

Appendix A-Bibliography.

**COMPUTER MODEL/DOE**

Campbell J.E., Longsine, D.E., and Cranwell, R.M., 1981 Risk Methodology for Geologic Disposal of Radioactive Waste: The NWFT/DVM Computer Code User's Manual NUREG/CR-2081, Sandia National Laboratory.

**COMPUTER MODEL/DOE**

Doctor, P.G., T.M. Miley, and C.E. Cowan, 1990. Multimedia Environmental Pollutant Assessment System (MEPAS) Sensitivity Analysis of Computer Codes. PNL-7296, UC-602, 630. Pacific Northwest laboratory, Richland, Washington.

**COMPUTER MODEL/DOE**

Droppo, J.G. Jr., D.L.Streng, J.W. Buck, B.L. Hoopes, R.D. Brockhaus, M.B. Walter and G. Whelen. 1989. Supplemental Mathematical Formulations: The Multimedia Environmental Pollutant Assessment System (MEPAS). PNL-7201. Pacific Northwest Laboratories. Richland, Washington.

**COMPUTER MODEL/DOE**

Droppo, J.G. Jr., D.L.Streng, G. Whelen, J.W. Buck, B.L. Hoopes and M.B. Walter. 1989. The Multimedia Environmental Pollutant Assessment System (MEPAS) Applications Guidance Volume 2 - Guidelines for Evaluating MEPAS Parameters PNL-7216. Pacific Northwest Laboratories. Richland, Washington.

**COMPUTER MODEL/DOE**

Fields, D.E.; Emerson, C.J.; Chester, R.O.; Little, C.A.; Hiromoto, G. Date: 1986, April. Title: PRESTO-II: A Low-Level Waste Environmental Transport and Risk Assessment Code. Corporate Author: Oak Ridge National Laboratory, Health and Safety Research Division, Oak Ridge, TN; Instituto de Pesquisas Energeticas e Nucleares, Sao Paulo, Brazil; Oak Ridge National Laboratory, Computing and Telecommunications Division, Oak Ridge, TN. Pub: ORNL-5970; 486 pp. Abstract: PRESTO-II (Prediction of Radiation Effects from Shallow Trench Operations) is a computer code designed for the evaluation

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of possible health effects from shallow-land waste-disposal trenches. The model is intended to serve as a non-site-specific screening model for assessing radionuclide transport, ensuing exposure, and health impacts to a static local population for a 1000-year period following the end of ground disposal operations at a waste site. Human exposure scenarios include normal releases (including leaching and operational spillage), human intrusion, and limited site farming or reclamation. Pathways and processes of transit from the trench to an individual or population include groundwater transport, overland flow, erosion, surface water dilution, suspension, atmospheric transport, deposition, inhalation, external exposure, and ingestion of contaminated beef, milk, crops, and water. Both population doses and individual doses as well as doses to the intruder and farmer may be calculated. Cumulative health effects in terms of cancer deaths are calculated for the population over the 1000-year period using a life-table approach. Data are included for three example sites: Barnwell, South Carolina; Beatty, Nevada; and West Valley, New York. A code listing and example input for each of the three sites are included in the appendices to this report.

#### **COMPUTER MODEL/DOE**

Gilbert, T.L. Yu, C., Yuan, Y.C., Zielen, A.J., Jusko, M.J., and A Wallo III, 1989. A Manual for Implementing Residual Radioactive Material Guidelines. Argonne National Laboratory publication ANL/ES-160, Argonne National Laboratory, Argonne, IL.

