and distribution data for particulates in powder and slurry samples.

Status: Accepted; commercially available

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: All particulates

Waste produced—None to very little

Overall cost—About \$10K and up

Efficacy/strengths—There are a variety of particle-size determination technologies on the market. These are mature technologies that can collect samples for particle-size distribution, and then allow further analysis to be performed on the collected material. There are several in situ, real-time monitoring devices, and the lower limit of detection is constantly being pushed back.

Science/Technology Needs: Routine analytical procedure development.

Implementation needs: In situ devices need to be implemented for more aggressive industrial hygiene/health physics protection of personnel and to ensure the control (i.e., prevent spread) of radioactive contamination.

Author: D. P. Hoffmann/615-574-3896

References: Vendor literature.

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: Organics, inorganics

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Field methods

Technology: Optical absorption spectroscopy (OAS). Measures the transmission of ultraviolet (UV), visible, and near infrared (IR) to determine the concentration of chemical species in gases, liquids, or solids. OAS can be applied to the analysis of any species that absorbs electromagnetic radiation in the region of excitation, UV through IR. Instrumentation varies from simple, inexpensive spectrometers to sophisticated systems that offer highly selective analysis of complex samples.

Status: Accepted; commercially available

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Organic; inorganic

Waste produced—None to minimal, solvent

Overall cost—\$10–\$50/sample; instrumentation, \$1K–\$100K

Efficacy/strengths—Fast response time, ppm to ppb level of detection for selected compounds, and remote nondestructive field analysis proven. Mixtures may be an analysis challenge.

Science/Technology Needs: Mature, field-portable IR technology is available; UV technology is being developed at ORNL.

Implementation Needs: It can be implemented for direct site/scenario needs.

Authors: D. P. Hoffmann/615-574-3896, E. A. Wachter/615-574-6248

References:

1. Edner, et al., *Appl. Opt.* **25**, 403 (1986).
2. L. G. Harsts and J. A. Howell, "UV and Light Absorption Spectrometry," *Anal. Chem.* **64**(12), June 15, 1992.
3. C. L. Putzig, et al., *Anal. Chem.* **64**(12), June 15, 1992.

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: Inorganic

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Laboratory methods

Technology: Powder X-ray diffraction (XRD). X-ray powder diffraction technique for phase identification based on measurement of structure-sensitive diffracted X-ray lines. It involves the characterization of materials by use of data that are dependent on the atomic arrangement in the crystal lattice.

Status: Accepted; commercially available

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual and automated applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Inorganic (U, Tc, Cr, CrO₄, Hg, Pb, ...)

Waste produced—None to 5 mL/sample

Overall cost—High capital costs for equipment, >\$100/sample

Efficacy/strengths—Phase identification of crystalline phases in solid samples. Approximately 1 wt% lower limit of detection. It can supply quantitative, stress/strain, and particle size information to perhaps >20% accuracy. Noncrystalline materials and most solid organics are not routinely detectable.

Science/Technology Needs: This is a mature technology. Model studies of the complex mixtures of interest are needed if quantitative analysis is desired.

Implementation Needs: Capital costs, \$50K minimum. Equipment available at ORNL, K-25 Site, and Y-12 Plant.

Author: D. P. Hoffmann/615-574-3896

References: Materials Science Department, Martin Marietta Energy Systems, Inc., Oak Ridge K-25 Site, Oak Ridge, Tenn. 37381-7272.

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: Physical

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: Laboratory (ex situ) characterization and monitoring

Technology: Optical microscopy. Visible light microscopes are used to determine the size, morphology and identification of solid materials.

Status: Accepted; commercially available

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Inorganic (U, Tc, Cr, CrO₄, Hg, Pb, ...); organic (solids)

Waste produced—None to 1 mL/sample; sample and sample holder become waste

Overall cost—\$50/sample minimum.

Efficacy/strengths—This is a mature technology. A variety of optical parameters and techniques can be used to identify, document, measure, and quantify samples. Sample analysis is labor intensive and requires interpretation of data.

Science/Technology Needs: A particle atlas of site-specific materials is needed to allow rapid identification.

Implementation Needs: A centralized image collection system is needed to establish a site-specific database. Capital costs, \$5K minimum. Instruments are available at ORNL, K-25 Site, and Y-12 Plant.

Author: D. P. Hoffmann/615-574-3896

References: Materials Science Department, Martin Marietta Energy Systems, Inc., Oak Ridge K-25 Site, Oak Ridge, Tenn. 37381-7272.

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: Inorganic

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Laboratory methods

Technology: Scanning electron microscopy (SEM). A focused, high-energy beam of electrons produces secondary and back-scattered electrons when it impinges on a sample in high vacuum. Because of its high-resolution spatial characteristics, the technique is suitable for texture analysis, mapping, and corrosion studies. It is frequently coupled with X-ray excitation to provide elemental information.

Status: Accepted; commercially available

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Inorganic (U, Tc, Cr, CrO₄, Hg, Pb, ...)

Waste produced—None to 5 mL/sample; includes sample holder

Overall cost—\$500/sample

Efficacy/strengths—The technology allows the documentation and analysis of very small particles approaching tens of angstroms. It allows sample preparation and collection to minimize the waste generated. It can magnify a sample in the range of 10x–800,000x. It is most powerful when used in conjunction with analytical attachments (EDS, WDS, image analysis) and differing electron imaging modes.

Science/Technology Needs: Routine methods development

Implementation Needs: This is a mature technology. Capital costs, ~\$100K minimum. Instruments available at ORNL, K-25 Site, and Y-12 Plant.

Author: D. P. Hoffmann/615-574-3896

References: Materials Science Department, Martin Marietta Energy Systems, Inc., Oak Ridge K-25 Site, Oak Ridge, Tenn. 37381-7272.

EM Problem: Decontamination and decommissioning

ORNL Problem: See Appendix A, list A

Problem Area/Constituents: Physical, inorganic

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Laboratory methods

Technology: Transmission electron microscopy (TEM). A beam of high-energy electrons is focused onto a sample in vacuum. Resolution of less than 1 μm permits the determination of microstructure approaching atomic dimensions, particle sizing, and microanalysis. Often coupled with X-ray techniques, this technique can be used to obtain elemental analyses.

Status: Accepted; commercially available

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Inorganic (U, Tc, Cr, CrO_4 , Hg, Pb, ...)

Waste produced— 1 mL/sample; sample and sample grid become waste

Overall cost—\$500/sample minimum

Efficacy/strengths—It has ultrahigh resolution (down to .75 Å). It is an accepted method for certain applications (e.g., asbestos, ceramics), and has a wide range of technical applications. It is most powerful when used in conjunction with its analytical capabilities (EDS, image analysis, electron diffraction).

Science/Technology Needs: Routine analytical procedure development

Implementation Needs: This is a mature technology. Capital costs, \$200K minimum. Instruments available at ORNL, K-25 Site, and Y-12 Plant.

Author: D. P. Hoffmann/615-574-3896

References: Materials Science Department, Martin Marietta Energy Systems, Inc., Oak Ridge K-25 Site, Oak Ridge, Tenn. 37381-7272.

EM Problem: Decontamination and decommissioning

ORNL Problem: See Appendix A, list A

Problem Area/Constituents: Inorganic

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: Field and laboratory methods

Technology: Energy dispersive X-ray spectroscopy (EDS, EDX, EDAX). It is a method for elemental analysis based on the separation of X ray according to their energies, by use of a lithium-drifted silicon proportional detector.

Status: Accepted; commercially available

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Inorganic (U, Tc, Cr, CrO₄, Hg, Pb, most metals, Al-V, ...)

Waste produced—None if in situ field measurement made, otherwise 5 mL/sample; sample and sample holder become waste.

Overall cost—\$100/sample

Efficacy/strengths—It allows rapid elemental analysis (beryllium and up) and quantitative analysis of solid samples. It is typically used in conjunction with electron microscopy. Although the detection limit is roughly 1 wt%, that is the detection limit of the area of the sample that is being probed (1 micrometer² or less). Thus, it is possible to analyze the individual materials that are present in the ppb range and lower for samples of select morphologies.

Science/Technology Needs: Improved resolution in field able equipment.

Implementation Needs: Training of operating personnel requires good knowledge of X-ray techniques. Capital costs, \$50K minimum. Laboratory-based instruments available at ORNL, K-25 Site, and Y-12 Plant.

Author: D. P. Hoffmann/615-574-3896

References:

1. Materials Science Department, Martin Marietta Energy Systems, Inc., Oak Ridge K-25 Site, Oak Ridge, Tenn. 37381-7272.
2. S. B. Török and R. E. VanGrieken, *Anal. Chem.* **64**(12), 180R (1992).

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: Inorganic

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: Field and laboratory methods

Technology: Wavelength dispersive X-ray spectroscopy (WDS, WDX). It is a method for qualitative and quantitative elemental analysis, using the wavelengths of characteristic X-ray emission lines, in which a single diffracting crystal is used to separate the wavelength from the sample.

Status: Accepted; commercially available

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Inorganic (U, Tc, Cr, CrO₄, Hg, Pb, most metals, Be-V, ...)

Waste produced—None if in situ field measurement made, otherwise about 5 mL/sample; becomes waste along with sample holder.

Overall cost— <\$100/sample

Efficacy/strengths—It allows rapid elemental analysis (beryllium and up) and quantitative analysis of solid samples. It is typically used in conjunction with electron microscopy. Although the detection limit is roughly 1 wt%, that is also the detection limit of the area of the sample that is being probed (1 micrometer² or less). Thus, it is possible to analyze individual materials that are present in the ppb range and lower for samples of select morphologies.

Science/Technology Needs: Field units need improved resolution.

Implementation Needs: Training in operation requires good knowledge of X-ray techniques. Capital costs, \$50K minimum. K-25 Site has a laboratory instrument.

Author: D. P. Hoffmann/615-574-3896

References:

1. Materials Science Department, Martin Marietta Energy Systems, Inc., Oak Ridge K-25 Site, Oak Ridge, Tenn. 37381-7272.
2. S. B. Török and R. E. VanGrieken, *Anal. Chem.* **64**(12), 180R (1992).

EM Problem: Decontamination and decommissioning

ORNL Problem: See Appendix A, list A

Problem Area/Constituents: Inorganic

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Laboratory methods

Technology: Electron diffraction (ED, SAED, LEED)

Status: Accepted

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Inorganic (U, Tc, Cr, CrO₄, Hg, Pb, ...)

Waste produced—1 mL/sample; sample and sample holder become waste

Overall cost—High capital equipment costs

Efficacy/strengths—When used in conjunction with transmission electron microscopy, this technology can provide phase identification of submicron particulates and impurities in a host matrix. It allows identification of asbestos.

Science/Technology Needs: Routine procedure development

Implementation Needs: None

Author: D. P. Hoffmann/615-574-3896

References: Materials Science Department, Martin Marietta Energy Systems, Inc., Oak Ridge K-25 Site, Oak Ridge, Tenn. 37381-7272.

EM Problem: Decontamination and decommissioning

ORNL Problem: See Appendix A, list A

Problem Area/Constituents: Physical

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: In situ characterization and monitoring

Technology: Nondestructive testing (NDT) for concrete

Status: Accepted; commercially available components

Temporal areas of evaluation: Pretreatment; posttreatment

Deployment evaluation: Manual and robotic applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Inorganic (U, Tc, Cr, CrO₄, Hg, Pb, ...)

Waste produced—None

Overall cost—Variable

Efficacy/strengths—The technology can determine the strength and capabilities of concrete without imparting any physical damage to the existing structure.

Science/Technology Needs: Testing protocols for evaluating and characterizing large concrete structures are needed.

Implementation Needs: A testing plan for site buildings and a field testing kit for site-wide deployment are needed.

Author: D. P. Hoffmann/615-574-3896

References: J. R. Clifton; Dialog File No. 265/266, ID No. 62266.

EM Problem: Decontamination and decommissioning

ORNL Problem: See Appendix A, list A

Problem Area/Constituents: Physical

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: Statistics, modeling, and data assessment

Technology: Inorganic cementitious matrix composites model

Status: Demonstration

Temporal areas of evaluation: Pretreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Inorganic (U, Tc, Cr, CrO₄, Hg, Pb, ...); radioactive (α , β , γ)

Waste produced—Not applicable

Overall cost—

Efficacy/strengths—The technology determines the structural properties of cementitious materials and how they evolve and interact with other materials. This will lead to a better understanding of concrete/contaminant interactions and should allow for optimization of various sampling and decontamination protocols.

Science/Technology Needs: Characterization of variations in cement for various structures of interest is needed. Matrix/contaminant interaction studies are needed.

Implementation Needs: No unusual needs

Author: D. P. Hoffmann/615-574-3896

References: T. Sugama; Dialog File No. 265/266; ID No. 55022; AS-253-EECD.

EM Problem: Decontamination and decommissioning

ORNL Problem: See Appendix A, list A

Problem Area/Constituents: Physical

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: Field and laboratory methods

Technology: Radiographic imaging. Use of either X rays or gamma rays and a suitable photographic film to perform nondestructive testing of numerous materials. The radiographic source is placed on one side of the material being tested and the film on the other.

Status: Accepted; commercially available

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Radioactive (α , β , γ)

Waste produced—None if digital technology, otherwise photographic waste is generated.

Overall cost—

Efficacy/strengths—Digital radiography can be used to determine the distribution of rad in low-level nuclear waste forms. Classical radiography can be used to provide spatial distribution information for radiological contaminants. Quantitative analysis is challenging.

Science/Technology Needs: Scattering and attenuation factors exhibited by the host matrix on the radiograph need to be better understood.

Implementation Needs: Medium to high capital equipment costs, \$25 minimum for digital system, photographic system is very inexpensive.

Author: D. P. Hoffmann/615-574-3896

References: R. T. Bernardi; Dialog File No. 265/266; ID No. 54711.

EM Problem: Waste management

ORNL Problem: See Appendix A, list C

Problem Area/Constituents: Physical

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Laboratory methods

Technology: Computer tomography (CT). A technique of producing cross-sectional, three-dimensional images from multiple views or projection data obtained with penetrating probe radiations, or by other means such as magnetic field gradients, by processing those data using a computer and mathematical image reconstruction techniques.

Status: Accepted; commercially available for X-ray and nuclear magnetic resonance

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Inorganic (U, Tc, Cr, CrO₄, Hg, Pb, ...)

Waste produced—None

Overall cost—High capital equipment costs

Efficacy/strengths—This is a nondestructive imaging technique that can characterize low-level nuclear waste for water content.

Science/Technology Needs: The technology is being developed and may apply to many scenarios.

Implementation Needs: Implementation needs are uncertain at this time.

Author: D. P. Hoffmann/615-574-3896

References: R. T. Bernardi; Dialog File No. 265/266; ID No. 54711.

EM Problem: Decontamination and decommissioning

ORNL Problem: See Appendix A, list A

Problem Area/Constituents: Physical

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: Field and laboratory methods

Technology: Radiation-induced segregation (RIS) model

Status: Demonstration

Temporal areas of evaluation: Pretreatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Inorganic (U, Tc, Cr, CrO₄, Hg, Pb, ...); radioactive (α, β, γ)

Waste produced—Not applicable

Overall cost—

Efficacy/strengths—This model can lead to a better understanding of the migration of contaminants and the creation of defect sites in materials caused by radiation effects.

Science/Technology Needs: Models need to be used to determine if high radiation fields and temperature combinations in reactor equipment allow for an enhancement of defect sites, which may cause variability in decontamination or dismantlement.

Implementation Needs: Same as Science/Technology Needs. Development costs are estimated at ~\$500K.

Author: D. P. Hoffmann/615-574-3896

References: L. E. Rehn; Dialog File No. 265/266, ID No. 795; 58403.

EM Problem: Decommissioning

ORNL Problem: See Appendix A, list A

Problem Area/Constituents: Fissionable materials

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: Statistics, modeling, and data assessment

Technology: Criticality indices (CI). This technology is used to indicate whether accumulations of fissionable material are a potential criticality hazard.

Status: Accepted; must be implemented to specifically address the D&D technologies to be used and suggest modifications needed for low- versus high-enrichment materials.

Temporal areas of evaluation: Pretreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Uranium

Waste produced—Not applicable

Overall cost—

Efficacy/strengths—The criticality needs of decontamination and decommissioning (D&D) efforts can quickly be identified as the enrichment level of the contaminant waste stream varies.

Science/Technology Needs: Routine applications of modeling calculations

Implementation Needs: Development costs are estimated at ~\$250K.

Author: D. P. Hoffmann/615-574-3896

References: B. L. Broadhead; Dialog File No. 265/266; ID No. 66669.

EM Problem: Remedial action

ORNL Problem: See Appendix A, list B

Problem Area/Constituents: General

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: Statistics, modeling, and data assessment

Technology: Subsurface complexation model

Status: Demonstration

Temporal areas of evaluation: Pretreatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Radioactive (α , β , γ); inorganic (U, Tc, Cr, CrO_4 , Hg, Pb, ...); organic (oil, polychlorinated biphenyls, volatile organic compounds, trichloroethylene, ...)

Waste produced—Not applicable

Overall cost—

Efficacy/strengths—This modeling, and our understanding of it, will allow a logical choice of waste management and disposal technologies and an understanding of where contaminants may migrate prior to environmental restoration activities.

Science/Technology Needs: Models that take into account the geological formations weather and surface chemistry that exist within the Oak Ridge Reservation need to be implemented. Understanding Tc chemistry is particularly important.

Implementation Needs: Routine applications of modeling

Author: D. P. Hoffmann/615-574-3896

References: D. L. Perry; Dialog File No. 265/266; ID No. 51826, ESD-60.

EM Problem: Decontamination and decommissioning

ORNL Problem: See Appendix A, list A

Problem Area/Constituents: Physical

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: In situ characterization and monitoring

Technology: Holographic imaging. A nondestructive testing technique that uses laser light to form a holographic image of an object on a special photographic plate. If the object has moved slightly or has been deformed, bands of interference fringes on the surface of the object will be seen. The frequency and width of these fringes is a measure of the amount of surface displacement.

Status: Accepted; commercially available

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Not applicable

Waste produced—None

Overall cost—

Efficacy/strengths—The technology allows in situ measurements to be taken of the stress/strain distribution over large areas. This will be extremely useful in understanding the risks in removing large pieces of equipment and applying high-pressure or high-energy decontamination techniques to equipment.

Science/Technology Needs: This is a mature technology.

Implementation Needs: A holographic imaging laboratory with field-portable units would be needed to allow holographic imaging of permanently-mounted components.

Author: D. P. Hoffmann/615-574-3896

References: MMES staff members.

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: Inorganic

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: Laboratory methods

Technology: Isotopic dilution mass spectrometry (IDMS). A method for quantitative determination of concentrations of elemental species by incorporating a standard that contains more than one isotope of the element of interest in the sample.

Status: Accepted; commercially available equipment

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Inorganic (U, Tc, La, Th, Te, Cr, CrO₄, Hg, Pb, ...); organic (oil, polychlorinated biphenyls, volatile organic compounds, trichloroethylene, ...); radioactive (α, β, γ)

Waste produced—None to approximately 5 mL/sample

Overall cost—\$100–\$1000/sample

Efficacy/strengths—It is able to measure the natural levels of long-lived fission products (technetium, iodine) and neutron-capture product (plutonium) as low as 10^7 atoms.

Science/Technology Needs: None

Implementation Needs: Moderate to high capital equipment costs, \$200K–\$400K

Author: D. P. Hoffmann/615-574-3896

References:

1. D. B. Curtis; Dialog File No. 265/266; ID No. 25825; ERWE552C.
2. D. W. Koppenaal, *Anal. Chem.* 62(12), 303R (1990).

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: Anions and cations

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: Laboratory and mobile lab characterization and analysis

Technology: Ion chromatography (IC). A type of liquid chromatography for the separation of ions based on their charge affinity for the ionic functional groups of the column packing. The ions are usually measured by conductivity detection.

Status: Accepted; equipment commercially available

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual and automated applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Inorganic (U, Tc, Cr, CrO₄, Hg, Pb, ...); Pu, other translls, RE; halides, PO₄³⁻, NO₃⁻.

Waste produced—To 100 mL/sample

Overall cost—\$100/sample

Efficacy/strengths—It has the ability to separate and quantify anions and cations in solution (ppm to ppb detection limits depending upon the matrix effects). It can be automated and performed in some on-line process applications. Mobile lab use.

Science/Technology Needs: A detector system that is optimized for the expected waste streams that will be generated needs to be determined. This type of system can be used for process control of waste generation.

Implementation Needs: Systems for process control of decontamination and decommissioning efforts are available. Low capital equipment costs, \$20K-\$50K.

Author: D. P. Hoffmann/615-574-3896

References: P. R. Haddad; Dialog File No. 265/266; ID No. 25460.

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: Personnel, clothing, uranium

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: Personnel monitoring

Technology: Personnel monitoring. Need for advanced methods of uranium analysis in body tissues.

Status: Preconceptual; there is a need for quantitative measurements of uranium in human components (hair, blood, nails) that can be used to verify exposure, both past and present. This benchmarking will allow the best health monitoring of workers.

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Radioactive (α , β , γ); inorganic (U, Tc, Cr, CrO_4 , Hg, Pb, ...); organic (oil, polychlorinated biphenyls, volatile organic compounds, trichloroethylene, ...)

Waste produced—To be determined

Overall cost—Variable

Efficacy/strengths—To be determined

Science/Technology Needs: Model studies are needed to correlate exposure and quantitative analysis from various human factors.

Implementation Needs: To be determined

Author: D. P. Hoffmann/615-574-3896

References: University of Sidney, Dialog File No. 265/266; ID No. 24317.

MODELING OF VOLATILE ORGANIC COMPOUNDS MIGRATION IN POROUS MATERIALS

CHAR-53-OL

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: General

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: Statistics, modeling, and data assessment

Technology: Modeling of volatile organic compounds (VOCs) migration in porous materials

Status: Demonstration

Temporal areas of evaluation: Pretreatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Organic (oil, polychlorinated biphenyls, VOCs, trichloroethylene, ...)

Waste produced—Method is intended to minimize waste in sampling and analysis.

Overall cost—

Efficacy/strengths—A better understanding of the migration of VOCs in porous materials will allow better predictions as to the extent of remediation or decontamination required for their disposal. This understanding will also allow a more intelligent application of solvent decontamination technologies to be used on porous media.

Science/Technology Needs: Models that are applicable to site-specific scenarios need to be developed.

Implementation Needs: Software and hardware are needed to implement the modeling systems. Development costs are estimated at ~\$250K.

Author: D. P. Hoffmann/615-574-3896

References: R. B. Wallace; Dialog File No. 265/266; ID No. 2P42ES04911-04 0004.

September 1993

MEMBRANES FOR SAMPLE COLLECTION AND CONCENTRATION

CHAR-55-OL

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: General

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Field methods

Technology: Membranes for sample collection and concentration. Membranes that are predominantly permeable to selected components in mixtures are exposed, then separated for accumulation or to facilitate analysis/detection.

Status: Accepted; demonstration

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual, automated, and robotic applications

Driver evaluation: Risk assessment

Applicable contaminant evaluation: Inorganic (U, Tc, Cr, CrO₄, Hg, Pb, ...); organic (oil, polychlorinated biphenyls, volatile organic compounds, trichloroethylene, ...); radioactive (α , β , γ)

Waste produced—Used membranes may be waste

Overall cost—\$50/sample

Efficacy/strengths—The use of membrane technology can assist in a large number of characterization and decontamination scenarios. The ability to use membranes for the selective separation and concentration of a contaminant allows the contaminant to be identified by cheaper, less-sensitive (typically) field-portable instrumentation.

Science/Technology Needs: System development or adaptation for specific applications; validation of the method with concurrent sampling.

Implementation Needs: Sample collection systems for site-specific applications are needed. Development costs are estimated at ~\$250K.

Author: D. P. Hoffmann/615-574-3896. Reviewed by R. D. Shelton/615-574-6829

September 1993

References:

1. J. M. Radovich; Dialog File No. 265/266; ID No. 008194.
2. R. E. Clement, M. L. Langhorst, and G. A. Elceman, "Environmental Analysis," *Anal. Chem.* 63(12), 270R, June 15, 1992.

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: General

Reference Requirements: Refer to the final chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Laboratory methods

Technology: Glow discharge ionization mass spectroscopy. This type of glow discharge is applicable for virtually any kind of solid sample or solution residue for elemental and isotopic analysis. All elements except gases from Li-Pu can be analyzed.

Status: Accepted

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Inorganic (U, Tc, Cr, CrO₄, Hg, Pb, ...); solution residues (oils, etc.)

Waste produced—None to approximately 5 mL/sample and/or sample residue

Overall cost—High capital costs, \$200K

Efficacy/strengths—It allows on-site monitoring of elements in a variety of host matrices. Quantification down to the ppb level is possible.

Science/Technology Needs: Relative sensitive factors for elements of interest need to be characterized for relevant matrices. Optimum sample preparation methods used to be developed. The relative merit of direct current and radio frequency glow discharges need to be evaluated.

Implementation Needs: A flat cell for use with the rf discharge needs to be developed. At present, instruments such as this are only in laboratories; a fieldable instrument needs to be developed. Development costs of ~\$500K for fieldable ion trap mass spectroscopy instrument.

Author: D. P. Hoffmann/615-574-3896. Reviewed by D. H. Smith/615-574-2449

References: MMES staff members.

EM Problem: Decontamination and decommissioning

ORNL Problem: See Appendix A, list A

Problem Area/Constituents: Physical

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Laboratory methods

Technology: Magnetic resonance imaging (MRI, NMRI). Imaging technology using the nuclear magnetic resonance phenomenon; most applications currently detect hydrogen but others are possible.

Status: Accepted

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Inorganic (U, Tc, Cr, CrO₄, Hg, Pb, ...); organic (oil, polychlorinated biphenyls, volatile organic compounds, trichloroethylene, ...); radioactive (α , β , γ)

Waste produced—None, entire sample is used in an in situ determination

Overall cost—To be determined

Efficacy/strengths—This mature, yet growing, technology has the potential to allow nondestructive inspection of the internal structure of materials and evaluation of system integrity. This type of technology may provide very useful information, not only for identifying how to dismantle an unknown, but for verifying the status of waste form integrity. Not applicable to metal (steel) containers.

Science/Technology Needs: Model studies for waste forms and various equipment parts are needed.

Implementation Needs: Instrumentation is needed. Development costs are estimated at ~\$200K. Very high capital equipment costs.

Author: D. P. Hoffmann/615-574-3896

References: M. P. Andre; Dialog File No. 265/266; ID No. 0004; 83381; 664.

September 1993

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: Dust, particulates, airborne organics

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Field methods

Technology: Air monitoring (AM). Encompasses several methods of monitoring particulate loading and characteristics including filtering, particle size analysis, etc. Collected samples can be analyzed for a host of different species.

Status: Accepted; systems commercially available

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual, automated, and robotic applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Inorganic (U, Tc, Cr, CrO₄, Hg, Pb, ...); radioactive (α , β , γ); organic (oil, polychlorinated biphenyls, volatile organic compounds, trichloroethylene, ...)

Waste produced—None to moderate (where sample filtering is performed or when sample solvent extraction is required)

Overall cost—Collection equipment, \$10K; samples, \$5–\$100/sample, depending on the species of interest.

Efficacy/strengths—Air monitoring during remediation activities should comply with Clean Air Act amendments (CAA, 1990). Hazardous air pollutants (HAPs) have been identified, and monitoring procedures are available for both gas and particle phases.

Science/Technology Needs: This is a mature sampling technology with EPA protocols.

Implementation Needs: This is a mature technology.

Author: D. P. Hoffmann/615-574-3896. Reviewed by J. M. Storey/615-576-7607

References:

1. M. D. Hoover; Dialog File No. 265/266; ID No. 62466.
2. F. W. Liberti, A. Febo, and M. Possanzini, *NATO ASI Ser.*, **252** (1988).
3. Graseby-Andersen Instruments Inc. (vendor), 404-691-1910.
4. D. L. Fox, "Air pollution," *Anal. Chem.* **63**(12), June 15, 1992.

EM Problem: Remedial action

ORNL Problem: See Appendix A, list B

Problem Area/Constituents: General

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Field methods

Technology: Tomographic seismic monitoring (TSI)

Status: Accepted; commercially available

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Inorganic (U, Tc, Cr, CrO₄, Hg, Pb, ...)

Waste produced—None

Overall cost—

Efficacy/strengths—TSI can allow the quantitation of the interaction between soil type and transport properties of toxic wastes. This information will have great potential to allow better sampling locations to be determined, leading to better characterization, as well as allowing a better determination of the area to be characterized.

Science/Technology Needs: To be determined

Implementation Needs: To be determined

Author: D. P. Hoffmann/615-574-3896

References: MMES staff members.

EM Problem: Decommissioning

ORNL Problem: See Appendix A, list A

Problem Area/Constituents: Physical

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Sample collection

Technology: Modeling of heterogeneous materials sampling. This technology allows quantification of contaminant of interest in "difficult-to-collect" substrates; can be applied to polychlorinated biphenyl (PCB)-contaminated concrete.

Status: Evolving; conceptual. This method would use hemometric-based data analysis to compare the collection of contaminants during sampling as a function of the host matrix porosity and collection method.

Temporal areas of evaluation: Pretreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Inorganic (U, Tc, Cr, CrO₄, Hg, Pb, ...); radioactive (α , β , γ); organic (oil, PCBs, volatile organic compounds, trichloroethylene, ...)

Waste produced—Method minimizes sampling waste.

Overall cost—

Efficacy/strengths—Would allow better quantitative evaluation of contaminants or porous media.

Science/Technology Needs: An experimental design, models need to be established.

Implementation Needs: A study needs to be performed. Development costs are estimated at ~\$300K.

Author: D. P. Hoffmann/615-574-3896

References: MMES staff members.

EM Problem: Decontamination and decommissioning; waste management

ORNL Problem: See Appendix A, lists A and C

Problem Area/Constituents: General

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Sample Collection

Technology: In situ solvent extraction. The sample is obtained by forcing solvent into the host matrix during or after low-angle drilling.

Status: Evolving; conceptual

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Inorganic (U, Tc, Cr, CrO₄, Hg, Pb, ...); radioactive (α , β , γ); organic (oil, polychlorinated biphenyls, volatile organic compounds, trichloroethylene, ...)

Waste produced—5-100 mL/sample; solvent used in extraction

Overall cost—Low

Efficacy/strengths—On-site collection of contaminant from diffusion boundary of porous media. Allows sample collection in difficult-to-access areas.

Science/Technology Needs: Model studies are needed to evaluate the technique.

Implementation Needs: Development costs, \$400K.

Author: D. P. Hoffmann/615-574-3896

Reference: MMES staff members.

MULTIANGLE DRILLING FOR DEPTH PROFILING OF CONTAMINANTS

CHAR-64-OL

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: General

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Sample collection

Technology: Multiangle drilling for depth profiling of contaminants. Applicable to heterogeneous materials.

Status: Demonstration; this system can utilize standard drilling equipment which is commercially available.

Temporal areas of evaluation: Pretreatment; posttreatment

Deployment evaluation: Manual and robotic applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Inorganic (U, Tc, Cr, CrO₄, Hg, Pb, ...); radioactive (α , β , γ); organic (oil, polychlorinated biphenyls, volatile organic compounds, trichloroethylene, ...)

Waste produced—Variable, from drilling activities and samples

Overall cost—Low

Efficacy/strengths—Although core drilling is a preferred technique to remove a sample that remains spatially resolved, it is not always possible to do so. Multiangle drilling should allow a summation of depth artifacts to be determined through analysis of each sample collected.

Science/Technology Needs: Model studies need to be performed.

Implementation Needs: Routine procedure development. Development costs, \$200K.

Author: D. P. Hoffmann/(615)574-3896

References: MMES staff members.

September 1993

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: Radioactive elements, alpha emitters

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified. DOE Order 5400.5, ANSI N13.12, and NRC 5

Subelement: Characterization

Alternative: Field methods

Technology: Long-range alpha detector (LRAD). It is a screening device for detecting alpha radioactivity on surfaces or personnel and in soil or waste. It measures ionized air drawn from a container holding a contaminated object, irrespective of shape.

Status: Demonstration

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual and automated applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Radioactive (α , β , γ)

Waste produced—None

Overall cost—\$10K/device, price should decrease after commercialization.

Efficacy/strengths—It detects surfaces/objects contaminated at or below release limits.

Measurements are semiquantitative but can be sensitive to ~100 dpm alpha.

Science/Technology Needs: MacArthur et al. (1992) has demonstrated the principle of the measurement technique. Measurement probes and other devices must be developed for specific applications and probe size reduction is needed.

Implementation Needs: Field testing is needed (~\$300K).

Author: C. S. Dudney/615-576-2712

Reference: D. W. MacArthur, et al., "Long-Range Alpha Detector," *Health Phys.* 63(3), 324-330 (1992).

GAS CHROMATOGRAPHY-FOURIER TRANSFORM INFRARED SPECTROSCOPY

CHAR-66-OL

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: Organics

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Laboratory methods

Technology: Gas chromatography-Fourier transform infrared spectroscopy (GC-FTIR). Organic compounds separated by gas chromatograph (GC) are identified by their infrared spectrum as they exit the GC and are quantified by the absorption of one or more wavelengths.

Status: Demonstration; commercial technology is available

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Organic (oil, polychlorinated biphenyls, volatile organic compounds, trichloroethylene, ...)

Waste produced—<1 mL/sample (not including standard preparation or waste GC column material)

Overall cost—About \$500/sample

Efficacy/strengths—GC-FTIR combines the separation capabilities of gas chromatography with the structural identification capabilities of Fourier transform infrared spectroscopy. The technique is complementary to gas chromatography-mass spectroscopy. It can provide isomer-specific identification.

Science/Technology Needs: Specific methods for targeted analytes and routine methods for unknown identification need to be developed. Software for data interpretation needs to be developed, and different commercial interface configurations for desired characteristics (sensitivity, reproducibility, etc.) need to be evaluated.

Implementation Needs: Capital costs, \$200K; development costs, \$400K. One instrument is available at ORNL.

September 1993

Author: G. B. Hurst/615-574-6691

References:

1. C. L. Putzig et al., *Anal. Chem.* **64**, 270R-302R (especially pp. 288-9) (1992).
2. G. A. Elceman, et al., *Anal. Chem.* **64**, 170R-180R (especially p. 175R) (1992).
3. GC-FTIR manufacturers: Biorad/Digilab, Cambridge, Mass., 617-499-4519
Mattson, Madison, Wis., 608-831-5515
Nicolet, Madison, Wis., 800-346-7288

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: Physical, inorganic

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Sample collection

Technology: Metallographic sectioning and preparation

Status: Accepted; equipment commercially available

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual, automated, and robotic applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Radioactive; inorganic (metals)

Waste produced—About 1 L liquid and spent abrasive per 1–6 samples

Overall cost—<\$500/sample

Efficacy/strengths—Provides representative sample that shows contaminant depth distribution.

Science/Technology Needs: Procedure development for specific applications is needed; then protocols for standardized preparation should be developed.

Implementation Needs: None. Facilities available at ORNL and K-25 Site (see also core drilling).

Author: G. C. Marsh/615-576-6913

Reference: Technique is used routinely for preparation of metallic, ceramic, and geological materials.

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: Radioactive elements, inorganic, organic, metals

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Sample collection

Technology: Optimization of sampling designs. Research and development in the statistical aspects of sampling diverse, extensive, and nonhomogeneous media.

Status: Demonstration

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual, automated, and robotic applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Radioactive (α , β , γ); inorganic (U, Tc, Cr, CrO_4 , Hg, Pb, ...); organic (oil, polychlorinated biphenyls, volatile organic compounds, trichloroethylene, ...)

Waste produced—Design is intended to minimize waste and analyses effort.

Efficacy/strengths—Appropriate sampling designs can prevent obtaining too little information when sampling is complete or spending too much money on a more than adequate number of samples.

Science/Technology Needs: Literature searches for useful sampling designs from investigations in other fields and new statistical methods for sampling design are needed.

Implementation Needs: Development costs are estimated at ~\$100K.

Author: J. L. Bock/615-576-5735

Reference: K-25 Site Statistical Services.

EM Problem: Decommissioning

ORNL Problem: See Appendix A, list A

Problem Area/Constituents: Inorganics

Reference Requirements: EPA regulations, ASTM methods. Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Laboratory methods

Technology: Atomic emission spectroscopy. Light emitted by one or more thermally stimulated elements is used for quantitative and qualitative analysis.

Status: Accepted; equipment commercially available

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual and automated applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Inorganic (all elements)

Waste produced—Very small quantities (<10 mL) of aqueous waste/sample

Overall cost—\$100-\$200/metal determined

Efficacy/strengths—It is a standard, well-accepted methodology for highly-sensitive and selective determination of elements alone or in chemical or physical combinations. Analysis is semiquantitative but an excellent screening analysis for most elements.

Science/Technology Needs: The technology is well-developed and applicable as is. Automation is necessary to prepare for large sample load.

Implementation Needs: Technology is available at ORNL.

Author: J. R. Stokely/615-574-4907

Reference: EPA regulations; Office of Solid Waste (SW-846), EPA CLP SOW 88, ASTM methods.

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: Inorganic

Reference Requirements: EPA regulations, ASTM methods. Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Laboratory methods

Technology: Inductively coupled plasma spectroscopy (ICP). Inductively coupled plasma is an analytical technique that uses a plasma to raise elements to an excited state. In this excited state the electrons in atoms and ions are promoted to higher energy levels. As the analyte travels through the cooler part of the plasma, the electrons fall back to lower energy levels. This change in energy level is accompanied by the emission of light at wavelengths that are specific to each particular element. The intensity of the light is directly proportional to the analyte concentration. This intensity is measured and converted to concentration values.

Status: Accepted; equipment commercially available

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual and automated applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Inorganic (U, Tc, Cr, CrO₄, Hg, Pb, ...)

Waste produced—Small quantities (<10 mL) of aqueous waste/sample

Overall cost—\$100–\$150/multielement analysis of metals

Efficacy/strengths—It is a standard, well-accepted methodology. It allows multielement analyses in the ppb and sub-ppb region. Because Argon is the gas of choice, application is limited to elements of mass in excess of 40. Several methods of detection are possible and several elements can be quantified simultaneously.

Science/Technology Needs: It is applicable as is. This is a well-developed technology.

Implementation Needs: This technology is available at ORNL, K-25 Site, and Y-12 Plant.

Author: J. R. Stokely/615-574-4907

Reference: EPA regulations, Office of Solid Waste (SW 846), EPA CLP SOW 88, ASTM Methods Manuals.

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: Inorganic

Note: It can be used for trace analysis of metals.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Laboratory methods

Technology: Inductively coupled plasma—mass spectroscopy (ICP-MS). Samples brought into a solvent or gas stream are injected into argon plasma and are subsequently mass analyzed.

Status: Demonstration; available but not fully developed. This is a new technology with little formal acceptance by regulatory and standards organizations.

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual and automated applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Inorganic (U, Tc, Cr, CrO₄, Hg, Pb, ...); long-lived radioactive elements

Waste produced—Small quantities (<10 mL) of aqueous waste/sample

Overall cost—Sample preparation is the major analytical cost and is similar to ICP spectroscopy (CHAR-77-OL).

Efficacy/strengths—It has multielement capability. It is more selective than ICP/AES. It can perform isotopic analysis.

Science/Technology Needs: It is applicable for multielement analysis of aqueous solutions. Development is in progress to use the technology for surface analysis, using laser ablation techniques and low specific activity, and long-lived radionuclides.

Implementation Needs: It is now available at ORNL. Capital costs, \$250K–\$350K; development costs, ~\$400K to extend to long-lived, low specific activity radionuclides.

Author: J. R. Stokely\615-574-4907

Reference: In-house methods, literature publications.

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: Soil

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Sample preparation

Technology: Sampling and mixing methods

Status: Accepted

Temporal areas of evaluation: Pretreatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Radioactive (α , β , γ); inorganic (U, Tc, Cr, CrO_4 , Hg, Pb, ...); organic (oil, polychlorinated biphenyls, volatile organic compounds, trichloroethylene, ...)

Waste produced—Samples become waste; methods are intended to minimize analytical waste and effort.

Science/Technology Needs: Methods of collecting representative samples and mixing samples into a homogeneous state need to be optimized.

Implementation Needs: Requires statistical sampling design and proper laboratory blenders, mixers, and other equipment. Development costs are estimated at ~\$250K.

Author: J. S. Watson/615-576-6297

References:

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: Soils

Reference Requirements: Refer to Vol. 1, Chapter 10, for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Sampling

Technology: Punch cores. Methodology for collecting contiguous core sample of solid objects by punch, drill, or other similar means.

Status: Demonstration

Temporal areas of evaluation: Pretreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Radioactive (α , β , γ); inorganic (U, Tc, Cr, CrO_4 , Hg, Pb, ...); organic (oil, polychlorinated biphenyls, volatile organic compounds, trichloroethylene, ...)

Waste produced—Samples become waste; method is intended to minimize sampling waste.
Efficacy/strengths—Produces samples suitable for contaminant depth profiling, versus conventional bulk analysis.

Science/Technology Needs: None

Implementation Needs: Need to set up methods and acquire equipment for coring sample matrices of importance at ORNL site. Development costs are estimated at ~\$300K.

Author: J. S. Watson/615-576-6297

Reference: Arid Site Identification.

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: Organic, inorganic

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Field methods

Technology: Portable Raman spectrometer. The identification and quantitation of molecular species is based on the principle that the vibrational energy of excited molecules can be observed and monitored. Raman spectra provide fingerprint identification of chemical species. No direct contact with the sample is necessary. Often used for remote sensing in inaccessible areas.

Status: Demonstration; field capabilities at ORNL
Predemonstration; current enhancement techniques

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual and automated applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Organic; inorganic

Waste produced—None

Overall cost—\$10/sample

Efficacy/strengths—Provides selective detection and identification of many species. No direct contact is necessary. It is nondestructive. Detection limit of hundreds to thousands ppm.

Science/Technology Needs: Portable equipment (laser, etc.) for in situ use is needed. Methods which exploit surface enhancement and resonance excitation for vastly improved sensitivity need to be developed.

Technical Task Plan RL401206 (FY 1992); relevance: high

Implementation Needs: Equipment is available at ORNL but has not been assembled for a specific application. Capital cost \$20K-\$50K.

Author: T. E. Barker/615-574-5042

References:

1. J. D. Ingle, Jr., and S. R. Crouch, *Spectrochemical Analysis*, Prentice Hall, New York, 1988.
2. D. L. Gerrard and J. Birnie, *Anal. Chem.* **64**(12), (1992).