#### **COMPUTER MODEL/DOE**

Gilbert, T.L.; Roberts, C.J. Date: 1983. Title: Long-Term Health Risks from Waste Contaminated with Radioactive Ore and Processing Residues: A New Approach to the Pathway Analysis Problem. Corporate Author: Argonne National Laboratory, Argonne, IL. Pub: CONF-830695; Proceedings of the Health Physics Society 28th Annual Meeting, Baltimore, MD, June 19-24, 1983 Abstract: Estimates of the relation between the long-term (100 to 10,000 years) health risks (H) to the maximally exposed individual and the source terms (S) from the long-lived radionuclides at sites contaminated by ore and processing residues are needed for developing appropriate waste-management guidelines and strategies. This relation may be expressed as a sum of products of source-to-exposure (E/S), exposure-to-dose (D/E), and dose-to-health-effects (H/D) conversion factors for individual pathways:  $H/S=(E/S)(D/E)(H/D)$ . The E/S factors present unusual problems and a major source of uncertainty

because of the complexity of the many environmental pathways, uncertainties in the environmental models and parameters, and uncertainties in the scenarios that determine individual exposure. A new analysis of the E/S factors for all major pathways has been carried out and combined with current estimates of D/E and H/D factors to obtain generic estimates of the D/S and H/S factors for a model site. A key feature is a natural analogue analysis that permits incorporation of data on average soil concentration, dietary intakes, and body burdens of naturally occurring radionuclides in order to supplement and modify estimates from individual pathway models, thereby obtaining more reliable conversion factors. The H/S factors are used to derive radionuclide concentration limits for contaminated sites that correspond to limits imposed by current radiation protection guidelines.

### **COMPUTER MODEL/DOE**

Miller, C.W.; Sjoreen, A.L.; Cotter, S.J. Date: 1986, February. Title: Estimating Doses and Risks Associated with Decontamination and Decommissioning Activities Using the CRRIS. Corporate Author: Oak Ridge National Laboratory, Oak Ridge, TN. Pub: CONF-860203; Health Physics Considerations in Decontamination and Decommissioning, Proceedings of the Health Physics Society 19th Midyear Topical Symposium, Knoxville, TN, February 2-6, 1986, 594 pp.; (pp. 125-133) Abstract: The Computerized Radiological Risk Investigation System (CRRIS) is applicable to determining doses and risks from a variety of decontamination and decommissioning activities. For example, concentrations in air from resuspended radionuclides initially deposited on the ground surface and the concentrations of deposited radionuclides in various soil layers can be obtained. The CRRIS will estimate exposure to radon and its progeny in terms of working-level months, and will compute the resulting health risks. The CRRIS consists of seven integrated computer codes that stand alone or are run as a system to calculate environmental transport, doses, and risks. PRIMUS output provides other CRRIS codes the capability to handle radionuclide decay chains. ANEMOS and RETADD-II calculate atmospheric dispersion and deposition for local and regional distances, respectively. Multiple ANEMOS runs for sources within a small area are combined on a master grid by SUMIT. MLSOIL is used to estimate effective ground surface concentrations for dose computations. TERRA calculates foodchain transport, and ANDROS calculates individual or population exposures, doses, and risks. Applications of the CRRIS to decontamination problems are discussed.

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**COMPUTER MODEL/DOE**

Moskowitz, P.D., R. Pardi, and R.J. McKinnon. 1995. Evaluating Technical Capabilities of Groundwater Models Used to Support Cleanup of Low-Level Radioactive Waste Sites: A Critique of Three Representative Models. Brookhaven National Laboratory, Upton, NY.

**COMPUTER MODEL/DOE**

Rish, W.R., 1988 Approach to Uncertainty in Risk Analysis. ORNL/TM-10746, Oak Ridge National Laboratory.

**COMPUTER MODEL/DOE**

Streng, D.L., and T.J. Bander. 1981. MILDOS - A Computer Program for Calculating Environmental Radiation Doses from Uranium Recovery Operations. NUREG/CR-2011, PNL-3767. Pacific Northwest Laboratories, Richland, WA.

**COMPUTER MODEL/EPA**

Fields, D.E., C.A. Little, F. Parraga, V. Rogers, and C.Y. Hung. 1987a PRESTO-EPA-POP: A Low-Level Waste Environmental Transport and Risk Assessment Code, Volume 1, Methodology Manual. EPA 521/1-87-024-1.