EM Problem: Decontamination and decommissioning

ORNL Problem: See Appendix A, list A

Problem Area/Constituents: Organic

Note: But some surfaces (wood, etc.) may present problems with background.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Laboratory methods

Technology: Infrared absorption (laser-based source). Surface contamination detected by absorption of infrared radiation.

Status: Accepted; commercial units available
Evolving technology; laser-based

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Not applicable

Applicable contaminant evaluation: Organic (oil, polychlorinated biphenyls, volatile organic compounds, trichloroethylene, ...)

Waste produced—None

Overall cost—Inexpensive (but moderate to expensive with laser)

Efficacy/strengths—Can be used as a diagnostic for the detection of organics. Selected detection limits in ppm range, but could go lower with lasers.

Science/Technology Needs: Laser source would enhance sensitivity, but cost and size would increase appreciably.

Implementation Needs: Inexpensive commercial units can be purchased. Detection limits are ppm. Laser-based systems need to be developed. Development costs are estimated at ~\$500K.

Author: M. R. Cates/615-574-8056

References:

EM Problem: Decommissioning

ORNL Problem: See Appendix A, list A

Problem Area/Constituents: Inorganic

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: Sampling

Technology: Laser ablation for sample collection. Laser ablation is the use of a laser to vaporize a small portion of a sample. This vapor is subsequently transported to an ICP or ICP-MS for qualitative and quantitative analysis.

Status: Demonstration; the technology for laser ablation is just now becoming commercially available.

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual and automated applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Organic; inorganic

Waste produced— <1 mL/sample

Overall cost— <\$10/sample

Efficacy/strengths—This technique can be used to sample and analyze solid materials by ablating away the surface, followed by analysis of the removed material. It can be used either as a field or laboratory collection technique and is applicable to all materials.

Science/Technology Needs: A program to develop the technique for practicing application of the analysis is needed. Depth profiling techniques are needed.

Implementation Needs: Coupling to appropriate detectors. Development costs are estimated at ~\$500K. Capital costs, ~\$200K.

Author: M. R. Cates\615-574-8056

References:

FLASHLAMP HEATING TO RELEASE OR DESORB SURFACE AND SUBSURFACE CONTAMINANTS

CHAR-87-OL

EM Problem: Decommissioning

ORNL Problem: See Appendix A, list A

Problem Area/Constituents: Inorganic

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Laboratory methods

Technology: Flashlamp heating to release or desorb surface and subsurface contaminants. Method relies on broad spectrum high power to vaporize and ionize sample. Power is lower than that of laser.

Status: Predemonstration

Temporal areas of evaluation: Pretreatment; posttreatment

Deployment evaluation: Manual and robotic applications

Driver evaluation: Technical assessment

Applicable contaminant evaluation: Radioactive; inorganic (U, Tc, Cr, CrO₄, Hg, Pb, ...); organic (oil, polychlorinated biphenyls, volatile organic compounds, trichloroethylene, ...)

Waste produced— <1 mL/sample

Efficacy/strengths—Surface and subsurface characterization and potential speed

Science/Technology Needs: Depth profiling and surface area sampled must be determined for each material. Means of sampling the plume must be developed for each analyte.

Implementation Needs: To be determined for specific applications. Development costs are estimated at ~\$500K.

Author: M. R. Cates/615-574-8056

References:

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EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: Organic

Reference Requirements: EPA regulations, OSHA-accepted technology. Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Laboratory methods

Technology: Gas chromatography—mass spectrometry. Utilizing the separation characteristics of various chromatographic columns, qualitative and quantitative data are obtained by correlating masses detected with the elution times.

Status: Accepted; commercially available

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual and automated applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Organic (oil, polychlorinated biphenyls (PCBs), volatile organic compounds, trichloroethylene, ...)

Waste produced:—Near zero for volatiles; about 1 mL/sample organic extract

Overall cost:—\$200–\$400/sample for volatiles; \$400–\$800/sample for semivolatiles; \$200–\$600 for PCBs.

Efficacy/strengths:—Standard EPA-accepted methods exist. It is useful for chemical identification and confident quantitation.

Science/Technology Needs: Technology is applicable as is. Benefit would be derived from faster chromatography because of shorter analysis time.

Implementation Needs: Technology is available at ORNL and K-25 Site.

Author: M. R. Guerin/615-574-4862

References: EPA regulations; the Office of Solid Waste (SW-846) Methods Compendium.

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: Organic

Reference Requirements: EPA regulations. Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Laboratory methods

Technology: Liquid chromatography—mass spectrometry. Organic compounds are separated by reverse phase liquid chromatography and identified by their mass spectrum. Quantitation is achieved by integrating selected ions.

Status: Demonstration; equipment commercially available

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Organic (oil, polychlorinated biphenyls, volatile organic compounds, trichloroethylene, ...); radionuclide complexes

Waste produced—20 mL of aqueous/organic solvent mixture (total) from liquid chromatography, and 1 mL from extract of sample.

Overall cost—\$500/sample

Efficacy/strengths—It is primarily for organic pollutants that cannot be gas chromatographed (polar, thermally labile, low volatility). Many of these are DOE-unique compounds. The method is complementary to gas chromatography-mass spectrometry.

Science/Technology Needs: Case-by-case development and demonstration for specific applications is needed. Technology is not currently in routine use; not available in Oak Ridge.

Implementation Needs: Hardware costs, \$200K; development costs, \$300K

Author: M. R. Guerin/615-574-4862

References: EPA Office of Solid Waste procedures (SW-846).

Reference: Personal knowledge as director of IT-MS program.

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EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: Organic

Reference Requirements: OSHA. Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: Field or laboratory methods

Technology: Direct sampling ion trap mass spectrometry (IT-MS). Organics are purged or otherwise directly introduced into the inlet of the IT-MS. Identification is achieved by monitoring specific ions or by MS-MS. Quantification is conducted by integrating characteristic ions.

Status: Predemonstration; method development needed. This technology is under development at ORNL. It was exported to the Savannah River Laboratory, and it is being considered for Hanford and Energy Systems deployment.

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Organic (oil, polychlorinated biphenyls, volatile organic compounds, trichloroethylene, ...)

Waste produced—None

Overall cost—It is application-specific.

Efficacy/strengths—It allows rapid (<5 min) determination of organics, continuous air monitoring, and possible real-time surface analysis. It is field-transportable for on-site analysis because the ion-trap detector is significantly smaller and lighter than other mass detectors. Detection limits, typically sub-ppm.

Science/Technology Needs: Methods need to be developed for specific applications.

Implementation Needs: Capital costs, \$100K; personnel are needed for development, training, and implementation costs, \$200K.

Author: M. R. Guerin/615-574-4862

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: Organics, inorganics

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Field methods

Technology: Portable luminescence detection. The detection of organic and inorganic chemicals using fluorescence, phosphorescence, and chemiluminescence. Samples are illuminated by a laser or conventional light source. Subsequent luminescence emissions are detected, yielding spectral information about the sample. This may be used to identify or qualitative analytes in a variety of background matrices.

Status: Predemonstration; demonstration

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Not applicable

Applicable contaminant evaluation: Organic (oil, polychlorinated biphenyls, volatile organic compounds, trichloroethylene, ...); inorganic

Waste produced—None if used in situ

Overall cost—\$5/sample

Efficacy/strengths—Luminescence detection can provide extremely sensitive detection and does not require direct contact. Synchronous fluorescence can differentiate compounds in mixtures and can be coupled to fiber optics for remote sensing.

Science/Technology Needs: The technology is mature, but may not provide absolute identification of compounds in complex mixtures.

Technical Task Plan OR121201 (FY 1992); relevance: high

Implementation Needs: Hardware is available at ORNL. Specific techniques need development, and procedures need to be written. Capital costs, >\$15K.

Author: J. M. Storey/615-576-7607

References:

1. J. D. Ingle, Jr., and S. R. Crouch, *Spectrochemical Analysis*, Prentice Hall, New York, 1988.
2. S. W. Allison et al., "Use of Fiber Optics and Laser-Induced Fluorescence for Remote Measurements in Strong Rotation," K/TS-11, 018, MMES, Oak Ridge Gaseous Diffusion Plant (June 1983). Also published in *Proc. Fifth Workshop on Gases in Strong Rotation*, University of Virginia, June 5-9, 1983.
3. S. W. Allison, G. T. Gillies, M. R. Cates, and B. W. Noel, "Fiber Optic Pulsed Laser Delivery for Remote Measurements," *Opt. Eng.* 26(6), 538-546, June 1987.
4. I. M. Warner and L. B. McGown, "Molecular Fluorescence, Phosphorescence, and Chemiluminescence Spectroscopy," *Anal. Chem.* 64(12), June 15, 1992.

EM Problem: Decontamination and Decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: Organic

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Laboratory methods

Technology: Laser ablation organic mass spectrometry. Organic compounds on the surface of an object or a sample are desorbed by laser ablation and are analyzed by mass spectrometry.

Status: Predemonstration; technology under development

Temporal areas of evaluation: Pretreatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Organic (oil, polychlorinated biphenyls, volatile organic compounds, trichloroethylene, ...);

Waste produced—Inconsequential

Overall cost— <\$500/sample

Efficacy/strengths—It can characterize nonvolatile, polar compounds that cannot be detected by other mass spectrometry techniques. A surface analysis (as opposed to bulk analysis) method.

Science/Technology Needs: Development of a sampling methodology (perhaps using a wipe of the surface) and testing on target compounds is needed.

Implementation Needs: Capital costs, \$120K; development cost, \$300K. See CHAR-86-OL.

Author: M. V. Buchanan/615-574-4868

References: MMES staff members.

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: Organic

Reference Requirements: No regulatory requirements need to be met to implement this technology. Some gas chromatography detectors need to be vented to prevent worker exposure to toxic pollutants. Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Alternative: Laboratory methods

Technology: Gas chromatography. The detector technologies include flame ionization, electron capture, thermal conductivity, photoionization, flame photometric, and thermionic. Constituents can also be identified by retention time and, in some cases, response by selective detector. Quantify by detector responses.

Status: Accepted; technology commercially available

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual and automated applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Organic (oil, polychlorinated biphenyls, volatile organic compounds, trichloroethylene, ...)

Waste produced—Minimal; it is only necessary to vent gas chromatographs using nondestructive detectors.

Overall cost—\$5K–\$25K/instrument, depending on needs, plus miscellaneous supplies (carrier goods, etc.)

Efficacy/strengths—It has high efficacy for a very wide variety of organic species, both volatile and semivolatile. It is good for a variety of species, and the analysis time is 10–60 min.

Science/Technology Needs: Technology needs are minimal. While improvements can be made, in general, the technology is ready to use.

Implementation Needs: A variety of gas chromatography equipment exists already at ORNL, K-25 Site, and Y-12 Plant.

Author: R. A. Jenkins/615-574-4871

References:

1. Open literature on the use of gas chromatography for determination of organic contaminants.
2. EPA SW-846 methods.
3. See also CHAR-100-OL for portable gas chromatograph.

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: Radioactive elements, alpha emitters

Reference Requirements: Technical Requirements—DOE Order 5400.5, ANSI N13.12, NRC 5, and NUREG 1.86. Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Field methods

Technology: Electret passive surface alpha monitor. It is a device that performs as a passive ion chamber when placed on a contaminated surface. Positive ions produced by alpha particles are drawn to a negatively charged Teflon electret screwed into the roof of the chamber. The electret voltage is gradually drained. Before and after exposure, the voltage is read on a simple hand-held voltmeter. The voltage drop is converted to an equivalent surface contamination (dpm/100 cm²) or soil contamination (pCi/g). Sensitivity is sufficient to quantify alpha contamination after a few hours of exposure even at the most stringent DOE release limit of 100 dpm/100 cm².

Status: Demonstration; the technology has been commercialized for radon monitoring and is easily adapted for monitoring surface alpha contamination.

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Radioactive (α)

Waste produced—None

Overall cost—\$15/electret unit (reusable); voltage reader, \$700

Efficacy/strengths—Monitor is sensitive (100 min. exposure for quantification) and has on-the-spot readout capability. A simple technology to use, it can be used in large numbers, and allows verification of cleanup to strictest limits.

Science/Technology Needs: The measurement principle is well established for measuring alpha activity in indoor air. The effects of potential confounding factors (e.g., dust, moisture, oils) need to be evaluated and ameliorated.

Implementation Needs: The limits of alpha monitoring in mixed radiation fields need to be defined. Algorithms for multidevice deployment should be developed and tested to give a high confidence level of not missing contamination on large area surfaces. Development of needed protocols will require 1-2 years of effort.

Author: R. B. Gammage/615-574-6256

References:

1. Pilot tests were completed and the data presented at the 1992 Health Physics Society Annual Meeting.
2. P. Kotrappa et al., "A Practical E-PERM (electret passive environmental radon monitor) System for Indoor ^{222}Rn Measurement," *Health Phys.* 58(4), 461-467 (1990).

ALPHA TRACK ETCH DETECTORS FOR SURFACE ALPHA CONTAMINATION

CHAR-96-OL

EM Problem: Decontamination and decommissioning; remedial action

ORNL Problem: See Appendix A, lists A and B

Problem Area/Constituents: Radioactive elements, alpha emitters

Reference Requirements: Technical Requirements—DOE Order 5400.5, ANSI N13.12, NRC 5, and NUREG 1.86. Refer to the regulatory compliance chapter in Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: Field methods

Technology: Alpha track etch detectors (ATDs) for surface alpha contamination. These are Alpha-sensitive plastics that can be cut to a size appropriate for specific applications (e.g., to fit inside pipes or in narrow crevices). After exposure, the plastic is developed chemically to visualize damage tracks produced by alpha emitting contamination. The track density is measured optically and converted to an equivalent dpm/unit area. The technology has been proven commercially while used as indoor radon monitors, with a million detectors sold. Deployment is simple and detectors can be used by workers with limited training. Chemical etching and track readings are highly automated with proven, developed quality assurance/quality control.

Status: Demonstration; the ATD technology is fully commercialized for radon monitoring and directly applicable for surface monitoring.

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Radioactive (α)

Waste produced—None, but detectors cannot be reused

Overall cost—A few dollars each

Efficacy/strengths—Less expensive than laboratory characterization and analysis. No alternative is available for in situ detection of contamination in restricted spaces such as cracks, crevices, or under furnishings. The detector has high sensitivity (100 min exposure for quantification at 220 dpm/100 cm²) and provides a permanent record of the radiation field. It is deployable on irregular and difficult to access surfaces and is small in size. It can be used in large numbers to sample large surface areas, with a high level of confidence that significant contamination has not been missed. Contamination is mapped with submillimeter

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resolution and small "hot" particles are identifiable. It allows for initial surface characterization and verification in release for unrestricted use and permanent recording of cleanup—detectors cannot be reused.

Science/Technology Needs: The technique is well established (i.e., commercially available) for measuring alpha activity in indoor air. Potentially confounding factors in surface or soil applications include unhomogeneously sized particles, moisture, oils, and radon in soil. Track etching and reading is an area for significant improvement.

Implementation Needs: Plastic monitors of different sizes and flexibilities need to be fabricated and tailored for specific tasks to be identified in on-site pilot testing. Deployment of detectors in large numbers will require establishment of on-site chemical etching and track reading capabilities. Methods to count tracks appearing in tight spray-like clusters produced by "hot" particles with conversion to a corresponding dpm/unit area are needed.

Author: R. B. Gammage/615-574-6256

References:

1. Pilot test results are available. A manuscript is in press, *Health Phys. J.*
2. M. D. Pearson et al., "A Multiyear Quality-Control Study of Alpha-Track Radon monitors," *Health Phys.* **62**(1), 87-90 (1992).

PHOTON ELECTRON REJECTING ALPHA LIQUID SCINTILLATION

CHAR-97-OL

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: Radioactive elements, alpha emitters

Reference Requirements: Technical Requirements—DOE Order 5400.5, ANSI N13.12, NRC 5, and NUREG 1.86. Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Laboratory methods

Technology: Photon electron rejecting alpha liquid scintillation (PERALS). A very sensitive (pCi/g) technique for measuring alpha-emitting isotopes.

Status: Accepted; commercially available

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual and automated applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Radioactive (α)

Waste produced—Spent acid and organic scintillants (1.5 mL/sample)

Overall cost—About \$20K for setup of analytical equipment; about \$50/sample

Efficacy/strengths—It is a very sensitive, isotopically-selective method that is capable of detecting 1 pCi/g of individual isotopes in soil or water. It is ideal for uranium. It has a commercially available reader, and scintillant cocktails are specific to each alpha emitter. It has the lowest detection limits of rapid radiological techniques.

Science/Technology Needs: Scintillation cocktails that are not toxic under RCRA law need to be developed for use in PERALS.

Implementation Needs: A PERALS laboratory is already set up at the ORNL DOSAR facility and at the Y-12 Plant. It can be adapted for rapid "on-line" monitoring of both airborne and loose contamination.

Author: R. B. Gammage/615-574-6256. Reviewed by C. S. Dudley/615-576-2712

References: J. R. Cadieux, "Evaluation of a Photoelectron-Rejecting Alpha Liquid-Scintillation (PERALS) Spectrometer for the Measurement of Alpha-Emitting Radionuclides," *Nucl. Instrum. & Methods in Phys. Res. A* **299**(1990), 119-122 (1990).

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**PORTABLE GAS CHROMATOGRAPH/ELECTRON
CAPTURE DETECTION FOR ANALYZING PCBs**

CHAR-100-OL

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: Organic

Reference Requirements: Ten ppb polychlorinated biphenyls (PCBs) in soil is the strictest EPA limit. Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Field methods

Technology: Portable gas chromatograph/electron capture detection (GC-ECD) for analyzing PCBs. PCBs are extracted, from soils and dust for example, with a solvent. The extract is then injected into a field gas chromatograph that separates the sample components and selectively detects halogenated species, including PCBs. Arachlors (PCB mixtures) are identified by their separation pattern and can be quantified using specific chromatographic peaks.

Status: Accepted

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Organic (oil, PCBs, volatile organic compounds, trichloroethylene, ...)

Waste produced—10–50 mL of methanol and hexane extractant/sample

Overall cost—A few dollars per analysis

Efficacy/strengths—Procedure was developed and verified by the EPA. One technician can conduct 20–30 analyses/day. One manager at a Superfund site estimated that on-site data during removal saved \$500K (360 analyses in 8 days). The method is accurate to below 10 ppb.

Science/Technology Needs: Written standard operating procedures are needed.

Implementation Needs: GC/ECD devices, ~\$15K/unit

Author: R. B. Gammage/615-574-6256

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**PORTABLE GAS CHROMATOGRAPH/ELECTRON
CAPTURE DETECTION FOR ANALYZING PCBs**

CHAR-100-OL

References: Dr. Tom Spittler, EPA Region I Director. Method description is available. User courses are given regularly.

Note: See CHAR-94-OL for laboratory GC.

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SYNCHRONOUS FLUORESCENCE SCREENING FOR POLYCYCLIC AROMATIC HYDROCARBONS

CHAR-101-OL

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: Organics [polycyclic aromatic hydrocarbons (PAHs)]

Reference Requirements: Ten ppb for general PAHs. Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Laboratory methods

Technology: Synchronous fluorescence screening for polycyclic aromatic hydrocarbons (PAHs). When light of a specific wavelength is directed onto a sample, certain organic compounds (such as PAHs) absorb and re-emit that light (fluoresce) at a higher wavelength. Analytes can be differentiated because they absorb and fluoresce at different wavelengths. Fluorescence intensity is quantitatively proportional to analyte concentration.

Status: Demonstration; instrumentation commercially available.
Predemonstration

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Organic (oil, polychlorinated biphenyls, volatile organic compounds, ...)

Waste produced—Solvent in milliliter quantities/sample

Overall cost—A few dollars per analysis

Efficacy/strengths—An easy concentration step allows detection at drinking water standards. It takes a few minutes per analysis.

Science/Technology Needs: Technology needs to be validated in the EPA program. Numerous situations at ORNL have involved the use of oils and lubricants.

Implementation Needs: Capital costs, \$25K for reader and \$25K for spectrofluorimeter; development costs, \$200K

Author: R. B. Gammage/615-574-6256. Reviewed by W. Fisher/615-574-5042

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**SYNCHRONOUS FLUORESCENCE SCREENING
FOR POLYCYCLIC AROMATIC HYDROCARBONS**

CHAR-101-OL

Reference: I. M. Warner and L. B. McGown, "Molecular Fluorescence, Phosphorescence, and Chemiluminescence Spectroscopy," *Anal. Chem.* **64**(12), June 15, 1992.

EM Problem: Decontamination and decommissioning; remedial action

ORNL Problem: See Appendix A, lists A and B

Problem Area/Constituents: Radioactive elements, long-lived fission products (Tc-99, I-127, etc.)

Reference Requirements: DOE Order 5400.5, ANSI N13.12, NRC 5, and NUREG 1.86. Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: Field and laboratory methods

Technology: Passive monitors for weak beta radionuclides. The thermally stimulated exoelectron (TSEE) technique is the weakly penetrating radiation analog to thermoluminescence, which is the standard for passive, solid-state dosimetry for strongly penetrating radiations. The exposed TSEE dosimeter is heated to liberate low-energy electrons from a thin surface layer. The thin exoactive layer is especially sensitive to low-energy beta radiations such as those from hydrogen-3, carbon-14 or technetium-99. The exoelectrons expelled during heating are counted in a Geiger or proportional counter, and the reading is converted to an equivalent dpm/unit area.

Status: Predemonstration

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Radioactive (β)

Waste produced—None

Overall cost—A few dollars per detector; it can be deployed in large numbers and reused.

Efficacy/strengths—It has a reusable thermoluminescence dosimeter-like chip with a signal-to-noise ratio of 10 after 100 min exposure for a mCi/cm^2 of tritium. Small size detectors are available for monitoring difficult-to-access locations. It is highly sensitive to weak beta emitters such as tritium, carbon-14 and technetium-99. Survey meters have low sensitivity and cannot access tight spaces.

Science/Technology Needs: A thorough evaluation of this technology is needed for differentiating technetium-99 from other radionuclides in mixed surface contaminations. Pairs of detectors, one with a beta absorber on its surface, will be needed to discriminate

weak beta from more penetrating radiations. Different types of ceramic exoelectron materials should be tested to select the most suitable type for H-3, Tc-99 and other applications.

Implementation Needs: Capital costs, \$20K for heater/reader. A commercial TSEE reader is available at ORNL. About \$100K will be needed for development.

Author: R. B. Gammage/615-574-6256

References:

1. R. B. Gammage, "Measuring Tritium With Exoelectron Dosimeters," *Nucl. Inst. Methods*, **127**, pp. 279-284 (1975).
2. B. Warner, W. Kriegseis, and A. Scharmann, "The Influence of H₂O adsorption on the Thermally Stimulated Exoelectron Emission (TSEE) of BeO Thin Films," *Physica Status Solidi (A)* **128**, 419-426 (1991).

THERMOLUMINESCENCE DOSIMETER ARRAY FOR SPATIAL CHARACTERIZATION OF ALPHA CONTAMINATION

CHAR-103-OL

EM Problem: Decontamination and decommissioning; remedial action

ORNL Problem: See Appendix A, lists A and B

Problem Area/Constituents: Radioactive elements, alpha emitters

Reference Requirements: DOE Order 5400.5, ANSI N13.12, NRC 5. Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Field methods

Technology: Thermoluminescence dosimeter array for spatial characterization of alpha contamination. A flexible sheet containing a fine grid of miniature thermoluminescence dosimeter elements that have a preferential sensitivity to alpha particles. Exposed sheets are then scanned with a laser beam to heat the individual chips and produce a readable thermoluminescence that is converted into a two-dimensional map. The laser scanning bleaches the dosimeter and readies the sheet for reuse.

Status: Demonstration; equipment commercially available

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Radioactive (α)

Waste produced—None

Overall cost—A few dollars/sample; reusable detector sheet (30 × 30 cm), \$225

Efficacy/strengths—The detector sheet contains 10,000 pixels. The limit of detection is 20 alpha particles on each pixel. It maps primary contamination fields, while discriminating alpha "hot spots."

Science/Technology Needs: The technique is well established, but investigation of potentially confounding factors is needed. Such factors may include moisture, oil, and radon.

Implementation Needs: It will need to be adapted to specific decontamination and decommissioning needs. The size and shape of detector sheets needs to be tailored to specific geometries. Discriminating ability in mixed radiation fields needs further definition. Capital costs, \$60K for a laser reader; development costs, ~\$200K.

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**THERMOLUMINESCENCE DOSIMETER ARRAY FOR SPATIAL
CHARACTERIZATION OF ALPHA CONTAMINATION**

CHAR-103-OL

Author: R. B. Gammage/615-574-6256

References: P. Braunlich, "Present State and Future of TLD Laser Heating," *Radiat. Protection Dosimetry* **34**(1/4), 345-351 (1990).

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EM Problem: Decontamination and decommissioning; waste management

ORNL Problem: See Appendix A, lists A and C

Problem Area/Constituents: Radioactive elements, alpha emitters

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Laboratory methods

Technology: Passive neutron detection. Instrument detects neutrons emitted from uranium deposits.

Status: Accepted

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual and robotic applications

Driver evaluation: Risk assessment; regulatory

Applicable contaminant evaluation: Radioactive (α , β , γ) for uranium determination

Waste produced—None

Overall cost—Labor for analysis

Efficacy/strengths—It should match the standard matrix for the sample to be useful for all matrices. This method can measure in place, or a large sample can be brought to the neutron detector. It is used for uranium determination if fluorine is present in the compound. It is presently used to measure uranium holdup. Practical detection limit is 50 g of uranium in the form of UO_2F_2 for a 1-h count.

Science/Technology Needs: None

Implementation Needs: Capital costs, \$20K/instrument

Author: R. C. Hagenhauer/615-574-8835

References: *Nondestructive Assay Measurements of Gaseous Diffusion Process Equipment*, K/ITP-237.

EM Problem: Decontamination and decommissioning; waste management

ORNL Problem: See Appendix A, lists A and C

Problem Area/Constituents: Radioactive elements

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Field methods

Technology: Tritium/beta/gamma floor scanner. A surface monitor that uses either a tritium windowless proportional counter or a xenon-filled beta/gamma proportional counter. These counters are mounted on a trolley designed to carry all of the system components.

Status: Demonstration; commercially available

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual and robotic applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Radioactive (tritium, beta, gamma)

Waste produced—None

Overall cost—Labor only

Efficacy/strengths—The system is useful for measuring gross fixed tritium and/or beta/gamma combinations on surfaces. It is portable and can be used to survey large areas. The sensitivity of the tritium detector is 0.15 Bq-cm^2 with a 2-s time constant. The use of this system on rough surfaces such as absorbent paper or wood, is not recommended because the accuracy of the reading is degraded under these circumstances.

Science/Technology Needs: None

Implementation Needs: Capital costs, \$5K/unit; routine procedure development

Author: K. E. Meyers/615-574-1504

References:

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: Radioactive elements

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Laboratory methods

Technology: Sodium iodide-germanium gamma spectroscopy. The NaI detector is used to quantify gamma emitters in items that allow the gammas to penetrate.

Status: Accepted; demonstration

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual and robotic applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Radioactive (α , β , γ)

Waste produced—None

Overall cost—Labor for each analysis

Efficacy/strengths—The technology is useful for detection of all gamma emitters. The system can measure radioactivity below the surface. A high-resolution Ge detector may be needed to determine correction factors for attenuation. Sensitivity for ^{235}U = 10 g; for ^{238}U = 500 g through detection of gamma-emitting daughters.

Science/Technology Needs: Correction factor methodology needs to be established.

Implementation Needs: Capital costs, \$20K for detectors

Author: R. C. Hagenhauer/615-574-8835

References: *Nondestructive Assay Measurements of Gaseous Diffusion Process Equipment*, K/ITP-237.

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: Fissile material on:

Concrete	Structural Steel	Roofing Materials	Tile
Wood	Porous Nickel	Sheet Metal	Pipes
Transite	Asbestos Insulation	Gaskets	Copper Wiring
Cylinders	Metal Equipment	Instruments	Nickel-Lined Steel
Porous Aluminum	Monel (67Ni/30Cu/1.4Fe)	Copper	Aluminum

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: Sample and laboratory methods

Technology: Neutron activation. Neutrons generated by ^{252}Cf or other neutron source interact with ^{235}U or other fissile actinides to cause fission. The delayed neutrons from fission are then detected to quantify the fissile content.

Status: Accepted; mature technology for ^{235}U measurement.

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual and automated applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Fissile actinides (usually ^{235}U , ^{239}Pu , ^{233}U)

Waste produced—None

Overall cost—\$50/sample to \$800/barrel

Efficacy/strengths—It is generally used for low-level determinations of fissile actinides in almost anything. It is specific for fissile actinides and useful in most any matrix. The most sensitive commercial unit for the nondestructive assay of uranium has a sensitivity of ~10 mg ^{235}U /55-gal drum. Less than 1 mg ^{235}U is detectable under optimum conditions.

Nondestructive—Sample can be archived and reanalyzed.

Science/Technology Needs: Routine development is needed for measurements on containers that are larger than 55-gal drums. Separate calibration standards are needed for each matrix. Possible interferences need to be evaluated.

Implementation Needs: Capital costs, \$0.5M-\$1.5M. Instrumentation and personnel currently exist at ORNL but need to be expanded to meet the expected work load. Upgrade and expansion costs are estimated to be \$250K.

Authors: F. Hagenhauer/615-574-8835; J. M. Keller/615-574-7063;
C. S. Durbin/615-576-2712

References:

1. *Capability and Limitation Study of the DOT Passive-Active Neutron Waste Assay Instrument*, LA-12237-MS.
2. "Activation Spectrometry in Chemical Analysis," pp. 159-162 in *Chemical Analysis Series*, Vol. 119, by S. J. Parry, John Wiley & Sons, Inc., 1991.
3. Pajarito Scientific Corp./505-662-4377.
4. APNEA system at ORNL.
5. F. J. Shultz/615-576-6870.

PROPORTIONAL COUNTER FOR ALPHA AND BETA ACTIVITY

CHAR-108-OL

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: Radioactive elements

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: Field and laboratory methods

Technology: Proportional counter for alpha and beta activity. Alpha and beta radiation emitted from the surface contamination is detected and counted.

Status: Accepted; commercially available

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual and robotic applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Radioactive (α , β)

Waste produced—None

Efficacy/strengths—It has sensitivity to 100 dpm/cm². Relatively inexpensive probes are available for wide areas of measurement, or it can be made small to measure inside pipes. It may be able to distinguish technetium activity from uranium.

Science/Technology Needs: This is a well-established technology. Some minor development may be needed to distinguish technetium activity from uranium. Probes for measuring vertical or overhead items are needed.

Implementation Needs: Normal; capital costs, \$500–\$2K

Author: R. C. Hagenhauer/615-574-8835

References: MMES staff members.

WASTE CURIE MONITOR (BAG OR BARREL COUNTER FOR LOW-LEVEL GAMMA RADIOACTIVITY)

CHAR-109-OL

EM Problem: Decommissioning

ORNL Problem: See Appendix A, list A

Problem Area/Constituents: Radioactive elements

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Laboratory methods

Technology: Waste curie monitor (bag or barrel counter for low-level gamma radioactivity). Gamma rays emitted by the contaminated samples are detected by the large plastic scintillators surrounding the 55-gal drums.

Status: Accepted; commercially available

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk assessment; regulatory

Applicable contaminant evaluation: Radioactive (γ)

Waste produced—None

Efficacy/strengths—It is good for measuring scrap lumber for low levels of activity (below 32 PCI/g). It is presently used for low-level measurements of combustible waste. Sensitivity for ^{235}U = 10 mg; for ^{238}U = 200 mg.

Science/Technology Needs: Development may be necessary for containers larger than the 55-gal drums.

Implementation Needs: Normal. Technology integration—it must be used in conjunction with a high-resolution gamma spectroscopy system to determine atomic abundance.

Author: R. C. Hagenhauer/615-574-8835

References: MMES Staff Members.

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FLUORESCENCE DIAGNOSIS OF CONTAMINATED SURFACES

CHAR-110-OL

EM Problem: Decontamination and decommissioning

ORNL Problem: See Appendix A, list A

Problem Area/Constituents: Organic, inorganic

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Sample collection

Technology: Fluorescence diagnosis of contaminated surfaces

Status: Predemonstration

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual, automated, and robotic applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Fluorescence of UF_6 , U, UO_2F_2 , etc.; inorganic (U, Tc, Cr, CrO_4 , Hg, Pb, ...); organic (oil, polychlorinated biphenyls, volatile organic compounds, trichloroethylene, ...)

Waste produced—None

Overall cost—Depends on the specific application. Equipment, assembly, and testing will comprise the costs.

Efficacy/strengths—It may be used in situ, with or without automation and fiber optics for limited access areas. It can certify when the surface/area is cleaned/decontaminated, which eliminates extra processing. It may eliminate expensive laboratory characterization, some degree of heavy equipment transport, and dismantling. It can monitor the status of processing in real-time. In general, fluorescence is sensitive to ppm for airborne situations.

Science/Technology Needs: A moderate amount of fluorescence spectroscopy work will be required for some contaminants to fill in the gaps of published fluorescence data. Technology requirements may be fulfilled by off-the-shelf lasers, detectors, and associated support equipment.

Technical Task Plan OR121201 (FY 1992); relevance: high

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Implementation Needs: The required equipment such as a laser (light source), optics, detectors, personal computers (for data acquisition), and interfaces must be purchased. Staff with extensive experience on-site in laser applications and optical design, field testing, and other appropriate technologies are available. On-site laboratory storage, assembly, and staging are available on-site. The procedures must be written.

Author: S. W. Allison/615-576-2725

References: Much literature that supports the efficacy of fluorescence-based analytical instrumentation for in situ sampling, measurement, and characterization, including:

1. S. W. Allison et al., "Use of Fiber Optics and Laser-Induced Fluorescence for Remote Measurements in Strong Rotation," K/TS-11, 018, MMES, Oak Ridge Gaseous Diffusion Plant (June 1983) [Also published in *Proc. Fifth Workshop on Gases in Strong Rotation*, (University of Virginia, June 5-9, 1983)].
2. S. W. Allison, G. T. Gillies, M. R. Cates, and B. W. Noel, "Fiber Optic Pulsed Laser Delivery for Remote Measurements," *Opt. Eng.* 26(6), 538-546 (June 1987).

**LASER ABLATION; INDUCTIVELY COUPLED PLASMA;
ATOMIC EMISSION SPECTROSCOPY**

CHAR-111-OL

EM Problem: Decommissioning

ORNL Problem: See Appendix A, list A

Problem Area/Constituents: Inorganic

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: In situ characterization and monitoring

Technology: Laser ablation; inductively coupled plasma; atomic emission spectroscopy. Laser ablation is the use of a laser to vaporize a small portion of a sample. This vapor is subsequently transported to an ICP or ICP-MS for qualitative and quantitative analysis.

Status: Demonstration

Temporal areas of evaluation: Pretreatment; posttreatment

Deployment evaluation: Robotic applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Inorganic (all elements)

Overall cost—Development, \$1M; low cost/sample

Efficacy/strengths—This technology will be accepted by the end of this year (1993) following the Fernald demonstration. It allows multiple elemental analyses.

Science/Technology Needs: Improvement in the robotic process for site-specific conditions (e.g., floor, wall, ceiling) is needed.

Implementation Needs: Instrumentation development is needed. Development costs are estimated at ~\$1M. Integration of laser ablation, ICP, and atomic emission technologies is the issue here.

Author: S. Y. Lee/615-574-6316

References: Contact Marvin Anderson, Ames Laboratory, Ames, Iowa 50010-6739; 515-294-4580.

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EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: Organic

Reference Requirements: Regulations for total petroleum hydrocarbons and polychlorinated biphenyls (PCBs). Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Laboratory methods

Technology: On-line supercritical fluid extraction—multidetector gas chromatography (SFE-GC). Supercritical fluids extract 1–10 g of soil, and the extracted analytes are accumulated in a cryofocusing unit prior to gas chromatography. Multiple detectors permit the simultaneous analysis of several pollutant types, such as petroleum hydrocarbons, PCBs, and pesticides. The method is much faster than conventional methods and produces no hazardous waste.

Status: Predemonstration; technology requires final development and demonstration.

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual and automated applications

Driver evaluation: Risk assessments; regulatory

Applicable contaminant evaluation: Organic (oil, PCBs, volatile organic compounds, trichloroethylene, ...)

Waste produced—Only 1–10 g of dry soil; no solvent water

Overall cost—Could be 25% or less than that of separate conventional analyses

Efficacy/strengths—Organic and solvent-contaminated wastes are not generated, as opposed to conventional organic analytical methods. There is also much faster sample turnaround (1–2 h) than with conventional methods (a few days). One commercial instrument is already available for the rapid determination of total petroleum hydrocarbons in soil by on-line SFE-GC. The SFE of PCBs has also been demonstrated. It appears highly likely that the two methods can be combined to allow the rapid and simultaneous analysis of both contaminants and others in soil and other solids.

Science/Technology Needs: The technology requires optimization for the most efficient extraction and chromatography of both total petroleum hydrocarbons and PCBs in a single operation.

Implementation Needs: Capital costs, \$60K; development costs, \$250K. The extraction and analysis conditions must be optimized, and the method validated.

Author: W. H. Griest/615-574-4864

References: Manufacturer's literature (CCS, Suprex, Dionex).

EM Problem: Remedial action

ORNL Problem: See Appendix A, list B

Problem Area/Constituents: General

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: Data and analysis management

Technology: Ultrasonic ranging and data system (USRADS). This system determines surveyor position by measuring the travel time of ultrasonic pulses from a backpack transmitter and associates the position with electronically transmitted data.

Status: Accepted; commercially available

Efficacy/strengths—Allows real-time determination of positions and greatly speeds sampling.

Science/Technology Needs: Adaptation to various data generation systems is needed.

Implementation Needs: None; currently in use.

Author: J. E. Nyquist/615-574-4646

References: J. E. Nyquist and M. S. Blair, *Geophysics* **56**, 1114-1121, July 1991.

EM Problem: Remedial action

ORNL Problem: See Appendix A, list B

Problem Area/Constituents: General

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Field methods

Technology: Ground-penetrating radar. Extremely short electromagnetic pulse returns interference by both metallic and nonmetallic objects.

Status: Accepted; commercially available

Science/Technology Needs: Improvements are needed in the depth of penetration and signal-to-noise and signal processing, particularly antenna design. Technology could be developed to measure subsurface plumes.

Implementation Needs: System costs, ~\$30K

Author: J. E. Nyquist/615-574-4646

References: Workshop on Noninvasive Geophysical Site Characterization, LA-12311-C.

ELECTRICAL AND ELECTROMAGNETIC DETECTION OF GROUND AND GEOLOGIC FEATURES

CHAR-125-OL

EM Problem: Remedial action

ORNL Problem: See Appendix A, list B

Problem Area/Constituents: General

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Field methods

Technology: Electrical and electromagnetic detection of ground and geologic features. These include measurements based on electrical conductivity and natural electrical potentials. Electromagnetic offset log survey (EOL) technology is based upon in situ measurements of subsurface resistivity for detecting anomalies. Resistivity measurements of the subsurface reflect the combined effects of the soil matrix and fluids within the soils (Archie's Law). Free phase hydrocarbons in the vadose zone, on the water table, and below the water table all have very high resistivity values compared to naturally occurring soil solids and pore fluids.

Status: Developed through accepted;
Demonstrated, EOL

Waste produced—None, except for that produced by test well drilling

Overall cost—Ca. \$50K for a 10-acre site for EOL

Efficacy/strengths—Useful for mapping site subsurface features which influence contaminant transport and which might be missed through drilling. Used airborne (Oak Ridge) and on the surface. Could be used in borehole applications. Might be developed for actual plume detection. Advent of digital computers and three-dimensional imaging software allows EOLs to be generated and viewed in the field in real time. A 10-acre site requires approximately one day and two to three sampling wells for site characterization of resistivity anomalies. Three-dimensional imaging can be used to pin-point location of worst hydrocarbon contamination. Soil sampling and drilling can then be conducted to quantify type and concentration of pollutant.

Science/Technology Needs: Development of site-specific techniques and data handling and imaging methods is needed. The Lawrence Livermore National Laboratory-developed borehole system could be adapted for use in Oak Ridge.

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ELECTRICAL AND ELECTROMAGNETIC DETECTION OF GROUND AND GEOLOGIC FEATURES

CHAR-125-OL

Implementation Needs: Development costs, ~\$200K; system costs, \$100K; ~\$200K to test on an established site (EOL). Commercial rental equipment is available.

Author: J. E. Nyquist/615-574-4646; J. Kauschinger/603-268-0816

References:

1. Workshop on Noninvasive Geophysical Site Characterization, LA-12311-C.
2. J. Culp, "Electromagnetic Offset Log Procedure," Internal Memorandum, Christensen-Boyles Brothers, Inc., 1993.

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EM Problem: Remedial action

ORNL Problem: See Appendix A, list B

Problem Area/Constituents: General

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Field methods

Technology: Seismic methods (refraction, profiling, reflection). Seismic methods measure elastic and acoustic subsurface parameters in underground and geologic formations.

Status: Developed through accepted. Refraction and deep reflection have been used successfully for years; however, shallow reflection capability (<30 m) is relatively recent.

Efficacy/strengths—Useful for identifying and mapping geological features which control contaminant migration.

Science/Technology Needs: Developed shallow sources should be tested. Techniques should be adapted and used for both vertical and horizontal bore holes.

Implementation Needs: Development costs, ~\$200K; system costs, \$50K. Commercial rental equipment is available.

Author: J. E. Nyquist/615-574-4646

References: Workshop on Noninvasive Geophysical Site Characterization, LA-12311-C.

EM Problem: Remedial action

ORNL Problem: See Appendix A, list B

Problem Area/Constituents: General

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Field methods

Technology: Microgravity methods. This technology involves measuring variations in the earth's gravitational field caused by differences in the densities of objects such as rocks, natural structures, and artifacts.

Status: Development

Efficacy/strengths—Gravity methods have been successfully used in the mining and petroleum industries. Increased sensitivity is needed for accurate, unambiguous interpretation. Microgravity has been used at ORNL.

Science/Technology Needs: Development of increased sensitivity for rapid, cost-effective subsurface detection and mapping is needed. Also, site-specific development is needed for detecting karst cavities and conduits.

Implementation Needs: Development costs, ~\$200K; system costs, ~\$60K. Commercial rental equipment is available.

Author: J. E. Nyquist/615-574-4646

References: Workshop on Noninvasive Geophysical Site Characterization, LA-12311-C.

EM Problem: Remedial action

ORNL Problem: See Appendix A, list B

Problem Area/Constituents: General

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Field methods

Technology: Magnetics. This technology involves measurement of anomalies in the direction, gradient, or intensity of the earth's magnetic field.