**COMPUTER MODEL/EPA**

Fields, D.E., C.A. Little, F. Parraga, V. Rogers, and C.Y. Hung. 1987b PRESTO-EPA-POP: A Low-Level Waste Environmental Transport and Risk Assessment Code, Volume 2, User's Manual. EPA 521/1-87-024-2.

**COMPUTER MODEL/EPA**

Hung, C.Y., 1989. User's Guide to the SYSCPG Program - A PC Version of the PRESTO-EPA-POP Operation System. USEPA 520/1-89-017.

**COMPUTER MODEL/EPA**

Hung, C.Y., 1992. User's Guide to the SYSCPG Program - A PC Version of the PRESTO-EPA-POP Operation System. USEPA 400R92003.

**COMPUTER MODEL/EPA**

MERREL, G.B., 1994. Modifications to the PRESTO-EPA-CPG Code to Facilitate the Analysis of Soil Contamination Sites. RAE-9231/6-1, U.S. EPA, Washington, D.C.

**COMPUTER MODEL/EPA**

Moskowitz, P.D., R. Pardi, M.P. DePhillips, and A.F. Meinhold, 1993. Computer Models Used to Support Cleanup Decision-Making at Hazardous and Radioactive Waste Sites. EPA 402-R-93-005, Office of Air and Radiation, USEPA, Washington, D.C.

**COMPUTER MODEL/EPA**

Rogers, V. and C. Hung. 1987a. PATHRAE-EPA: A Low-Level Radioactive Waste Environmental Transport and Risk Assessment Code, Methodology and User's Manual. EPA 520/1-87-028, Office of Radiation Programs, USEPA, Washington, D.C.

**COMPUTER MODEL/EPA**

Rogers, V. and C. Hung. 1987b. Low-Level and NARM Radioactive Wastes, Model Documentation, PRESTO-EPA-BRC. EPA 520/1-87-027, Office of Radiation Programs, USEPA, Washington, D.C.

**COMPUTER MODEL/EPA**

Rogers, V. and C. Hung. 1987c. PRESTO-EPA-DEEP A Low-Level Radioactive Waste Environmental Transport and Risk Assessment Code, Methodology and User's Manual. EPA 520/1-87-025, Office of Radiation Programs, USEPA, Washington, D.C.

**COMPUTER MODEL/EPA**

Rogers, V. and C. Hung. 1987d. PRESTO-EPA-CPG A Low-Level Radioactive Waste Environmental Transport and Risk Assessment Code,

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Methodology and User's Manual. EPA 520/1-87-026, Office of Radiation Programs, USEPA, Washington, D.C.

### **COMPUTER MODEL/EPA**

USEPA, 1993 PRESTO-EPA: A Low-Level Radioactive Waste Environmental Transport and Risk Assessment Code - Methodology and User's Manual. USEPA, Washington, D.C.

### **COMPUTER MODEL/NRC**

Mills, M. and D. Vogt, 1983. A Summary of Computer Codes for Radiological Assessment. NUREG/CR-3209, US Nuclear Regulatory Commission, Washington, D.C.

### **CONSIDERATION or JUSTIFICATION/Commercial**

Burris, J.A.; Buckley, S.E. Date: 1993. Title: Ecological Risk Management in Superfund. Corporate Author: ABB Environmental Services, Inc., Washington, DC. Pub: CONF-930570; Proceedings of the Second Annual Federal Environmental Restoration Conference and Exhibition, Washington, DC, May 25-27, 1993. Hazardous Materials Control Resources Institute, Greenbelt, MD, 477 pp.; (pp. 190-193) Abstract: Ecological Risk Assessments at Superfund sites are undertaken to support the remediation decisions. Benefits to human health and the environment, as well as remediation costs, are considered in the decision making process. The cost of remediation is understandably linked to the amount of acceptable residual risk, and the confidence that the assessor has in the assessment results. This paper provides an introduction to the ecological risk assessment process in Superfund and ecological risk management. Two examples of the risk management process are provided. Each illustrates the importance of considering ecological risk management during the assessment process and before actual decision making takes place.