Status: Accepted; an aerial survey has been completed in Oak Ridge.

Efficacy/strengths—Useful for detecting buried ferrous metal objects

Science/Technology Needs: Development of methods to minimize interference is needed.

Implementation Needs: Development costs, ~\$200K; deployment costs, \$15K. Commercial rental equipment is available.

Author: J. E. Nyquist/615-574-4646

References: Workshop on Noninvasive Geophysical Site Characterization, LA-12311-C.

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: Radioactive elements, inorganic, metals

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: Laboratory, characterization, and analysis with some development could be applied to field methods.

Technology: Supercritical fluid extraction of inorganics. Extraction of metal ions from liquid and solid material by supercritical carbon dioxide.

Status: Predemonstration; it has been demonstrated in the laboratory for only a few metals.

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual and automated applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Inorganics; actinides; long-lived fission products; etc

Waste produced—Minimal

Efficacy/strengths—Generates minimal waste

Science/Technology Needs: New technology; the optimum extraction conditions, including chelators to add to supercritical fluid, need to be determined.

Implementation Needs: Equipment costs, \$30K; development costs, \$400K

Author: J. M. Keller/615-574-7063

References: C. M. Wal, R. Brauer, and K. E. Laintz, *Extraction of Metal Ions from Liquids and Solids by Supercritical Carbon Dioxide*, 33rd ORNL/DOE Conference on Analytical Chemistry in Energy Technology, Gatlinburg, Tenn., October 6-8, 1992.

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: Radioactive elements

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: Laboratory (with some development, could be applied to field methods)

Technology: Radioanalytical procedures. General upgrade and modernization of radiochemical separation technology.

Status: Development

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual and automated applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Radioactive species

Waste produced—Meets waste minimization criteria for new procedures

Efficacy/strengths—Provides a path for introducing new technology

Science/Technology Needs: Considerable new technology is available but lacks sufficient validation to meet quality assurance requirements. Other areas are at the basic development stage.

Implementation Needs: Some instrumentation and personnel currently exist at ORNL to develop new procedures but need to be expanded to meet increased work load. Development costs, \$600K/year for 5 years.

Author: J. M. Keller/615-574-7063

References: MMES staff members.

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: Radiochemical, inorganic

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: Laboratory (but with some development could be applied to field methods)

Technology: High-pressure ashing (HPA) for sample preparation. HPA is useful for the dissolution of organics and other difficult to dissolve materials. HPA involves acid digestion under elevated pressure which permits the use of higher acid temperatures than can be achieved at atmospheric pressure. For example, nitric acid, under pressure at 300°C, becomes a very strong oxidizer.

Status: Demonstration; commercially available but lacks validation to meet QA requirements

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual and automated applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Radiochemical and inorganic species in an organic matrix

Waste produced—Depends on sample analyzed but typically small

Efficacy/strengths—Eliminates the need for perchloric acid with most applications

Science/Technology Needs: Commercially available but lacks sufficient validation to meet quality assurance requirements. Some special sample types may be at the development stage.

Implementation Needs: Some equipment and personnel are currently available at ORNL to develop new procedures but needs to be expanded to meet increased work load. Development costs, \$60K-\$120K/year for 2 years.

Author: J. M. Keller/615-574-7063

References: MMES staff members.

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: Radiochemical, inorganic, organic

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Laboratory characterization

Technology: Contamination control—analytical equipment. Analytical equipment/instrumentation frequently requires extensive instrument modification to contain equipment in radiochemical hoods, glove boxes, or hot cells. The characterization of radioactive waste, such as sludge from waste tanks, hot cell decontamination and decommissioning, and other forms of higher level radioactive waste, requires containment and sometimes shielding to protect the analyst. The type of major instruments that need to be available for this work include ICP, ICP-MS, GC-MS, GFAA, Ion Chromatograph, microwave oven for sample preparation, etc. Depending upon the degree of containment and shielding needed, the lead time for implementation can be 6 months to a year.

Status: Accepted; mature technology. Requires special expertise but must be done for higher levels of radioactivity.

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual and automated applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: All analytical measurements

Waste produced—Not applicable

Efficacy/strengths—Contamination control and ALARA

Science/Technology Needs: Commercially available for some systems but usually done on a case-by-case basis due to facility limitations and different containment requirements.

Implementation Needs: Some equipment and personnel are currently available at ORNL but need to be expanded to meet the expected increase in work load. Implementation includes engineering design, fabrication of containment/shielding, and modification of facility. Typical cost for containment of an ICP in a glove box was ~\$150K several years ago, not including the cost of the instrument.

Author: J. M. Keller/615-574-7063

References: MMES staff members.

September 1992

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: General

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Sample preparation

Technology: Radioactive sample preparation. Conventional EPA and other sample preparation methods are adapted for the unique requirements of preparing radioactive samples for analysis. Methodology focuses on the DOE ALARA principle and regulatory agency acceptance. Methods minimize waste generation and maximize efficiency in radiochemical hood, glove box, and hot cell work.

Status: Demonstration; current work shows that methods can be adapted to meet these needs.

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Organic; inorganic; radioactive elements; physical properties

Waste produced—One objective of the technology is to reduce the production of secondary laboratory waste.

Overall cost—Determined by the specific procedure and its complexity, but cost minimization is an objective of the technology. Method development costs and duplication of effort among the DOE laboratories will be eliminated.

Efficacy/strengths—Technology development leads to improved radioactive sample preparation methods, which are specifically designed to be conducted in a radiochemical hood, glove box, or hot cell. They will be more efficient, observe the ALARA principle, and are more likely to be accepted by regulators.

Science/Technology Needs: Adaptation of EPA and other methods, and development of new technologies for the safe and efficient preparation of radioactive samples for analysis.

Implementation Needs: Development costs, \$500/year for two years; personnel and facilities are available.

Author: W. H. Griest/615-574-4864

References:

1. B. A. Tomkins, et al., "Determination of Regulatory Organic Compounds in Radioactive Waste Samples. Volatile Organics in Aqueous Liquids," *Anal. Chem.* **61**, 2751-2756 (1989).
2. B. A. Tomkins, et al., "Determination of Regulatory Organic Compounds in Radioactive Waste Samples. Semivolatile Organics in Aqueous Liquids," *Anal. Chem.* **62**, 253-257 (1990).
3. W. H. Griest and J. L. Botts, "Radioactive Waste Analysis: An Inside Look," *Environ. Lab*, 14-19, April/May, 1992.

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: General

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Laboratory methods

Technology: Capillary zone electrophoresis. A very high resolution separation tool applicable to the determination of charged inorganic or organic species on the basis of electrophoretic mobilities. With micellar mobile phases, neutral species also can be separated by partition. The minimal sample volume requirements (a few nanoliters injected from a few microliters) make it ideal for the analysis of samples with very limited volumes or high radioactivity.

Status: Demonstration; the technology is gaining widespread acceptance in biomedical applications and appears useful for remedial action and waste management applications. Instrumentation commercially available.

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual and automated applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Organic; inorganic; radioactive elements

Waste produced—Minimal, <1 mL

Overall cost—\$300/sample

Efficacy/strengths—Very high resolution method with wide applications, including polar organic degradation products of DOE-unique organic compounds and chelated metals or radionuclides in waste tanks and burial grounds. Absolutely minimal sample volume requirements (a few microliters for nanoliter injections) make the technology ideal for highly limited or very radioactive sample analysis.

Science/Technology Needs: Adaptation and validation for the specific target compounds and sample matrices at the ORNL site.

Implementation Needs: Hardware costs, \$30K–\$60K; development costs, \$250K

Author: W. H. Griest/615-574-4864

References: K. H. Row, W. H. Griest, and M. P. Maskarinec, "Separation of Modified Nucleic Acid Constituents by Micellar Electrokinetic Capillary Chromatography," *J. Chrom.* **409**, 193-203 (1987).

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: General

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Sample preparation

Technology: Supercritical fluid extraction of organics. Analytes are efficiently extracted from a sample in an extraction cell under supercritical fluid conditions of high pressure and relatively low temperature. Analyte decomposition is reduced, and recoveries are improved versus those achieved by conventional extraction methods.

Status: Predemonstration; technology requires final development

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual and automated applications

Driver evaluation: Risk and technology assessments; regulatory

Applicable contaminant evaluation: Organic; radioactive elements; inorganic

Waste produced—Very little versus that produced by conventional extraction methods (~1 mL)

Overall cost—\$100–\$200/sample

Efficacy/strengths—The method is applicable to both organic analytes and, with the addition of chelators to the extraction fluid, to both metals and radionuclides. It achieves a faster, more efficient extraction than conventional methods, and vastly reduces solvent waste. It can be directly interfaced with an analytical instrument for highly sensitive analyses. It applies particularly in preparing building materials for analysis.

Science/Technology Needs: Extraction conditions need to be optimized for the specific target analytes and matrices at ORNL. If radionuclides and metals are targeted, then the most effective chelators must be selected.

Implementation Needs: Hardware costs, \$30K; development costs, \$300K; automated equipment costs, ~\$100K

Author: W. H. Griest/615-574-4864

References: Instrument manufacturer's data sheets (Suprex, ISCO, Dionex, CCS).

ADAPTATION OF THE EPA TOXICITY CHARACTERISTIC LEACHING PROCESS FOR USE WITH RADIOACTIVE SAMPLES

CHAR-209-OL

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: General

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Sample preparation

Technology: Adaptation of the EPA toxicity characteristic leaching process (TCLP) for use with radioactive samples. The EPA TCLP leaching test protocol, consisting of an extraction of wastes with acidic buffers, is adapted to meet the DOE ALARA principle and other unique requirements for handling radioactive materials. TCLP procedures for glove box and hot cell use are included.

Status: Predemonstration; some work has been conducted at ORNL, but full adaptation and testing remain to be done.

Temporal areas of evaluation: Pretreatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Regulatory

Applicable contaminant evaluation: Organic; inorganic; radioactive elements

Waste produced—Small masses of leached sample will remain. One objective of the technology will be to reduce laboratory waste to the absolute minimum.

Overall cost—Will depend upon degree of shielding or containment required for the sample.

Efficacy/strengths—This technology will replace the current EPA protocol, which was not designed for use with radioactive materials. It provides a safe means of conducting the TCLP leaching.

Science/Technology Needs: The leaching equipment and protocol must be adapted to glove box and hot cell operations.

Implementation Needs: Development costs, \$450K. Equipment must be modified and tested under containment and shielding.

September 1993

**ADAPTATION OF THE EPA TOXICITY CHARACTERISTIC
LEACHING PROCESS FOR USE WITH RADIOACTIVE
SAMPLES**

CHAR-209-OL

Author: W. H. Griest/615-574-4864

References:

1. W. H. Griest and J. R. Stokely, Jr., "Characterizing Mixed Wastes: Scientific Perspective," pp. 14-24, preprints from the Eighth Annual Waste Testing and Quality Assurance Symposium, WPA Workshop IV on *Characterizing Mixed Wastes*, Arlington, Va., July 16, 1992.
2. "Clarification of RCRA Hazardous Waste Testing Requirements for Mixed Waste," Draft Guidance, U.S. Nuclear Regulatory Commission, Washington, D.C., March, 1992.

September 1993

IN SITU SOLID PHASE MICROEXTRACTION OF ORGANICS

CHAR-210-OL

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: Organic

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Sample collection

Technology: In situ solid phase microextraction of organics. Organics are collected from liquids, in areas inaccessible or too hazardous for conventional sampling, by sorption into a thin polymer film supported on a fused silica microfiber, extending from a protective sheath. The fiber is then withdrawn into the sheath, removed from the sampling site, and returned to the laboratory for analysis.

Status: Predemonstration; has been demonstrated on the laboratory bench.

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technology assessments; regulatory

Applicable contaminant evaluation: Organic

Waste produced—None, except for any necessary decontamination of sheath at the sampling site. No laboratory waste produced.

Overall cost—\$200/sample

Efficacy/strengths—The technology allows sampling and analysis of liquids in locations which cannot be reached using conventional technologies or which are too hazardous to collect a sample for return to the laboratory, as in highly radioactive waste tanks. There is very little waste produced at the sampling site, and none in the analytical laboratory.

Science/Technology Needs: Develop protective sheath and apparatus for field sampling

Implementation Needs: Development cost, \$250K

Author: W. H. Griest/615-574-4864

September 1993

References:

1. C. Arthur et al., "Solid Phase Micro-extraction: An Attractive Alternate," *Environ. Lab.*, 10-14, December 1992/January 1993.
2. C. L. Arthur et al., "Environmental Analysis of Organic Compounds in Water Using Solid Phase Micro Extraction," *J. High Resol. Chrom.* 15, 741-744, 1992.

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: Organics

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Laboratory methods

Technology: Solid phase microextraction analysis method. Organic compounds, which have been collected on the fused silica microfiber in the field, are thermally desorbed into the inlet of a gas chromatograph-mass spectrometer (GC-MS) and are analyzed using EPA GC-MS protocols without any sample preparation or solvent waste.

Status: Predemonstration; technology is demonstrated but requires refinement for quantitative analysis.

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Automated applications

Driver evaluation: Risk and technology assessments; regulatory

Applicable contaminant evaluation: Organic

Waste produced—None, organic solvents are not required

Overall cost—\$500/sample

Efficacy/strengths—No sample preparation is required, and laboratory staff are not exposed to hazardous solvents or to radionuclides from the sampling site. It is fast and simple to conduct.

Science/Technology Needs: Adapt a conventional automated sample injector and develop quantitative method. Influence of waste sample characteristics on partition coefficient and sampling efficiency must be determined.

Implementation Needs: Hardware costs, \$20K; development costs, \$300K

Author: W. H. Griest/615-574-4864

References:

1. C. Arthur et al., "Solid Phase Micro-extraction: An Attractive Alternate," *Environ Lab* 10-14, December 1992/January 1993.
2. C. L. Arthur et al., "Environmental Analysis of Organic Compounds in Water Using Solid Phase Micro-extraction," *J. High Resol. Chrom.* 15, 741-744, 1992.

EM Problem: Decontamination and decommissioning

ORNL Problem: See Appendix A, list A

Problem Area/Constituents: Fissile material

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives:

Technology: Fissile material locator/profiler. The ^{252}Cf Source-driven Neutron/Gamma Noise Analysis Method is an absolute method that (1) determines the neutron multiplication constant, k , of fissile systems without the need for calibration at or near the critical state; (2) provides information that can be used for fissile assays and distributions; and (3) because of its high sensitivity to various parameters, such as cross sections, can be used to validate calculations. (See CHAR-44-OL and CHAR-107-OL.)

Status: Approved; ^{252}Cf Neutron/Gamma Noise Analysis Method has been used successfully by Knolls Atomic Power Laboratory, Los Alamos, Hanford and Argonne National Laboratories, and the Oak Ridge Y-12 Plant.

Waste produced—None

Efficacy/strengths—The ^{252}Cf Source-driven Neutron/Gamma Noise Analysis Method is invaluable for fissile systems for which there are criticality safety concerns. It determines the neutron multiplication factor, k , without requiring calibration at or near the critical state, as required by other subcriticality measurement methods. The method is nonintrusive, and measurements can be made accurately and in short periods of time. Fissile assays and distributions studies, as well as system characterizations, can be performed. The data acquisition and processing system has been developed and is available for measurements.

Science/Technology Needs: Although the method has been used successfully to measure the subcriticality of a wide range of fissile configurations, each new configuration needs to be studied to determine the proper positioning of detectors to assure accurate measurements.

Implementation Needs:

Author: John T. Mihalcz/615-574-5577

References:

There are over 200 references by the author covering both liquid and solid fissile systems. The following three references indicate the capability of the measurement method:

1. J. T. Mihalcz, et al., "Dynamic Subcriticality Measurements Using the ^{252}Cf -Source Driven Noise Analysis Method," *Nucl. Sci. and Eng.* **104**, 314-338 (1990).
2. J. T. Mihalcz, et al., " ^{252}Cf -Source-Driven Neutron Noise Measurements of Subcriticality for an Annular Tank Containing Aqueous Pu-U Nitrate," *Nucl. Tech.* **94**, 336-360 (1991).
3. J. T. Mihalcz, et al., " ^{252}Cf -Source-Driven Noise Measurements of Subcriticality for a Slab Tank of Aqueous Pu-U Nitrate," *Nucl. Sci. and Eng.* **107**, 35-57 (1991).

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: Biological waste; see Appendix A, lists A, B, and C

Problem Area/Constituents: Pathogen surveillance

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Laboratory methods

Technology: Pathogen surveillance. Microbiological testing of air and water samples is used to prevent infection of workers by environmental pathogens. Sampling is routinely conducted at cooling towers. Sampling can be provided on demand at other potential problem areas (burial grounds for biological waste, water damaged work areas, eyewash stations, circulating water cooling systems, etc.).

Status: Accepted; pathogenic bacteriology
Demonstrated; pathogenic virology

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Pathogenic microorganisms

Waste produced—No RCRA or radioactive material is added to the samples.

Overall cost—\$50–\$250/sample after laboratory has been set up; nonrecurring cost of \$250K for laboratory equipment.

Efficacy/strengths—Potential microbiological hazards at ORNL include: coliform bacteria, protozoa (including amoebae), *Legionella*, viruses, pathogenic bacteria, and allergens (including fungi and molds). Potential sources of these hazards include: cooling towers [*Legionella*, protozoa (including amoebae), and pathogenic bacteria]; eyewash stations (amoebae and bacteria); water cooling systems (amoebae, bacteria, and *Legionella*); water damaged work areas (fungi, mold, bacteria, and coliform bacteria); and ORNL burial grounds and landfills (viruses, amoebae, bacteria, and fungi). Pathogenic bacteriology, using classical and molecular techniques, is available on-site using techniques currently accepted by the scientific community. Pathogenic virology capability is not currently available on-site.

Science/Technology Needs: The pathogenicity of newly discovered bacteria associated with free-living amoebae needs delineation since such amoebae are ubiquitous and can harbor

and amplify known pathogens. There is a need to develop pathogenic virology capabilities. Equipment necessary for speciation by DNA fingerprinting and phospholipid fatty acid analysis, which can further aid in the identification of isolates not readily speciated by conventional methodology, are needed.

Implementation Needs: Hardware costs, \$80K-\$90K; development costs, \$250K

Author: R. L. Tyndall/615-574-0686

References:

1. "Section III, *Legionella*-Protozoa Interrelationships," pp. 129-162 in *Legionella: Current status and Emerging Perspective*, eds., J. M. Barbaric, R. F. Breiman, and A. P. Dufour, American Society for Microbiology, Washington D. C., (1993).
2. E. H. Lennette, A. Balows, W. J. Hauster, Jr., and H. J. Shadomg, *Manual of clinical Microbiology*, 4th edition, American Society for Microbiology, Washington D. C., (1985).
3. Perkin Elmer Cetus Enviro Amp *Legionella* Kits, Instruction Manual (1992).

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: Radioactive elements

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Field methods

Technology: Bubble dosimeters for neutron flux. These dosimeters are an integral part of a field neutron dosimetry system for use where neutron sources and shielding are not well known. They are capable of measuring neutron doses equivalent in low-level fields and providing simple spectral information. This information can be compiled with the response from existing personal thermoluminescence dosimeter detectors to provide appropriate energy correction factors and improve the accuracy of personnel neutron dosimetry.

Status: Accepted; active and passive dose equivalent detectors and passive spectrometer sets. Further development will be needed for use as a passive or active neutron spectrometer in an alarming neutron dose rate meter.

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation:

Applicable contaminant evaluation: Radioactive elements (n)

Waste produced—Very little; devices are reusable, some can be zeroed

Overall cost—Nonrecurring costs—imaging equipment, \$2K; commercially available reader, \$50K. Recurring costs— ~\$2-\$3/measurement; ~\$100/passive unit (6/set)

Efficacy/strengths—Limit of detection is about 0.5 mrem. Energy range of spectrometer set is 0.01-20 MeV, nearly the dose equivalent for personal dosimetry units. This system will enhance ALARA practice by providing immediate indication of neutron dose. The technology will be most useful in waste management and remedial action activities involving handling of unknown amounts of ^{252}Cf or other neutron-emitting radionuclides.

Science/Technology Needs: The measurement principle is well established for measuring neutron flux around personnel. The technique must be evaluated for potential confounding effect in other, less benign, environments. ~\$200K is needed to develop acoustic coupler for

applications requiring real-time measurement of neutron dose rate and a less expensive, automated bubble counter for reliable processing of passive detection results.

Implementation Needs:

Author: M. A. Buckner/615-574-5859

References: *Radiation Protection Dosimetry*, **32**(1), 21-43 (1990).

X-RAY FLUORESCENCE FOR IN SITU MONITORING OF TOXIC HEAVY METALS

CHAR-219-OL

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: General

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: Detection/measurement-field

Technology: X-ray fluorescence (XRF) for in situ monitoring of toxic heavy metals. An energetic X-ray source is used to irradiate the sample. The emitted X rays are detected and analyzed to identify the element source. This technology can be used for in situ monitoring of toxic heavy metals in paints, on surfaces, and in soils. Portable XRF units are commercially available and have been widely used for screening painted surfaces for lead contamination.

Status: Accepted; commercially available

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Inorganic (Pb, Hg, Cr, Tc, U, Th, Ra, etc.)

Waste produced—None

Overall cost—\$50K/unit; each unit could be used for years while making many measurements (5-25) per day (~\$25/measurement for labor costs).

Efficacy/strengths—This technology is already in use in HUD and EPA programs for the detection of lead in paint. Commercially available units are portable and are capable of analyzing homogenized samples for heavy metal contamination. Also, the units can be used to detect metals in situ or on surfaces. The technology was evaluated in the EPA Site Program.

Science/Technology Needs: Personnel training in interpretation of results

Implementation Needs: Substrate effects need to be studied. The lower limit of detection for some metals on surfaces needs to be measured (~\$200K).

Author: D. L. Wilson/615-576-3208

September 1993

X-RAY FLUORESCENCE FOR IN SITU MONITORING OF TOXIC HEAVY METALS

CHAR-219-OL

References:

1. Scitec Corp. (map spectrum analyzer)/800-466-5323.
2. HNU Systems, Inc. (SEFA/P portable X-ray fluorescence analyzer)/617-964-6690.

September 1993

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: General

Reference Requirements: Refer the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement:

Alternatives:

Technology: Network architecture with integrated workstations. Network access to all types of computer systems from a personal desktop computer permits rapid, convenient transfer of data and project information. Since powerful engineering workstations are available at reasonable cost, integration of quite different kinds of activities by a single user is possible. Multitasking capabilities allow a user to switch back and forth between very different applications, running in different windows, and to quickly and easily move large blocks of information between these different applications. These systems will share files, output devices (e.g., laser printers), and expensive hardware, such as specialized information storage systems, across a network.

Status: Demonstration; commercial engineering workstations support this technology. These capabilities are migrating to the newer PCs and are expected to be more widely available in the near future. Knowledge of how to integrate a variety of different activities on a common platform is still not widespread, so what is now possible needs to be demonstrated. Otherwise, desktop system capabilities will be enhanced in a piecemeal fashion, where the pieces do not work well together, if at all.

Waste produced—Not applicable

Overall cost—

Efficacy/strengths—This is a powerful tool for people trained to make use of it. The amount of training required will vary considerably, depending on how well the user interface is designed. It is currently possible to develop or purchase user interfaces that minimize initial training requirements and almost eliminate the need to refer to a user's manual to make effective use of a new application.

Science/Technology Needs: The current legacy of older operating systems (DOS, MacDOS), which were not designed to support integration of desktop applications with each other and with network services, is the greatest obstacle.

Implementation Needs: This technology is best introduced in the context of a commitment to use open system standards for all new computer acquisitions, i.e., the POSIX suite of standards, use of TCP/IP for communications, and selection (and publication) of standards for all graphical user interfaces.

Author: John K. Munro, Jr./615-574-0635

References:

EM Problem: Remedial action

ORNL Problem: See Appendix A, list B

Problem Area/Constituents: General

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives:

Technology: Multisensor fusion measurement systems. The ability to combine custom-designed integrated circuits with sensors now permits fabrication of compact, "intelligent" measurement systems. Not only can these systems report results of individual sensor readings, but they can be combined to report derived data at the same time. Integrated circuits can be designed locally and given to a commercial fabricator who will implement the design in silicon. This technology has great potential for development and use of portable measuring devices.

Status: Predemonstration; the aerospace industry has pushed development in this area significantly, especially for combining measurement techniques based on electromagnetic scattering (radar) with other sensor measurements.

Waste produced—Not applicable

Overall cost—

Efficacy/strengths—Use of multisensor fusion technology often has more compact packaging, greater reliability, lower power requirements, and more rugged construction.

Science/Technology Needs: Fiber-optic technology integrated with silicon technology is one way to combine multiple types of measurements (e.g., gamma radiation levels, temperature, pressure) in a single, compact package resulting in a "smart" sensor. Devices that make measure radiation level and temperature simultaneously have been fabricated. Other combinations are possible. Signals from sensor arrays (charge coupled devices, a bundle of optical fibers) integrated with digital processing chips, in some cases all placed on the same silicon substrate, permit rapid complex measurements or measurements under otherwise adverse environmental conditions to be taken. The reduction in package size may allow for more rugged, reliable devices.

Implementation Needs: Commercial facilities (MOSIS) can manufacture integrated circuit chips to a customer's individual design specifications, as expressed in a circuit design layout.

Chip design and layout software exist (some in the public domain) for a small group of instrument makers to design their own application specific integrated circuits (ASICs). Fiber-optic technology has developed enough so that these two technologies can be integrated, as one route to a multisensor fusion implementation. Chip fabrication costs can run as low as a few thousand dollars. Chip design costs must primarily cover people's time, typically a few months to a year for simpler applications. With further integration of digital processing capabilities, several types of information, both directly measured and derived data, can be obtained from the same compact package.

Author: John K. Munro, Jr./615-574-0635

References:

DETECTION AND MEASUREMENT SYSTEMS WITH FEATURE EXTRACTION

CHAR-223-OL

EM Problem: Remedial action

ORNL Problem: See Appendix A, list B

Problem Area/Constituents: General

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives:

Technology: Detection and measurement systems with feature extraction. Algorithms based on fuzzy set theory, fractals, neural nets, wavelet transforms, and other new fields of mathematics can be used with multisensor fusion technology to provide high levels of "intelligent measurement," especially feature extraction, in compact packages suitable for portable instruments needed to make field measurements.

Status: Predemonstration; with appropriate training of the measurement system and application of feature recognition methods, this technology can be very effective and reliable.

Waste produced—Not applicable

Overall cost—

Efficacy/strengths—Measurement systems with feature extraction (edge detection, pattern recognition, noise signature analysis) capabilities are useful when nondestructive or noninvasive identification or characterization methods are required. This kind of technology is also especially useful for field measurements or for use in hazardous environments.

Science/Technology Needs: Sensor and measurement technology components are better developed than the application methods that use recently developed mathematical approaches for feature extraction. The best ways to integrate the component technologies to take advantage of the new analysis techniques need to be developed. Wavelet transforms are particularly useful for edge detection in images. Neural nets require construction and use of "training sets" that cover the range of items expected to be encountered, particularly for environments where identification of materials must be made on the basis of a number of indirect measurements. Methods based on fuzzy sets are useful in situations in which decisions must be made based on incomplete or conflicting information.

Implementation Needs: Most measurement systems with feature extraction must first be applied to known cases.

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**DETECTION AND MEASUREMENT SYSTEMS
WITH FEATURE EXTRACTION**

CHAR-223-OL

Author: John K. Munro, Jr./615-574-0635

References:

September 1993

FRACTALS USED TO SELECT MODELS FOR MATERIAL TRANSPORT IN POROUS MEDIA

CHAR-225-OL

EM Problem: Decontamination and decommissioning; remedial action

ORNL Problem: See Appendix A, lists A and B

Problem Area/Constituents: General

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement:

Alternatives:

Technology: Fractals used to select models for material transport in porous media. Many different computer models exist for calculating material transport rates, flow patterns, and other effects in porous media. Fractal concepts can be used to discriminate, using measurements based on length scales, between flow regimes and characteristics of the media through which flows occur to determine what model assumptions and which approximations are appropriate for a particular application. Fractal concepts should be particularly useful in selecting a candidate from a set of lumped parameter models.

Status: Evolving; one of the early application areas of the mathematical concepts of fractals and fractal geometry has been to flow in porous media. Another is flow control in fluidized beds.

Waste produced—Not applicable

Overall cost—Unknown

Efficacy/strengths—Ability to model and understand material transport mechanisms

Science/Technology Needs: Application of fractal concepts (and chaotic behavior in dynamic systems) to physical systems is a new field. Enough is understood about applying the concepts to problems of flows in porous media to be useful in classifying existing models.

Implementation Needs: This technology deals with concepts and applications which are expressed in mathematical terms. Hence, hardware development requirements are minimal or nonexistent. Implementation will be almost entirely in terms of software that must be developed and applied to results obtained from other application software or to data.

Author: John K. Munro, Jr./615-574-0635

September 1993

**FRACTALS USED TO SELECT MODELS
FOR MATERIAL TRANSPORT IN POROUS MEDIA**

CHAR-225-OL

References: D. L. Turcotte, *Fractals and Chaos in Geology and Geophysics*, Cambridge University Press, 1992.

September 1993

SAMPLING PROGRAM CONFIGURATION MANAGEMENT SYSTEM

CHAR-228-OL

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: General

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives:

Technology: Sampling program configuration management system. A sample management and tracking information system will be needed to support a number of related activities and to maintain lists of references to data associated with each sample. This system should include logging information for each sample (location from which sample was taken, date, environmental conditions at time of extraction, analyses performed, and results found). If a complex sequence of analyses must be performed and deadlines and schedules are critical, tracking and notification mechanisms must be available. Information about who is performing the analyses, what procedures are being used, and who must be contacted if problems arise (i.e., maintain a complete audit trail) is needed. This system will be most useful if it is implemented in a distributed computing environment (e.g., using a client/server access architecture) so all technical staff and managers who need access to the data have it. Information related to sample preparation may need to include references to applicable standards and regulations which may specify certain tests (e.g., if unexpected difficulties arise during extraction, preparation, or analysis, regulations serving as a basis for a sampling protocol may need to be consulted so that alternative actions can be considered).

Status: Accepted; a major component of quality assurance programs for most engineering disciplines. Support documents must describe its structure, implementation (who is responsible for what, identification of items to be tracked, and what means will be used to track items), and operation. A range of application software to assist with configuration management is available both commercially and in the public domain. A set of basic tools is usually included in the support software associated with most UNIX-based operating systems.

Waste produced—Not applicable

Overall cost—

Efficacy/strengths—This technology can satisfy most quality assurance requirements for large projects in a cost-effective and reliable manner.

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SAMPLING PROGRAM CONFIGURATION MANAGEMENT SYSTEM

CHAR-228-OL

Science/Technology Needs: Enhancements to commercial products will be required to provide the level of support needed for a large sampling program (such as for the characterization stage of restoration activities). Functional areas that will benefit most from enhancements are the user interface, mechanisms that link related items of information for future reference, and services that will allow access to information from other host systems connected to high speed networks.

Implementation Needs: Instead of setting up one large all-encompassing system, separate configuration management systems should be considered for each of the following: Characterization Sampling Program, Remedial Action, Waste Management, and Decontamination and Decommissioning. However, an information access mechanism should be identified to provide easy, fast access to related information in one of the other areas. The breakdown by area suggested here is based on the belief that the degree of coupling between areas will not be strong. Interoperability of systems used in each major area and between areas is a more significant issue.

Author: John K. Munro, Jr./615-574-0635

References:

September 1993

EM Problem: Remedial action; waste management

ORNL Problem: See Appendix A, lists B and C

Problem Area/Constituents: General

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives:

Technology: Configuration management system. An information system to track the status of remediation activities and support services will be needed. Most engineering projects are managed by breaking them into a succession of phases (conceptualization, requirements identification, specification, implementation, installation, operation and maintenance, dismantlement) that compose the project life cycle. Use of such an approach is particularly important for highly regulated activities requiring periodic reviews, use of formalized procedures, and adherence to a project quality assurance plan. Configuration management is one of the major topics addressed by quality assurance standards. Most remediation activities at DOE sites will have to be conducted according to the highly regulated conditions mentioned above. An appropriately designed and implemented automated information system is an essential component needed to achieve the level of reliability and consistency required by the applicable standards.

Status: Accepted; a major component of quality assurance programs for most engineering disciplines. Support documents must describe its structure, implementation (who is responsible for what, identification of items to be tracked, and what means will be used to track items), and operation. A range of application software to assist with configuration management is available both commercially and in the public domain. A set of basic tools is usually included in the support software associated with most UNIX-based operating systems.

Waste produced—Not applicable

Overall cost—

Efficacy/strengths—This technology can satisfy most quality assurance requirements for large projects in a cost-effective and reliable manner.

Science/Technology Needs: Enhancements to commercial products will undoubtedly be required to provide the level of support needed for a large remediation program (such as the characterization stage of activities). Functional areas that will benefit most from

enhancements are the user interface, mechanisms that link related items of information for future reference, and services that will allow access to information from other host systems connected to high speed networks.

Implementation Needs: Instead of setting up one large all-encompassing system, separate configuration management systems should be considered for each of the following: Characterization Sampling Program, Remedial Action, Waste Management, Decontamination and Decommissioning. However, an information access mechanism should be identified to provide easy, fast access to related information in one of the other areas. The breakdown by area suggested here is based on the belief that the degree of coupling between areas will not be strong. Interoperability of systems used in each major area and between areas is a more significant issue.

Author: John K. Munro, Jr./615-574-0635

References:

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: General

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives:

Technology: Hazard analysis expert system. Many different hazards will be encountered in carrying out the broad range of environmental restoration activities at the DOE sites, especially the major sites. The range and types of hazards will require analysis of (1) health and physical hazards, (2) equipment malfunctions or failures, and (3) hazards (short- and long-term) to the public and the environment from restoration activities. Hazards that must be addressed in some manner are identified by environmental laws and regulations, engineering standards, federal and state oversight agencies. Keeping up with the amount of information in this area as well as applying it to cleanup activities is very difficult. Expert system technology can help to effectively manage this and assist in identifying conflicting regulations.

Status: Demonstration. Expert system technology has worked very well in some applications and has been a great disappointment in others. Success or failure depends critically on how well the problem domain has been analyzed and how thoroughly the knowledge base has been specified. A demonstration is definitely required.

Waste produced—Not applicable

Overall cost—

Efficacy/strengths—A well-constructed hazard analysis expert system has the potential to be a very useful, widely used tool. No one person can hope to know about all the hazards that must be identified and evaluated with respect to the cleanup problems at DOE sites. Automated text searching, rule application, and logical analysis tools or aids must be used to accomplish the cleanup tasks in reasonable time, at reasonable cost, and with high reliability and consistency. A good hazard analysis expert system can greatly help achieve this.

Science/Technology Needs: Availability of and access to specification and design tools to develop a knowledge base and structure of the rules are the biggest needs.

Implementation Needs: The implementation strategy and process used are the most important elements in developing a successful hazard analysis expert system. A powerful, complex system may not be required in order to provide valuable service. Important categories of information include (a) lists of identified, known hazards related to specific types of problems and (b) descriptions of methods (including references) used for hazard analysis/identification and to prevent occurrences.

Author: John K. Munro, Jr./615-574-0635

References:

APPLICATION OF APPROXIMATE REASONING TO DATA ANALYSIS/EVALUATION

CHAR-234-OL

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: General

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives:

Technology: Application of approximate reasoning to data analysis/evaluation. Situations frequently arise in which choosing a course of action can be particularly difficult, especially if careful, reasoned justification must be provided to document what was done. A decision must often be made when the information incomplete or very imprecise, resulting in a course of action based on assigning probabilities to what information is available and on developing tables of likely outcomes from experience. Well-defined procedures for reaching decisions based on incomplete or uncertain information exist based on multi-valued or fuzzy logic. Another situation that occurs is having to choose between conflicting requirements. Again, a probabilistic approach to analyzing the problem can be used to make a choice. A third area is new, a result of developing very sensitive measurement techniques, so that levels of toxic substances can be measured well below naturally occurring background levels. As a consequence, regulatory guidelines can specify clean up standards that are much more stringent than what nature provides. Sensitive measurement techniques are related to this because statistical or other types of analyses are capable of indicating the significance of a particular measurement. All of these benefit from using approximate reasoning techniques.

Status: Demonstration; computing technology and resources exist and can be acquired at modest cost. The biggest expense is for time of the technical people to build the knowledge base, collection of rules needed, and table of probabilities needed for applying the rules.

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Driver evaluation: Risk and technical assessments; regulatory

Waste produced—Not applicable

Overall cost—

Efficacy/strengths—One of the greatest benefits from applying the methods of approximate reasoning to analysis and evaluation of a particular problem is the increased understanding of associated causes and consequences. Effective application of the methods often requires

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CHAR-234-OL

that problems be studied from other points of view than those normally used. Assumptions must be challenged. A new type of disciplined analysis must be used.

Science/Technology Needs: The ability to include capabilities to document the sequence of rules and facts used to find a solution is needed. The technology and methods used for approximate reasoning have many areas in common with theorem prover applications.

Implementation Needs: This technology is heavily dependent on having people capable of analyzing the problem(s) and the problem domain to determine how to appropriately apply the analysis techniques to the problems. Excellent computing resources exist, but they must be used effectively.

Author: John K. Munro, Jr./615-574-0635

References:

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FIBER-OPTIC DETECTION AND MONITORING SYSTEM (INTELLIGENT MATERIALS)

CHAR-240-OL

EM Problem: Remedial action; waste management

ORNL Problem: See Appendix A, lists B and C

Problem Area/Constituents: General

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives:

Technology: Fiber-optic detection and monitoring system (intelligent materials). Techniques for embedding thin optical fibers in surface coatings applied to structural materials open up possibilities for detecting rupture, abrasion, or corrosion of container wall surfaces. Fibers can be arranged so that transmitted beams of light are totally contained within the fibers until a break occurs. The presence of a break is detected internally by a sudden loss of light intensity at the end of the fiber opposite the light source or externally by the sudden appearance of light at the point of the break. Embedded optical fibers can also be given special coatings that allow them to monitor temperature or ionizing radiation levels.

Status: Evolving; this technology holds much promise for continuous monitoring of radioactive waste storage systems. It should be considered for activities where immediate notification of materials failure is required. Candidate sensors that can respond to variable service conditions such as temperature, pressure, light, electric, or magnetic fields have been identified. This technology should be useful for monitoring containers used to ship hazardous materials.

Temporal areas of evaluation: Posttreatment

Driver evaluation: Technical assessment; regulatory

Waste produced—Not applicable

Overall cost—

Efficacy/strengths—The combination of optical fibers with structural materials to monitor structural integrity reliably and at low cost, either visually or with recording instruments, has many attractive features. Maintenance should be minimal in many cases. Some types of optical fibers are even able to tolerate high radiation levels well enough to be useful in some applications.

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FIBER-OPTIC DETECTION AND MONITORING SYSTEM (INTELLIGENT MATERIALS)

CHAR-240-OL

Science/Technology Needs: Long-term stability and environmental testing are needed before considering applications for long-term radioactive waste monitoring applications.

Implementation Needs: Technology integration of fiber optics with the appropriate structural material is needed. The field of intelligent material systems is relatively new. Development costs are not known at this time, especially for adapting this technology to a highly regulated activity such as shipment of radioactive or mixed wastes.

Author: John K. Munro, Jr./615-574-0635

References:

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EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: General

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives:

Technology: Task scheduling aids (for decontamination and decommissioning, remedial action, and waste management). Scheduling aids need to go beyond many of the usual commercial project management applications to allow easier integration of the consequences of regulatory constraints, organizational policy and operating rules, and links to related projects. Planning for environmental restoration activities is much more complex, due to the highly regulated types of activities involved, than the projects most commercial applications were designed to treat. In some cases the scheduling aids may need to include access to expert systems or other such specialized applications (e.g., use of approximate reasoning, discrete simulations of processes)

Status: Demonstration; need to show how the various component technologies can best be integrated and what modifications to current commercial products would be most beneficial.

Waste produced—Not applicable

Overall cost—

Efficacy/strengths—Deals effectively with the large number and variety of regulatory constraints that affect schedules.

Science/Technology Needs: Technology improvement (being able to incorporate consequences of regulatory constraints) and integration of complementing technologies (expert systems, approximate reasoning, linking to databases across networks) are the primary needs.

Implementation Needs: Data validation will be needed. Scheduling aids are difficult to test other than by experience because most testing scenarios present such idealized situations. So that these aids can become useful and reliable forms of assistance, A strong maintenance effort must be established to assure that needed improvements are made.

Author: John K. Munro, Jr./615-574-0635

References:

STORED MATERIAL NEURAL NET IDENTIFICATION SYSTEM

CHAR-242-OL

EM Problem: Remedial action; waste management

ORNL Problem: See Appendix A, lists B and C

Problem Area/Constituents: General

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives:

Technology: Stored material neural net identification system. Many drums containing mixed waste cannot be opened to identify the contents. In many cases, information exists about what materials are stored in a collection of drums. What and how much of these materials are in a particular drum is not known. Nondestructive methods must be used to obtain the data, from which the specific contents, amounts, and spatial distribution can be determined. When the number and types (e.g., >10) of measurements needed becomes large, the complexity of the task, using traditional methods, becomes too great to use. Neural network analyses are capable of handling complex identification tasks if an adequate training environment can be set up.

Status: Demonstration; could provide a base of experience in designing effective training material for the combination of measurements used to provide input data for the neural net identification system.

Temporal areas of evaluation: Pretreatment

Waste produced—Not applicable

Overall cost—

Efficacy/strengths—When appropriately used, this technology can be very effective. One application area in which it is becoming widely used is to evaluate credit risks of loan applications. It is useful in situations where a functional form or a mathematical description needed to relate measurement data to identification of contents does not exist or the number of factors to be considered in interpreting the data correctly is large.

Science/Technology Needs: Neural net applications similar to the one proposed here are in regular use, reliable, and easy to use. A number of software implementations and tools exist that are easy to set up for an assembly-line type of inspection and characterization process.

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**STORED MATERIAL NEURAL NET
IDENTIFICATION SYSTEM**

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Implementation Needs: Most of the work will have to be concentrated in setting up and calibrating the different measurement stations for gamma-, X-ray, neutron, and acoustic measurements to assure that the data given to the neural net analyzer is of the best possible quality.

Author: John K. Munro, Jr./615-574-0635

References:

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EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: General

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives:

Technology: Instrument response models for remote sensing. System reliability analysis methods used to design fault-tolerant systems for satellite sensor and data acquisition systems can be applied to the development of remote sensor systems used on robotic end effector units that must operate in high radiation environments. These methods make extensive use of physical and chemical models of the sensor mechanisms for generating measurable signals and subsequent steps in processing the signals so the entire instrument response can be simulated. Once the models have been developed, consequences of various failure modes can be studied so that the instrument design can be made more fault-tolerant with respect to the hazards expected to be encountered where the instrument will be used.

Status: Accepted; instrument response models have been used for many years to evaluate satellite sensor, control, and communication systems.

Waste produced—Not applicable

Overall cost—

Efficacy/strengths—This technology is useful when the cost of equipment or the consequences of a failure in a particular application are great enough to justify its use. This technology has been used extensively to recover data from the Hubble Space Telescope.

Science/Technology Needs: Information necessary for developing models of the instrument subsystems and measurement processes must be provided.

Implementation Needs: Instrument response models are usually represented in software that executes on a computer, so implementation needs would be those of software developed for engineering and scientific applications.

Author: John K. Munro, Jr./615-574-0635

References:

FIBER-OPTIC SYSTEMS FOR MEASURING MULTIPLE PHYSICAL VARIABLES

CHAR-248-OL

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: General

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement:

Alternatives:

Technology: Fiber-optic systems for measuring multiple physical variables. Fiber-optic technology provides a medium for transmitting information efficiently, with low noise levels, requiring low (sometimes no) power, and occupying very little space. Optical fibers can be manufactured so that a single fiber with appropriate coatings can be used in the simultaneous measurement (using multiple wavelengths of light) of more than one physical quantity, such as radiation level and temperature. Multiple fibers can be combined for compact sensor arrays that provide spatial information. These and other attributes make this technology an attractive candidate for long-term monitoring applications.

Status: Predemonstration; proof-of-principle of this technology can be demonstrated in devices suitable for use in underground waste storage tanks. Current development efforts are directed toward extending the range of types of measurements that can be combined into a single device for use in hazardous waste storage monitoring applications.

Deployment evaluation: Manual, automated, and robotic applications

Waste produced—None

Overall cost—

Efficacy/strengths—This technology can be usefully applied to some combinations of measurements that require no power (passive monitoring). Optical fiber technology can be used very effectively in applications in which limited access paths are a prime consideration. Optical fiber can also provide electrical isolation.

Science/Technology Needs: A range of applications can be developed using this technology.

Implementation Needs: Extensive investments should not be required to set up basic fabrication facilities. This technology should lend itself well to economies of scale in the manufacture of rugged, replaceable devices that should require low (or no) maintenance.

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**FIBER-OPTIC SYSTEMS FOR MEASURING
MULTIPLE PHYSICAL VARIABLES**

CHAR-248-OL

Author: John Munro, Jr./615-574-0635

References:

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EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: General

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: Data analysis

Technology: Analysis of censored data. Analysis of data containing a mixture of censored (less than limits) and observed data to produce mathematically defensible means, estimates, and confidence intervals. The data produced during an environmental investigation usually consists of the amount of various elements found in the sample. Often the amount of an element in the sample is less than the measuring device is able to detect that element, or it is just not there. In such cases the amount of the element indicated in the sample data, is given as less than some amount. As a result, rules-of-thumb have been created to produce estimates of mean levels and confidence bounds, even if the data is of dubious quality. Current literature contains correct and logically sound methods of dealing with this problem. It is assumed that the data may have to be transformed to obtain a usable probability distribution. This proposal is to further adapt these methods of analysis to fit the problems present in the current environmental data. The result would be mathematically defensible estimates and confidence bounds.

Status: Demonstration; some work is available in the literature. The application likely will have to be expanded to meet current needs.

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual and automated applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Inorganic; organic; physical

Waste produced—None

Overall cost—Some mathematical development and computer programming

Efficacy/strengths—This kind of estimation routine will allow for the full use of both censored (less than) and observed data in an orderly way in the data analysis. It will eliminate the need for "rules of thumb" that are currently used when censored (less than) data are present in the data set.

Science/Technology Needs: Computer work station with access to appropriate data bases

Implementation Needs: Access to appropriate data bases, computer time, mathematical development time, and programming time

Author: W. E. Lever/615-574-3129

References: See appropriate JASA articles.

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: General

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Data analysis

Technology: Quality control for measurement processes. Much of the creditability of an experimental study is governed by the creditability of the data used in the study. The quality of the measurement process must be continually evaluated to determine the quality of technical measurements. This evaluation can be done by injecting NIST-type standard samples into the measurement stream, then monitoring the results over time. Use of standard samples requires the development of quality control charts that monitor the mean and variability levels of the measurement devices. In addition to monitoring the consistency of the measurement process, information must be developed that gives limits on the accuracy of the process. This again can be done through the measurement of NIST-type standards.

Status: Accepted

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Radioactive; inorganic; organic; physical

Waste produced—Not applicable

Overall cost—Personnel time

Efficacy/strengths—Quality Control is practiced by most laboratories and production processes to ensure production of a quality product.

Science/Technology Needs: Data from standards evaluations

Implementation Needs: Access to Quality Standard measurements

Author: W. E. Lever/615-574-3129

References: Statistical literature.

STATISTICAL METHODS FOR THE ANALYSIS OF LARGE DATA SETS

CHAR-251-OL

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: General

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Data analysis

Technology: Statistical methods for the analysis of large data sets. Statistical methods that look for significant patterns in large data bases need to be developed. These methods will need to employ sampling studies, exploratory data analysis procedures, and visual methods. The development of these procedures will include the use of both theoretical and applied data analysis procedures, along with a mesh of graphical methods to identify and analyze patterns of interest in the data.

Status: Conceptual

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: General

Waste produced—None

Overall cost—May need considerable computer, mathematical, and software development time

Efficacy/strengths—The evaluation of large data bases will allow the study of relationships between large areas and the intercorrelation of the multitude of measurements made and recorded in the data bases.

Science/Technology Needs: To survey many areas, statistical methods that take advantage of new parallel processors may need to be developed.

Implementation Needs: Possible large-scale computer needs and software development time.

Author: W. E. Lever/615-574-3129

References: EPM research reports.

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EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: General

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Sampling design

Technology: Sequential sampling plans. A series of sampling efforts will likely be required in the investigation of previously unexplored waste sites. The location of each set of new samples will depend on the information gained from the previous samples. This procedure will require a sampling plan design, coupled with a sequential type decision procedure that will specify when to continue sampling and where to locate the new sample points.

Status: Accepted

Temporal areas of evaluation: Pretreatment

Deployment evaluation: Manual applications

Driver evaluation: risk assessment; regulatory

Applicable contaminant evaluation: Radioactive; inorganic; organic; physical

Waste produced—None

Overall cost—

Efficacy/strengths—Directly applicable to hot spots

Science/Technology Needs: Experimental site data

Implementation Needs: Initial planning time

Author: W. E. Lever/615-574-3129

References: Professional literature.

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: General

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: Sampling design and data collection

Technology: Spatial sample and data analysis plans. Spatial sampling and data analysis plans are often used to evaluate areas for unknown deposits. Generally these plans are used by mineral and oil explorers to map soil structures and mineral deposits. This type of information will also be needed during the study of waste deposits, so that appropriate decision procedures can be formulated for the further exploration of the site or the clean up of the site.

Status: Accepted

Temporal areas of evaluation: Pretreatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: General

Waste produced—None

Overall cost—

Efficacy/strengths—Directly applicable to finding hot spots. Spatial sampling plans have been used in geostatistic applications (mining/oil exploration) for a long time. A wealth of recent work has been produced in other areas for the specific purpose of site characterization.

Science/Technology Needs: Personnel and computer time; access to survey data

Implementation Needs: Time and data

Author: W. E. Lever/615-574-3129

References: Professional literature.

EM Problem: Remedial action; waste management

ORNL Problem: See Appendix A, lists B and C

Problem Area/Constituents: Organic

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Sample collection

Technology: Solid sorbent sampling for airborne organics. Airborne target species and co-contaminants are collected by drawing air through tubes packed with one or more sorbent materials. Different sorbents may be used for different classes of compounds. The tubes are sealed following sampling and returned to a laboratory for analysis. Conversely, they may be analyzed on-site using field analytical equipment. Sorbed species are usually removed by solvent elution or thermal desorption.

Status: Demonstration; technology is available, but validation is required for particular sampling conditions and target species.

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual, automated, and robotic applications

Driver evaluation: Risk assessment; regulatory

Applicable contaminant evaluation: Organics (volatile organic compounds; semivolatile organic compounds)

Waste produced—None to minimal. Some sorbent tubes can be reused, while others cannot. Total waste for nonreusable tubes is ~10 cm³/sample.

Overall cost—\$1-\$50/tube, depending on sorbent

Efficacy/strengths—It permits collection and concentration of vapor phase organic contaminants for subsequent analysis.

Science/Technology Needs: Methods must be developed and validated for specific applications.

Implementation Needs: Depends on contaminants, development costs ~\$100K-\$200K

Authors: M. R. Guerin and R. A. Jenkins/615-574-4862

References:

1. C. E. Higgins, R. A. Jenkins, and M. R. Guerin, "Organic Vapor Phase Composition of Sidestream and Environmental Tobacco Smoke from Cigarettes," pp. 140-145, *Proceedings of the 1987 EPA/APCA Symposium on Measurement of Toxic and Related Air Pollutants*, (1987).
2. R. A. Jenkins, C. E. Higgins, T. M. Gayle, G. W. Allin, and R. R. Smith, "Field experiences with a multisorbent arrayed sampler for the in situ collection of vadose zone volatile organic compounds," presented at the Third International Symposium for Field Screening Methods for Hazardous Wastes and Toxic Chemicals, Las Vegas, February 24-26, 1993.
3. Numerous EPA and OSHA methods.

EM Problem: Remedial action

ORNL Problem: See Appendix A, list B

Problem Area/Constituents: Soil, sediments, ground water

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives:

Technology: *Dynamic modeling of material transport. Development, adaptation, and use of computer simulations to predict the transport and chemistry of contaminant movement in soils and ground water to determine measurement system requirements, and to analyze data obtained from sampling. Simulation programs and methods developed for similar projects can be further developed and adapted to the task of tracking contamination. This technology will be essential for designing measurement, data recording, and data analysis programming needs. Otherwise, interpretation of data of insufficient quality or quantity (spatially and temporally) may lead to erroneous conclusions, and then in turn to either insufficient or excessive remedial action.*

Status: Accepted; measurement, data collection, and data analysis programs are being established with (apparently) insufficient technology available to assure that adequate data will be taken and that the interpretation of the results will be valid.

Waste produced—Not applicable

Overall cost—

Efficacy/strengths—This project would reduce the risks of deploying elaborate but inadequate monitoring systems, reaching erroneous conclusions about the extent or nature of remediation required (capping, isolation, entombment, etc.), and failing to properly assess the results of remedial measures taken.

Science/Technology Needs: Models and simulations of the soils and ground-water characteristics of the sites under study need to be developed, tested, and verified in time to be factored in to the measurement, data collecting, and data analysis phases of the program.

Implementation Needs: Resources to develop and verify the simulations should be deployed before extensive measurement research and development and actual data collection and analysis is done to characterize sites, plan remedial action, and assess the results of cleanup activities.

Author: S. J. Ball/615-574-0415.

References: O. L. Smith, *Soil Microbiology: A Model of Decomposition and Nutrient Cycling*, CRC Press, Boca Raton, Florida, 1982.

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SOIL/SEDIMENT SAMPLING FOR VOLATILE ORGANICS ANALYSIS

CHAR-256-OL

EM Problem: Remedial action

ORNL Problem: See Appendix A, list B

Problem Area/Constituents: Organics

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Sample collection

Technology: Soil/sediment sampling for volatile organics analysis (VOA). The technology, specific for sampling soils and sediments, prevents the loss of volatile organic compounds by taking an ~5-g sample in a special coring device. The aliquot is ejected into a VOA vial, which is carried to the laboratory for direct analysis in the VOA vial.

Status: Demonstration; previous work has shown that soils can be sampled for volatile organics analysis but further work is needed to adapt to the specific needs of the ORNL site.

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk assessment; regulatory

Applicable contaminant evaluation: Organics (volatile organic compounds)

Waste produced—None, laboratory waste from analysis is reduced to only 5 g soil and 5 mL water in a single vial.

Overall cost—<\$50/sample

Efficacy/strengths—The technology prevents the loss of volatile organics encountered in conventional EPA sampling methods, and laboratory waste is reduced to the absolute minimum.

Science/Technology Needs: Adaptation of the procedure to the specific applications required at the ORNL site.

Implementation Needs: Development costs, ~\$100K

Author: W. H. Griest/615-574-4864

References: R. A. Jenkins, ORNL Analytical Chemistry Division.

September 1993

SAMPLING UNDERGROUND STORAGE TANKS FOR VOLATILE ORGANICS

CHAR-257-OL

EM Problem: Remedial action

ORNL Problem: See Appendix A, list B

Problem Area/Constituents: Organics

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Sample collection

Technology: Sampling underground storage tanks (USTs) for volatile organics. Technology for the qualitative identification of volatile organics present in underground storage tanks (particularly nuclear process waste tanks), using collection and concentration of tank headspace on solid sorbent media, followed by laboratory or field analysis. Sorbent traps are kept outside the USTs, so as not to be exposed to radioactive contamination.

Status: Demonstration; the technology has been applied at the Hanford USTs. The technology is based on reasonably well proven air sampling methods, but specific applications must be validated.

Temporal areas of evaluation: Pretreatment

Deployment evaluation: Manual and automated applications

Driver evaluation: Risk assessment; regulatory (OSHA)

Applicable contaminant evaluation: Organic

Waste produced—None

Overall cost—\$500–\$1000/sample

Efficacy/strengths—Sample is isolated from the overall matrix in the field, and only reusable sample collection media are transported to the laboratory for analysis. Because air can be filtered prior to sampling, there is no rad material to dispose of.

Science/Technology Needs: Adapt laboratory purge and trap techniques to field sampling within or immediately outside tanks, particularly USTs, for nuclear process waste.

Implementation Needs: Hardware costs, \$10K; development costs, \$250K

Author: W. H. Griest/615-574-4864

September 1993

**SAMPLING UNDERGROUND STORAGE TANKS
FOR VOLATILE ORGANICS**

CHAR-257-OL

References:

1. R. A. Jenkins, et al., "Field Experiences with a Multisorbent Arrayed Sampler for the In Situ Collection of Vadose Zone Volatile Organic Compounds," presented at the Third International Symposium for Field Screening Methods for Hazardous Wastes and Toxic Chemicals, Las Vegas, February 24-26, 1993.
2. C. V. Thompson, R. A. Jenkins, and C. E. Higgins, "A Thermal Desorption Method for the Determination of Nicotine in Indoor Environments," *Environ. Sci. & Tech.* **23**, 249-435, April 1989.

EM Problem: Remedial action

ORNL Problem: See Appendix A, list B

Problem Area/Constituents: General

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Physical measurements

Technology: In situ ground-water flow meter. Radial temperature sensors mounted in a probe that are lowered into a 3-in. diameter well indicate the ground-water flow rate and direction.

Status: Conceptual; permanent probe has been demonstrated at Sandia National Laboratory.

Temporal areas of evaluation: Pretreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk assessment; regulatory

Applicable contaminant evaluation: Physical

Waste produced—Only from well drilling

Overall cost—Mainly in installation, a few thousand dollars/well

Efficacy/strengths—Remote, real-time measurements to aid in the understanding of hydrologic and contaminant fluxes in ground-water flow zone

Science/Technology Needs: Construct probe, demonstrate in laboratory and field

Implementation Needs: Development costs, ~\$400K

Author: W. H. Griest/615-574-4864

References: J. S. Hicks/615-576-7342.

EM Problem: Remedial action

ORNL Problem: See Appendix A, list B

Problem Area/Constituents: General

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Field methods

Technology: Ground-water discharge location. Visible surface springs and seeps are sampled for contaminants. Other areas of contaminated ground-water discharge (seep) into streams are located by sampling streams at specified intervals and analyzing for elements of interest (^3H and ^{90}Sr in particular).

Status: Accepted; used at the ORNL site

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk assessment; regulatory

Applicable contaminant evaluation: Organic; inorganic; radioactive elements

Waste produced—Depends on number of samples and analyses requested

Overall cost—Depends on number of samples collected and the analyses conducted

Efficacy/strengths—Allows identification of contaminant pathways and prioritization of remediation efforts

Science/Technology Needs: Design of sampling and analyses required on this site

Implementation Needs: Setup costs, ~\$50K

Author: W. H. Griest/615-574-4864

References: D. Hicks/615-574-7380.

INTEGRATED MICROPROCESSOR/SENSOR MONITORING FOR RADIOACTIVE WASTE STORAGE CONTAINERS

CHAR-260-OL

EM Problem: Waste management

ORNL Problem: See Appendix A, list C

Problem Area/Constituents: General

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives:

Technology: Integrated microprocessor/sensor monitoring for radioactive waste storage containers. The combination of fiber optic, solar cell, high power density batteries, and microprocessor technologies provide a means for large scale automated monitoring of radioactive waste storage. The fiber-optic component can be used in a variety of ways: embedded in containment structures (use of intelligent materials technology), a signal transmission medium well-suited for low-power applications, and a convenient medium to enable combining two or more sensor measurements (multi-sensor fusion applications). Use of fiber with microprocessors not only permits advanced digital processing techniques to be used in low-power environments, but permits reductions in package size, more rugged construction to permit use in harsh environments, and perhaps allow manufacturing advantages of economies of scale in large numbers of units that are easy to replace. Rugged, modular, compact units would also promote more reliable and easier maintenance.

Status: Predemonstration; even though the component technologies are still evolving, they are mature enough to be considered for use in an integrated system that uses automated monitoring of stored hazardous wastes.

Waste produced—None

Overall cost—

Efficacy/strengths—Low power consumption, compact and rugged packaging, modular design to permit easy maintenance and replacement of failed units allow this technology to automate large scale monitoring economically.

Science/Technology Needs: Integrating the component technologies is the greatest need. It is likely that basic research will be needed to accomplish successful integration.

Implementation Needs: Technology integration. Most of the work to date in combining microprocessor and sensor technologies in low power, compact systems has occurred in

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INTEGRATED MICROPROCESSOR/SENSOR MONITORING FOR RADIOACTIVE WASTE STORAGE CONTAINERS

CHAR-260-OL

military applications. The results of those development efforts should transfer to the area of hazardous waste storage monitoring.

Author: John K. Munro, Jr./615-574-0635

References:

September 1993

EM Problem: Remedial action; waste management

ORNL Problem: See Appendix A, lists B and C

Problem Area/Constituents: Radioactive elements

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Field methods

Technology: Waste drum gamma activity monitor. The monitors are commercially available. The scanning system consists of a fixed-height turntable onto which the drum to be measured is loaded. To the side of the turntable a germanium detector views the drum through a collimator. The detector is raised on a lead-screw operated platform under computer control in fixed vertical segments. At each measurement point the drum is rotated while spectral data is acquired for that segment. Each segment is analyzed to produce an assay of the total drum activity inventory.

Status: Accepted

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk assessment; regulatory

Applicable contaminant evaluation: Radioactive (γ)

Waste produced—None

Overall cost—\$175K

Efficacy/strengths—Typically, for light waste matrices and a 30-min measuring time, the following detection limits (per drum) are obtained: ^{239}Pu , 0.2 g; ^{137}Cs , 5 kBq; ^{60}Co , 5 kBq. The maximum drum size is 200 L, and the maximum drum weight is 500 kg. After analysis, a permanent record of the drum's nuclide inventory is produced.

For dense drum contents, correction is needed for gamma-ray attenuation in the drum. the correction method may be via differential absorption, transmission source measurement, or nuclides to be measured.

Science/Technology Needs: None, the units are commercially available.

Implementation Needs: Technology is commercially available.

Author: K. E. Meyer/615-574-1504

References: D. F. G. Reher and B. Denecke, *Nucl. Instrum. & Methods in Phys. Res. A312*, 273-277 (1992).

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: Organic

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Alternative: Field methods

Technology: Gas chromatography in the field. Using flame ionization, electron capture, thermal conductivity, photoionization, flame photometric, or thermionic a variety of environmentally important analytes can be determined.

Status: Accepted

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual and automated applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Organic (oil, polychlorinated biphenyls, volatile organic compounds, trichloroethylene, ...)

Waste produced—Minimal, it is only necessary to vent gas chromatographs using nondestructive detectors

Overall cost—\$5K-\$25K/instrument, depending on needs, plus miscellaneous supplies (carrier goods, etc.)

Efficacy/strengths—It has high efficacy for a very wide variety of organic species, both volatile and semivolatile organics. It is good for a variety of species, and the analysis time is 10-60 min.

Science/Technology Needs: Technology needs are minimal. While improvements can be made, in general, the technology is ready to use.

Implementation Needs: A variety of gas chromatography equipment exists already at ORNL and may be useful for many needs. Various groups at ORNL are capable of handling large samples (see references).

Author: J. M. Storey/615-576-7607

References:

1. There is a tremendous amount of open literature on the use of gas chromatography for determination of organic contaminants associated with decontamination and decommissioning activities. Also EPA SW-846 methods.
2. Organic Analytical Group; Analytical Chemistry Division, ORNL.

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: Radioactive elements, alpha emitters

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Field methods

Technology: Portable gamma-ray scintillometers. In either a single-channel or multichannel format, they are available commercially. The instrument consists of a sodium iodine crystal, photomultiplier tube, portable battery operated power supply, pulse height analyzer, and readout. For the single-channel case, the energy window is set appropriately for the isotope of interest, the measurement is made, and the reading can be converted directly into a value for the isotope concentration. When using a multichannel instrument, the isotope spectra are recorded simultaneously and may be permanently stored and analyzed at a future time.

Status: Accepted

Temporal areas of evaluation: Pretreatment; posttreatment

Driver evaluation: Risk and technical assessments

Applicable contaminant evaluation: Radioactive (γ)

Waste produced—None

Overall cost—\$11K for a complete portable multichannel spectroscopy system

Efficacy/strengths—The application is for quantitative measurements of fixed low-level gamma contamination on surfaces. This technique is not useful for small ($<100 \text{ cm}^2$) or hard-to-access areas. The detection limit is $0.2 \mu\text{g g}^{-1}$ for thorium and uranium with measurement times of one hour (single channel) and fifteen minutes (multichannel). Good for all gamma emitters.

Science/Technology Needs: Robotic technology is needed for remote control applications.

Implementation Needs: The technology is commercially available. Specialized detector holders may need to be developed for particular applications.

Author: K. E. Meyers/615-574-1504

References: J. T. Hutton and J. R. Prescott, "Field and Laboratory Measurements of Low-Level Thorium, Uranium, and Potassium," *Nucl. Tracks Radiat. Meas.* **20**, 367-370 (1992).

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: Organic

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Field methods

Technology: Ion mobility mass spectrometry. Provides a means for the rapid separation and identification of complex mixtures based on the mobility of ions in an electric field at atmospheric pressure.

Status: Predemonstration.

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: General

Applicable contaminant evaluation: Organic

Waste produced—

Overall cost—\$50K

Efficacy/strengths—Ion mobility mass spectrometry offers the potential for very rapid (<1 s) analysis of complex mixtures.

Science/Technology Needs: Software control of high-speed data acquisition and interpretation and instrument control are needed.

Implementation Needs: Hardware costs, ~\$30K; software development costs additional.

Author: J. Storey/615-574-6248

References: E. A. Wachter, HASRD-ORNL, personal communication.

EM Problem: Decontamination and decommissioning

ORNL Problem: See Appendix A, list A

Problem Area/Constituents: Organic liquids and gases; inorganic liquids and gases; waste streams

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Laboratory methods

Technology: Surface-enhanced Raman scattering. Raman spectroscopy is a technique that uses scattered light resulting from photon-molecule collisions to investigate molecular properties. When a monochromatic light beam is incident on systems such as gases, liquids, or solids, most of it is transmitted without change. However, a small portion of the incident light is scattered. Although most of the scattered light has the same wavelength as the incident radiation, a small part of it occurs at different wavelengths. The scattering of light at different wavelengths is called Raman scattering. Surface-enhanced Raman scattering (SERS) is greatly enhanced Raman scattering observed from molecules adsorbed at a roughened metal surface.

Status: Evolving

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual, automated, and robotic applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Organic (oil, polychlorinated biphenyls, volatile organic compounds, trichloroethylene, ...)

Waste produced—1-100 mL/sample (dependent on the procedure)

Overall cost—Highly variable, \$250K-\$400K

Efficacy/strengths—This technology is a combination of electrochemical and spectroscopic techniques which can yield highly specific information about contaminant identity and quantity in the sampled system.

Science/Technology Needs: System development and validation for specific needs

Implementation Needs: Hardware costs, \$10K-\$250K; development costs, ~\$150K

Author: R. D. Shelton/615-574-5042

References: M. M. Carrabola, R. B. Edmonds, and R. D. Rauh, *Anal. Chem.* **59**, 2559-2563 (1987).

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: Radioactive elements; inorganic metals

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: Laboratory, characterization, and analysis with some development could be applied to field methods.

Technology: Neutron activation analysis (NAA). This analytical technique is based on the measurement of sample radioactivity after activity has been induced by irradiation with neutrons.

Status: Accepted; mature technology

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual and automated applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Inorganics; total organic halides; fissile material (^{235}U , ^{233}U , ^{239}Pu); long-lived fission products (^{129}I).

Waste produced—Minimal solid waste generated; usually no liquid waste produced

Overall cost—\$200/sample, if NAA facility already in place

Efficacy/strengths—Nondestructive; sample can be archived and reanalyzed; generates minimal waste, and is a mature technology.

Science/Technology Needs: Mature technology; start-up studies need to be done to evaluate possible interferences.

Implementation Needs: Instrumentation and personnel currently exist at ORNL but need to be expanded to meet the expected work load. Estimated cost of upgrade and expansion is \$250K.

Author: J. M. Keller/615-574-7063

References: W. D. Ehmann and D. E. Vance, *Radiochemistry and Nuclear Methods of Analysis*, John Wiley & Sons, Inc. (1991).

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: Radioactive elements

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: Radioactive elements; laboratory characterization.

Technology: Liquid scintillation counting (LSC). It is most frequently used to measure low energy beta emitters such as tritium and carbon-14. The technique is also useful for many of the other beta emitters found around DOE facilities, such as technetium-99 and strontium-90. More recent systems can discriminate between beta and alpha which makes the technique attractive for gross alpha and gross beta measurements.

Status: Mature technology; commercially available

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual and automated applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Low-energy beta emitters

Waste produced—Generates organic waste contaminated with radioactivity

Efficacy/strengths—Instrumentation designed for high sample load and can count and process data unattended. May be ideal for screening samples, smears, etc., for gross alpha/beta content. Mature and well accepted technology.

Science/Technology Needs: Commercially available and mature

Implementation Needs: Some equipment/personnel are currently available at ORNL but need to be expanded to meet the expected increase in work load. Instrumentation costs range from \$30K-\$40K for appropriate systems.

Author: J. M. Keller/(615)574-7063

References:

1. D., Horrocks, *Applications of Liquid Scintillation Counting*, Academic Press, N.Y., 1974.
2. *Radiochemical Determination of Gross Alpha and Gross Beta Particle Activity in Water*, Radiochemistry Procedures Manual, EPA 520/5-84-006, August 1984.

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: Radioactive elements

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: Radioactive elements, laboratory characterization, field methods

Technology: Gamma-ray spectrometry. It is used for the measurement of gamma emitting radionuclides. A complete system consists of a detector, amplifier, analog to digital converter, multichannel analyzer (MCA), and computer. Modern detectors are high purity germanium (HPGe) and are available with efficiencies that range from 10% to >100% with typical energy resolution of 1.8–2.0 KeV FWHM at 1332 KeV.

Status: Mature technology

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual and automated applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: All gamma emitters

Waste produced—Minimal waste generated

Efficacy/strengths—Mature and well accepted technology

Science/Technology Needs: The technology is commercially available and mature.

Implementation Needs: Some equipment/personnel are currently available at ORNL but need to be expanded to meet the expected increase in work load. Detector costs range from \$10K–\$50K, depending upon the required efficiency and resolution. The MCA/computer/software requirements for acquiring and processing spectra adds another \$10K to total cost.

Author: J. M. Keller/(615)574-7063

References:

1. MMES staff members.
2. Literature publications.
3. In-house methods.

EM Problem: Decontamination and decommissioning; remedial action; waste management

ORNL Problem: See Appendix A, lists A, B, and C

Problem Area/Constituents: General

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: Radioactive elements; field methods

Technology: Advanced radiation monitors. A digital display with replaceable "smart" probes is used to determine alpha and beta contamination (multiple probes also can be employed).

Status: Predemonstration

Temporal areas of evaluation: Pretreatment; treatment; posttreatment

Deployment evaluation: Manual and robotic applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Radioactive elements

Waste produced—None

Overall cost—

Efficacy/strengths—Self-calibrating "smart" probes and the ability to use several probes at a time or a probe capable of determining alpha and beta activities. Can also measure activities on irregularly shaped surfaces.

Science/Technology Needs: Development of additional probes is needed.

Implementation Needs: Development costs, \$400K over 2 years

Author: W. H. Griest/615-574-4864

References: W. L. Brian/615-576-6844.

EM Problem: Remedial action; waste management

ORNL Problem: See Appendix A, lists B and C

Problem Area/Constituents: General

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternative: Sample collection

Technology: Sampling of heterogeneous wastes. Statistical approaches, strategies, and methods for removing a representative sample for analysis are developed for laboratory and field analyses.

Status: Conceptual

Temporal areas of evaluation: Pretreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Inorganic; organic; radioactive elements

Waste produced—Depends on number and size of samples

Overall cost—To be determined

Efficacy/strengths—Development of this technology will solve a long-standing sampling problem, reduce costs, and increase confidence in the characterization of heterogeneous wastes.

Science/Technology Needs: Development of statistical approaches, strategies, and methods for removing a representative sample must be developed.

Implementation Needs: ~\$2.8M over 3 years

Author: W. H. Griest/615-574-4864

References: Draft TTP by R. A. Jenkins and D. J. Downing.

SAMPLING INTERFACE SYSTEM FOR SURFACE CONTAMINATION BY ORGANICS

CHAR-271-OL

EM Problem: Decontamination and decommissioning; waste management

ORNL Problem: See Appendix A, lists A and C

Problem Area/Constituents: Organics

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: Organics; field methods

Technology: Sampling interface system for surface contamination by organics. The technology consists of a rapid thermal surface heating interface system for direct sampling, ion trap mass spectrometry, allows rapid determination of organics, such as polychlorinated biphenyls and fuel or oil residues, from surfaces such as floors, walls, and even insulation.

Status: Conceptual

Temporal areas of evaluation: Pretreatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk assessment; regulatory

Applicable contaminant evaluation: Organics

Waste produced—None

Overall cost—To be determined

Efficacy/strengths—Interface and software will allow rapid and positive determination of organic surface contamination in the field using direct sampling ion trap mass spectrometry.

Science/Technology Needs: Development of rapid heating interface and software for rapid contaminant identification by direct sampling ion trap mass spectrometry are needed.

Implementation Needs: Development costs, \$775K over 3 years

Author: W. H. Griest/615-574-4864

References:

September 1993

EM Problem: Remedial action

ORNL Problem: See Appendix A, list B

Problem Area/Constituents: General

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: Sample collection (field methods)

Technology: SEAMIST inverted membrane. Technology utilizes an inflatable membrane with surface mounted instruments (smears, lysimeters, adsorbents, etc.) and is deployed inside of vertical or horizontal bore holes for in situ characterization.

Status: Demonstrated; successfully used at Lawrence Livermore for characterization of a tritium site, and at the Savannah River Integrated Demonstration Project.

Temporal areas of evaluation: Pretreatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk assessment; regulatory

Applicable contaminant evaluation: Organic; inorganic; radioactive elements

Waste produced—Any wastes from decontamination of drill head or membrane

Overall cost— ~\$15K for 100-ft SEAMIST bag with surface-mounted lysimeters every 10 ft; rental of membrane canister is ~\$1K.

Efficacy/strengths—Inflatable membrane can by-pass borehole constrictions and be successfully deployed through severely deviating horizontal bore holes. It also can retrieve instrumentation package and redeploy additional instruments using same borehole. Retrieved instruments are reeled inside of a canister which provides significant hazard protection for the field technician retrieving the instruments.

Science/Technology Needs: Cold test facility of buried waste in a trench

Implementation Needs: ~\$600K, 6-month cold test demonstration

Author: J. Kauschinger/603-268-0816

References: B. Mallon, S. A. Martins, et. al., "SEAMIST Soil Sampling for Tritiated Water: First Year's Results," Sixth National Outdoor Conference, Las Vegas, Nev., May 9-13, 1992.

EM Problem: Remedial action

ORNL Problem: See Appendix A, Est B

Problem Area/Constituents: Hydrofracture

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: Sample collection (field methods)

Technology: Hydrofracture ground-water monitoring. In situ measurement and sampling activities can be applied to the existing wells or new wells. In situ measurements include gamma radioactivity, temperature, conductivity, and down-hole pressure monitoring from the borehole. Ground-water samples can be taken from one or more locations within the well bore to characterize the waste site.

Status: Accepted; in situ logging tools have been in use by industry, and multiport Westbay samplers are in use at ORNL and Y-12 and are accepted by regulators.

Temporal areas of evaluation: Pretreatment; posttreatment

Deployment evaluation: Manual applications

Driver evaluation: Risk and technical assessments; regulatory

Applicable contaminant evaluation: Radioactive elements; physical properties

Waste produced—Only from decontamination of instruments

Overall cost—To be determined

Efficacy/strengths—Monitoring is designed specifically for the highly radioactive and saline environment of the hydrofracture area.

Science/Technology Needs: Due to the high radiation levels inside the bore holes, improvements in the detection and sensitivity of the in situ measurement instruments may be necessary. Also, the instrumentation must be resistant to the highly saline conditions of the well-bore fluids and ground water.

Implementation Needs: Development costs, \$500K for corrosion resistant casing, probes, and cables; \$1.75M to install in situ ground-water monitoring equipment in 25 deep wells; monitoring costs, \$200K/year using down-hole samplers; \$1.25M for installation of probes for down-hole monitoring of gamma activity, temperature, conductivity, and pressure; additional manpower costs, ~\$150K/year.

Author: G. Underwood/615-483-9032

References:

September 1993

SEDIMENT SAMPLING FROM RESTRICTED ACCESS LOCATIONS

CHAR-276-OL

EM Problem: Remedial action

ORNL Problem: See Appendix A, list B

Problem Area/Constituents: General

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Characterization

Alternatives: Field methods

Technology: Sediment sampling from restricted access locations. Representative cores of sediments or sludges are sampled from underground storage tanks or other restrictive access locations using techniques which do not disturb the sediment, are able to sample several locations from a single, narrow access pipe or hatch, and can be conducted safely in high radiation fields.

Status: Predemonstration; it is based upon refinement of current methods

Temporal areas of evaluation: Pretreatment

Deployment evaluation: Manual and automated applications

Driver evaluation: Risk assessment; regulatory

Applicable contaminant evaluation: Organic; inorganic; radioactive elements

Waste produced—Only wastes are from decontamination of sampling equipment

Overall cost—\$300-\$1000/sample

Efficacy/strengths—Technology is applicable to restrictive access sampling locations with high radiation fields.

Science/Technology Needs: Develop articulated sampling arm with coring device

Implementation Needs: Hardware costs, \$50K; development costs, \$400K

Author: W.H. Griest/615-574-4864

September 1993

**SEDIMENT SAMPLING FROM
RESTRICTED ACCESS LOCATIONS**

CHAR-276-OL

References:

1. M. B. Sears et. al., "Sampling and Analysis of Radioactive Liquid Wastes and Sludges in the Melton Valley and Evaporator Facility Storage Tanks at ORNL," ORNL/TM-11652, Oak Ridge National Laboratory, Oak Ridge, Tenn., September 1990.
2. C. V. Thompson, R. A. Jenkins, and C. E. Higgins, "A Thermal Desorption Method for the Determination of Nicotine in Indoor Environments," *Environ. Sci. & Tech.* **23**, 249-435, April 1989.

September 1993

EM Problem: Decommissioning

ORNL Problem: See Appendix B, lists E and G

Problem Area/Constituents: See Appendix B, lists E and G

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Decontamination

Alternative: Bulk decontamination methods

Technology: Solvent extraction. Selective removal of organic contaminants by dissolution in a solvent.

The technology could be applied as a "factory style" process in either batch or continuous fashion. Contaminated materials are fed into processing equipment, and cleaned material exits. This would be applicable to concrete scabble, transite (asbestos-reinforced concrete), or metal shards. A countercurrent extractor would appear to be an appropriate contactor. The availability of both lab- and pilot-scale equipment could be pursued.

The technology could also be portable, with the solvent being applied to a localized spot using a device patterned after a carpet cleaning machine.

Status: Accepted. Mature technical field, but specific extractants have not been identified for all radionuclides, PCB extraction from concrete, etc. An attractive solvent, triethylamine, has been evaluated for organic extraction from sludge (TTP OR-373-AH) and found to be a very effective solvent. Industrial processing equipment that uses triethylamine is commercially available.

Solvent recycle and off-gas treatment equipment could easily be adapted for use.

Waste produced—Produces a liquid raffinate stream

Overall cost—\$5 to \$50/lb

Efficacy/strengths/weaknesses—Difficult to apply in situ; has been demonstrated remotely but not for waste materials.

Science/Technology Needs:

Technology development: (1) Surveys and tests of specific extractants applicable to PCB-contaminated concrete, transite, and metal are needed; (2) A portable "spot" remover can be developed or adapted from commercial devices.

Technology demonstration: (3) Applicability of rotary contractor, solvent recycle, and, if appropriate because of solvent selection, an off-gas treatment system.

Implementation Needs:

Development costs: <~\$250K, \$500K, and \$1000K for 1, 2, and 3, respectively, assuming availability of lab scale and pilot-scale extraction units from ORNL and industrial participation in demonstration.

Deployment: No unusual costs. Development (pilot-scale) equipment may be used in production.

Author: R. L. Fellows/615-576-5632. Reviewed by J. R. DeVore/615-574-7092

References: MMES Staff members.

EM Problem: Decommissioning

ORNL Problem: See Appendix B, lists E and G

Problem Area/Constituents: See Appendix B, lists E and G

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Decontamination

Alternative: Bulk decontamination methods

Technology: Incineration. Contaminated combustible materials are burned. Contamination is collected in the ash and off-gas treatment system. The volume of the waste is reduced.

Status: Accepted. The incineration of contaminated combustible building materials is common in the nuclear industry.¹

Waste produced—Depends on the design of the incinerator and the ash content of the waste being fed.

Overall cost—Capital costs, \$26M; operating costs, \$10/lb²

Science/Technology Needs:

Implementation Needs: About 8–10 years will be required for writing an environmental impact statement, holding public hearings, and obtaining the necessary TSCA, RCRA, NESHAP, and Clean Air Act permits.³

Author: D. H. Bunch/615-576-0201

References:

1. R. Kohout, "Incineration," *Radioactive Waste Technology*, eds., A. A. Moghissi, et al., American Society of Mechanical Engineers and American Nuclear Society, 1986.
2. T. O. Rogers, telephone conversation with D. H. Bunch, May 28, 1992.
3. L. V. Gibson, Jr., telephone conversation with D. H. Bunch, June 16, 1992.

EM Problem: Decommissioning

ORNL Problem:

Problem Area/Constituents: Removed tile, wood and sheetrock; and roof tar and felt material. Contamination includes U, Th, Molten Salt, fission products, Cs, Sr, and Co isotopes.

Reference Requirements:

- Federal Facility Compliance Agreements (e.g., FFCA for Oak Ridge Site and
- FFCAs for PCBs)
- Applicable federal and state laws and regulations (e.g., Clean Air Act and Toxic Substance Control Act)
- DOE orders

Subelement: Decontamination

Alternative: Bulk decontamination methods

Technology: Dry heat (bulk roasting). The effective application of dry heat to the above problem areas is uncertain and untried. A significant amount of bench-scale laboratory studies would be needed to define the applicability of the process. Volume reduction is a certainty for wood materials, and the tar and felt would be effectively ashed. The final disposition of the contaminants must be determined by bench testing.

Status: Evolving. To be successful, the well-established technology must be demonstrated as an effective contaminant removal. The contaminants characteristics must be matched to the decontamination advantages of the process.

Waste produced—The contaminants characteristics must be matched to the decontamination advantages of its development need.

Overall cost—Typical for this process, ~\$10/lb of feed.

Efficacy/strengths/weaknesses—Secondary and tertiary waste streams must be defined in development.

Science/Technology Needs: The availability of engineered equipment is adequate provided that laboratory studies verify effective contamination removal by heat. Secondary waste treatment would need to be addressed. Compliance is a major concern for higher contamination levels and could require an extended approval period.

Implementation Needs: The ability to collect gas phase contaminants and separate them from the clean air needs to be developed. Following this, the gas phase contaminant must be converted to a suitable form for long-term containment and storage.

Author: R. B. Alderfer/615-576-0225

References: MMES staff members.

EM Problem: Decommissioning

ORNL Problem: See Appendix B, lists E and G

Problem Area/Constituents: See Appendix B, lists E and G

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Decontamination

Alternative: Bulk decontamination methods

Technology: Chemical leaching. Contaminated materials are fed into processing equipment, and cleaned materials exit for the selective removal of contaminants. The technology could be applied as a "factory style" process in either batch or continuous fashion and as a portable technology (e.g., the solvent being applied in some way to a localized spot and vacuumed).

Status: Evolving technology. Although leaching for removal of PCBs with organic solvents has been developed to a considerable extent, the method has not yet been applied to the large number of contaminants (mostly radionuclides) at ORNL. The technology is probably best described as preconceptual when applied to ORNL problems since the efficacy of the technology cannot be determined until lab studies are concluded. The operating costs are roughly estimated at $<\$1/\text{ft}^2$ of surface assuming the method is effective. Waste solutions would be generated that would contain the extracted contaminants. This solution would require recycle or disposal.

Science Technology Needs: Literature studies to select effective agents and laboratory studies are needed. Demonstrations will follow if warranted.

Implementation Needs: Development costs, \$350K for a laboratory study to confirm efficacy, \$350K for application tools (shop vac or carpet cleaner-style machine) that would be used to clean surfaces, \$400K to develop waste treatment facilities; capital costs, \$1M for a bulk leaching operation facility; additional capital costs, \$1M for waste treatment facilities.

Author: R. L. Fellows/615-576-5632. Reviewed by E. B. Munday/615-576-5806

References: MMES staff members.