### **CONSIDERATION or JUSTIFICATION/Commercial**

Chidambariah, V.; Travis, C.C.; Trabalka, J.R.; Thomas, J.K. 1992. A Risk-based Approach to Prioritize Underground Storage Tanks. pp. 136-139. Proceedings of Federal environmental restoration conference and exhibition. Conference title - 1992 Hazardous Materials Control Research Institute (HMCRI) federal environmental restoration conference and exhibition, Vienna, VA, 15-17 Apr. 1992.

Abstract: The purpose of this paper is to present a risk-based approach for rapid prioritization of low level liquid radioactive waste underground storage tanks (LLLW USTs) for possible interim corrective measures and/or ultimate closure. The ranking of LLLW USTs is needed to ensure that tanks with the greatest potential for adverse impact on the environment and human health receive top priority for further evaluation and remediation. Wastes from the LLLW USTs at the Oak Ridge National Laboratory (ORNL) were pumped out at the time the tanks were removed from service. The residual liquids and sludge contain a mixture of radionuclides and chemicals. Contaminants of concern that were identified in the liquid phase of the inactive LLLW USTs include, the radionuclides, strontium-90, cesium-137 and uranium-233 and the chemicals, carbon tetrachloride, trichloroethene, tetrachloroethene, methyl ethyl ketone, mercury, lead and chromium. The risk-based approach for prioritization of the LLLW USTs is based upon three major criteria: (1) leaking characteristics of the tank; (2) location of the tanks; and (3) toxic potential of the tank contents.

#### **CONSIDERATION or JUSTIFICATION/DOE**

Adler, D. Date: 1988, October. Title: Presentation on the Role of Risk Assessment in FUSRAP Remedial Planning. Corporate Author: Bechtel National, Inc., Oak Ridge, TN. Pub: CONF-8810239; Remedial Action Programs Annual Meeting, Proceedings of a U.S. Department of Energy Conference, Gaithersburg, MD, October 18-20, 1988, 456 pp.; (pp. 5-59 - 5-74) Abstract: Although the primary emphasis of the FUSRAP program is to mitigate hazards by removing and disposing of contamination exceeding relevant generic guidelines, current FUSRAP protocol allows for application of supplemental risk-based standards in unique cases where generic standards are inappropriate. This presentation provides background information on the rationale supporting current generic cleanup standards, and how site-specific, risk-based standards can be applied to improve the cost effectiveness of overall remedial strategies.

#### **CONSIDERATION or JUSTIFICATION/DOE**

Alexander, D.R. Date: 1991, December 30. Title: A Proposal for Establishing Environmental Restoration Clean Up Levels of Radioactive Contamination from a Risk Based Perspective. Corporate Author: Westinghouse Idaho Nuclear Company, Inc., Idaho Falls, ID. Pub: WINCO-11770; CONF-9111253; Proceedings of the Department of Energy Technical Information Exchange Meeting, Augusta, GA, November 17-20, 1991; (4 pp.) Abstract: Due to the large quantities

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of low-level radioactively contaminated soil encountered at the Idaho National Engineering Laboratory and the lack of available disposable facilities, anticipated storage and disposal problems are imminent. The space available for disposal of the low-level radioactively contaminated soil in the present Radiological Waste Management Complex is very limited. The removal and disposal of low-level radioactively contamination in soil is prohibitive. The status of radioactivity as carcinogenic poses a societal and regulatory obstacle in the environmental restoration process. The use of the risk assessment, as applied to chemically based hazardous substances, must be applied to low level radiological contamination in establishing clean up standards.

### **CONSIDERATION or JUSTIFICATION/DOE**

Bilyard, G.R.; Bascietto, J.J.; Beckert, H. Date: 1992, October. Title: Regulatory and Institutional Considerations in the Application of Ecological Risk Assessment at Department of Energy Facilities. Corporate Author: Pacific Northwest Laboratory, Richland, WA; U.S. Department of Energy, Washington, DC. Pub: CONF-921029; Waste Management and Environmental Restoration, Proceedings of the Eighth Annual DOE Model Conference, Oak Ridge, TN, October 18-22, 1992, 228 pp.; (7 pp.) Abstract: Ecological risk assessment is a promising tool that the U.S. Department of Energy (DOE) can use to help meet its regulatory and institutional obligations during environmental restoration activities. It can also provide information for resource management decisions. The adoption of ecological risk assessment has several implications for DOE, including the need to define a process for using ecological risk assessment to support regulatory compliance and institutionally mandated activities. This paper first identifies regulatory requirements and institutional considerations that could be important to DOE. Considering the often diverse characteristics of DOE sites, a process for using ecological risk assessments at DOE sites is proposed in this paper.

### **CONSIDERATION or JUSTIFICATION/DOE**

Buck, J.W.; Strenge, D.L.; Droppo, J.G., Jr. 1990. Analysis of Risk Indicators and Issues Associated with Applications of Screening Model for Hazardous and Radioactive Waste Sites. Dec. 1990. Pacific Northwest Laboratories, Richland, WA. Contract number - DOEAC06-76rl01830 Report number - PNL-SA-18892 20-22 Feb 1991. National research and development conference on the control of hazardous materials, Anaheim, CA (USA) Abstract: Risk indicators, such as

population risk, maximum individual risk, time of arrival of contamination, and maximum water concentrations, were analyzed to determine their effect on results from a screening model for hazardous and radioactive waste sites. The analysis of risk indicators is based on calculations resulting from exposure to air and waterborne contamination predicted with Multimedia Environmental Pollutant Assessment System (MEPAS) model. The different risk indicators were analyzed, based on constituent type and transport and exposure pathways. Three of the specific comparisons that were made are: (1) population-based versus maximum individual-based risk indicators; (2) time of arrival of contamination, and (3) comparison of different threshold assumptions for noncarcinogenic impacts. Comparison of indicators for population and maximum individual-based human health risk suggests that these two parameters are highly correlated, but for a given problem, one may be more important than the other. The results indicate that the arrival distribution for different levels of contamination reaching a receptor can also be helpful in decisions, regarding the use of resources for remediating short- and long-term environmental problems. The addition of information from a linear model for noncarcinogenic impacts allows interpretation of results below the reference dose (RFD) levels that might help in decisions for certain applications. The analysis of risk indicators suggests that important information may be lost by the use of a single indicator to represent public health risk and that multiple indicators should be considered. 15 refs., 8 figs., 1 tab.

#### **CONSIDERATION or JUSTIFICATION/DOE**

Hammonds, J.S.; Hoffman, F.O.; White, R.K.; Miller, D.B. Date: 1992, October. Title: Background Risk Information to Assist in Risk Management Decision Making. Corporate Author: Oak Ridge National Laboratory, Oak Ridge, TN. Pub: ES/ER/TM-40; 15 pp. Abstract: The evaluation of the need for remedial activities at hazardous waste sites requires quantification of risks of adverse health effects to humans and the ecosystem resulting from the presence of chemical and radioactive substances at these sites. The health risks from exposure to these substances are in addition to risks encountered because of the virtually unavoidable exposure to naturally occurring chemicals and radioactive materials that are present in air, water, soil, building materials, and food products. To provide a frame of reference for interpreting risks quantified for hazardous waste sites, it is useful to identify the relative magnitude of risks of both a voluntary and involuntary nature that

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are ubiquitous throughout east Tennessee. In addition to discussing risks from the ubiquitous presence of background carcinogens in the east Tennessee environment, this report also presents risks resulting from common, everyday activities. Such information should not be used to discount or trivialize risks from hazardous waste contamination, but rather to create a sensitivity to general risk issues, thus providing a context for better interpretation of risk information.