EM Problem: Decommissioning

ORNL Problem: See Appendix B, lists C, E, and G

Problem Area/Constituents: See Appendix B, lists C, E, and G

Reference Requirements:

- Federal Facility Compliance Agreements (e.g., FFCA for Oak Ridge Site)
- Applicable federal and state laws and regulations (e.g., Clean Air Act, RCRA, NEPA, and NESHAP)
- DOE orders

Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Decontamination

Alternative: Bulk decontamination methods

Technology: Catalytic extraction process (CEP). An induction or electric arc furnace is used to form a molten metal bath. It can use the molten bath not only as a means for metal purification but also as a high temperature, high energy density medium for more effective reduction of hazardous waste materials, such as PCBs, hydrocarbons, and cyanide, to nonhazardous materials. The molten metal (about 3,000°F) provides much more effective contact with the material in a smaller volume than is possible with the hot gases in a conventional incinerator.¹

Status: Predemonstration. CEP was developed by a commercial vendor to use standard "off-the-shelf" steel industry equipment.¹ The use of a molten metal bath to more effectively disassociate hazardous materials with valuable or usable constituents that may be potentially recovered is unique. CEP reportedly will allow many hazardous wastes to be processed ten times more effectively than an incinerator, since the molten metal bath at 3,000°F provides much better thermal contact than hot gases. If the wastes being processed require oxygen, it is added as pure oxygen rather than air, and off-gases are 1/5-1/50 the volume of an incinerator for the same amount of material. Capital costs are estimated at one-half that of an incinerator, and operating costs are estimated at one-third that of an incinerator's operating costs. The costs to incinerate mixed wastes in the TSCA incinerator at K-25 is estimated² at \$6/lb if solids were fed with liquids. Thus the payback potential for CEP is great. This process has not yet been used to incinerate or smelt scrap bearing radioactivity³, but the experience from Y-12 and elsewhere for smelting can be used to roughly gauge expected success when applied to melt processing. Experiments at Y-12 have shown that mild steel, stainless steel, nickel, copper, and Monel can be purified by smelting to levels of

0.01 ppm–4.0 ppm residual uranium. Aluminum was more difficult to purify with levels of residual uranium remaining at concentrations from 3 ppm–100 ppm. Technetium reportedly was not removed.⁴ Hesmatpour and Copeland⁵ report better results for aluminum (1 ppm–2 ppm). Based on information contained in a report by Kellogg et al.,⁶ a cost of roughly \$0.93/lb of metal smelted may be estimated, which includes capital and operating costs. Their estimate concludes that if a *de minimus* standard is obtained, thus allowing the ingots to be sold, the value of the metal could totally pay for the project. The wastes would be in the form of radioactive slag and perhaps scrubber solution (although wet scrubbers may be avoided in many applications).¹ Quantities are not available, but Kellogg et al.⁶ estimated that ~50 lb of slag would be generated per ton of scrap metal processed by smelt purification. CEP is likely to be a very satisfactory method for disposal of combustible wastes.

Science/Technology Needs: Technology: The report that technetium is not removed by smelting may seriously damage the prospect of using this method for metal purification if a suitable fluxing agent cannot be demonstrated. Also, the poor results reported in removing aluminum must be further investigated. The use of CEP as a substitute for incineration of mixed waste has not been done on any scale at this point and must be developed.

Implementation Needs: The technology development will require further lab- and pilot-scale evaluation. Detailed requirements for the development of CEP production phase could not be obtained but are assumed to closely resemble those roughly estimated for smelt purification. The costs are briefly enumerated as follows: development costs, \$3M–\$5M; capital costs, 1/2 the amount of an incinerator of equal capacity (~\$16M); operating costs, 1/3 the amount of a TSCA incinerator (\$2–\$3/lb for nonmetals, \$0.93/lb for metal smelting).

The following requirements are based on that assumption. The development costs would include a small electric induction furnace, two full-time technical people (one with experience in metallurgy); and analytical, maintenance, and other support personnel. The duration may be 24 months and the development costs are roughly estimated by the investigator at \$2.0M–\$3.5M. The following requirements for a smelt facility are listed by Kellogg et al.:⁶ scrap handling and preparation, scrap transportation, scrap weighing and drying facility (the scrap must be heated prior to placing in the smelter to drive off oil and water), 8-ton capacity electric induction furnace with two crucibles, mold preparation and cooling, slag process refractory repair, flux storage and preparation, ingot dumping and storage, offices, laboratory and control room, maintenance areas, and personnel convenience stations. Capital and operating costs were not indicated, but as mentioned above, an overall cost of roughly \$0.93/h can be estimated based on their conclusions that all costs could be recovered from the sale of 90,000 tons of metal presently in the DOE inventory (valued at \$102 million in 1982 dollars) assuming a *de minimus* is established. (About 74% of the metal value is nickel, which amounts to only 11% by weight of the metals in the Kellogg study.)

Most likely no existing facility at ORNL will satisfy the operational requirements of this facility (the Kellogg study assumes new facilities are constructed). The design and construction phase will require the support of many engineering disciplines: structural and site engineering, engineering mechanics, process design, electrical engineering, instrument engineering, safety engineering, and metallurgy. Numerous support services will be required:

health physics, industrial hygiene, health, safety, environmental, and analytical. Numerous construction and maintenance craftsmen will be required: welders, carpenters, electricians, mechanics, ETI personnel, and supervisors. These requirements cannot be quantified at present. The establishment of a *de minimus* standard is very critical for the success of this project since the resulting ingots cannot be sold without this legislation.

Author: E. B. Munday/615-576-5806

References:

1. J. D. Smith, "Molten Metal Technology," *EI Digest*, Industrial and Hazardous Waste Management Environmental Information LTD, July 1991.
2. T. Rodgers, Martin Marietta Energy Systems, Inc., personal communication with E. B. Munday, June, 1992.
3. Victor Gatto, Molten Metal Technology, Inc., personal communication with E. B. Munday, June 1992.
4. Y-12 Plant data
5. B. Hesmatpour and G. L. Copeland, *The Effects of Slag Composition and Process Variable on Decontamination of Metallic Wastes by Melt Refining*, ORNL/TM-7501, Union Carbide Corporation, January 1981.
6. D. R. Kellogg et al., *Metal-Smelting Facility*, CONF-820418-13, DE-82 013539, Union Carbide Corporation Nuclear Division, 1992.

EM Problem: Decommissioning

ORNL Problem:

Problem Area/Constituents: Transite contaminated with the following:

- U
- oil
- U and oil
- U and Tc
- oil and PCBs
- U, oil, and PCBs
- U, Tc, and oil
- U, Tc and actinides
- U and PCBs
- U, Tc, oil, and PCBs
- U, Tc, actinides, oil and PCBs

Reference Requirements:

- Federal Facility Compliance Agreements (FFCAs), e.g., FFCA for Oak Ridge Site
- FFCAs for PCBs
- Applicable Federal and State laws and regulations, e.g., Clean Air Act and Toxic Substance Control Act
- DOE orders

Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Decontamination

Alternative: Bulk decontamination methods

Technology: Vacuum (low pressure)

Status: Accepted. A proprietary, vacuum-based process for removing soluble Cr^{+6} from transite sheets used as exterior walls of a large building at a facility operated by Allied Signal. It has used a vacuum in conjunction with dilute acids to decrease Cr^{+6} from 7 ppm to below 4 ppm (bulk decontamination residual concentration). The low separation efficiency makes this a doubtful process candidate and there is no experience of removing radiological contaminants. Any process for removing transite contaminants must begin at the problem definition stage.

Science Technology Needs: Development—The characteristic specific contaminants must be matched to the advantages of decontamination by vacuum under vacuum conditions.

Implementation Needs: Large blower systems are needed to draw a vacuum on the building; sprayer systems are needed to spray acid on the material. Capital and operating costs are considered proprietary. Capital costs, ~\$1M-\$10M; operating costs, \$2-\$8/ft².

Author: R. B. Alderfer/615-576-0225

Reference: J. Harrigan, International Dismantling and Machinery Corp., South River, N.J., personal communication to R. Alderfer, Martin Marietta Energy Systems, Inc., June 5, 1992.

EM Problem: Decommissioning

ORNL Problem: See Appendix B, lists C and H

Problem Area/Constituents: See Appendix B, lists C and H

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Decontamination

Alternative: *Chemical surface cleaning (fixed and transferable contamination) methods*

Technology: Chemical foams. Used to remove smearable contamination from contacted surfaces.

Status: Accepted. Widely used throughout the nuclear industry.

Foam is used as a carrier of chemical decontamination agents (in the early 1980s, detergents and wetting agents), not as the agent itself. It is sprayed onto component walls or the component is filled with the foam. For vertical surfaces, decontamination agents are suspended in a thick dry foam that is applied to the surface to be cleaned. Ideally, a light, even coating (1-2 in. thick) is formed, with a resident time on vertical surfaces of at least several minutes. It can be sprayed on and wiped, rinsed, or vacuumed off. Repeated applications can give "several orders of magnitude reduction in surface contamination." More recently, gels have been preferred for equipment exteriors, and foams are used for circulating in pipes and systems in situ.

Waste produced—Small amount of contaminated sulfonated detergents, synthetic wetting agents, coupling agents, rinse water, and drying cloth.

Overall cost—The technology itself is inexpensive, but development and scale-up costs will probably require significant financial support.

Efficacy/strengths/weaknesses—

Advantages: Good method for large components with complex shapes and internal in situ decontamination to eliminate smearable contamination prior to dismantlement. Low final waste volume. Remote application is easily done.²

Disadvantages: Fully controlled foaming times are needed. It is difficult to keep foam circulating while integrally filling large cavities. It is not appropriate for use on cracked surfaces or where there are deep or convoluted crevices.

Effectiveness: Decontamination effectiveness using Turco was 63-92%, with a decontamination factor (DF) of 2.7 to 12.5 on painted surfaces inside a hot cell, in one study.¹ On unpainted carbon steel, it was 75-90% effective. It does not remove oxides, but it does remove lightly bonded contaminants. The contact time is too short to obtain DFs currently desired in a batch process (spraying or filling). One approach is to fill the component and then circulate the foam for as long as necessary.² Currently in use at Rockwell International using a spray system developed by TURCO.

Science/Technology Needs: Full control over the mean bubble dimensions and the volume swell factor are needed, indicating that some basic research will be necessary.

Implementation Needs: Scale-up/development of the process to a size appropriate for ORNL use. Estimated costs follow: Development costs, \$1M-4M; capital costs, < \$50K; operating costs, \$0.50-\$2/ft².

Author: D. E. Beck/615-574-0706. Reviewed by J. R. DeVore/615-574-7092

References:

1. J. M. Harris, J. R. Miller, R S. Freezer, J. H. Walter, "Foam Process for Application of Decontaminating Agents," from the International Conference on Decontamination of Nuclear Facilities, Niagara Falls, Canada, September 19, 1982.
2. J. R. Costes, J. P. Gouchon, M. Montjole (Commissariat a l'Energie Atomique, France) "Recent Developments in Gel and Foam Decontamination Processes Applied to Decommissioning," Proceedings of the Nuclear and Hazardous Waste Management International Topical Meeting (Spectrum '88), pp. 24-29, Pasco, Wash., Sept. 11-15, 1988, Published by ANS, LaGrange Park, Ill., September 1988.

EM Problem: Decommissioning

ORNL Problem: See Appendix B, lists C and H

Problem Area/Constituents: See Appendix B, lists C and H

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Decontamination

Alternative: Chemical surface cleaning methods

Technology: Chemical gels. Used to remove smearable contamination from contacted surfaces.

Status: Demonstration.

Waste produced—After spraying and rinsing the gel film two or three times, the volume of waste to be neutralized was four or five times less than that for decontamination of the same item by chemical solutions such as nitric acid. Treatment of the acidic and basic wastes can be by phosphate precipitation, sulfate precipitation, simple neutralization, or neutralization and addition of preformed nickel ferrocyanide precipitate.¹

Overall cost—Capital cost, <\$50,000; operating cost, \$0.50–\$2.00/ft².

Efficacy/strengths/weaknesses—Chemical gels are most suited to in situ decontamination of large surfaces.¹ Gel is used as a carrier of chemical decontamination agents, not as the agent itself. It is sprayed on to component walls; allowed to work; and then scrubbed, wiped, rinsed, or peeled off. Solutions with viscosities of 300-600 cps form a reasonably stable film on the contaminated surface. An airless compressor can be used for spraying the gel and, with a change in heads, for rinsing. Typical reagent combinations are a nitric-hydrofluoric-oxalic acid mixture and a nonionic detergent mixed with a carboxymethylcellulose gelling agent, with aluminum nitrate used as a fluoride chelating agent. Steps include scraping and vacuuming of solid waste material, preliminary hot water rinsing, and gel spraying throughout the cell.

Advantages: It is a good method for large component in situ removal of smearable contamination. Minimum secondary waste volumes.² Remote application is readily done.
Disadvantages: It is a complex system that requires laboratory optimization for each change in variables. Costly and time-consuming for decommissioning but possibly worthwhile for maintenance and cleaning operations. Reagent action is limited by the solution viscosity,

which reduces the ion diffusion rate at the gel/surface interface. Amount of active reagents in gel film must be kept low ($<10 \text{ g/m}^2$).

Effectiveness: The decontamination factor can be as high as 100.¹ In some cases, as many as three gel applications have been required (e.g., two acid and one base applications).

Science/Technology Needs: Complex gel formulation with a number of compounds may be required, depending on the objectives. With any change in variables, laboratory optimization will be necessary. Development costs may be \$1M-\$4M.

Implementation Needs: Normal.

Author: D. E. Beck/615-574-0706. Reviewed by J. R. DeVore/615-574-7092

References:

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EM Problem: Decommissioning

ORNL Problem: See Appendix B, lists C and H

Problem Area/Constituents: See Appendix E, lists C and H

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Decontamination

Alternative: Chemical surface cleaning (fixed and transferable contamination) methods

Technology: Organic acid treatments.

Status: Demonstrated. The technology is currently in use by BNFL at Capenhurst Gaseous Diffusion Plant. BNFL uses citric and sulfuric acids in sequence for removal of uranium and technetium, respectively, from metal surfaces (mostly wrought aluminum). The citric acid portion is dilute ("soft"), with correspondingly low corrosion. The carboxylate ion is strongly complexing. The ability to remove other radionuclides has not been demonstrated.

Waste produced—Secondary wastes are (1) citric acid containing metal ions, especially uranium, and (2) sulfuric acid containing metal ions, especially technetium and nickel. Citric acid is relatively benign to the environment, biodegradable, and treatable by ion exchange removal of radionuclide and other metal ions. Remaining effluent may be treatable at sewage treatment plant (POTW). Sulfuric acid is also treatable by ion exchange (IX) with possible recycle of cleaned acid. Tertiary wastes are depleted IX resins. NOTE: SEG and possibly other companies compact and solidify IX resin wastes on contract or they will provide complete IX services.

Overall cost—Total net costs for the Capenhurst decontamination project are expected to be around one hundred million pounds (U.S. \$62M in May 1993). Four years ago, BNFL's operating cost was approximately \$300/metric ton. Ours would rate higher because of more sophisticated effluent treatment needs. Capital costs will include spray booth and tank installation with fluid recirculation systems but will not be significantly higher for the BNFL process than for any other proven acid dissolution decontamination system.

Efficacy/strengths/weaknesses—

Limitations: If uranium recovery is required, citric acid may be inappropriate. Citric tends to prevent uranium precipitation. Although the BNFL process works well on wrought aluminum, it may have only limited success with cast aluminum.³ There is no data available for radionuclides other than uranium or technetium

Advantages: Demonstrated effectiveness in decontamination of gaseous diffusion plant facilities. BNFL is willing to market the technology.

Effectiveness: BNFL process achieved surface decontamination factors of 300 for uranium alpha and 40 for technetium beta.¹ Decontaminated to below British standards for release as scrap: 11.1 Bq/g alpha, and 0.4 Bq/g beta. The high-enrichment portion of Capenhurst decontamination was completed in 1985. Recycled to metals market were 1,000 tons aluminum, 1700 tons steel and 350 tons other metals.² The low-enrichment portion of the facility is now in the process of decontamination.

Science/Technology Needs: Technology development needs: Pilot plant development for waste treatments (ion exchange columns) to verify ability to meet standards and regulations. More fundamental studies are needed in secondary waste disposal.⁴

Technical Task Plan OR111102 (FY 1992); relevance: high

Implementation Needs:

Development: The financial resources necessary for purchase of technology, regulatory compliance, pilot-scale decontamination and waste treatment demonstrations. For personnel, a Ph.D. and/or an engineer to direct development. Costs, \$400K-\$1000K.

Implementation: The financial resources necessary for retrofit of facility, environmental compliance, and procedural requirements.

Hardware: No present ORNL facility could be adapted for citric acid cleaning. BNFL's expertise may reduce the amount of original research, paperwork, etc., necessary to begin implementation.¹ In general, decontamination with BNFL's citric acid process should pose no undue difficulties or unusual resource needs. It may well be less costly to implement than the familiar nitric acid process would be due to the relative nontoxicity and ease of treating secondary waste stream. Capital costs would be \$4M-\$10M if new equipment is required; operating costs would be \$300/2200 lb (BNFL estimate).

Author: D. E. Beck/615-574-0706. Reviewed by J. R. DeVore/615-574-7092

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EM Problem: Decommissioning

ORNL Problem: See Appendix B, lists A, B, C, E, F, H

Problem Area/Constituents: See Appendix B, lists A, B, C, E, F, H

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Decontamination

Alternative: Chemical surface cleaning (fixed and transferable contamination) methods

Technology: Fluoboric acid treatment. Decontamination and decommissioning (D&D) using fluoboric acid (HBF_4) in dipping baths, loop systems, or by spraying.

Status: Demonstration. Technology was designed specifically for D&D.¹ Attacks nearly every metal surface and metallic oxide or concrete surface. Removes oxide and contaminated outer layer in controllable, uniform, and efficient manner. Unrestricted use of materials should be possible after decontamination, due to high decontamination factor (DF); however, corrosion is high (DF is a function of the depth of metal removed).

Waste produced—The fluoboric acid technology generates metal waste as a result of surface removal. About 1-g of this waste is generated per square meter per micron depth of bare metal removal. The acid can be electrolytically regenerated and recycled, with the radioactive waste plated out at the cathode and solidified in cement. Final quantity of cement-solidified waste is 20–50 g/m² decontaminated metal. Other waste treatment options are neutralization and precipitation with solidification in cement (200–500 g/m² or treatment by ion exchange followed by solidification of the resin in cement (400–700 g/m²). The optimum material for solidification of this waste needs to be determined.²

Overall cost—Capital costs in 1990 to set up a plant for decontaminating 5 tons/day of steel was \$1.3M (\$774K excluding development, planning and buildings).² Operating costs will be relatively low; this is a very simple process. The plant can be manufactured in modular form² and installed in existing buildings.

Efficacy/strengths/weaknesses—The reaction is heterogeneous and for metals (Me) proceeds as follows:

1. $n\text{HBF}_4 + \text{Me} = \text{Me}(\text{BF}_4)_n + n/2 \text{H}_2$
2. $n\text{HBF}_4 + \text{metallic oxide} = \text{Me}(\text{BF}_4)_n + \text{water}$

Fluoboric (or fluosillicic) acid can also scabble and clean cement and brickwork. If it is contaminated to a depth of only a few millimeters, concrete flooring and structures can be

returned to unrestricted use.¹ Fluoboric acid exhibits low-vapor pressure and requires only the standard precautions for acid or base work.

Science/Technology Needs: Depends to a certain extent on similarities between ORNL and Chernobyl operations.² Results of the technology usage at Chernobyl may answer many questions for us.

Implementation Needs: Equipment, fabrication of all key plant parts from polypropylene or from Halar-coated metal.

Author: D. E. Beck/615-574-0706. Reviewed by J. R. DeVore/615-574-7092

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EM Problem: Decommissioning

ORNL Problem: See Appendix B, lists C and H

Problem Area/Constituents: See Appendix B, lists C and H

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Decontamination

Alternative: Chemical surface cleaning (fixed and transferable contamination) methods

Technology: Inorganic acid treatments. The removal of tightly adhered contamination using nitric acid solutions in spray booth or dipping decontamination processes. Use of other inorganic acids. Concentrated (pH <2) solution with concurrent corrosion is used; however, additives (1% urea) and modifications can greatly reduce corrosion. Decontamination factor (DF) for concentrated acid treatment is in the 100 range.³

Status: Accepted. Nitric acid decontamination has been the preferred method at ORNL for cleaning items in various facility operations since the 1940s. In addition, the technique has been widely used at building K-1420 at the K-25 Site and at Portsmouth's X-705 facility. Generally, all DOE sites decontaminate for maintenance but not for release.

Waste produced—Large quantities of corrosive nitrates are produced. Difficult and expensive to treat by today's standards; however, Portsmouth has built a biodenitrification facility which meets National Pollutant Discharge Elimination System outfall standards. Prior to biodenitrification, waste treatment would likely involve removal of radionuclides by neutralization/precipitation. Waste is presently evaporated and the concentrate stored, with the distillate treated at the Process Waste Treatment Plant and Nonradiological Wastewater Treatment Plant prior to discharge.

Overall cost—Nitric acid decontamination was used extensively at most DOE plants, but data is not available regarding costs. Currently, Portsmouth plant is developing a data base to track costs,³ but it will not contain historical data.

Efficacy/strengths/weaknesses—Advantages/effectiveness: Excellent DFs, but secondary waste requires treatment and disposal as an RCRA waste.

Although nitric acid is by far the most common, sulfuric acid has been used in decontamination, notably to dissolve nickel-plating prior to removal of technetium at the

nickel-steel interface.⁵ Other inorganic acids, such as hydrochloric, are rarely mentioned in the literature. The exception is fluoboric acid, for which a separate input sheet is written.

Science/Technology Needs: Adaptations of modifications to system (e.g., scrubbers, filters, treatment for nitrates and heavy metals) are needed to meet regulatory requirements.⁹ Possible development of nitric acid/hydrogen fluoride decontamination methods with or without ultrasonic agitation.^{7,8} Continuing research and development, waste treatment, and volume reduction are needed. Possible research and development in control of base metal dissolution.

Implementation Needs: Nitrate treatment facility either on site or accessible to decontamination facility. Support personnel to sample, analyze, develop treatments, and ensure compliance with RCRA regulations will be necessary; thus, operating costs may be relatively high.

Author: D. E. Beck/615-574-0706. Reviewed by J. R. DeVore/615-574-7092

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EM Problem: Decommissioning

ORNL Problem: Concrete, painted concrete, sheet metal, structural steel, concrete block, tiled concrete, stainless steel pipe exterior, stainless steel pipe interior, small diameter stainless steel pipe exterior, small diameter stainless steel pipe interior, stainless steel sheet, HRT high density concrete, steel plate, pulsefeeder pump.

Problem Area/Constituents: Uranyl sulfate, fission products, corrosion products, Cs-137, Sr-90, H-3, Pm-147, Am-241, Co-60, Ir-192, Gd-153, P-32, Kr-85, Pu-238, Cm-244, U-BE-Li-F, Th, I, Pu, Cf, Np, Pa, other beta-gamma emitters.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Decontamination

Alternative: Chemical surface cleaning (fixed and transferable contamination) methods

Technology: Detergent treatment. The use of alkaline sodium carbonate, ammonium carbonate, sodium EDTA, sodium citrate, trisodium phosphate other sequestering agents, and detergents for surface washing and removal of particulates; the use of alkaline permanganate to oxidize chromium in high-Cr oxides (preconditioning the oxide for further treatment).

Status: Accepted/demonstrated. Surface smearable decontamination with caustic chemicals (essentially soap and water scrubbing) is accepted technology at ORNL. Using alkaline potassium permanganate to dissolve high-chromium oxides by oxidizing the chrome content in pressurized water reactors (PWRs) has been demonstrated. The latter may or may not be relevant to ORNL needs; the need for dissolution of high-Cr oxides appears unique to PWRs in the commercial sector. The caustic hand-scrubbing process was applied to cleaning small items.

Waste produced—Moderate quantities of contaminated caustic solutions are produced. Simple neutralization and precipitation has been the traditional treatment. The sludge produced could be solidified and the effluent sent to the Tank Farm.

Overall cost—Caustic decontamination is used extensively at ORNL, in conjunction with nitric acid, but at this time cost information is not available. Capital costs could be minimal, but scrubbing with caustic solutions is labor intensive.

Efficacy/strengths/weaknesses—Effectiveness: Decontamination factors (DFs) for removal of smearable contaminants are also not available; however, items cleaned with caustic

chemicals can many times be green-tagged by Health Physics personnel (<20 dpm alpha, <200 dpm beta-gamma).

Science/Technology Needs: None for removal of smearable contamination with carbonates, soaps, etc.

Implementation Needs: This is an established process that could be implemented at ORNL with no major changes. Capital costs, ~<\$10K; operating costs, ~>\$1/ft.

Author: D. E. Beck/615-574-0706. Reviewed by J. R. DeVore/615-574-7092

References: T. Swan, M. G. Segal, W. J. Williams, M. E. Pick, LOMI Decontamination Reagents and Related Preoxidation Processes, EPRI-NP-5522M, Research Project 1329-1. Prepared by Central Electricity Generating Board, Berkeley Nuclear Laboratories, UK, for the Electric Power Research Institute, Palo Alto, Calif., December 1987.

EM Problem: Decommissioning

ORNL Problem: See Appendix B, lists C and H

Problem Area/Constituents: See Appendix B, lists C and H

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Decontamination

Alternative: Chemical surface cleaning (fixed and transferable contamination) methods

Technology: Redox treatments. Various "designer" combinations, which include the following:

Citrox: A two-step process using an alkaline permanganate oxidizing step followed by a citric acid-oxalic acid reducing step.

LOMI (low oxidation-state metal ion): A one-step process that uses vanadous picolinate solution to reduce ferric ion to ferrous (using vanadium ion) and subsequent chelation with picolinate.

Cerium solutions in acid (cerium nitrate): Solutions of cerium IV in inorganic acids (nitric, sulfuric, sulfamic, etc.) in several different formulations appear to oxidize with cerium, followed by complex formation with an inorganic acid, to keep metals in solution.

Status: Demonstrated. Nuclear power plant decontamination; predemonstration, gaseous diffusion plant and fluoride film decontamination

Waste produced—

Citrox: Produces largest quantity ion-exchange resin waste of the three technologies discussed.

LOMI: Volume of secondary waste generated is about one-half that of the Citrox process. It does contain relatively high metal concentrations which could be precipitated out before passing the remaining waste through ion-exchange columns. A cation resin from DOW and an anion resin from Rohm & Haas are effective in cleaning the waste stream. Cleanup by ion-exchange is straightforward and very efficient. However, disposal of ion exchange resins is becoming a problem.

Cerium solutions in acid: The spent ceric acid solution can be cleaned with a mixed anion-cation exchange resin and reused, or neutralized, evaporated, and disposed of as solid waste. In order to recycle, the Cell can be oxidized back to CeIV by oxidizing with ozone or peroxide. Subsequent passage through ion exchange columns will remove most radioactive metal ions. Uranyl and plutonyl will pass through and can then be recovered by solvent extraction or more ion exchange. Disposal of ion exchange resins or solidified wastes may present a problem. Another option is for electrolytic regeneration of the spent ceric acid solution.

Overall cost—Capital cost, >\$1M; operating cost, <\$1/ft²

Citrox: Operating costs are relatively high, especially for a two-step process.

LOMI: No hard cost data have been collected, but both capital and operating costs are probably higher than for Citrox.

Cerium solutions in acid: Cerium solutions are nearly as effective as permanganate solutions for oxidation. However, cerium solutions are more expensive. Research and development are necessary for application of the process to ORNL equipment.

Efficacy/strengths/weaknesses—

Citrox: A mixture of oxalic and citric acids (Turco 4521 is a Citrox reagent) has been used since the early 1980s to decontaminate boiling water reactors (BWRs). Its decontamination factors (DFs) ranged from 3 to 17 in a 1984 series of tests.¹ P-Citrox (Citrox with pre-oxidation by alkaline permanganate) was developed for Pressure Water Reactors (PWRs), oxides of which have a high percentage of chrome. The purpose of the AP step is to oxidize and remove chrome from the high-chromium (>20%) oxide film prior to completion by citric and oxalic acids. Addition of preoxidation step to Citrox process increases the DF by a factor of 10 to 100, for high-chrome oxides.

Disadvantage: There can be intergranular attack and stress corrosion cracking on steel when oxalic acid is present in the decontamination solution.

LOMI: Is a noncorrosive process using a vanadous picolinate solution to rapidly reduce iron-based oxides. LOMI was developed in response to the oxalic acid corrosion problems mentioned above and has been used for decontamination of BWRs and PWRs since the mid-1980s. It is often combined with a preoxidation step, making it a process of two or more steps using acidic or alkaline permanganate or both. Multi-step processes may be NP-LOMI (nitric acid/permanganate), AP-LOMI (alkaline permanganate), or AP/NP/LOMI, depending on the substrate. Other LOMI combinations can be tailored, such as LOMI-NP-LOMI, etc., to obtain the optimum decontamination.²

Advantage: An advantage to LOMI is that it has proven to be unaffected by the incorporation of nickel in the oxide lattice, which can make dissolution of iron-based oxides by simple complexing acids difficult.³

Disadvantage: Possible storage problems; both permanganate and LOMI solutions are thermodynamically unstable when exposed to water. Tailoring is essential for efficient

decontamination; not only from system to system, but sometimes within the system (e.g., chromium content in the oxide can vary from location to location within a piece of equipment).

Effectiveness: The overall decontamination factor (DF) at Monticello recirculation system was 22.9 (removal of 96% of the contamination), using LOMI. On high-chrome equipment, the DF was 3.6 (removal of 72%). LOMI was less effective than a Citrox process in decontaminating a TMI-2 reactor cooling system.⁴

Cerium solutions in acid: These solutions are the most recent developments in REDOX decontamination. They produce a high DF, are excellent for use on complex configurations, and produce a resolution rate higher than electropolishing.⁶ Cerium oxidation is also called promising for TRU decontamination.⁷ At least one of the ceric acid methods, using tetrasulfato ceric acid, is patented.⁸

Advantage: Ceric acid solutions eliminate the need for separate oxidizing and decontaminating solutions. Wide applicability to complex configurations. Dilute (soft) processing and temperatures as low as 70°C help keep corrosion rates low.

Disadvantage: New technology, requiring more development. Must be tailored to substrate and oxide film.

Effectiveness: A solution of ceric acid and inorganic acid was found to remove more than 97% of contamination in a reactor cooling system.⁹ For greater effectiveness, ceric acid cleaning may be followed by conventional decontamination (mixture of a chelate and an organic acid) and a final rinse with deionized water.

Science/Technology Needs: All REDOX techniques will require demonstration to determine their usefulness in decontaminating of gaseous diffusion operations and applicability to fluoride-based contaminant films. It is estimated that development costs could be greater than \$1M to bring a REDOX decontamination development through bench-scale and demonstration phases.

Technical Task Plan OR111102 (FY 1992); relevance: high

Implementation Needs: Not applicable

Author: D. E. Beck/615-574-0706. Reviewed by J. R. DeVore/615-574-7092

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EM Problem: Decommissioning

ORNL Problem: See Appendix B, lists C and H

Problem Area/Constituents: See Appendix B, lists C and H

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Decontamination

Alternative: Chemical surface cleaning methods

Technology: Electropolishing. A surface removal process that is traditionally applied to metallic (conductive) substrates. The electropolished area is defined by the path of the electric current (the path of lowest resistance) from electrode to substrate, hence a rough surface is smoothed because the "high" spots are closer to the electrode than the low spots. Cracks or crevices will not be electropolished until the surrounding "high" areas are removed. Traditionally applied as a portable or "localized" technology on small areas, the solvent and electricity are applied in some way to a localized spot.

Could be applied as a "factory style" process in batch fashion to contaminated parts. Contaminated materials are fed into processing equipment, and cleaned material exits.

Status: Demonstration

Waste produced—A contaminated electrolyte solution is a product of this process.

Efficacy/strengths/weaknesses—The amount of surface removed is proportional to factors such as current, time, and voltage. These factors can be increased so that the entire surface is removed. For smooth contaminated materials, the level of decontamination is dependent on transport of electropolishing products away from the cleaned surface, and in practice levels of zero added contamination can be achieved.

Limitations: Electropolishing is essentially a "line-of-sight" process, so cracks, crevices, areas out of sight of, or shadowed by, the electrode will not be decontaminated. Contaminated electrolytes must be removed for complete decontamination to be achieved. Electropolishing is difficult to apply to in situ equipment.

Science/Technology Needs: Primary and secondary waste treatment and solution recycle need to be developed. Cleanup principles (e.g., ion exchange and filtering) are well established, so that only design and demonstration are needed.

Implementation Needs: Development costs, ~\$400K-\$1M; operating costs, ~>\$1/ft², with additional capital costs.

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References: MMES staff members.

EM Problem: Decommissioning

ORNL Problem: See Appendix B, list H

Problem Area/Constituents: See Appendix B, list H

Reference Requirements:

- Clean Air Act, NEPA, NESHAP, FFCAs
- Applicable federal and state laws and regulations
- DOE orders

Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Decontamination

Alternative: Chemical surface cleaning (fixed and transferable contamination) methods

Technology: Gas phase decontamination. A strong fluorinating gas (most likely chlorine trifluoride) is used to fully fluorinate solid deposits, which are contaminating inside metal surfaces, to form volatile fluorides that can be recovered. This technology only applies to decontamination of radionuclides that form volatile fluorides.

Status: Predemonstration. Uranium contamination only; preconceptual, other radionuclides. As reported by Bundy and Munday,¹ efforts to decontaminate gaseous diffusion process equipment, bearing uranium deposits as the principle contaminant, have been undertaken by personnel at the US/DOE gaseous diffusion plants at different times with varied success. On going lab-scale studies² at the K-25 Site indicate that chlorine trifluoride (ClF_3) is capable of reacting with uranium deposits at room temperature much faster than previously believed, which suggests a novel approach to decontaminating the equipment by sealing it, evacuating it, and then adding a subatmospheric static charge of ClF_3 for an extended period. Recent lab studies have demonstrated the ability to remove uranium deposits from copper tubing that was taken from a cascade to below the detection level of an alpha meter following a three-month exposure to ClF_3 at subatmospheric pressure. The costs for handling the wastes are included in the operating cost estimate of \$15K/item of gaseous diffusion equipment.

The applicability of the process to other radionuclides of interest in decommissioning efforts at ORNL has not been evaluated; but in general, the technology applies only to substances that form volatile fluorides. The conditions necessary to form volatile fluorides can be expected to vary considerably from those observed for fluorination of uranium compounds. The status of the technology applied to contaminants other than uranium is probably best described as preconceptual.

Science/Technology Needs: Lab studies must be conducted to demonstrate feasibility of the process, and full-scale demonstration should be done provided the lab results are favorable. A production-scale process will require development of a method to recycle excess fluorinating agents. The gas phase process will require handling off-gases, which will generate liquid scrubber wastes, and dry chemical trap wastes, which will be contaminated with uranium or other radionuclides.

Technical Task Plan ADS416 (FY 1992); relevance: high

Implementation Needs: The operating costs for processing equipment depends greatly upon the condition and configuration of the equipment. K-25 site gaseous diffusion equipment bearing uranium contamination is presently the only basis for rough cost estimation. If a single "00" converter that weighs 28,800 lb is decontaminated by gas phase treatments for \$15K, the cost would be \$0.52/lb. This cost would be reduced much more if an entire cell containing ten converters and compressors can be treated at once. The capital costs for full-scale production equipment is estimated at \$3M (most of this amount is already included in the \$2.26M capital cost for the full-scale demonstration).

Further lab studies and a full-scale demonstration are expected to cost \$4.95M: \$345K for lab studies, \$2.26M for capital costs, and \$2.345M for operating costs. Additional lab studies and demonstrations will be required depending upon how many different contaminants are evaluated as candidates for gas phase decontamination. The demonstration is expected to require two full-time technical people (one chemical engineer and one chemical technologist), as well as analytical, maintenance, and other support personnel. The design and construction phase will require about \$864K in support from the following disciplines of Energy Systems engineering staff: engineering mechanics, process design, electrical engineering, instrument engineering, and safety engineering. Most of the construction activities will be conducted by the construction supervisor. Support services will include: Health Physics, Industrial Hygiene, Health and Safety, and Environmental and Analytical Services. The equipment needs will include an evacuation pump, gas manifolds and off-gas handling equipment; including chemical traps, scrubbers, and stacks with isokinetic samplers. Gas analyzers will also be required for quantitative gas analysis. The equipment will be mounted on a trailer.

The production equipment and requirements will be similar to the full-scale demonstration, except additional equipment must be constructed for UF_6 recovery and possibly off-gas recycling. These additions are expected to add about \$685K to the capital costs. The operating costs, listed under "Status" above, are estimated at \$15K/item. Full production operation is expected to require the following personnel assuming only one crew: two chemical operators and one supervisor plus support from technical division, analytical services, and health physics. Additional personnel would be needed for final material disposition.

Author: E. B. Munday/615-576-5806

September 1993

References:

1. R. D. Bundy and E. B. Munday, *Investigation of Gas-Phase Decontamination of Internally Radioactively Contaminated Gaseous Diffusion Process Equipment and Piping*, 91-25.1 84th Annual Meeting & Exhibition, Vancouver, B.C., June 16-21, 1991, Air & Waste Management Association, Pittsburgh, Pennsylvania.
2. E. B. Munday and D. W. Simmons, *Feasibility of Gas-Phase Decontamination of gaseous Diffusion Equipment*, K/TCD-1048, Martin Marietta Energy Systems, Inc., February 1993.
3. E. B. Munday, rough preliminary design and estimates, Martin Marietta Energy Systems, Inc., June 1992.

EM Problem: Decommissioning

ORNL Problem: See Appendix B, lists A, C, E, and G

Problem Area/Constituents: See Appendix B, lists A, C, E, and G

Reference Requirements:

- Federal Facility Compliance Agreement for Oak Ridge Site
- Federal Facility Compliance Agreement for PCBs
- Clean Air Act
- Toxic Substance Control Act
- DOE orders

Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Decontamination

Alternative: Chemical surface cleaning methods

Technology: Biological surface cleaning. Living organisms are used to clean or mobilize surface contamination.

Status: Evolving technology (preconceptual). A knowledge base exists for biological treatment of various contaminants; however, there is no database for application of the technology to surface decontamination. The technology is likely to work if methods can be developed to apply a layer of microbes to surfaces to be decontaminated, supply needed nutrients to the microbes, and finally remove the microbe layer from the decontaminated surface. The technology may possibly be applied in situations where other technologies cannot be used (e.g., microbes could be transported by water to contaminated internal surfaces of equipment that are inaccessible to other technologies). At this time, an estimate of the expected decontamination efficiency cannot be made. The waste generated would be the contaminated layer of microbes removed from the treated surface. An estimate of the quantity of waste cannot be made at this time.

Science/Technology Needs: A research project that investigates the feasibility of using biological treatment for decontamination of surfaces is needed.

Technical Task Plans ID121103 (Fy 1992); relevance: unknown
RF101205 (FY 1992); relevance: unknown

Implementation Needs: Because of its preconceptual status, an estimate of the capital and operating costs of the technology cannot be made at this time. The cost of a research and development project on surface decontamination by biological treatment would most likely range from \$300K-\$600K/year.

Author: J. H. Wilson/615-576-4413

References: MMES staff members.

EM Problem: Decommissioning

ORNL Problem: Enrichment process buildings, process support buildings, electrical switch gear, pumping stations, laboratory facilities, special development facilities, administrative facilities, and cooling towers

Problem Area/Constituents: Painted concrete, tiled concrete, sheet metal, structural steel, aluminum, steel pipe (interior and exterior), and electrical components

- Structural steel/U, oils
- Metal equipment (exterior)
- Steel equipment
- Aluminum/U
- Steel/chromates
- Sheet metal/U, oils, PCBs
- Steel pipe/As, chromates, Ba, dioxins, asbestos
- Steel cylinders

Reference Requirements:

- Federal Facility Compliance Agreements (e. g., FFCA for Oak Ridge Site)
- Applicable federal and state laws and regulations (e. g., Clean Water Act and Toxic Substance Control Act)
- DOE orders

Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Decontamination

Alternative: Chemical surface cleaning methods

Technology: Ultraviolet light (UV)/ozone. Oxygen molecules absorb UV to form ozone that dissociates to form atomic oxygen. Furthermore, the contaminant molecules are excited and/or dissociated by the absorption of UV. The excited contaminant molecules and the free radicals produced by dissociation of contaminant molecules react with atomic oxygen to form simpler, volatile molecules, such as carbon dioxide, water, and N₂.

Status: Predemonstration. In the semiconductor industry UV/ozone surface-cleaning is an effective method of removing a variety of contaminants from surfaces. Representative contaminants include various oils such as human skin oils, cutting oil, and vacuum pump oil; solder fluxes; greases; and cleaning solvent residues such as acetone, ethanol, methanol, isopropyl alcohol, trichloroethane, and trichlorotrifluoroethane. In most instances UV/ozone

surface-cleaning is a simple-to-use process that is inexpensive to set up and operate. Cleaning systems are available commercially primarily for the semiconductor industry. The method can produce clean surfaces in air or in a controlled atmosphere, at ambient to slightly elevated temperatures.

However, there are limitations to this cleaning method. Only those contaminants that will dissociate and react with atomic oxygen to form simpler, volatile molecules, such as carbon dioxide, water, and N_2 , are effectively removed. There are safety issues involved with the use of UV, the presence of mercury in the UV lamps, and the generation of ozone. The distance of the surface from the UV source has to be minimized for best cleaning results. And because inorganic contaminants such as dust, salts, and solid oxides cannot be removed by this method, precleaning is necessary.

The specific application to decontamination is in the problem definition stage since UV/ozone cleaning technology exists and may have some applicability to cleaning tasks. The efficacy of this technology to the particular target areas/problem constituents is unknown at this time.

Additional Comments:

Amount of waste produced—The UV/ozone cleaner operates with O_2 and produces active ozone gas. No significant addition to the waste stream is expected because gas flow would be of the order of $10 \text{ ft}^3/\text{min}$ or less. The existing waste will be converted to a different form (gaseous) and will be collected in a standard HEPA system. The operating gas (ozone) will most likely combine with the waste, forming some new materials. These new materials will also be in gaseous form and will also be handled with standard systems.

Overall cost—An operating UV/ozone system should have a capital cost of less than \$100K, including exhaust gas handling. The equipment could be handled by a single person at less than \$100/h. The gas consumption would be around $10 \text{ ft}^3/\text{min}$ with a cost of about \$0.10/ ft^3 . The electrical cost will be less than \$60/h, based on 100 kW @ \$0.06 kW/h. The cleaning ratio, which will be demonstrated in a proof-of-principle experiment, is unknown and depends heavily on the waste.

The cost leading to an operating commercially produced system is expected to be less than \$800K.

Science/Technology Needs: The potential of the UV/ozone surface cleaning method to reduce organic contaminants to rather innocuous byproducts warrants further development. Especially, development of a safe, portable, efficient system is desirable. Techniques of combining this method and other efficient methods for removing contaminant metals, oxides, etc., would be particularly advantageous and justifies further investigation. However, its efficacy in removing the specific organic and radioactive contaminants is not demonstrated. Using a commercial UV/ozone hardware, laboratory scale experiments could be conducted to establish a data base of cleaning rates on removing organic contaminants from different substrates and to develop necessary techniques to handle the waste generated. Subsequently,

the equipment would be incorporated with robotic, remote, and automatic operations with computer control.

Technical Task Plan RF101205 (FY 1992); relevance: unknown

Implementation Needs: Development activities: to address science needs, the approximate cost of equipment and staff time is \$800K (capital equipment, \$200K). For the above activities, the staff are required to be highly trained in the fields of plasma technology and photochemistry: one-half would be scientists at the M.S. and/or Ph.D. level, and one-half would be highly trained technicians at the B.S. level.

Authors: W. L. Gardner/615-574-1121 and W. D. Nelson/615-574-0966

References: J. R. Vig, "UV/Ozone Cleaning of Surfaces, Semiconductor Cleaning Technology/1989," *Electrochem. Soc. Proc.*, **90-9**, 105-113 (1990).

EM Problem: Decommissioning

ORNL Problem: See Appendix B, lists A and E

Problem Area/Constituents: See Appendix B, lists A and E

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Decontamination

Alternative: Chemical surface cleaning methods

Technology: Electromigration. Removal of contaminants using electric potential to cause ion migration. This process will leave the surface intact and usable.

Status: Predemonstration. Electromigration was investigated and developed to a limited extent on a laboratory scale. The phenomenon has been demonstrated on concrete and a patent application has been made by K-25 developers (Bostick et al.).¹

It may be applied as a portable or "localized" technology on select areas, with the solvent and electricity being applied to a localized spot. Significant (90+%) contamination reductions have been shown during the demonstration of the technology. Parametric studies have not been successful because a reliable test system to evaluate the migration on concrete remains to be developed.

Enough information is available from the demonstration to suggest this process is very likely to be developed to the point that concrete decontaminated via this route will meet safety guidelines for nonradiological areas.

Waste generated by electromigration, if solvent recycle is adapted, may typically be loaded ion exchange resin.

Science/Technology Needs: Science: Several aspects require fundamental evaluation. Selection of the best characteristics for a working fluid that cause migration of all contaminants to the surface (electrolyte) remains to be evaluated. Concrete imbibing studies that evaluate the flow or migration mechanism are needed. A reliable test system has not yet been developed to allow parametric studies.

Technology: Electromigration has been demonstrated in concrete but no process optimization has occurred. Electromigration solvents for use on horizontal surfaces, gels for vertical surfaces, ceilings, etc., still remain to be developed, as do the specific large-scale containment

structures for solutions. Cheap electrode materials need to be identified, and recycle of the solutions must be designed.

Technical Task Plans ADS416 (FY 1992); relevance: high
AL121104 (FY 1992); relevance: high

Implementation Needs: Implementation needs may be quite modest. Since the process is intended to be an in situ technology, only development facilities are necessary. Process equipment will consist of power supplies, electrodes, etc., the sizes of which will be determined by the surface area to be decontaminated.

Development costs, about 4 PY or \$1000K, which would be offset by the effective value of the buildings that are recovered for beneficial use. Capital costs, ~\$200K; operating costs, ~5/ft².

Deployment costs, modest with little equipment or labor.

Documentation, consultation with the developer.

Authors: W. D. Bostick/615-574-6827 and R. L. Fellows/615-576-5632. Reviewed by E. B. Munday/615-576-5806

References: W. D. Bostick et al., "Electroosmotic Decontamination of Concrete," K/TCD-1054, Martin Marietta Energy Systems, Inc., March 1993.

EM Problem: Decommissioning

ORNL Problem: See Appendix B, lists A, B, C, E, F, G, and H

Problem Area/Constituents: See Appendix B, lists A, B, C, E, F, G, and H

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Decontamination

Alternative: Chemical Surface Cleaning Methods

Technology: Chelation treatment. Selective removal of organic and inorganic compounds by chemical dissolution with organic chelating agents, such as carboxylic acids. The agent breaks the chemical bond between the contaminant ion and the substance it is attached to and forms a soluble complex. Additional reagents, such as surfactants and emulsifiers, can be added depending on the situation. The technology differs from solvent extraction in that an acid solution is not required (acts at or near pH-neutral). Both loose and fixed contamination can be removed using these agents with either batch or continuous process (with optional ultrasonic agitation), a spray booth, or through in situ application by wet-vac cleaning machine. Chelating agents can be destroyed in solution, producing a filterable sludge-containing contaminant. Waste products from chelate solution are nonhazardous, nonfuming, have no gas evolution, and are biodegradable.

Status: Demonstration. The technology has been employed at various facility operations and nuclear power plant sites, achieving acceptable decontamination levels resulting in unconditional release.

Waste produced—The technology minimizes waste through oxidative destruction of chelate agents, partitioning of organics (including PCBs), and concentration of radionuclides precipitated out in the flocculent sludge, which can be further dewatered. Oxidation of chelating agents removes any potential for mixed classification from that source.

Overall cost— <\$1/ft² for large areas

Efficacy/strengths/weaknesses—Excellent decontamination factors. Easy to apply in situ, since the agents act at neutral pH and are nonhazardous, nonfuming, have no gas evolution, and are biodegradable. Worker safety is positively affected versus acids, solvents, and heavy equipment used for bulk extraction. Simple waste minimizing treatment and disposal as a non-RCRA waste.

Science/Technology Needs: Current validation of updated chelating agents is underway at ORNL to confirm total efficacy and economic advantages.

Implementation Needs: Application equipment for in situ decontamination. Support personnel and equipment to sample, analyze, develop appropriate concentrations, ensure oxidation of organics, and/or complete partitioning will be needed. Spray booth or dipping tank facilities with heating capabilities are desirable on-site or accessible to the decontamination facility.

Author: J. R. DeVore/615-574-7092

References:

1. *Chelant Mixture Regeneration with Strong Acid Cation and Weak Base Anion Resin Mixtures*, Nutek Canada Limited and Prime Energy Systems, Ltd., Downsview Ontario, 1977.
2. "Chemical Decontamination of Large Metal Objects," Bouchard and D'Muhala, September 1993 paper to be delivered, American Nuclear Society Global, Seattle.
3. "Ultrasonic Cleaning," *Decontamination of Nuclear Reactors and Equipment*, Ronald Press, ed., A. J. Ayers, Hanford Operations, USAEC, 1970.
4. "Ultrasonic Decontamination of Control Rod Drive Mechanisms," General Dynamics Corp., Electric Boat Division, 1963.

EM Problem: Decommissioning

ORNL Problem: See Appendix B, lists C and H

Problem Area/Constituents: See Appendix B, lists C and H

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Decontamination

Alternative: Metal refining

Technology: Smelt purification. Purifies metals by adding suitable fluxes that will react with the impurities when the metal is melted. The impurities are then removed from the slag that separates from the molten metal and floats to the top. The items requiring smelting must be cut to suitable size for addition to the smelter.

Status: Demonstration. Smelt purification of radioactive metals has been performed by a large number of investigators on a lab-scale and by some investigators on a large-scale. The metals include mild steel, stainless steel, nickel, copper, monel, aluminum, and others. Metal purification has been demonstrated to levels of 0.01–4.0 ppm residual uranium. Aluminum smelting was not as successful (3–100 ppm). Heshmatpour and Copeland¹ report better results for aluminum (1–2 ppm). Technetium reportedly is not removed by smelt purification.

Waste produced—It has been estimated that about 50 lb of slag would be generated per ton of metal smelted. No figures for off-gas treatment are available.

Overall cost—Scientific Ecology Group, Inc., personnel estimate² the costs (operating and capital combined) of metal smelting at \$0.65–\$2.00/lb depending on the type and configuration of the metal. Steel will probably cost \$0.65–\$0.95/lb to process. Kellogg et al. estimated that the capital and operating costs of smelting the 90,000 tons of DOE scrap metal presently on hand at the K-25 Site could be recovered through sale of the metal if a *de minimis* were established. The quantity of metals at ORNL is probably not sufficient to be cost effective unless added to the quantities at the K-25 Site. Based on their conclusion, a cost of roughly \$0.93/lb of metal can be estimated in 1992 dollars. Construction of a new facility with an 8-ton capacity, electric induction furnace capable of handling ~6 tons/h ferrous or 1.6 tons/h nonferrous metals.

Science/Technology Needs: The report that Technetium is not removed by the process may seriously damage the prospect of using this method if a suitable fluxing agent cannot be demonstrated. The poor results reported in removing aluminum must be further investigated. Other problem isotopes would have to be identified.

Implementation Needs: The technology development needs will require further lab and pilot-scale evaluation. The development costs will include a small electric induction furnace; two full-time technical people (one with experience in metallurgy); and analytical, maintenance, and other support personnel. The duration may be 24 months and the development costs are roughly estimated by the investigator at \$3M-\$5M.

Kellogg et al. have listed the following requirements for a smelt facility: scrap handling and preparation; scrap transportation; scrap weighing and drying facility (the scrap must be heated prior to placing in the smelter to drive off oil and water); eight ton capacity electric induction furnace with two crucibles, mold preparation, and cooling; slag processing, refractory repair, flux storage and preparation; ingot dumping and storage; offices, laboratory, and control room; maintenance areas; and personnel convenience stations. Capital and operating costs were not indicated, but as mentioned above, an overall cost of roughly \$0.93/h can be estimated based on their conclusions that all costs could be recovered from the sale of 90,000 tons of metal presently in the DOE inventory (valued at \$102M in 1982 dollars) assuming a *de minimis* is established. About 74% of the metal value is the nickel, which amounts to only 11% by weight of the metals in the Kellogg study. Nickel was not used extensively at ORNL. Most likely no existing facility will satisfy the operational requirements of this facility (the Kellogg study assumes new facilities are constructed). The design and construction phase will require the support of numerous engineering disciplines: structural, site, electrical, instrument, and safety engineering, as well as engineering mechanics, process design, and metallurgy. Numerous support services will be required: health physics, industrial hygiene, health, safety, environmental, and analytical services. Numerous construction and maintenance craftsmen will be required: welders, carpenters, electricians, mechanics, EIT personnel and supervisors. These requirements cannot be quantified at present. The establishment of a *de minimis* standard is very critical for the success of this project since the resulting ingots cannot be sold without this legislation.

Author: E. B. Munday/615-576-5806. Reviewed by J. R. DeVore/615-574-7092

References:

1. B. Heshmatpour and G. L. Copeland, "The Effects of Slag Composition and Process Variables on Decontamination of Metallic Wastes by Melt Refining," Union Carbide Corporation, January 1981.
2. Douglas Jamesian, Scientific Ecology Group, Inc., personal communication to E. B. Munday, Martin Marietta Energy Systems, Inc., June 1992.
3. D. R. Kellogg et al., *Metal-Smelting Facility*, CONF-82041-13, DE 82 013539, Union Carbide Corporation Nuclear Division, 1982.

EM Problem: Decommissioning

ORNL Problem: See Appendix B, lists C and H

Problem Area/Constituents: See Appendix B, lists C and H

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Decontamination

Alternative: Metal refining

Technology: Electrorefining. As a nickel purification method, it uses an electrolysis cell that contains a flat anode made from the impure nickel and a flat cathode made from pure nickel. The pure nickel used for the cathode is stripped off of a stainless steel blank, which was briefly used as a cathode. An electrolytic solution provides a conductive medium for the voltage applied between the anode and cathode that causes the impure nickel to ionize into positive nickel ions in the solution and nickel ions at the cathode to plate out. The anode and cathode compartment are separated by a porous diaphragm. Impurities in the nickel anode that are less than nickel in the electromotive series will usually drop out as a sludge beneath the anode. Impurities greater than nickel in the electromotive series will travel with the nickel ions. Therefore, the anode solution is continuously circulated by pump from the anode compartment to a purification train and cathode compartment where the pure nickel is plated out on the cathode. The direction of the solution flow through the diaphragm is from cathode to anode. Electrorefining would require that the scrap nickel be smelted and poured into suitable anode molds first.¹ Leach/electrowinning technology (DCON-34-OL) combines leaching with electrorefining and avoids the need to smelt the scrap nickel into anodes by substituting a process that leaches the nickel into an electrolytic solution.

Status: Predemonstration. Electrorefining is a well-established commercial technology. However, this technology cannot be considered mature concerning its use for decontaminating radioactive metal since this application is much less established. Uranium is easier to remove than technetium, which means this method will likely allow favorable decontamination factors. The method has not been evaluated for treatment of metals other than nickel. An evaluation to determine the cost effectiveness of recovering other metals would be required. Nickel is not used extensively at ORNL.

Waste produced—Recycle of the electrolytic solutions is assumed with resulting mixed solid waste bearing nickel uranium, technetium, and other compounds amounting to roughly 2% by weight of the nickel processed.⁴

Overall cost—The cost of an operating facility with a 10-million-pound/year capacity is estimated at \$2M capital and \$6/lb operating costs. The operating costs exceed the present value of nickel (\$3.60/lb) because commercial nickel companies operate on a much larger scale.³ The development costs are estimated at \$3M.

Science/Technology Needs: Pilot-scale testing of this method is needed with special attention to decontamination efficiency and recycle of the electrolytic solutions.

Implementation Needs: An electrorefining plant used for recovery of nickel would also require a smelting and anode forming facility to form the impure nickel into anodes of proper configuration. A tank house containing the electrolytic cells and an electrical capacity of roughly 1 kWh/lb nickel refined are required. The capital costs altogether are estimated at \$200M, and the operating costs are estimated at \$6/lb of nickel.³ The development costs are roughly estimated at \$3M. Estimates of the number of personnel are not yet available. The design will require the support of virtually all engineering disciplines. Facility operation will require process and electrical engineers, supervisors with at least two years technical background, chemical operators, electricians, mechanics, and general shop crafts. Metallurgical and analytical chemistry support is also required. To allow sale of the resulting purified nickel, either a *de minimis* level must be established in the United States or permission must be obtained to sell the metal in Europe where a *de minimis* level exists.

Author: E. B. Munday/615-576-5806. Reviewed by J. R. DeVore/615-574-7092

References:

1. J. R. Boldt, Jr., *The Winning of Nickel*, D. Van Nostrand Company, Inc., Princeton, N.J., 1967.
2. Dr. T. Snyder, Scientific Ecology Group, Inc., personal communication to E. B. Munday, Martin Marietta Energy Systems, Inc., July 1992.
3. L. G. Guglielmin, INCO Exploration and Technical Services, Inc., personal communication to E. B. Munday, Martin Marietta Energy Systems, Inc., July 1992.
4. Rough estimate by E. B. Munday, Martin Marietta Energy Systems, Inc., July 1992.

EM Problem: Decommissioning

ORNL Problem: See Appendix B, lists C and H

Problem Area/Constituents: See Appendix B, lists C and H

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Decontamination

Alternative: Metal refining

Technology: Leach/electrowinning. This process would begin by pulverizing the impure metal and then leaching it (dissolve the metal into an electrolytic solution). At ORNL, International Nickel Company (INCO) has proposed that contaminated nickel could be leached into a solution containing dissolved chlorine gas and copper ions. The copper acts as a chlorine exchange agent for the nickel to form soluble nickel chloride. The required chlorine gas is generated as a by-product during the electrowinning of the nickel from the solution. Except for small amounts, the copper is recycled. Uranium in the leach solution is removed by solvent extraction, stripped with weak aqueous chlorine solution, and recovered by precipitation with sodium hydroxide as sodium diuranate. The electrolytic solution containing the nickel is plated onto a cathode.¹ Leach/electrowinning avoids smelting anodes as required in the electrorefining method, but requires a leaching step that was not needed in the electrorefining method.

Status: Predemonstration. Leach/electrowinning is a well-established commercial method for producing nickel from nickel ore, but is not used commercially to refine impure nickel. Scientific Ecology Group, Inc. (SEG), has conducted bench-scale evaluations that purified nickel contaminated with technetium to less than 1 bq/g (the European release standard). The method used to get the nickel into solution and the purification train are proprietary information of SEG.² Uranium is easier to remove than technetium, which means this method will likely allow favorable decontamination factors. Personnel at INCO prefer leach/electrowinning to electrorefining because it is believed that leach/electrowinning will give a purer product and leaching will have operational advantages to smelting anodes.¹ The method has not been evaluated for treatment of metals other than nickel. An evaluation to determine the cost effectiveness of recovery of other metals besides nickel would be required. Nickel is not used extensively at ORNL.

Waste produced—Recycle of the electrolytic solutions is assumed with resulting mixed solid waste bearing nickel, uranium, technetium, and other compounds amounting to roughly 2% by weight of the nickel processed.³

Overall cost—The costs of an operating facility with a 10-million-pound/year capacity are estimated by INCO at \$200M capital and \$3.80/lb operating costs. The operating costs exceed the present value of nickel (\$3.60/lb) because commercial nickel companies operate on a much larger scale. The development costs are estimated by INCO at ~\$440K if the work were done at their facilities. These cost figures compare closely to the electrorefining process because of the similarity of the processes and because both estimates are very approximate.

Science/Technology Needs: Pilot-scale testing of this method is needed with special attention to the leaching process, decontamination efficiency, and recycle of the electrolytic solutions. The development work by SEC may satisfy some of this requirement.

Implementation Needs: A leach/electrowinning plant would require a size-reduction facility, a leaching facility, and a tankhouse for the electrolytic cells. Electrical capacity to supply roughly 1 kWh/lb nickel refined is required.³ The capital costs altogether are estimated at \$200 million, and the operating costs are estimated at \$3.80/lb of nickel.¹ The development costs are estimated by INCO in two phases: Phase 1 would be a bench scale, batch operation requiring \$170K and Phase 2 would be a continuous small scale process with recycle of solutions and would cost an additional \$270K.¹ These estimates assume the development activities are done at INCO's facility. Estimates of the numbers of personnel are not yet available. The design will require the support of virtually all engineering disciplines. Facility operation will require process engineers, electrical engineers, supervisors with at least 2 years technical background, chemical operators, electricians, mechanics, and general shop crafts. Metallurgical and analytical chemistry support is also required. To allow sale of the resulting purified nickel, either a *de minimis* must be established for the United States or permission must be obtained to sell the metal in Europe where a *de minimis* standard exists.

Author: E. B. Munday/615-576-5806. Reviewed by J. R. DeVore/615-574-7092

References:

1. L. G. Guglielmin, INCO Exploration and Technical Services, Inc., personal communication to E. B. Munday, Martin Marietta Energy Systems, Inc., July 1992.
2. Dr. T. Snyder, Scientific Ecology Group, Inc., personal communication to E. B. Munday, Martin Marietta Energy Systems, Inc., July 1992.
3. Rough estimate by E. B. Munday, Martin Marietta Energy Systems, Inc., July 1992.

EM Problem: Decommissioning

ORNL Problem: See Appendix B, lists A, B, C, E, F, and H

Problem Area/Constituents: See Appendix B, lists A, B, C, E, F, and H

Reference Requirements:

- Federal Facility Compliance Agreement for Oak Ridge Site
- Federal Facility Compliance Agreement for PCBs
- Clean Air Act
- Clean Water Act
- Toxic Substance Control Act
- DOE orders

Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Decontamination

Alternative: Mechanical abrasive methods

Technology: Ultrahigh-pressure water (UHPW). An ultrahigh-pressure intensifier pump pressurizes water up to 55,000 psi and forces it through small-diameter nozzles, generating high velocity waterjets at speeds up to 3,000 ft/s. The nozzles may be mounted in various types of cleaning heads for different contaminated surfaces. The waterjets thoroughly penetrate and remove surface contaminants. Care must be taken so as to not damage the substrate. The UHPW cleaning head, attached to a lance, may be manually moved about on the surfaces being decontaminated. The decontamination efficiency depends on the applicator translation speed. Remote operation of the UHPW cleaning head would be desirable. Also, in some applications (such as decontamination of hot cells), remote operation will be required. Consequently, the adaptation of the equipment to a robotics control system would be necessary.

Status: Accepted by industry. UHPW decontamination technology is available and has been used by industry. The addition of abrasives is also available for industrial cutting and milling. Before acceptance at ORNL and other DOE sites, the issues of criticality, wastewater treatment, and prevention of spread of contamination must be addressed. The technology can produce high levels of decontamination. Removal of a galvanized layer from sheet metal has been demonstrated. Waste generated is contaminated water from the cleaning operation. In cleaning concrete, for example, a typical flow rate for one cleaning head would be 3–5 gal/min at a surface treatment rate of about 1 ft²/min.

Science/Technology Needs: Existing vacuum systems, which recover water from the cleaning (or power) head of the unit, need to be developed further. To minimize waste generation, a water treatment system is needed for decontamination of the wastewater so that the water can be recycled and reused in the UHPW cleaning operation. The system must be capable of treating contaminants specific to the site and reducing their concentrations to allowable levels for water recycle. Remote operation will necessitate the adaptation of the ultrahigh-pressure cleaning heads and the vacuum collection systems to a robotic control system. A data base on UHPW cleanup experience is desirable. This could be developed through communication with the Water Jet Technology Association. The data would be useful in optimization of cleaning parameters in future UHPW decontamination activities. Nozzle configuration, water pressure and flow rate, distance of the cleaning head to the substrate, and the geometric complexities of the substrate are all parameters that need to be evaluated.

Implementation Needs: Development costs: For development and demonstration of a water recycle system, in combination with UHPW decontamination, an estimate of funding requirements is \$1.2M. Personnel requirements are estimated to be \$1.7M (approximately 50% engineer and 50% technician time) and 4.1 FTEs (approximately 10% P&E, 45% engineer, and 45% technician time) for FY 93 and FY 94, respectively. The cost of a robotic control system is estimated at \$250K.

Deployment costs: FLOW International supplies ultrahigh-pressure power units, with intensifier pumps rated at pressures of 40,000 to 55,000 psi, are supplied at costs up to \$200K. Several ultrahigh-pressure tools are available for use with the power unit. Operating costs for a UHPW unit would primarily involve labor costs. Assuming a minimum two-person operation (at a labor rate of \$40K/year/person) of a UHPW unit during the day shift, operating costs would be approximately \$350/day. These costs do not include either the disposal cost of the wastewater that is generated or the capital and operating costs of a system to treat the wastewater and recycle it to the UHPW unit. Development of an acceptable water recycle system is needed to establish estimates for the latter costs. Personnel training for supervisors and for operators will be needed for operation of the UHPW unit and recycle system. Facilities for performing prototype cleaning operations for each decontamination project would be beneficial. Capital costs: UHPW system, >\$500K with vacuum system; glove box, >\$50K; and work room, ~\$250K. Operating costs are estimated at >\$2/ft².

Author: J. H. Wilson/615-576-4413

References: MMES staff members, especially C. E. Benson.

EM Problem: Decommissioning

ORNL Problem: See Appendix B, lists A, B, C, E, and F

Problem Area/Constituents: See Appendix B, lists A, B, C, E, and F

Reference Requirements:

- Federal Facility Compliance Agreements (e.g., FFCA for Oak Ridge Site)
- Applicable Federal and State laws and regulations (e. g., Clean Water Act & Toxic Substance Control Act)
- DOE orders

Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Decontamination

Alternative: Mechanical surface substrate removal methods

Technology: Shot blasting. Uses mechanically accelerated iron shot (pellets). After the shot hits the surface to be cleaned, it is recovered by a magnetic system and recirculated.

Status: Accepted. Commercial units are available¹ that have been used in one step to prepare large areas of concrete floors for painting, cleaning rust and marine growth from ship hulls, and cleaning structural steel elements. A Wheelbrator Blastrac is being used to decontaminate floors at the K-25 Site. Cleaning rates for floors are quoted as being faster than acid etching, sandblasting, and scarifying by factors of 1.7, 1.3, and 2.0, respectively.² Portable machines with design rates of 2,500 ft²/h are available.³ The method is considered advantageous because it is commercially available and has considerable cleaning experience on various surfaces.⁴ Shot blasting differs from sand blasting in that it can be controlled to give more accurate results.⁵ Decontamination factors on the order of 10-100 and costs on the order of \$10/m² are reported for similar technologies.⁴ Shot is recycled many times during cleaning, but ultimately erodes and becomes part of the waste stream at the rate of approximately 0.1 lb/m².

Science/Technology Needs: Technology improvement is needed in waste minimization related to blast media erosion and disposal, containment of waste, and demonstration of specific blast-media substrate/contaminant capabilities, including determination of decontamination factors and process automation. Development of a medium level demonstration facility to evaluate these factors will require ~4PY technical staff, plus ~4PY technicians, and will cost on the order of \$1.5M.

Implementation Needs: This technology, while developed and commercially available, will require a system for processing the waste that will result. For instance, use of the device will generate contaminated dust, gases, and/or fluids. This will require a system to separate and package the contaminants. An integrated pilot facility will cost on the order of \$4M. Design, fabrication, and operation will require ~20PY effort, of which about 30% will be technical staff.

Author: H. H. Haselton/615-574-1115. Reviewed by J. H. Wilson/615-576-4413

References:

1. Blastrac Division the Wheelbrator Corp., 27 Amlajack Blvd., Shenandoah, Ga. 30265.
2. "The Original Blastrac Portable Shot Blast Cleaning Systems the Preferred Way to Prepare Floor Surfaces," Wheelbrator B218.00A.
3. "The Original Blastrac Portable Shot Blast Cleaning Systems Specifications," Wheelbrator B219.00B CC/2-90.
4. "Cleanup of Large Areas Contaminated as a Result of a Nuclear Accident," IAEA Technical Report 300, 1989.
5. *Metals Handbook*, Vol. 5, *Surface Cleaning, Finishing and Coating*, Ninth Edition, 1978.

EM Problem: Decommissioning

ORNL Problem: See Appendix B, lists A, B, E, and F

Problem Area/Constituents: See Appendix B, lists A, B, E, and F

Reference Requirements:

- Federal Facility Compliance Agreement for Oak Ridge Site
- Federal Facility Compliance Agreement for PCBs
- Clean Air Act and Toxic Substance Control Act
- DOE orders

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Subelement: Decontamination

Alternative: Mechanical abrasive methods

Technology: Scabblers/scarifiers. This technology decontaminates a concrete substrate by using mechanical impact methods to remove the contaminated surface. Many vendors market units that use high-speed reciprocating tungsten-carbide tipped pistons to pulverize protective coatings, laitance, and concrete substrate in a single-step process. Other types of units use a shrouded needle scaler to remove concrete from outside edges and inside corners, as well as from wall surfaces. These units are also used for removing lead-based coatings and contamination from steel surfaces. The solid debris produced by mechanical scabbling is removed and collected by a vacuum system. Mechanical scabblers are usually operated manually. If desired, in order to generate more uniform removal rates, or required (i.e., high levels of radioactivity), the units could be adapted for remote-controlled operation).

Status: Accepted. The technology has been used for decontamination purposes in numerous applications involving hazardous and/or radioactive contaminants. Because the technology involves removal of contaminated surfaces, the decontamination efficiency should be 95% or higher. The waste generated is the pulverized surface layer that is collected by a vacuum system. The amount of waste generated depends upon the depth of the surface layer that needs to be removed to achieve decontamination. For example, two different commercial units provide removal of concrete at rates of 3–4.5 in.³/min (8–12 lb/h) and 60 in.³/min (160 lb/h), respectively, at a removal depth of 1/16 in.

Science/Technology Needs: Remote operation will require the adaptation of the scabbler to a robotic control system.

Implementation Needs: Development costs: Robotic control system, ~\$250K. Deployment costs: The capital costs of the two different commercial units mentioned above are \$10K and \$110K, respectively. Operating costs for a scabbler would primarily involve labor costs. Assuming a minimum two-person operation (at a labor rate of \$40K/year/person) of a scabbler during the day shift, operating costs would be approximately \$350/day. Training of personnel to operate mechanical scabblers will be needed.

Author: J. H. Wilson/615-576-4413

References: MMES staff members.

EM Problem: Decommissioning

ORNL Problem: See Appendix B, lists A, B, C, E, and F

Problem Area/Constituents: See Appendix B, lists A, B, C, E, and F

Reference Requirements:

- Federal Facility Compliance Agreements (e.g., FFCA for Oak Ridge Site)
- Applicable Federal and State laws and regulations (e.g., Clean Water Act and Toxic Substance Control Act)
- DOE orders

Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Decontamination

Alternative: Mechanical surface substrate removal methods

Technology: Grit blasting. Commonly known as sand blasting, this pneumatic cleaning process can use a wide variety of grits.

Status: Accepted by industry. Grit blasting has been used many times in the nuclear industry with applications ranging from heavily contaminated pipework, contamination fixed in the oxide, to lightly contaminated surfaces. Commercial units are readily available.¹ Typical abrasives include sand, glass beads, metallic beads, and soft materials such as nut shells and rice hulls. Grit blasting has been shown to be an efficient cleaning method, with unlimited decontamination factors being obtained.² Grit blasting is widely used in industry for removing all classes of scale and rust from a wide range of metal products.³ Waste production rates depend on the media/surface combination. Highly abrasive grits will clean more effectively and faster than soft grits but will ultimately become part of the waste stream. Waste production rates, including grit plus filters, could range from 0.005 to 0.1 lb/ft².

Science/Technology Needs: Technology improvement is needed in waste minimization related to blast media erosion and disposal; containment of waste and vacuum systems; and demonstration of specific blast-media substrate/contaminant capabilities, including determination of decontamination factors and process automation. Cost of a medium scale facility to evaluate these factors is estimated to be \$1.5M.

Implementation Needs: This technology, while developed and commercially available, will require a system for processing waste. For instance, use of the device will generate contaminated dust, gases, and/or fluids. This will require a system to separate and package

the contaminants. Cost of a pilot demonstration is estimated to be \$4M. Application of this technology requires staff with technician training.

Authors: J. H. Wilson/615-576-4413

References:

1. Progressive Blasting Systems, 4201 Patterson, S. E., Grand Rapids, MI 49508.
2. *Metals Handbook*, 9th Ed., Vol. 5, "Surface Cleaning, Finishing and Coating," 1978.
3. *Cleanup of Large Areas Contaminated as a Result of a Nuclear Accident*, IAEA Technical Report 300, 1989.

to a level at which little or no etching of the oxide layers occurs. With the higher speeds available, the centrifuge technology can remove hard oxide layers from steel, thereby removing both zinc coatings from galvanized steel/sheet metal and nickel plating from brass screws. Cutting has been demonstrated at higher pellet speeds for aluminum and copper, and during experimental evaluation sufficient damage has been observed to steel and ceramics to include them in the potential cutting list. For very very hard materials, a pellet gun can be developed to cut or destroy any construction material. A brief program with the Air Force Warner Robins Air Logistics Center demonstrated the removal of the urethane and epoxy paint surfaces from F-15 aircraft at a rate of 120 ft²/h for a 15-HP accelerator. Because the pellets evaporate to gaseous CO₂ upon impact, the secondary waste stream is limited to the materials removed from the surface. The contaminants are released during the blast to the surrounding air. A vacuum shroud surrounding the blast nozzle and covering the impact area could be used to produce a negative pressure and collect the airborne contaminants in a conventional HEPA filtering system. The secondary waste stream would thereby be limited to the HEPA filters. The capital cost of a 30-HP centrifuge blaster capable of accelerating 1 ton/h of CO₂ at speeds up to 400 m/s would be \$100K-\$200K. The unit would be remotely manipulated by an operator and would be capable of cleaning rates of 200-2000 ft²/h depending on the nature of the surface to be cleaned.

CO₂ costs—\$50/h

Electricity costs 30 kW @ \$.06/h—\$1.80/h

Labor one person @ \$100/h—\$100/h

Total cost—\$151.80/h

Cost/ft²—\$0.075/ft² @ 2000 ft²/h to \$0.75/ft² @ 200 ft²/h

Because the removal or etching rate of the surface varies dramatically with the specific application, data on specific decontamination efficiencies needs to be determined to obtain accurate cost estimates. However, decontamination factors for compressed air systems range from 3 to >5000 for various materials.⁵ Due to the higher speed capability and the increased throughput capabilities, the costs will be one-fifth or less than that of present compressed air systems.

Waste produced—No additional waste is produced by the system. Existing waste is converted into a more acceptable and easier to handle form.

Overall cost—Development costs, \$750K; the operating cost is stated above.

Efficacy/strengths/weaknesses—The CO₂ centrifugal system is very efficient and is usable for a wide variety of contaminants and substrates.

Science/Technology Needs: The fundamental concepts of centrifugal pellet accelerator are well proven and have been demonstrated. The only science and technology needs are those associated with tailoring the accelerator to the particular contamination problem. In most cases this will simply be adjusting the pellet speed and determining the specific decontamination rate. In some contaminated environments, it may be desirable to detect the degree of contamination and develop feedback control that will speed the overall cleaning rate and thus help reduce operating cost. Since the CO₂ is in a gaseous state after impact, they can be collected in normal gas collection systems. The blasted off materials will require only

EM Problem: Decommissioning

ORNL Problem: See Appendix B, Lists A, B, C, E, F, and H

Problem Area/Constituents: See Appendix B, Lists A, B, C, E, F, and H

Reference Requirements:

- Federal Facility Compliance Agreements (e.g., FFCA for Oak Ridge Site)
- Applicable Federal and State laws and regulations (e.g., Clean Water Act and Toxic Substance Control Act)
- DOE orders

Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Decontamination

Alternative: Mechanical surface substrate removal

Technology: Centrifuge cryogenic CO₂ pellet blasting. It uses a high-speed rotating wheel to accelerate CO₂ pellets. The centrifuge system is 25 times more efficient than commercial compressed air CO₂ systems and can attain much higher pellet speeds. For example, the centrifuge with a 4 hp electric motor replaces a 100 hp air compressor system used in the commercial system and can strip paint at a rate five times that of the commercial system. This increased capability will allow cleaning and etching at greatly increased rates. In comparison to the compressed air technology, the centrifuge system can achieve much higher and more controllable pellet speeds. The centrifuge CO₂ system can also produce the same or more aggressive etching than the ultrahigh water blasting system, with comparable or increased efficiencies, and comparable capital equipment costs. The most important difference is that the CO₂ method is dry. This makes CO₂ blasting technology usable in enriched uranium decontamination areas and eliminates the need for downstream water decontamination system. Collection of mobilized contamination is a key technology driver for this concept.

Status: Predemonstration. CO₂ pellet blasting, using compressed air to accelerate the pellets, is a demonstrated and effective technology for decontaminating equipment at nuclear reactor sites without producing secondary wastes.^{1,2} The use of centrifuge pellet acceleration has been established in the DOE Fusion Energy Program to form and accelerate pellets of frozen deuterium and tritium for fueling fusion reactors.³ This technology includes accelerating pellets of argon and CO₂ for the purpose of cleaning heavy oxidation deposits from uranium surfaces as part of the DOE Y-12 waste minimization program.⁴ Using commercially available cryoblasting hardware to clean uranium is not feasible because the pellet speeds are limited

established collection technology. There will be no additions and surprises in the waste stream problem.

Implementation Needs: An existing accelerator developed for the Y-12 waste minimization program should be upgraded to operate in a laboratory for scoping studies. Additions to the system would be a high throughput pellet maker (up to a ton per hour) and a particulate collection system. This unit would be operated to collect decontamination data (and rates). If the application chosen is one with extreme contamination, a robot system would be designed along with the application specific accelerator. The resulting unit would be field tested, demonstrated, and put to use.

The high speed cryogenic-pellet decontamination project (centrifugal-accelerator CO₂ pellet blaster) applies directly to numerous decontamination problems (concrete, painted concrete, concrete block, tiled concrete, stainless steel sheet, structural steel, steel plate, galvanized metals, and heavily oxidized metals). The development cost of a concrete cleaning CO₂ blaster unit would be about \$750K. Additional applications would require further equipment modifications and cost. The pellet accelerator capital cost is estimated at \$100K. Additional capital costs would be required for the waste collection system. The operating cost is indicated above.

Authors: C. A. Foster/615-574-1128 and W. D. Nelson/615-574-0966

References:

1. Alpheus Cleaning Technologies, 9105 Milliken Ave., Rancho Cucamonga, Calif. 91730.
2. Cold Jet, 455 Wards Corner Rd., Loveland, Ohio 45140.
3. C. A. Foster, "Solid Deuterium Centrifuge Pellet Injector," *J. Vac. Sci. Tech. A*1(2), 952-958 (1983).
4. C. A. Foster, "Surface Impact Cleaning by High-Speed Cryogenic Pellets," *Second International Workshop on Solvent Substitution*, Phoenix, Ariz., December 10-13, 1991.
5. R. J. Dabolt, *Evaluation of Pelletized Carbon Dioxide as a Fluidized Abrasive Agent for Removal of Radioactive Contamination*, Document No. ER-89-002 (1989), Chem-Nuclear Systems, 220 Stoneridge Dr., Columbia, S.C. 29210.

EM Problem: Decommissioning

ORNL Problem: See Appendix B, lists A, B, C, E, and H

Problem Area/Constituents: See Appendix B, lists A, B, C, E, and H

Reference Requirements:

- Federal Facility Compliance Agreement for Oak Ridge Site
- Federal Facility Compliance Agreement for PCBs
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- Clean Water Act
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- DOE orders

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Subelement: Decontamination

Alternative: Mechanical surface substrate removal

Technology: Ice blasting. It is similar to other decontamination technologies that direct a high velocity stream of fine particles, such as shot, grit, cryogenic pellets, or plastic pellets, onto a surface to remove contamination. The contaminated wastewater generated by the melting ice particles is the controlling medium for the displaced contamination. The water must then be treated for discharge by processing in commercially available evaporators. The cleaning head may be manually moved about on the surfaces being decontaminated. Decontamination efficiency depends on the applicator translation speed, cleaning head distance from substrate, operating pressure, and geometric complexities of the substrate.

Status: Accepted. Ice blasting technology has been used recently for decontamination at the Oconee Nuclear Power Plant in Seneca, South Carolina. Decontamination testing was performed at ORNL.

Ice blasting will remove coatings and some fixed surface contamination, but it will not take off concrete to a significant depth. The waste produced is contaminated wastewater. The amount of wastewater generated depends upon the ice blasting rate. For example, a unit recently demonstrated at ORNL operated at 11 gal/h.

Science/Technology Needs: Remote-controlled operation of the cleaning head would be desirable. Also, in some applications (such as decontamination of hot cells), remote operation

will be required. Consequently, the adaptation of the equipment to a robotics control system would be necessary.

Implementation Needs: A commercially available evaporator will be required. Because of the low volume of water generated during operation, evaporation—and not recycle—will likely be more cost-effective. Capital costs, \$60K–\$90K for an evaporator. Remote operation will require the adaptation of the ice blasting and water collection systems to a robotics control system.

Development Costs: The cost of a robotics control system is estimated at \$250K (personal communication with C. E. Benson).

Deployment Costs: The capital cost of an ice blasting machine such as that used at a nuclear power plant, as mentioned above, would be \$155K. Operating costs for an ice blasting unit would primarily involve labor costs. Assuming a minimum two-person operation (at a labor rate of \$40K/year/person) of an ice blasting unit during the day shift, operating costs would be ~\$350/day. Training of personnel to operate the ice blasting equipment and the wastewater treatment system will be needed.

Author: J. H. Wilson/615-576-4413

References: C. E. Benson

EM Problem: Decommissioning

ORNL Problem: See Appendix B, lists A, B, C, E, F, and H

Problem Area/Constituents: See Appendix B, lists A, B, C, E, F, and H

Reference Requirements:

- Federal Facility Compliance Agreement for Oak Ridge Site
- Federal Facility Compliance Agreement for PCBs
- Clean Air Act
- Toxic Substance Control Act
- DOE orders

Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Decontamination

Alternative: Mechanical surface removal methods

Technology: Supercritical CO₂ blasting. Supercritical CO₂ (above its critical temperature of 87.8°F and at high pressure) is pressurized by an ultrahigh-pressure intensifier pump up to 55,000 psi and forced through nozzles, generating high velocity CO₂ jets at speeds up to 3,000 ft/s. The nozzles may be mounted in different cleaning heads for various contaminated surfaces. The CO₂ jets thoroughly penetrate and remove surface contaminants without damaging the healthy substrate. The removed contaminants, any of the substrate surface layer that may be removed, and the CO₂ are captured by a vacuum recovery system. In the recovery system, the substrate surface layer, if removed, and the contaminants are collected by a cyclone separator and a HEPA filter. The CO₂, now in the gaseous state, is discharged to the atmosphere or recovered and recycled to the supercritical cleaning step.

Status: Predemonstration. This technology is being developed by a private company. Similar to the ultrahigh-pressure water process, which has been demonstrated to remove the galvanized layer from sheet metal, the supercritical CO₂ technology should produce high levels of decontamination. The waste generated is the removed contaminants and the substrate surface layer collected in the vacuum recovery system. The CO₂ is either discharged to the atmosphere or recycled to the supercritical cleaning operation.

Science/Technology Needs: Evaluation of the effect of operating parameters (e.g., pressure, distance between nozzle and substrate, traversing speed of cleaning head) on the removal of various contaminants from different substrates is needed.

Implementation Needs: Development costs: The cost of a development program for the supercritical CO₂ blasting technology is estimated to be from \$250K-\$1M (Dave Monserud). Deployment costs: The capital cost of a commercial supercritical CO₂ cleaning unit is estimated to be \$150K (Dave Monserud). Operating costs for a supercritical CO₂ unit would primarily involve labor costs and cost of CO₂. Assuming a minimum two-person operation (at a labor rate of \$40K/year/person) of a CO₂ blasting unit during the day shift, labor costs would be approximately \$350/day. The cost of CO₂ will depend upon the blasting rate, which would be determined during the development phase of the technology. Other implementation needs include personnel training for operation of the supercritical CO₂ decontamination unit and vacuum recovery system and facilities for performing prototype cleaning operations for each decontamination project (personal communication with C. E. Benson).

Author: J. H. Wilson/615-574-4413

References:

1. MMES staff members, especially C. E. Benson.
2. Dave Monserud, FLOW International Corporation, Seattle, Wash.

EM Problem: Decommissioning

ORNL Problem:

Problem Area/Constituents: Capable of removing a wide variety of contaminants, including U, Tc, actinides, PCBs, oils, etc., from exterior surfaces of concrete, structural steel, metal equipment, Monel, copper, and aluminum

Reference Requirements:

- Federal Facility Compliance Agreements (e.g., FFCA for Oak Ridge Site)
- Applicable Federal and State laws and regulations (e.g., Clean Water Act and Toxic Substance Control Act)
- DOE orders

Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Decontamination

Alternative: Mechanical surface substrate removal

Technology: Plastic pellet blasting. A cleaning process similar to sand blasting that uses less abrasive plastic pellets.

Status: Demonstrated. Plastic pellet blasting is a widely used alternative to sand blasting for applications in which it is desirable to remove surface contamination or contaminated coatings while imparting minimal damage to the substrate.^{1,2} Cost of the media is high (\$1-\$2/lb) and pellet erosion can also be a factor, but cyclone systems are capable of recycling pellets up to thirty times for reuse. Cleaning rates of up to 4 ft²/min are quoted for a 1/2 in. nozzle at 30 psi with operating costs in the range of \$0.20-\$2.15/ft² or \$45-\$65/h using skilled labor.³ Plastic media has some advantages over grits, like sand and metal shot, in that it can more easily be separated from eroded metallic substrate and it can be disposed of by incineration, thus giving it the potential to significantly reduce waste disposal costs.

Science/Technology Needs: Technology improvement is needed in waste minimization related to blast media erosion and disposal; containment of waste; and demonstration of specific blast-media-substrate/contaminant capabilities, including determination of decontamination factors and process automation. Cost of a medium level demonstration facility involving about 6-8 PY will be about \$1.5M.

Implementation Needs: This technology, while developed and commercially available, will require a system for processing the waste. The device will generate contaminated dust, gases,

and/or fluids. This will require a system to separate and to package the contaminants. Cost of a pilot facility will be about \$4M. Application of the technology requires staff with technician training.

Author: J. H. Wilson/615-574-4413

References:

1. Stripping Technologies, 2949 E. Elvira Rd., Tucson, Ariz. 85706.
2. Progressive Blasting Systems, 4201 Patterson, SE, Grand Rapids, Mich. 49508.
3. K. E. Abott, *Plastic Media Blasting—The Maturing of the Technology*, 27th Annual Aerospace/Airline Plating & Metals Finishing Forum & Exposition, San Antonio, Tex., March 26-28, 1991.

EM Problem: Decommissioning

ORNL Problem: See Appendix B, lists A, B, C, E, and F

Problem Area/Constituents: See Appendix B, lists A, B, C, E, and F

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Decontamination

Alternative: Mechanical surface removal methods

Technology: Hand grinding, honing, scraping. Hand-held, power-driven grinding equipment is used to remove the surface from the contaminated object.

Status: Accepted. Grinding with hand-held power grinders has been successfully used for small-scale decontamination.¹

Waste produced—Surface layer of item being decontaminated, spent grinding media (such as emery paper), and the HEPA filters on the vacuum system.

Overall cost—Operating costs, ~\$1/ft²; capital costs, \$150K (\$5K with vacuum system).

Efficacy/strengths/weaknesses—Grinding is effective only on surface contamination.

Science/Technology Needs: None

Implementation Needs: Vacuum collection system with appropriate filters

Author: D. H. Bunch/615-576-0201

References: M. O. Beeler, telephone conversation with D. H. Bunch, June 16, 1992.

EM Problem: Decommissioning

ORNL Problem: See Appendix B, lists A, B, C, E, and H

Problem Area/Constituents: See Appendix B, lists A, B, C, E, and H

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Decontamination

Alternative: Mechanical surface removal methods

Technology: Automated grinding. Remotely-operated, power-driven grinding equipment with a manipulator for turning and moving the contaminated item is used to remove the top surface layer of the contaminated object.

Status: Conceptual. Grinding has been successfully used for small scale decontamination. This grinding was done with hand-held power grinders.¹ Remotely-operated grinding equipment is available,² but no references to its use for decontamination have been found.

Waste produced—The surface layer of the item being decontaminated plus the grinding media (such as emery paper).

Overall cost—Capital cost, \$250K-\$500K; development cost, \$600K

Efficacy/strengths/weaknesses—Grinding is effective on only surface contamination.

Science/Technology Needs: The applicability of this technology to items with rad contamination should be demonstrated.

Implementation Needs: Vacuum collection system with appropriate filters

Author: D. H. Bunch/615-576-0201

References:

1. M. O. Beeler, telephone conversation with D. H. Bunch, June 16, 1992.
2. Don Noll, Harry G. Movat Company, telephone conversation with D. H. Bunch, June 15, 1992.

EM Problem: Decommissioning

ORNL Problem: See Appendix B, list C

Problem Area/Constituents: See Appendix B, list C

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Decontamination

Alternative: Mechanical surface removal methods

Technology: Metal milling. A machine shaves off a layer of metal.

Status: Accepted. Milling has been used to decontaminate metal items.¹ This method is most suitable when there are many similar items to be decontaminated because there is a 1/2 to 3/4 h setup time required between differently shaped items.²

Waste produced—The top layer (up to 1/8 in.) of the metal would be chipped off.¹

Overall cost—Capital costs, ~\$150K; operating costs, ~\$17.50/ft²; Development cost, \$3M for remote operation

Efficacy/strengths/weaknesses—This method can remove only surface contamination.

Science/Technology Needs: Improvement—the technology to remotely operate this equipment needs to be developed and demonstrated.

Implementation Needs: The contaminated equipment must be removed and disassembled before this technology can be used.

Author: D. H. Bunch/615-576-0201

References:

1. M. A. Trisel, telephone conversation with D. H. Bunch, June 5, 1992.
2. N. F. Knueman and M. A. Trisel, personal communication to D. H. Bunch, June 12, 1992.

EM Problem: Decommissioning

ORNL Problem: See Appendix B, lists A, B, E, and F

Problem Area/Constituents: See Appendix B, lists A, B, E, and F

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Decontamination

Alternative: Mechanical surface removal methods

Technology: Concrete milling. A machine shaves away the top layer of the concrete. For large-area horizontal surfaces the large milling vehicles used by paving contractors would be employed. Smaller equipment is available for milling smaller areas.

Status: Conceptual. The equipment is commercially available, but no reference to its use for decontamination has been found.¹

Waste produced—The top 6–25 mm of the concrete is removed.¹

Overall cost—For large areas: Capital costs, \$50K–\$363K (this does not include the cost of trucks to haul away the debris); operating costs, \$0.5M–\$1.6M/mile.²

For small areas: Capital costs, \$11K;³ operating costs, \$0.75/ft².

Efficacy/strengths/weaknesses—This technology is only suited for horizontal surfaces.

Science/Technology Needs: Improvement—the technology to operate this equipment remotely needs to be developed and demonstrated.

Implementation Needs: Development costs, \$3M for remote operation

Author: D. H. Bunch/615-576-0201

References:

1. M. M. Barbier and C. V. Chester, "Decontamination of Large Horizontal Concrete Surfaces Outdoors," *Proc. of the Concrete Decontamination Workshop*, Richland, Wash., September 1980.
2. V. Chester, telephone conversation with D. H. Bunch, June 4, 1992.
3. John Summer, ASPC, Bellevue, Tenn. facsimile to D. H. Bunch, March 29, 1993.

EM Problem: Decommissioning

ORNL Problem: See Appendix B, lists A, B, E, and F

Problem Area/Constituents: See Appendix B, lists A, B, E, and F

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Decontamination

Alternative: Mechanical surface removal methods

Technology: Explosive. The top 3–4 in. of concrete are removed by detonating carefully placed and timed explosive charges.

Status: Accepted. Blasting has been used to decontaminate nuclear reactor shielding.¹ Demonstration may be needed for other applications.

Overall cost—Capital costs, \$50K; operating costs, \$50/ft²

Science/Technology Needs: Safety concerns need to be resolved; care must be taken to contain the dust and to prevent structural damage to the building being decontaminated and the surrounding structures.¹ Improvements in the methods of applying explosives and in the uniformity of the detonation are needed.² The explosion will generate toxic organic vapors.³ The technology to control these vapors must be developed and demonstrated.

Implementation Needs: A certified blasting technician will be needed.²

Development costs: \$1M–\$4M

Author: D. H. Bunch/615-576-0201

References:

1. T. S. Laguardia, "Concrete Decontamination and Demolition methods," *Proc. of the Concrete Decontamination Workshop*, Nuclear Energy Services, Inc., Pacific Northwest Laboratory, September 1980.
2. *Decontamination and Decommissioning Integrated Demonstration Strategy*, pp. 2–38, draft for review, November 1991.
3. John Googin, written comments on draft of *Oak Ridge K-25 Site Technology Logic Diagram*, November 1992.

EM Problem: Decommissioning

ORNL Problem: See Appendix B, Lists A, B, C, E, and H

Problem Area/Constituents: See Appendix B, Lists A, B, C, E, and H

Reference Requirements:

- Federal Facility Compliance Agreements (e.g., FFCA for the Oak Ridge Site)
- Applicable federal and state laws and regulations
- Clean Water Acts and Toxic Substance Control Act
- DOE orders.

Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Decontamination

Alternative: Surface cleaning (transferable contamination) methods

Technology: Compressed-air cryogenic CO₂ pellet blasting. Similar to traditional sandblasting except that pellets made of solid CO₂ (dry ice) are used instead of sand. Depending on the pellet impact velocity and the substrate material, the pellets clean by removing surface contamination or removing/etching the substrate. As in sandblasting, the surfaces to be decontaminated must be accessible to the blast nozzle.

Status: Demonstration. This technology is commercially available.^{1,2} It has been used at nuclear reactor sites to decontaminate hand tools and some equipment.³⁻⁶ With a person operating the "gun," it requires a few minutes to decontaminate a hand tool. The operation of the device is tiring to the operator so that either a remote manipulator or frequent rest periods would be required for large tasks or continuous use.

Since the dry ice pellets evaporate on contact, the secondary waste stream is minimized. The contamination "blasted" from the surface is collected via vacuum/HEPA filtration system, which is either a closely coupled shroud over the surface or a specially designed room air filtration system. The secondary wastes generated would be limited to the HEPA and rough filters. The technology is known to be effective at removing smearable contamination. The removal of fixed contamination depends on the nature of the bonding. The technology, for example, can remove paint and loose rust, but it is not aggressive enough to etch steel or remove black oxide from steel. Tests using a CO₂ system for decontamination are limited, but a fixed contamination reduction ratio of 3:1 was reported for concrete at a rate of 90 ft²/h and 5000:1 for angle iron at 10 ft²/h.³

Waste produced—This system uses large volumes of compressed air to accelerate CO₂ pellets. This air will need to be processed to extract primary waste components once the contaminating waste is mobilized.

Science/Technology Needs: Since the cleaning rate is a dominant factor in the cost, and it is highly variable, depending on the nature of the specific contaminant and surface material, more extensive tests need to be done to produce accurate cost estimates.

Implementation Needs: Waste handling, design, and construction of equipment to handle the waste stream is needed. Application of this technology requires staff with technician training. The operating cost of a typical unit is approximately \$160K. For a 100-kW unit at \$.06 kWh, energy costs would be \$6/h. Labor costs for a manually operated system would require two operators, alternating, at \$200/h. A remotely manipulated/robotics system could reduce labor costs by allowing multiple guns to be operated by one person. Manual operation would be \$216/h @ 100 ft²/h = \$2.0/ft²; 10 ft²/h = \$20/ft². A remote manipulator system with one operator and four guns would be \$164/h @ 400 ft²/h = \$0.41/ft²; @ 40 ft²/h = \$4.10/ft².

Authors: C. A. Foster/615-574-1128 and W. D. Nelson/615-574-0966

References:

1. Alpheus Cleaning Technologies, 9105 Milliken Ave., Rancho Cucamonga, Calif. 91730.
2. Cold Jet, 455 Wards Corner Rd. Loveland, Ohio 45140.
3. Chem Nuclear Systems, *Evaluation of Pelletized Carbon Dioxides a Fluidized Abrasive Agent for Removal of Radioactive Contamination*, April 1989.
4. Power Reactor and Nuclear Fuel Development Corporation, "Overview and Strategy for Managing TRU Waste," PNC/DOE/PNC Specialist Meeting, October 17-18, 1989.
5. Environmental Alternatives: Summary and Analysis for a Carbon Dioxide Blasting Demonstration at Georgia Power Company, Hatch Station.
6. TTI Engineering, "Report on Nondestructive Cleaning Decontamination Facility at Surry Power Station," November 1990, Seminar viewgraphs from seminar held March 22, 1991.

EM Problem: Decommissioning

ORNL Problem: See Appendix B, lists A, C, and E

Problem Area/Constituents: See Appendix B, lists A, C, and E

Reference Requirements:

- Federal Facility Compliance Agreement for Oak Ridge Site
- Federal Facility Compliance Agreement for PCBs
- Clean Air Act
- Clean Water Act
- Toxic Substance Control Act
- DOE orders

Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Decontamination

Alternative: Surface cleaning (transferable contamination) methods

Technology: High-pressure water (5,000–20,000 psig). Blasting of surfaces with high pressure water will remove deposits that are tightly adhered to substrate materials. Water pressure at the nozzle of commercially available high-pressure blasting systems is typically 5,000–20,000 psig, and flow rates vary from 4 to >100 gpm. When used with chemical additives, this technique can be effective for decontaminating piping trays, overhead surfaces, upper regions of walls, gratings, pumps, and similar items. However, splashing from blast operations can be extensive and result in recontamination if precautions are not taken. In the use of this decontamination technology, the high-pressure-water cleaning head may be manually moved on the surfaces being decontaminated. Because the decontamination efficiency depends on the applicator translation speed, as well as on other operating parameters, remote operation of the high-pressure-water cleaning head would be desirable. Also, in some applications (such as decontamination of hot cells), remote operation will be required. Consequently, the adaptation of the equipment to a robotics control system would be necessary.

Status: Accepted. High-pressure water blasting has been used very successfully to decontaminate various large and complex surfaces at nuclear power plants. These include coolant pump impellers and cavities, fuel storage racks and handling equipment, floor drains and sumps, reactor cavity walls, pipes, and valves. When used as a preliminary step to wiping or scrubbing activities, decontamination factors (DFs) in the range of 50 are commonly achieved for loosely deposited and loosely adherent contamination. Experience has

demonstrated that blasting effectiveness becomes negligible when the cleaning nozzle tip is more than 10-12 in. away from the surface being cleaned. However, before acceptance at ORNL and other DOE sites, the issues of wastewater treatment and prevention of spread of contamination must be addressed. The waste generated is the contaminated water from the cleaning operation. The waste production rate is essentially the same as the water rate in the cleaning step, which can range from 4-100 gpm.

Science/Technology Needs: To minimize waste generation, a water treatment system is needed to decontaminate the wastewater so that the water can be recycled and reused in the high-pressure water cleaning operation. Remote operation will necessitate the adaptation of the mobile high-pressure water and vacuum collection systems to a robotics control system.

Implementation Needs: Development costs: For development and demonstration of a water recycle system, in combination with high-pressure water decontamination, an estimate of funding requirements is \$1.2M. Personnel requirements are estimated to be \$1.7M (approximately 50% engineer and 50% technician time) and 4.1 FTEs (approximately 10% P&E, 45% engineer, and 45% technician time) for FY 93 and FY 94, respectively. The cost of a robotics control system is estimated at \$250K. This is based on the cost of a system that is available from the Remotek Company. Estimated cost of a glove box is <\$50K; work room, >\$250K. Operating cost will be \$0.06-\$2/ft².

Deployment costs: The capital cost of a high-pressure water cleaning unit will be \$50K-\$75K.

Operating costs: A high-pressure water cleaning unit would primarily involve labor costs. Assuming a minimum two-person operation (at a labor rate of \$40K/year/person) during the day shift, operating costs would be approximately \$350/day. Personnel training for operation of a high-pressure water unit and a water treatment and recycle system would be required.

Author: J. H. Wilson/615-574-4413

References: MMES staff members.

EM Problem: Decommissioning

ORNL Problem: See Appendix B, lists A, C, E, and H

Problem Area/Constituents: See Appendix B, lists A, C, E, and H

Reference Requirements:

- Federal Facility Compliance Agreement for Oak Ridge Site
- Federal Facility Compliance Agreement for PCBs
- Clean Air Act
- Clean Water Act
- Toxic Substance Control Act
- DOE orders

Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Decontamination

Alternative: Surface cleaning (transferable contamination) methods

Technology: Superheated water (e.g., at conditions of 300 psi and 300°F). Directed as a high velocity stream on a surface to remove contamination. The contaminated wastewater that is must be treated for discharge or for recycle back to the operation. The superheated water cleaning head may be manually moved about on the surfaces being decontaminated. Also, a hand-held wand may be more conveniently used for vertical surfaces, equipment surfaces, etc. Because the decontamination efficiency depends on the applicator translation speed, as well as on other operating parameters, remote operation of the superheated water cleaning head would be desirable. Also, in some applications (such as decontamination of hot cells), remote operation will be required. Consequently, the adaptation of the equipment to a robotic control system would be necessary.

Status: Accepted. Technology is available and has been used by industry. However, before acceptance at ORNL and other DOE sites, the issues of wastewater treatment and prevention of spread of contamination must be addressed. Because of the relatively low operating pressures (as compared to ultrahigh-pressure water at 30,000–50,000 psi), superheated water will only remove surface contamination that is soluble or loosely bound to the surface. In these cases, the decontamination efficiency should be high. However, for tightly bound or imbedded surface contamination, removal may be insignificant. The waste generated is the contaminated water from the cleaning operation. The wastewater generation rate for a typical commercial unit ranges from 0.4–2 gpm.

Science/Technology Needs: To minimize waste generation, a water treatment system is needed to decontaminate the wastewater so that the water can be recycled and reused in the superheated water cleaning operation. Remote operation will necessitate the adaptation of the mobile cleaning and vacuum collection system to a robotic control system.

Implementation Needs: Development costs: For development and demonstration of a water recycle system, in combination with superheated water decontamination, an estimate of funding requirements is \$1.2M. Personnel requirements are estimated to be \$1.7M (approximately 50% engineer and 50% technician time) and 4.1 FTEs (approximately 10% P&E, 45% engineer, and 45% technician time) for FY 93 and FY 94, respectively. The cost of a robotic control system is estimated at \$250K. This is based on the cost of a system that is available from a private company.

Deployment costs: The capital cost of a basic unit (spray-vacuum cleaning system) is \$175K. Various attachments are available for specialty cleaning.

Operating costs: A superheated water cleaning unit would primarily involve labor costs. Assuming a minimum two-person operation (at a labor rate of \$40K/year/person) of a cleaning unit during the day shift, operating costs would be approximately \$350/day. Training of personnel for operation of the superheated water cleaning unit and the wastewater treatment system will be needed. Other capital costs include <\$50K for a glove box and >\$250K for a work room. Operating costs will be \$0.05-\$2/ft².

Author: J. H. Wilson/615-574-4413

References: MMES staff members.

EM Problem: Decommissioning

ORNL Problem: See Appendix B, lists A, B, C, E, F, and H

Problem Area/Constituents: See Appendix B, lists A, C, E, and H

Reference Requirements:

- Federal Facility Compliance Agreement for Oak Ridge Site
- Federal Facility Compliance Agreement for PCBs
- Clean Air Act
- Clean Water Act
- Toxic Substance Control Act
- DOE orders

Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Decontamination

Alternative: Surface cleaning (transferable contamination) methods

Technology: Water flushing. Low-pressure, hot- or cold-water flushing is used to dissolve readily soluble contaminants or flush loosely deposited particles to a central area for collection by flushing.

Status: Accepted. Flushing with hot or cold water is often used following scrubbing, especially on floors, or as a pretreatment for other decontamination processes. The effectiveness of flushing is enhanced by the use of squeegees to force the water and contaminants to collection or drain areas. The technique is not effective on fixed, nonsoluble contamination but should be effective for exterior (transferable) contamination. The waste generated is the contaminated water from the flushing operation.

Large quantities of liquid waste are produced that may contain particulates or soluble radionuclides. Even though water flush decontamination is used extensively at most DOE plants, data regarding costs is not available. Costs for processing low-level liquid waste and process waste at ORNL are \$10/gal and \$0.08/gal, respectively. Decontamination factors depend on the nature of the contaminant and the amount of water used.

Science/Technology Needs: To minimize waste generation, a water treatment system is needed to decontaminate the wastewater so that the water can be recycled and reused in the water flushing operation.

Implementation Needs: Development costs: For development and demonstration of a water recycle system, in combination with water flushing, an estimate of funding requirements is \$1.2M. Personnel requirements are estimated to be \$1.7M (approximately 50% engineer and 50% technician time) and 4.1 FTEs (approximately 10% P&E, 45% engineer, and 45% technician time) for FY 1993 and FY 1994, respectively.

Deployment costs: Capital costs for water flushing will be <\$5K. Operating costs for a water flushing unit would primarily involve labor costs. Assuming a minimum two-person operation (at a labor rate of \$40K/year/person) during the day shift, operating costs would be approximately \$350/day or <\$1/ft².

Authors: J. R. DeVore/615-574-7092

References: MMES staff members.

EM Problem: Decommissioning

ORNL Problem: See Appendix B, lists A, C, E, and H

Problem Area/Constituents: See Appendix B, lists A, C, E, and H

Reference Requirements:

- Federal Facility Compliance Agreement for Oak Ridge Site
- Federal Facility Compliance Agreement for PCBs
- Clean Air Act
- Clean Water Act
- Toxic Substance Control Act
- DOE orders

Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Decontamination

Alternative: Surface cleaning (transferable contamination) methods

Technology: Steam cleaning. Combines the solvent action of water with the kinetic energy effect of blasting. At relatively high temperatures, the solvent action is increased and the water volume requirements are reduced (compared to water blasting). The steam cleaning head may be manually moved about on the surfaces being decontaminated. Also, a hand-held wand may be more convenient to use on vertical surfaces, equipment surfaces, etc. Because the decontamination efficiency depends on the applicator translation speed, as well as on other operating parameters, remote operation of the steam cleaning head would be desirable. Some applications (such as decontamination of hot cells) will require remote operation. Consequently, the adaptation of the equipment to a robotics control system would be necessary.

Status: Accepted. The technique has proven useful, especially on complex shapes and large surfaces. Good results can be obtained for surface decontamination with minimum rad waste volumes. Steam cleaning is quite effective for encrusted salt formations where leakage of chemically treated water has occurred. However, before acceptance at ORNL and other DOE sites, the issues of wastewater treatment and prevention of the spread of contamination must be addressed. The waste generated is the contaminated condensed steam from the cleaning operation.

Efficacy:—Not expected to be effective for removing fixed contamination on equipment interiors. Effectiveness for removing transferable contamination must be demonstrated.

Science/Technology Needs: To minimize waste generation, a water treatment system is needed for decontamination of the wastewater so that the water can be recycled and reused in the steam cleaning operation. Remote operation will require the adaptation of the mobile heating and vacuum collection systems to a robotics control system.

Implementation Needs: Development costs: For development and demonstration of a water recycle system, in combination with steam decontamination, an estimate of funding requirements is \$1.2M. Personnel requirements are estimated to be \$1.7M (approximately 50% engineer and 50% technician time) and 4.1 FTEs (approximately 10% P&E, 45% engineer, and 45% technician time) for FY 1993 and FY 1994, respectively. The cost of a robotics control system is estimated at \$250K. This is based on the cost of a system that is available from the Remotek Company.

Deployment costs: The capital cost of a steam cleaning unit will be \$50K–\$75K. Operating costs for a steam cleaning unit would primarily involve labor costs. Assuming a minimum two-person operation (at a labor rate of \$40K/year/person) of a steam cleaning unit during the day shift, operating costs would be approximately \$350/day or \$0.05–\$2/ft². Personnel training for operation of a steam cleaning unit and water recycle system will be needed. Capital costs, <\$50K for glove box and ~\$250K for work room.

Author: J. H. Wilson/615-574-4413

References: MMES staff members, especially C. E. Benson.

HAND BRUSHING USED TO REMOVE SURFACE CONTAMINATION

DCON-56-OL

EM Problem: Decommissioning

ORNL Problem: See Appendix B, lists A, C, and E

Problem Area/Constituents: See Appendix B, lists A, C, and E

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Decontamination

Alternative: Surface cleaning methods

Technology: Hand brushing used to remove surface contamination. Hand brushes are used to remove surface contamination

Status: Accepted. Brushing is a common decontamination technique.¹

Waste produced—HEPA filters on the vacuum cleaner used to pick up the particles generated by brushing and the worn brushes

Overall cost—Capital costs, negligible; operating costs, \$1/ft²

Efficacy/strengths/weaknesses—Brushing is effective for smearable contamination and less effective for fixed contamination.²

Science/Technology Needs: None

Implementation Needs: Disassembly of contaminated equipment

Author: D. H. Bunch/615-576-0201

References:

1. Paul Osbourne, telephone conversation with D. H. Bunch, August 10, 1992.
2. R. P. Allen, "Overview of Nonchemical Decontamination Techniques," *American Nuclear Society Executive Conference on Decontamination Techniques*, CONF-840956, September 1984.

September 1993

EM Problem: Decommissioning

ORNL Problem: See Appendix B, lists A, C, E, and H

Problem Area/Constituents: See Appendix B, lists A, C, E, and H

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Decontamination

Alternative: Surface cleaning methods

Technology: Automated brushing. Power-driven brushes are used to remove smearable contamination

Status: Demonstration. This technology has been used at Rocky Flats to remove plutonium contamination from the inside of pipes.¹ Tests would be needed to demonstrate its effectiveness for other contaminants on other substrates.

Waste produced—The HEPA filters on the vacuums used to pick up the particles of contamination and the worn brushes

Efficacy/strengths/weaknesses—Brushing is effective for smearable contamination and less effective for fixed contamination. The interior of the pipes at Rocky flats was cleaned to shiny metal.¹

Science/Technology Needs: Test to demonstrate that this technology is effective for the problems at ORNL.

Implementation Needs: Development costs, \$200K-\$1M

Overall cost—Capital costs, \$250K (remotely operated system); operating costs, \$300/linear foot of pipe¹

Author: D. H. Bunch/615-576-0201

References: T. Karas, Rocky Flats, telephone conversation with D. H. Bunch, May 13, 1993.

EM Problem: Decommissioning

ORNL Problem: See Appendix B, lists A, C, and E

Problem Area/Constituents: See Appendix B, lists A, C, and E

Reference Requirements:

- Federal Facility Compliance Agreement for Oak Ridge Site
- Federal Facility Compliance Agreement for PCBs
- Clean Air Act
- Clean Water Act
- Toxic Substance Control Act
- DOE orders

Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Decontamination

Alternative: Surface cleaning (transferable contamination) methods

Technology: Sponge blasting. Using 110 psig air as the propellant, the Sponge-Jet system decontaminates by blasting surfaces with various grades of patented water-based urethane foam cleaning media. The foam may be used dry or wetted for a variety of surface contaminants such as oils, greases, lead compounds, chemicals, and radionuclides. The following two types of foam cleaning media are used: (1) a nonaggressive grade that is used for surface cleaning of sensitive or otherwise critical surfaces, and (2) aggressive grades that are impregnated with abrasives that can remove tough materials such as paints, protective coatings, and rust (it can also roughen concrete and metallic surfaces if desired). The cleaning heads of the Sponge-Jet unit are similar to those of other blasting technologies and could be readily adapted to a robotic control system. Robotic control is required in applications where workers could be exposed to unacceptable levels of contamination.

Status: Accepted. The technology is relatively new. It is currently being used by a company in Tennessee that produces projectiles containing uranium and by a nuclear power plant in Pennsylvania. Extensive data on decontamination factors are not available. Foam blasting media are recyclable in a closed-cycle wash unit that centrifugally launders the cleaning media. The media typically can be recycled eight to ten times. On the first time through, the sponge blasting unit uses 6–8 ft³ of media per hour at a surface cleaning rate of about 1 ft²/min. Thus, the solid waste produced (foam media with the absorbed contaminants) is approximately 0.01 ft³/ft² of surface cleaned. For waste minimization purposes, the contaminated washwater from the wash unit can be treated and recycled.

Science/Technology Needs: To minimize waste generation, a water treatment system is needed to decontaminate the wastewater so that the water can be recycled and reused in the sponge blasting operation. The system must be capable of treating the contaminants specific to the site and reducing their concentrations to allowable levels for water recycle. Remote operation will require the adaptation of the cleaning heads to a robotic control system.

Implementation Needs: Development costs: The cost of a robotic control system is estimated at \$250K Remotek Company (personal communication with C. E. Benson). For development and demonstration of a water recycle system in combination with sponge blasting, an estimate of funding requirements is \$1.2M. Personnel requirements are estimated to be \$1.7M (approximately 50% engineer and 50% technician time) and 41 FTEs (approximately 10% P&E, 45% engineer, and 45% technician time) for FY93 and FY94, respectively.

Deployment costs: Operating costs for a sponge blasting unit would primarily involve labor and material costs. Assuming a minimum two-person operation (at a labor rate of \$40K/year/person) of a blasting unit during the day shift, labor costs would be approximately \$350/day. A conservative estimate of blasting media material costs is \$70/h. Based on an eight hour day with about 75% operating time, operating costs would be approximately \$2/ft² of surface cleaned. The capital cost of a standard sponge blasting unit is \$13K. A sifter unit, used to separate the used blasting media from debris such as paint flakes, rust particles, etc., costs \$6K. The blasting media wash unit is not standard and is designed for each specific application.

Author: J. H. Wilson\615-574-4413

References: J. R. Cavallo, Sponge-Jet, Inc., 10 Grove St., P.O. Box 206, Dover, N.C., 03820
Phone: 603-742-8350.

EM Problem: Decommissioning

ORNL Problem: See Appendix B, list H

Problem Area/Constituents: See Appendix H. None of the ORNL surface cleaning problems with asphalt contamination with C, H, O, P. seems directly applicable to thermal treatment by hot air. Contaminated PCBs could conceivably be removed from surfaces; however, the large-scale containment, separation, condensation, and ultimate disposal present insurmountable obstacles at present for planning realistic evaluations.

Reference Requirements:

- Federal Facility Compliance Agreements (e.g., FFCA for Oak Ridge Site and FFCA for PCBs)
- Applicable federal and state laws and regulations (e.g., Clean Air Act and Toxic Substance Control Act)
- DOE orders

Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Decontamination

Alternatives: Surface cleaning and bulk decontamination methods

Technology: Hot air stripping. There is no known or proposed use of the hot air stripping process to directly treat any of the ORNL decontamination and decommissioning substrates and contaminants. The basic air-stripping technology is well known for volatiles in liquids, and many commercial designs are readily available if secondary treatment or effluent is required. Any released contaminants would likely stay with the volatiles of the asphalt.

Status: Evolving. Currently at the problem definition stage. What the technology should do needs to be determined.

Waste produced—Since no significant substrate will be removed, there is the potential to minimize waste volume.

Overall cost—Too early to define

Efficacy/strengths/weaknesses—See above

Science/Technology Needs: Specific needs depend on specific secondary treatment requirements.

Implementation Needs: These would depend on the concentration and condition of the secondary decontamination wastes.

Author: R. B. Alderfer/615-576-0225

References: MMES staff members.

EM Problem: Decommissioning

ORNL Problem: See Appendix B, list H

Problem Area/Constituents: Internal pipe sections including stainless, carbon steel, INOR-8 alloy, aluminum, and copper materials contaminated with uranyl sulfate, F.P., C.P., Cs-137, Sr-90, U, Th, M.S., TlF₃, contamination levels range from 1-100 R/h.

Reference Requirements:

- Federal Facility Compliance Agreements (e.g., FFCA for Oak Ridge Site)
- Applicable federal and state laws and regulations (e.g., Clean Air Act and Toxic Substance Control Act)
- DOE orders

Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Decontamination

Alternative: Surface cleaning methods

Technology: Dry heat roasting. The technology is simple in concept and well developed and accepted by industry. Its application in surface decontamination has not been demonstrated.

Status: Evolving. Currently at the problem definition stage. It must be determined what the technology will do.

Waste produced—Because no substrate is removed, the waste could potentially be minimal.

Overall cost—Too early to calculate

Efficacy/strengths/weaknesses—Collection of volatiles and their processing represents a major technological hurdle.

Science/Technology Needs: Technology improvement needs would include pilot studies of specific solutions needing treatment and comparison to other alternatives.

Implementation Needs: This technology is not appropriate at this time because none of the ORNL problem substrates needing treatment are applicable to dry heat decontamination.

Author: R. B. Alderfer/615-576-0225

References: MMES staff members.

SOLVENT WASHING TO REMOVE RADIOLOGICAL CONTAMINATION

DCON-61-OL

EM Problem: Decommissioning

ORNL Problem: See Appendix B, lists A, B, C, E, F, and H

Problem Area/Constituents: See Appendix B, lists A, B, C, E, F, and H

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Decontamination

Alternative: Chemical surface cleaning methods

Technology: Solvent washing to remove radiological contamination. Contaminated items are washed in solvent. An automated system is used to spray and recover the solvent.

Status: Conceptual

Waste produced—Only the surface material removed.¹

Overall cost—\$300K (1980 dollars). Development costs, ~\$1M to identify and demonstrate the replacement solvent. Labor costs, an average of 7.5 min/item was required when decontaminating small items such as pipe wrenches, vise grips, and lard cans.² Plutonium-contaminated items at Richland, Washington, were rinsed with Freon.³ Solvents that are less damaging to the environment need to be identified and demonstrated.⁴ The vendor who supplied the equipment for Richland ten years ago no longer sells it.⁵

Efficacy/strengths/weaknesses—This technique is mainly applicable to smearable contamination.⁶

Science/Technology Needs: Solvents that are less damaging to the environment need to be identified and demonstrated.

Implementation Needs: Nothing unusual

Author: D. H. Bunch/615-576-0201. Reviewed by J. R. DeVore/615-574-7092

References:

1. C. E. Wilson, "High Pressure Freon Decontamination of Remote Equipment," Proceedings of the International Topical Meeting on Remote Systems and Robotics In Hostile Environments, American Nuclear Society, 1987.

September 1993

**SOLVENT WASHING TO REMOVE
RADIOLOGICAL CONTAMINATION**

DCON-61-OL

2. Decontamination and Decommissioning Integrated Demonstration Strategy (draft for review), November 1991.
3. R P. Allen, telephone conversation with D. H. Bunch, June 17, 1992. Decontamination and Decommissioning Integrated Demonstration Strategy (Draft for Review), November 1991.
4. D. E. Fowler, Telephone conversation with D. H. Bunch, June 5, 1992.
5. R P. Allen, "Overview of Nonchemical Decontamination Techniques," PNL-SA-12562, p. 7, September 1984.
6. Richard P. Allen, H. W. Arrowsmith, and M. W. McCoy, "New Decontamination Technologies for Environmental Applications," Environmental Decontamination, Proceedings of the workshop, December 4-5, 1979, Oak Ridge, Tenn., CONF-791234, February 1981.

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SOLVENT WASHING TO REMOVE ORGANICS

DCON-62-OL

EM Problem: Decommissioning

ORNL Problem: See Appendix B, lists C and H

Problem Area/Constituents: See Appendix B, lists C and H

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Decontamination

Alternative: Chemical surface cleaning methods

Technology: Solvent washing to remove organics

Status: Conceptual

Waste produced—Solvent degreasing was used successfully at the K-25 Site, but its use was stopped to avoid exposing the workers and the environment to the hazardous solvents. Other solvents might be available, but their effectiveness would have to be demonstrated.¹ Maintenance mechanics have used degreasing equipment at the K-25 Site.

Overall cost—\$400K (1992 dollars) for a 4000-lb capacity unit. Labor costs, one operator for one hour to load, clean, and unload 4000-lb of metal.²

Efficacy/strengths/weaknesses—This equipment is produced by a number of manufacturers³ and its use for removing organic surface contamination is common in a variety of industries.¹

Science/Technology Needs: Solvents that are less damaging to the environment need to be identified and demonstrated.

Implementation Needs: Not applicable

Author: D. H. Bunch/615-576-0201. Reviewed by J. R. DeVore/615-574-7092

References:

1. Bruce Walker, personal communication to D. H. Bunch, June 5, 1992.
2. David West, Durr Corp., phone conversation with D. H. Bunch, June 8, 1992.
3. Thomas Register of American Manufacturers, Thomas Publishing Company, N.Y., pp. 7651-7663, 1992.

EM Problem: Decommissioning

ORNL Problem: See Appendix B, lists A, C, and E

Problem Area/Constituents: See Appendix B, lists A, C, and E

Reference Requirements:

- Federal Facility Compliance Agreement for Oak Ridge Site
- Federal Facility Compliance Agreement for PCBs
- Clean Air Act
- Toxic Substance Control Act
- DOE orders

Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Decontamination

Alternative: Surface cleaning (transferable contamination) methods

Technology: Strippable coatings. A coating, such as a water-based organic polymer, is applied to a contaminated surface by methods such as spraying, brushing, and rolling (as may be used for paint). When the coating dries, it is either manually stripped from the surface or, in the case of "auto-release" coatings, it is collected by vacuuming. The surface contamination is removed with the coating, producing a dry, hard, nonairborne waste product. Water-based strippable coatings are intended for use in decontaminating smooth and semirough porous surfaces, including steel, concrete, aluminum, wood, and painted surfaces.

Status: Accepted. The technology has been used for decontamination purposes in applications involving hazardous and/or radioactive contaminants. The waste product is the solid polymer that contains the removed contaminants. Typical coverages would be 50 ft²/gal of polymer. Strippable coatings are very effective. However, the application and removal times are relatively long in some instances, the cost of materials is high, and the radioactive waste aspects for disposal must be carefully considered. Most commercial strippable coatings may be incinerated.

Science/Technology Needs: A potential area of improvement for strippable coatings is the reduction of material costs.

Implementation Needs: Development costs: The technology needs listed above for strippable coatings are rather general. The costs of such improvements to the companies supplying the coatings would be difficult to estimate.

Deployment costs: The cost of a spray unit for applying strippable coatings is <\$10k. The cost of the polymer is \$50-\$70/gal. At the coverage stated above, the cost of materials per unit area of contaminated surface would be \$1-\$1.40/ft².

Author: J. H. Wilson/615-574-4413

References: MMES staff members.

EM Problem: Decommissioning

ORNL Problem: General: areas with loose contamination

Problem Area/Constituents: See Appendix B, lists A, B, C, E, and G

Reference Requirements:

- Federal Facility Compliance Agreements (e.g., FFCA for Oak Ridge Site and FFCA for PCBs).
- Applicable federal and state laws and regulations (e.g., Clean Air Act and Toxic Substance Control Act)
- DOE orders

Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Decontamination

Alternative: Surface decontamination methods

Technology: Vacuum cleaning. Use of a vacuum cleaner to remove, by air entrainment, loosely adhering contamination

Status: It is widely accepted by industry for removing loose solid contaminants. When solids are present in significant amounts but are not loose, they may be broken free by hand scraping or more automated means and then vacuumed by a HEPA filtration vacuum systems. Dust-laden areas are also good candidates where the possibility of contamination exists.

Science/Technology Needs: Development—Cleanable, reusable prefilters and HEPA filters should be developed to minimize wastes.

Implementation Needs: Disassembly of contaminated equipment and possible prior loosening of the deposits using another technology are needed to use this technology.

Capital cost, <\$10K; operating cost, >\$1/ft²

Author: R. B. Alderfer/615-576-0225 and J. H. Wilson/615-576-4413

References: MMES staff members.

EM Problem: Decommissioning

ORNL Problem: See Appendix B, List C

Problem Area/Constituents: See Appendix B, List C

Reference Requirements:

- FFCA for K-25 Site
- RCRA and TSCA regulations as applied to solvents used in washing and organic contaminants on the metal surfaces (oils, PCB, etc.)
- NRC NUREG 1.86 as applied to release standards for radioactive surface contamination

Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Decontamination

Alternative: Surface cleaning (transferable contamination) methods

Technology: Ultrasonic cleaning. It uses the scrubbing action of liquid excited by ultrasonic frequencies to remove surface deposits of oils, organics, and loosely bound solids from metals, plastic, glass, and other solids. It produces no abrasion, distortion, or changes in most solids and is ideally suited for delicate or valuable parts and materials that are to be reused.

Status: Accepted. The cost of application is high compared to that of other decontamination methods. The cost is greater than \$2/ft² and it may exceed \$10/ft².

Ultrasonic cleaning has been used for many years in the private sector and government installations for removing surface contamination from relatively small metal parts that can fit into an ultrasonic bath. This technology has been demonstrated on a plant scale at Y-12 for the past 4 years as a substitute for solvent washing. Initial funding was provided by HAZWRAP and DOE-ALO. Ultrasonic Cleaning is not used at ORNL on a large scale. The technology will work well for loosely bound surface deposits such as dust, dirt, organic, oils, PCBs, etc., on metal equipment, sheet metal, and solid depleted uranium. The technique is not practical for large items that would require size reduction. It is ineffective for tightly bound materials such as paints, varnishes, and other materials that are difficult to remove. The technique may generate secondary wastes that are expensive to manage (such as solvent and detergent solutions requiring processing). The technique is intended for valuable parts which could be recycled "as is" after cleaning. The technique is also good for removing deposits in difficult-to-access places, and it may be useful for electronic parts and electric motors.

Science/Technology Needs: Technology development needs to include definition of acceptable cleaning liquids that (1) are not hazardous, (2) can be separated from the contaminants, and (3) can be reused to minimize secondary wastes. Technology improvements should include more aggressive cleaning action.

Implementation Needs: The technology is sufficiently mature to be used in most decontamination and decommissioning (D&D) applications without the need for additional personnel and educational investments. Investment in means to produce a more aggressive cleaning action may be cost effective and could likely be accomplished on a pilot scale for about \$1M. If the needs for more aggressive cleaning within the DOE D&D were great enough, private suppliers of ultrasonic equipment would likely bear the cost of its development. Capital costs, \$10K-\$100K; operating costs, \$2-\$10/ft² or more.

Author: J. M. Kennerly/615-574-9935. Reviewed by E. B. Munday/615-576-5806

References:

1. L. M. Thompson, R. F. Samandl, and H. L. Richards, "Solutions for the Chlorinated Solvent Debacle, " YDB 904, Rev. 1.
2. L. M. Thompson and R. F. Samandl, "Ultrasonic Aqueous Cleaning as a Replacement for Chlorinated Solvent Cleaning," report in preparation.

EM Problem: Decommissioning

ORNL Problem: See Appendix B, lists A, B, and E

Problem Area/Constituents: See Appendix B, lists A, B, and E

Reference Requirements:

- Federal Facility Compliance Agreement for Oak Ridge Site
- Federal Facility Compliance Agreement for PCBs
- Clean Air Act
- Toxic Substance Control Act
- DOE orders

Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Decontamination

Alternatives: Thermal surface and substrate removal methods

Technology: Microwave scabbling. This technology directs microwave energy at a concrete surface, using a specialized waveguide applicator, and heats the concrete and free water present in the concrete matrix. Continued heating produces thermal- and steam-pressure-induced mechanical stresses that cause the concrete surface to burst. The concrete particles from this steam explosion are small enough to be removed by a vacuum system, yet less than 1% of the debris is small enough to pose an airborne contamination hazard. The process is fast, dry, generates little dust, and avoids mechanical impacts. The microwave applicator head may be manually moved about on the concrete surfaces being decontaminated. Because the rate and depth of surface removal depend on the applicator translation speed, remote operation of the mobile microwave equipment would be desirable. Also, in some applications (such as decontamination of hot cells), remote operation will be required. Consequently, the adaptation of the equipment to a robotics control system would be necessary.

Status: Predemonstration. In FY 1991, ORNL demonstrated¹ reliable removal of noncontaminated concrete surfaces using microwave energy. At microwave frequencies of 2.45 GHz and 10.6 GHz, continuous concrete removal rates of 1.1 cm³/s at 5.2 kW and 2.1 cm³/s at 3.6 kW, respectively, were obtained. Removal rate and removal depth are controlled by choosing the proper frequency and varying the power and translation speed of the applicator on the concrete surface. Higher frequencies preferentially remove surface contamination. A mobile prototype microwave concrete removal machine is being built at ORNL during FY 1992-FY 1993. A rugged, compact, and electrically efficient microwave applicator that is better integrated with the required concrete debris collection system is

being developed.² In 1987, a group from Japan reported on a mobile microwave decontaminator that could perform removal at a rate of $11 \text{ cm}^3/\text{s}$.³ This removal rate was equal to that of the fastest commercial mechanical concrete breaking machines. It is anticipated that, with an upgrade of power and improvements to the applicator design to spread out the microwave power in a larger area, concrete removal rates comparable to or exceeding those obtained with conventional concrete removal equipment can be achieved.⁴ The microwave technique is a dry process that generates little dust and avoids the need to work when the concrete surfaces are wet. Because microwave scabbling removes the contaminated concrete surface, the decontamination efficiency should be 100% if there is no recontamination from the removed scabble. The waste generated is concrete rubble that has particle diameters lying primarily in the range of 1–10 mm. The quantity of waste generated depends upon the translation speed of the microwave applicator and the depth of the concrete surface layer that is removed. For example, for a removal depth of 10 mm and a surface area treatment rate of $1 \text{ ft}^2/\text{min.}$, 150 lb/h of concrete waste would be generated.

Science/Technology Needs: The development and testing of a mobile prototype microwave concrete removal machine needs to be completed (TTP No. OR-3DAA; DOE No. OR-1012-04). Significant improvements in concrete removal rates and efficiencies can be achieved by modeling the microwave scabbling process as an unsteady, three-dimensional, finite-element, nonlinear, thermal and mechanical stress problem. Because the microwave absorption properties of concrete are critically dependent on temperature and frequency, the frequency and temperature dependent dielectric properties of concrete are being measured and the data will be used in a one-dimensional model developed at Florida International University to characterize the stresses generated in the concrete under the conditions of rapid microwave heating.^{5,6} Extensions of this work to three dimensions will follow. Remote operation will necessitate the adaptation of the mobile microwave and vacuum collection systems to a robotics control system. In addition, the development of real-time monitoring sensors for measuring the progress of the decontamination process is needed so that only the contaminated portion of the concrete is removed, thus minimizing the amount of waste produced.

Technical Task Plans OR101112 (FY 1992); relevance: high
 OR101107 (FY 1992); relevance: high

Implementation Needs: Development costs: The cost for development and testing of a mobile prototype microwave concrete removal machine is estimated to be \$2.5M for FY 1993–1995.² The personnel requirements are 2.5 FTEs per year (50% technical, 50% support personnel). The cost of a robotics control system is estimated at \$250K. This is based on the cost of a system that is available from the Remotek Company (personal communication with C. E. Benson).

Deployment costs: A credible estimate of capital cost for a microwave scabblers unit cannot be made until a prototype unit has been developed and demonstrated. Operating costs for a scabblers would primarily include power and labor costs. Assuming a two-person (at a labor rate of \$40K/year/person) operation of a 100-kW unit at 75% usage during the day shift,

operating costs would be approximately \$350/day. Training personnel to operate the microwave scabbler at DOE sites will be needed. Also, this training will need to be included in any technology transfer activities.

Author: J. H. Wilson/615-576-4413

References:

1. T. L. White, R. G. Grubb, L. P. Pugh, D. Foster, Jr., and W. D. Box, "Removal of Contaminated Concrete Surfaces by Microwave Heating—Phase I Results," published in the proceedings of the 18th American Nuclear Society Symposium on Waste Management, Waste Management '92, Tucson, Ariz., March 1-5, 1992.
2. TTP No. OR-3DAA (DOE No. OR-1012-04).
3. H. Yasunaka et al., "Microwave Decontaminator for Concrete Surface Decontamination in JPDR," *Proc. Int. Decommissioning Symp.*, 109-115, October 4-8, 1987.
4. T. L. White, private communication with J. H. Wilson.
5. W. Li et al., "Heat Transfer with a Radiation Contaminated Slab Applying a Microwave Heating Technique," in press, ASME Trans., *J. of Heat Transfer*, ASME National Heat Transfer Conference, San Diego, Calif., August 8-11, 1992.
6. W. Li et al., "Heat and Mass Transfer in a Contaminated, Porous Concrete Slab Subjected to Microwave Heating," 1992 Annual Winter Meeting of ASME, Anaheim, Calif., November 25-December 2, 1992.

EM Problem: Decommissioning

ORNL Problem: Enrichment process building, process support building, electrical and electrical switch gear, pumping stations, laboratory facilities, special development facilities, administrative facilities, and cooling towers. Deposit removal.

Problem Area/Constituents: Most contaminants on concrete, concrete blocks, painted concrete, tiled concrete, sheet metal, structural steel, and aluminum. See also Appendix B, lists A, B, C, and E.

Reference Requirements:

- Federal Facility Compliance Agreements (e.g., FFCA for Oak Ridge Site)
- Applicable federal and state laws and regulations (e.g., Clean Water Act and Toxic Substance Control Act)
- DOE orders

Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Decontamination**Alternatives:** Thermal surface and substrate removal methods

Technology: Plasma torch. Uses an inert gas passing through a high-power DC or RF arc discharge to produce a very-high-temperature gas stream that is capable of melting nearly all uncooled materials. Such torches are used in plasma synthesis and decomposition of materials.

Status: Potential uses in decontamination of materials include breaking down oils and PCBs into less harmful or harmless substances, rapid spalling of concrete, and using the difference in coefficient of thermal expansion to delaminate contaminants from underlying substrates. The torch's inert gas is recyclable and creates no additional waste stream of its own, as compared to the carbon dioxide and NO_x product created by a combustion torch. Plasma torches exist commercially to weld and cut materials that either have a very high melting temperature or require an inert atmosphere to prevent oxidation.

Waste produced—The Plasma torch can operate with either an inert gas like argon or an active gas. In the inert mode, no significant addition to the waste stream is expected because gas flow from the torch would only be of the order of 10 ft³/min. The existing waste will be converted to a different form (gaseous) and will be collected in a standard HEPA system. In the active gas mode the operating gas will most likely combine with the waste, forming new

material. This new material will also be in gaseous form and will also be handled with standard systems.

Overall cost—An operating plasma torch system should have a capital cost of less than \$100K, including exhaust gas handling. The equipment could be handled by a single person at less than \$100/h. The gas consumption would be around 10 ft³/min, with a cost of about \$0.10/ft³. The electrical cost will be less than \$60/h, based on 100 kW @ \$0.06 kW/h. The cleaning ratio is unknown and depends heavily on the waste. The cost leading to an operating, commercially produced system is expected to be less than \$500K.

Science Technology Needs: While plasma torch technology exists, its efficacy in removing various organic and radioactive contaminants has not been demonstrated. Elevation to the predemonstration stage involves laboratory-scale experiments, which will be designed using experimental results obtained from on-going development activities associated with plasma cleaning and fluorination technologies. The laboratory equipment will be constructed and operated for generating high-temperature thermal plasmas to destroy organic contaminants and to vaporize and encapsulate heavy metals. A database of decontamination rates by plasma torch techniques needs to be established. The equipment required for plasma torch cleaning of large surface areas that are contaminated will be developed to accommodate robotic, remote, and automatic operations with computer control. Also, computer modeling of plasma-surface interactions will be used to provide significant improvements in the removal rate and efficiencies of plasma torch methods. Standard filters can be used to clean the working gas.

Implementation Needs: Development costs: To address science needs, the approximate cost of equipment and staff time is about \$500K (capital equipment, \$200K). For these activities, the personnel must be highly trained in the fields of plasma technology and chemistry. One-half are scientists with masters or doctoral degrees, and one-half are highly trained technicians with bachelor of science degrees.

Author: W. L. Gardner/615-574-1121 and W. D. Nelson/615-574-0966

References: J. R. Hollis, *Environ. Progress* 2,7 (1983).

EM Problem: Decommissioning

ORNL Problem: See Appendix B, lists A, B, C, E, and H

Problem Area/Constituents: See Appendix B, lists A, B, C, E, and H

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Decontamination

Alternative: Thermal surface removal methods

Technology: Laser heating. This method removes contaminants at the surface or at very shallow depths below the surface. Energy from a continuous-wave or pulsed laser is absorbed at the surface, and the rapid temperature rise causes material to evaporate or decompose to a carbonaceous residue.

Status: Laser-based photothermal heating is currently being considered by the military as a method for removing organic coatings (e.g., polyurethane paint) from metal and composite surfaces. A prototype paint-removal system was built by BDM International and is now being tested by the Air Force. This system uses a CO₂ laser-based system to remove a 2-mil-thick coating of paint at a rate of about 2.5 ft²/min.

The primary application for laser-based photothermal heating is when large surface areas need a high degree of decontamination with the absolute minimum amount of waste generation. The technology produces only the material that is removed from the surface as waste (all the vaporized material is collected in a filtration system).

Science/Technology Needs: The existing laser-based photothermal heating systems can be evaluated for possible use on decontamination problem areas. Other systems using lasers, with different operational parameters (e.g., wavelengths, pulse durations), should also be considered for application on decontamination problem areas.

Technical Task Plan CH101102 (FY 1992); relevance: high

Implementation Needs: The successful development of this technology will require commercial vendors of laser-based photothermal heaters be encouraged to adapt existing systems to meet the requirements of specific problem areas. Commercially available systems should be capable of turn-key operation by trained technicians. The Air Force paid BDM International about \$1M to develop the prototype system being tested, but it is not unrealistic

to estimate that future systems will have a cost on the order of several hundred thousand dollars.

Author: D. B. Smith/615-574-2196

References: Dann J. Flesher, Westinghouse-Hanford Laboratory, Hanford, Wash., personal communications to D. B. Smith, Oak Ridge National Laboratory, July 7, 1992, and May 14, 1993.

EM Problem: Decommissioning

ORNL Problem: See Appendix B, lists A, B, C, E, and H

Problem Area/Constituents: See Appendix B, lists A, B, C, E, and H

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Decontamination

Alternative: Thermal surface removal methods

Technology: Laser etching and ablation (i.e., methods for removing contaminants at the surface or at very shallow depths below the surface). Energy from pulsed laser beams is absorbed at very shallow depths below the surface, and a combination of photochemical and photothermal effects causes thin layers of material to be rapidly ejected from the surface. Laser ablation is therefore not strictly a thermal effect.

Status: Predemonstration. Several university research groups and national laboratories have used the technology to remove radiological and organic contaminants from a variety of surface types. Hanford-Westinghouse is conducting laboratory and field tests of a prototype laser-based decontamination system.

Waste produced—This technology produces a minimal amount of waste. The primary waste produced is the material removed from the surface, which is collected in a filtration system. The filters used in this filtration system constitute the only secondary waste stream.

Science/Technology Needs: Laser etching and ablation for decontamination needs additional laboratory study before a technology demonstration can be done. The versatility and effectiveness of the technique has been demonstrated, and the hardware and other materials required for implementing the technique (e.g., lasers, optics, vacuum and filtration systems) already exist. A concerted effort to bring all of the components together in a prototype turn-key system is needed. Furthermore, the functional requirements for the technology (e.g., where is the contamination located?, what degree of decontamination is required?) are being defined as the problem areas are characterized. The development of the technique will need to be coordinated with these requirements.

Technical Task Plan CH101102 (FY 1992); relevance: high

Implementation Needs: The successful development of laser etching and ablation decontamination will require a team of researchers directed toward its development. There

are several laboratories and many qualified researchers available. A best guess of the human resources required is that 5 PY of effort over a period of one to two years will be sufficient to develop and demonstrate a prototype system. Most of the hardware needed will consist of off-the-shelf equipment such as laboratory glove boxes, laser systems, and data acquisition systems. A rough estimate of the financial investment required for development and demonstration is several million dollars over a three-year period.

The successful deployment of the technology will require a transfer of the technology from laboratory researchers to a commercial manufacturer. The prototype system would serve as the basis for larger-scale or mass production systems. In concept, a laser-based decontamination system should lend itself to a very high degree of automation, and a commercially available system should be capable of turn-key operation. One technician would be capable of overseeing the operation of multiple systems.

Author: D. B. Smith/615-574-2196

References:

1. M. C. Edelson, Ames Laboratory, Ames, Iowa, personal communication to D. B. Smith, Oak Ridge National Laboratory, March 26, 1993.
2. H. M. Pang, D. Baldwin, and M. C. Edelson, "Macroscopic Surface Cleaning Using a High Repetition Rate Ultraviolet Laser," *Proc. of the IEEE Lasers and Electro-Optics Society (LEOS '92)*, p. 150, Hynes Convention Center, Boston, November 16-19, 1992.
3. H. M. Pang, et al., "Laser decontamination: A new strategy for facility decommissioning," *Proc. of the International Topical Meeting on Nuclear and Waste Management (SPECTRUM '92)*, p. 1335, Boise, Idaho, August 23-27, 1992.

EM Problem: Decommissioning

ORNL Problem: Enrichment process building, process support building, electrical and electrical switch gear, pumping stations, laboratory facilities, special development facilities, administrative facilities, and cooling towers. Deposit removal.

Problem Area/Constituents: Metal equipment and sheet metal contaminated with uranium, oil, and polychlorinated biphenyls. See also Appendix B, lists C and H.

Reference Requirements:

- Federal Facility Compliance Agreements (e.g., FFCA for Oak Ridge Site, FFCA for PCBs)
- Applicable federal and state laws and regulations (e.g., Control Act)
- DOE orders

Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Decontamination

Alternatives: Thermal surface and substrate removal methods

Technology: Plasma surface cleaning. With a reactive plasma, chemically reactive species clean contaminated surfaces by chemisorption, reaction and desorption, or gasification. For example, in oxygen plasma cleaning, oxygen atoms, ozone, and UV photons (reactive species) convert hydrocarbon contaminants into volatile products. This plasma cleaning technology is being developed for the DOE's waste minimization program. The plasma cleaning technology can be developed for decontamination for oil- and PCB-contaminated metal process equipment.

Status: Predemonstration. Plasma surface cleaning methods by glow discharge are commonly and effectively used for cleaning high-bonding-energy contaminants from surfaces of metals, metal oxides, and glasses.¹ Plasma cleaning is done in vacuum chambers for accelerators and magnetic fusion devices.² Recently tritium contaminated hardware has been plasma cleaned with a decontamination factor of 1000.³ Plasma processes of etching and deposition are also used in material processing and microelectronic manufacturing in industry.⁴⁻⁷ Extrapolating these plasma cleaning techniques for decomposing and destroying oil and PCB contaminants in metal process equipment is feasible. Based on known plasma assisted etching rates, decontamination rates by reactive plasmas are expected to be higher than that by gas phase decontamination methods. Moreover, the plasma cleaning process provides a means of separating and recovering uranium from the mixed uranium contaminants, recycling the process equipment, reducing the volume of generated secondary wastes, and helping to minimize the final waste deposition cost. Though additional radio

frequency or microwave power is required, the plasma cleaning techniques will be approximately a factor of ten cheaper and faster than the gas cleaning techniques. Together with a scrubber, the supporting equipment used for the gas phase decontamination system, including thermal management system, vacuum system, computer control and monitors can be used for the waste generated in plasma cleaning methods. It is the author's opinion that a savings of a factor of ten could be realized in a production environment.

Waste produced—Plasma cleaning is effective for cleaning surface contaminants. It can be operated to remove the contaminated surface layer only. Thus, the amount of waste produced will be minimal. In fact, plasma chemical reactions can be employed to destruct hazardous contaminants into innocuous gaseous products. Because plasma cleaning is a unique cleaning process for achieving atomic-level cleaning, valuable substrate metals or hardware can be recycled for other applications.

Overall cost—Plasmas of argon/oxygen have been used to clean oil contaminants on a metal surface at a rate of 2.7 $\mu\text{m}/\text{min}$. For a contaminated substrate with a dirty surface layer of 20 μm , with a plasma apparatus capable of creating uniform plasma over 5 ft^2 and having an average plasma cleaning rate of 3 $\mu\text{m}/\text{min}$, the estimated overall cleaning rate is about 45 ft^2/h . Such a plasma cleaning machine could require 50 kW to operate (@ \$0.06 kW/h) and cost about \$3/h. Using 50 atm/L/h for operating the plasma device might cost \$0.50/h. Using computer control, a skillful operator (@ \$100/h) may be able to oversee the operation of two plasma cleaning devices. Each plasma cleaning device will clean 45 ft^2/h @ <\$53.5/h (or <\$1.20/ ft^2). If an enhanced plasma cleaning technique can be developed to achieve a rate of 6 $\mu\text{m}/\text{min}$, then the area cleaning rate of each machine can be increased to 90 ft^2/h , and the operating cost can be lowered to <\$0.60/ ft^2 .

Efficacy/strengths/weaknesses

Efficacy—The plasma cleaning process is an excellent technique to remove contaminants without creating additional secondary waste. It is capable of cleaning interior surfaces as well as exterior surfaces. It could be used to clean contaminated equipment and hardware, which could be recycled for other industrial and governmental applications.

Strengths—Plasma processing devices have been used in manufacturing microelectronics, which require the process equipment to be operated in an ultraclean environment. Of course, this cleaning device can be designed and operated to meet environmental regulations. It always operates in a chamber at sub atmospheric pressures, and no effluent gaseous products will leak out to the atmosphere without being exhausted through a filter system.

Weaknesses—It needs additional development to demonstrate large surface area cleaning on real contaminated substrate, to maximize cleaning rate, and to minimize secondary waste production.

Science Technology Needs: A plasma decontamination method should be developed to fulfill certain science and technology needs, even though plasma discharges have been used in laboratories and industry for cleaning and etching of many materials. Prototype equipment

is to be constructed and operated for generating reactive plasmas to clean oil and PCB contaminants. A database of decontamination rate on oil cleaning and PCB destruction needs to be established. The capability of plasma generation and cleaning on internal surfaces of contaminated equipment that have large surface areas needs to be established. Also, computer modeling of plasma-surface interactions will be used for providing significant improvement in the removal rate and efficiencies of plasma methods. The modeling will provide guidance on key technical issues associated with geometrical configuration, size, time dependent, and nonlinear plasma chemical reactions. Collection systems for vaporized contaminants should be demonstrated.

Implementation Needs: An experimental facility has been built and used to demonstrate cleaning capability for some Y-12 Plant materials. This facility needs to be upgraded to handle the specific contaminated materials that may be present in some parts of the ORNL facility. With the upgraded facility, cleaning rates and decontamination rates would be established. Next, a prototype would be designed, constructed, and demonstrated. This would be followed by operational equipment supplied by the industry.

The plasma surface cleaning technology project directly applies to numerous decontamination problems. For instance, it will be useful for cleaning stainless steel sheet, cleaning machine parts for reuse, cleaning PCBs and other contaminants, etching metallic surfaces including oxides, and recovering clad surfaces. The overall development cost (to show proof of principle) for the total of these items is estimated at \$1M. The plasma cleaning equipment capital cost cannot be accurately estimated at this time for the range of applications indicated, but it is expected to be in the \$100K-\$500K range. Operational cost is expected to be very small because of the very low power requirements and limited labor requirements (for maintenance and handling of parts to be cleaned and for operation of the system).

Author: C. C. Tsai/615-574-1124 and W. D. Nelson/615-574-0966

References:

1. K. L. Mittal, "Surface Contamination: An Overview," *Proc. Symp. on Surface Contamination: Its Genesis, Detection and Control*, pp. 1-45, Washington, D.C., September 13-14, 1978.
2. H. F. Dylla, "Glow Discharge Techniques for Conditioning High-Vacuum Systems," *J. Vac. Sci. Technol. A6* (3), May-June 1988.
3. W. T. Shmayda et al., "Plasma-Driven Decontamination Technique," *Canadian Fusion Fuels Technology Report*, 8(3), May 1992.
4. J. W. Coburn, "Surface Processing With Partially Ionized Plasmas," *IEEE Trans. on Plasma Science*, 19(6), December 1991.
5. D. L. Flamm, "Plasma Chemistry in Etching," *Proc. of the NATO Advanced Study Institute on Plasma-Surface Interactions and Processing of Materials*, pp. 35-55, Alicante, Spain, September 4-6, 1988.
6. H. W. Lehmann, "Applications of Plasma Etching," *ibid.*, 1988, pp. 345-375.
7. In the draft document of the DOE Environmental Management D&D Workshop, Knoxville, Tenn., August 12-16, 1991.

EM Problem: Decommissioning

ORNL Problem: Enrichment process building, process support building, electrical and electrical switch gear, pumping stations, laboratory facilities, special development facilities, administrative facilities, and cooling towers. Deposit removal.

Problem Area/Constituents: Uranium contamination (interior); uranium-contaminated tanks. See also Appendix B, list H.

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Decontamination

Alternative: Thermal surface removal methods

Technology: Plasma etching/fluorination. Using a fluorine plasma discharge, volatile fluorides are produced, along with chemically reactive fluorine atoms, that promote rapid etching. The contaminated metal surfaces are exposed to energetic ions, electrons, and photons. The decontamination rate is greatly enhanced. The plasma etching and fluorination technology can be developed for in situ decontamination of DOE process equipment.

Status: Predemonstration. Plasma surface cleaning methods by glow discharges are commonly and effectively used for cleaning high-bonding energy contaminants from surfaces of metals, metal oxides, and glasses. Plasma cleaning is done in vacuum chambers for accelerators and magnetic fusion devices. Recently, tritium-contaminated hardware has been plasma cleaned with a decontamination factor of 1000. Plasma processes of etching and deposition are also used in material processing and microelectronic manufacturing in industry. The plasma cleaning and etching is a predemonstration technology. Extrapolating these plasma cleaning techniques for gasifying and recovering uranium deposits in uranium process equipment is feasible. Based on plasma-assisted etching rates, decontamination rates by reactive plasmas will be higher than that by gas phase decontamination methods. Moreover, the plasma cleaning process provides a means of separating and recovering uranium from the mixed uranium contaminants, recycling the process equipment, reducing the volume of generated secondary wastes, and helping to minimize the final waste deposition cost.

Although requiring additional radio frequency or microwave power, the plasma cleaning and fluorination techniques could be cheaper and faster than the gas cleaning techniques. The supporting equipment used for the gas phase decontamination system, including a gas handling system for trapping uranium hexafluoride, thermal management system, vacuum system, computer control, and monitors, can be used for the waste generated in plasma

cleaning and fluorination methods. Since the plasma surface cleaning methods are expected to be much faster than the gas phase decontamination method, it will potentially save (in conjunction with the gas phase system) tens of millions of dollars for the decontamination and decommissioning (D&D) of gas diffusion plants. About \$5M for development costs and \$1M capital equipment costs will be required.

If successfully developed, the prototype plasma fluorination hardware could decontaminate a 10-m³ tank in 1 month and cost \$0.25M (or \$0.75M per stage). It is the author's opinion that a savings of a factor of ten could be realized in a production environment. Wastes would be vaporized contaminants plus filters and HEPA filters from the collection system.

Waste produced—The plasma etching/fluorination technology would not produce additional secondary waste. It will gasify uranium into UF₆, which can be recovered by collection on a cold trap and reprocessed to recover uranium for other applications.

Overall cost—At higher etching rates, the plasma etching/fluorination technology should cost less than the gas phase decontamination. Given an average plasma etching rate of 1 μm/min, the overall area etching rate of a 5-ft² plasma etching machine is estimated to be about 15 ft²/h for etching a 20-μm-thick surface layer. It could take 50 kW (@ \$0.06 kW/h) to operate such a plasma cleaning device and cost about \$3/h. Using gas at 5 atm/L/h for operating the plasma device may cost \$0.50/h. Using computer control, a skillful operator (@ \$100/h) could clean 15 ft² @ <\$103.5/h (or <\$7/ft²). If an enhanced plasma cleaning technique can be developed to achieve a rate of 10 μm/min, then the area cleaning rate can be increased to 150 ft²/h, and the operating cost can be lowered to <\$0.7/ft².

Efficacy/strengths/weaknesses

Efficacy—The plasma etching process is an excellent technique to remove uranium contaminants without creating additional secondary waste. It is capable of etching interior surfaces as well as exterior surfaces. It could be used to etch uranium and produce gaseous UF₆, which could be collected for recovering valuable uranium for other applications.

Strengths—Plasma-enhanced decontamination may have two separate applications: fluorination and inert gas cleaning. As a first step, as outlined in the proposal, it is appropriate that this work be carried out in a nonradiological environment, with limited application of hazardous gases. This technology may be used as an alternative to gas phase decontamination. Plasma processing devices have been used in manufacturing microelectronics. It is a useful tool for the electronics industry because fluorine plasmas are very reactive in gasifying materials. The etching device can be designed and operated to meet OSHA regulations. It always operates in a chamber at sub atmospheric pressures, and no effluent gaseous products will leak out to the atmosphere without being exhausted through a filter system.

Weaknesses—It needs scientific data on etching/fluorinating rates for decontaminating real substrate contaminated with uranium and its compounds. It also needs further development

for demonstrating large-surface-area etching on real contaminated substrate, maximizing etching rate, and performing both the collection of gaseous UF_6 and the recovery of uranium.

Science/Technology Needs: Data on cleaning rates for contaminants and substrates of interest are needed. The capability of plasma etching on deposits in complex equipment with large surface areas needs to be established.

Implementation Needs: An experimental facility has been built and used to demonstrate cleaning capability for some Y-12 Plant materials. This facility needs to be upgraded to handle the specific contaminated materials that may be present in some parts of the ORNL facility. With this upgraded facility, cleaning rates and decontamination rates would be established. Next, a prototype would be designed, constructed, and demonstrated. This would be followed by operational equipment supplied by industry. Finally, a collection system with appropriate filters for the vaporized deposits would be needed to use this technology.

The plasma surface cleaning technology project directly applies to numerous decontamination problems. For instance, in addition to the removal of uranium deposits, it will be useful for cleaning stainless steel sheet, cleaning machine parts for reuse, cleaning PCBs and other contaminants, etching metallic surfaces including oxides, and removing clad surfaces. The overall development cost (to show proof of principle) for the total of these items is estimated in a technical task plan at \$1.3M. Thus, the prorated development cost for the machine parts cleaning area would be about \$250K. The plasma etch equipment capital cost cannot be accurately estimated at this time for the range of applications indicated, but it is expected to be in the \$100K-\$500K range. Operational cost is expected to be very small because of the very low power requirements and limited labor requirements (for maintenance and handling of parts to be cleaned and for operation of the system).

Author: C. C. Tsai/615-574-1124 and W. D. Nelson/615-574-0966

References: MMES staff members.

EM Problem: Decommissioning

ORNL Problem: See Appendix B, lists A, B, C, E, and H

Problem Area/Constituents: See Appendix B, lists A, B, C, E, and H

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Decontamination

Alternative: Thermal surface removal methods

Technology: Flashlamp cleaning. A method for removing contaminants at the surface or at very shallow depths below the surface. Energy from a high-energy xenon flashlamp is absorbed at the surface, and the ensuing rapid temperature rise causes material to evaporate or decompose to a particulate residue. Flashlamp systems are being evaluated for radionuclide decontamination applications at various DOE sites.

Status: Radiological decontamination using high-energy xenon flashlamps is in the demonstration phase. Hanford-Westinghouse is conducting laboratory tests of xenon flashlamp systems for removing radionuclide contamination from the surfaces inside metal storage vessels.

The primary application for flashlamp cleaning is large surface areas that need a high degree of decontamination with the absolute minimum amount of waste generation. The technology produces as waste only the material that is removed from the surface (all the vaporized material is collected in a filtration system).

Science/Technology Needs: The commercially available flashlamp systems and prototype decontamination systems should be evaluated for possible use on contaminated areas.

Implementation Needs: The successful development of this technology will require that commercial vendors of xenon flashlamp systems be encouraged to adapt their systems to meet the requirements of specific problem areas. Commercially available systems should be capable of turn-key operation by trained technicians. Currently available systems cost \$50K-\$100K.

Author: D. B. Smith/615-574-2196

Reference: Dann J. Flesher, Westinghouse-Hanford Laboratory, Hanford, Wash., personal communications to D. B. Smith, Oak Ridge National Laboratory, July 22, 1992 and May 14, 1993.

EM Problem: Decommissioning

ORNL Problem: See Appendix B, lists C and H

Problem Area/Constituents: See Appendix B, lists C and H

Reference Requirements: Refer to the Regulatory Compliance chapter of Vol. 1 (Pt. A, B, or C as appropriate) for potentially applicable proposed and promulgated environmental laws, signed and pending agreements for the Oak Ridge Reservation, radiation protection standards, DOE orders, and nonregulatory guidance. As site- and waste-specific characteristics are provided for each technology, specific regulatory requirements will be specified.

Subelement: Decontamination

Alternative: Bulk decontamination methods

Technology: Transmutation. Long-lived radioactive isotopes are transformed into radioactive isotopes with shorter half lives through the use of neutron capture, proton capture, or fission. To avoid activation of the stable isotopes, which the radioisotope to be transmuted is mixed with, the stable isotopes must be separated. The radioactive species is then exposed to the neutron or proton flux for a sufficient time to completely transmute the long-lived isotope into stable or shorter-lived isotopes. A particle accelerator would be used to produce protons (and neutrons with a spallation source and moderator), or a fission reactor would be used.

Status: Preconceptual. Although this idea has been advanced for several years, until the advent of Strategic Defense Initiative particle accelerators, sufficiently powerful accelerators were not available.

Waste produced—Potential waste reduction by decreasing the half-life of the irradiated radioisotope.

Overall cost—No cost data is available, but the development cost of technologies like this is extremely expensive.

Efficacy/strengths/weaknesses—Advantages: conversion of long-lived waste into shorter-lived waste (converts TRU into short-lived fission products). The only method applicable to activation product wastes. Disadvantages: Applicability to activation product wastes would depend upon the availability of a suitable isotope separation technique so that the bulk of unactivated material is preserved.

Science/Technology Needs: Development of a suitably intense neutron or proton source to reduce reaction times is needed. Tests of the suitability of direct waste irradiation is needed. Development of isotope separation techniques for long-lived activation products is needed.

Implementation Needs: A long-term development program is needed.

Authors: J. R. DeVore and H. H. Haselton/615-574-7092

References: *R&D Magazine* 43 (1993).

Appendix A: ORNL PROBLEMS FOR CHARACTERIZATION

List A: Problems Related to Decontamination and Decommissioning

ORNL Facilities Already in D&D Program

Building 3001 ORNL Graphite Reactor
Building 3005 Low-Intensity Test Reactor
Building 3042 Oak Ridge Research Reactor
Building 3087 Oak Ridge Research Reactor Heat Exchanger
Building 3505 Metal Recovery Facility
Building 3506 Waste Evaporator Facility
Building 3515 Fission Product Pilot Plant
Building 3517 Fission Product Development Laboratory Inactive Cells
Building 4507 High-Level Chemical Development Laboratory
Building 7500 Homogeneous Reactor Experiment
Building 7503 Molten Salt Reactor Experiment
Building 7852 Old Hydrofracture Facility
Building 9201-3 Mezzanine Storage Tank (Y-12)
Building 9201-3 Coolant Salt Technology Facility (Tritium Test Loop)
Building 9201-3 Molten Salt Corrosion Loop
Building 9419-1 Decontamination Facility
Shielded Transfer Tanks

Isotope Facilities Scheduled for D&D Program

Building 3026-C Krypton-85 Enrichment Facility
Building 3028 Alpha Powder Facility
Building 3029 Source Development Laboratory
Building 3030 Radioisotope Production Laboratory-C
Building 3031 Radioisotope Production Laboratory-D
Building 3033 Radioactive Gas Processing Facility
Building 3033-A Actinide Fabrication Facility
Building 3038 Isotope Research Materials Laboratory
Building 3047 Radioisotope Development Laboratory
Building 3093 Storage Cubicle for Krypton
Building 3099 Storage Pad
Building 3118 Radioisotope Production Laboratory-H
Building 3517 Fission Products Development Laboratory
Building 7025 Tritium Target Facility

ORNL Special-Case Facilities

Building 3019-A Radiochemical Development Facility
Building 3019-B High-Level-Radiation Analytical Facility

List B: Problems Related to Remedial Action

WAG^a	1	Buried wastes (SWSAs^b 1 and 2), tanks, impoundments, pipelines, and soils/sediments
WAG	2	Soils/sediments and ground water/surface water
WAG	3	Buried wastes (SWSA 3), soils/sediments, and ground water/surface water
WAG	4	Buried wastes (SWSA 4), pipelines, soils/sediments, and ground water/surface water
WAG	5	Buried wastes (SWSA 5), tanks, impoundments, pipelines, soils/sediments, and ground water/surface water
WAG	6	Buried wastes (SWSA 6), soils/sediments, and ground water/surface water
WAG	7	Pits and trenches, pipelines, and soils/sediments
WAG	8	Tanks, impoundments, pipelines, and ground water/surface water
WAG	9	Tanks, impoundments, and ground water/surface water
WAG	10	Hydrofracture and ground water/surface water
WAG	11	Soils/sediments and ground water/surface water
WAG	13	Soils/sediments
WAG	17	Tanks

^aWAG = Waste area grouping

^bSWSA = Solid waste storage area

List C: Problems Related to Waste Management**Solid wastes**

Asphalt; building materials	Discarded filters	Other heterogeneous debris
Biological wastes	Fiberglass insulation	Scrap ferrous metals
Combustible debris	Fissile materials	Scrap nonferrous metals
Compactible debris	Graphite moderator	Sealed radioactive (RAD) sources
Concrete rubble and gravel	Irradiated and spent fuel elements and components	Spent ion exchange media
Discarded asbestos; transite	Lab packs	Steam plant ash

Solid-liquid wastes

Coal yard run-off sludge	Other RCRA hazardous wastes
Corrosive wastes	Toxic organic wastes
Infectious medical wastes	Toxic metal wastes
Ignitable and reactive wastes	Waste processing sludges

Liquid wastes

Listed halogenated solvents	Process/dilute liquid low-level wastes
Listed nonhalogenated solvents	REDC acidic aqueous RAD wastes
Melton Valley and Radiochemical Engineering Development Center (REDC) caustic aqueous RAD wastes	REDC liquid organic RAD wastes
	Sanitary/industrial waste water

Gaseous wastes

Adsorbable radioactivity in gases	Particulates in gases
Entrained vapors/acids in gases	RAD in gases
Inorganics in gases	Semi-volatile organic compounds in gases
Nitrogen oxides in gases	Sulfur oxides in gases
Nonadsorbable RAD in gases	Volatile organic compounds in gases
Orphan gas cylinders	

Appendix B

ORNL PROBLEMS AND PROBLEM AREA/CONSTITUENTS FOR DECONTAMINATION

ORNL Problem

List A:

Oak Ridge Research Reactor (ORR)
 biological shield
 Building 3028 hot cell interiors
 Building 3029 hot cell interiors
 Building 3030 hot cell interiors
 Building 3031 hot cell interiors
 Building 3032 hot cell interiors
 Building 3036 floor
 Homogeneous Reactor Test (HRT) structure
 Building 3517 hot cell interiors
 Building 9419-1 floor, first floor
 molten salt (M.S.) cells
 Building 3038 cell interiors

List B:

ORR hot cell interiors, floors, cell faces
 Building 3028 hot cell interiors, floors,
 cell faces
 Building 3029 cell faces
 Building 3030 floors & cell faces
 Building 3031 floors & cell faces
 Building 3032 floors & cell faces
 Building 3033 cell faces
 Building 3036 floors
 Building 3015 high bay floors & cell faces
 Building 9201-3 coolant salt (C.S.) cell
 Building 9201-3 M.S. cell
 Building 3038 cell floor & surface

List C:

ORR hot cell liners
 Building 3028 hot cell liners
 Building 3029 hot cell liners
 Building 3030 hot cell liners
 Building 3031 hot cell liners
 Building 3032 hot cell liners
 Building 3033 process piping
 Membrane between HRT concrete
 Building 3029, cell 2 wall
 7500 high bay area
 Molten Salt Reactor Experiment (MSRE)
 exterior siding
 ORR building siding
 Building 3028E charging area
 Building 3029 exterior walls
 Building 3030 siding/interior walls
 Building 3031 siding/interior walls
 Building 3032 siding/interior walls
 Building 3033 siding/interior walls
 Building 3036 siding/interior walls
 MSRE building structure
 ORR steel building structure
 Building 3028E steel structure

Problem Area/Constituents

List A:

Concrete: fission products (F.P.), corrosion
 products (C.P.)
 Concrete: F.P., Cm-244, Pm-147, Am-241
 Concrete: Cs-137, Sr-90, Co-60, Ir-192
 Concrete: 43 beta/gamma emitters
 Concrete: Gd-153, Am-241
 Concrete: P-32, Am-241
 Concrete: Cs-137, Sr-90
 Concrete: high-density F.P., C.P.-induced
 Concrete: C-137, Sr-90, Co-60
 Concrete: U, Th M.S.

 Concrete: Sr-90, Cs-137, Co-60, I-12

List B:

Painted concrete: F.P., transuranics (TRU)
 Painted concrete: F.P., Cm-244, Pm-147,
 Am-2
 Painted concrete: Cs-137, Sr-90, Co-60, Ir-192
 Painted concrete: 43 beta/gamma emitters
 Painted concrete: Gd-153, Am-241
 Painted concrete: P-32, Am-241
 Painted concrete: H-3, Kr-85
 Painted concrete: Cs-137, Sr-90
 Painted concrete: Cs-137, Sr-90, Co-60
 Painted concrete: U, Th, C.S.
 Painted concrete: U, Th, M.S.
 Painted concrete: Sr-90, Cs-137, Co-60, I-129

List C:

Stainless steel: F.P., C.P.
 Stainless steel: F.P., Cm-244, Pm-147, Am-241
 Stainless steel: Cs-137, Sr-90, Co-60, Ir-192
 Stainless steel: 43 beta/gamma emitters
 Stainless steel: Gd-153, Am-241
 Stainless steel: P-32, Am-241
 Stainless steel: H-3, Kr-85
 Steel plate: F.P., C.P.
 Steel plate: Cs-137, Sr-90, Co-60, Ir-192
 Sheet steel: Cs, Sr, TRU, Co-60
 Sheet steel

 Sheet steel: F.P.
 Sheet steel: F.P., TRU
 Sheet steel: Cs-137, Sr-90, Co-60, Ir-90
 Sheet steel: 43 beta/gamma emitters
 Sheet steel: Gd-153, Am-241
 Sheet steel: P-32, Am-241
 Sheet steel: H-3, Kr-85
 Sheet steel: Cs-137, Sr-90
 Structural steel
 Structural steel: F.P.
 Structural steel: F.P., TRU

ORNL Problem**List D:**

Building 3029 structure
 Building 3030 steel building structure
 Building 3517 hot cell liners
 Building 3038 glove boxes
 Building 3038 glove boxes & cell interiors
 Building 3517 interior/exterior walls
 Building 9201-3: 3 walls & floors M.S. cells
 Building 9201-3: 3 walls & roof C.S. cell
 Building 3031 structure
 Building 3032 structure
 Building 3033 structure
 Building 3036 structure
 Building 3517 structure
 Building 9419-1 structure & stair frame
 C.S. cell frame
 M.S. cell & equipment frames
 Building 3038 structure
 HRT pressure vessel & HRT structure
 HRT process piping
 MSRE off-gas system
 ORR demineralizer piping (outside pool)
 Building 3517 process piping & tankage
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 Structural steel: 43 beta/gamma emitters
 Stainless steel: Cs-137, Sr-90, Co-60
 Stainless steel: Pu-238, Am-241, Cm-244
 Stainless steel: Pu, Cf, Cm, Np, Pa, U, Sr, Cs, Co, I
 Sheet steel: Cs-137, Sr-90, Co-60
 Sheet steel: U, Th, M.S.
 Sheet steel: U, Th, C.S.
 Structural steel: Gd-153, Am-241
 Structural steel: P-32, Am-241
 Structural steel: H-3, Kr-85
 Structural steel: Cs-137, Sr-90
 Structural steel: Cs-137, Sr-90, Co-60
 Structural steel: U, Th, M.S.
 Structural steel: U, Th, H-3, C.S.
 Structural steel: U, Th, M.S.
 Structural steel: Sr-90, Cs-137, Co-60, I-129
 Steel plate: F.P., C.P.
 Stainless steel pipe exterior: UO_2SO_4 , F.P., C.P.
 Stainless steel pipe exterior
 Stainless steel pipe exterior: F.P., C.P.
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List E:

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 Concrete block: F.P.
 Concrete block: F.P., TRU
 Concrete block: Cs-137, Sr-90, Co-60, Ir-192
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 Tiled concrete: 43 beta/gamma emitters
 Tiled concrete: Gd-153, Am-241
 Tiled concrete: P-32, Am-241
 Tiled concrete: H-3, Kr-85
 Tiled concrete: Cs-137, Sr-90
 Tiled concrete: Cs-137, Sr-90, Co-60
 Tiled concrete: U, Th, M.S.
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ORNL Problem**List F:**

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 MSRE off-gas system
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 Tiled concrete: Gd-153, Am-241
 Tiled concrete: P-32, Am-241
 Tiled concrete: H-3, Kr-85
 Tiled concrete: Cs-137, Sr-90
 Tiled concrete: Cs-137, Sr-90, Co-60
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 Wood/sheet rock: 43 beta/gamma emitters
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 Steel pipe interior: U, Th, C.S.
 Steel pipe interior: U, Th, M.S.
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