### **CONSIDERATION or JUSTIFICATION/EPA**

Bascietto, J.J. Date: 1992, October. Title: Development of Ecological Risk Assessment - An Historical Perspective. Corporate Author: U.S. Department of Energy, Office of Environmental Guidance, Washington, DC. Pub: CONF-921029; Waste Management and Environmental Restoration, Proceedings of the Eighth Annual DOE Model Conference, Oak Ridge, TN, Oct. 18-22, 1992, 228 pp.; (8 pp.) Abstract: This paper gives the history of the U.S. Environmental Protection Agency's (EPA's) effort to develop a regulatory framework for ecological risk, beginning in the 1980s. This effort arose from the EPA's difficulty in establishing the proper level of ecological risk for the cancellation of two pesticides (diazinon and carbamate carbofuran). Diazinon, which was canceled first in 1990 after a six-year special review by the EPA, was less widely used and less toxic than carbamate carbofuran, which was canceled in 1991 after another six-year special review. EPA's 1992 framework for ecologic risk was the first published consensus document on generic ecological risk assessment principles, and is expected to form the basis for all future EPA ecological risk assessments. The current EPA regulatory framework, which is based on these early ecological risk assessment efforts, is given in another paper in this same conference session.

### **CONSIDERATION or JUSTIFICATION/EPA**

Boyd, M.; Nelson, C.B.; Martin, J.A.; Ralston, L. Date: 1992, March. Title: A Review of the Superfund Risk Assessment Approach for Quantifying Radiation Risks. Corporate Author: U.S. Environmental Protection Agency, Washington, DC; Cohen (S.) and Associates, Inc., McLean, VA. Pub: CONF-920307 (Vol. 1); Waste Management '92: Working Towards a Cleaner Environment, R.G. Post (ed.), Proceedings of a Symposium, Tucson, AZ, March 1-5, 1992, Vol. 1, 994 pp.; (pp. 505-508) Abstract: When the Environmental Protection Agency (EPA) calculates the risk of developing cancer from radiation exposure at Superfund sites containing radioactive

material, it must consider the risks from ingestion and inhalation of radioactivity as well as from external radiation. This paper will focus on the derivation and application of slope factors for estimating the age-averaged lifetime excess cancer incidence (including fatal and nonfatal radiogenic cancers) per unit intake or exposure to the radionuclides of concern from these three exposure pathways. This paper has been reviewed in accordance with the U.S. Environmental Protection Agency's peer and administrative review policies and approved for presentation and publication.

### **CONSIDERATION or JUSTIFICATION/Other**

Morgan, M.G., and M. Henrion, 1990. Uncertainty. a Guide to Dealing with Uncertainty in Quantitative Risk and Policy Analysis. Cambridge University Press, NY.

### **CONSIDERATION or JUSTIFICATION/Other**

Wartenberg, D., and R. Simon. 1995. Comment: Integrating epidemiologic data into risk assessment. American Journal of Public Health. 85(4):491-493. April, 1995.

### **ECOLOGICAL/Commercial**

ASCE. 1989. Proceedings of the 1989 Specialty Conference Austin, TX, USA CD- 1989 Jul 10-12. Publ by ASCE, New York, NY, USA. ASCE, Environmental Engineering Div, USA; Univ of Texas at Austin, Civil Engineering Dep, Austin, TX, USA; ASCE, Texas Sect, Austin, TX, USA; American Acad of Environmental Engineers, USA. Abstract- The volume contains 117 papers presented at the conference. The papers are grouped under general topics that include point-of-entry/point-of-use water treatment devices, activated sludge wastewater treatment, multi-media environmental risk assessment, effluent polishing, radon mitigation in new construction, hazardous waste site cleanup, treatment facility design and operation, sludge management, surface water quality assessment and modeling, mixed waste and low-level radioactive waste disposal.

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### **ECOLOGICAL/Commercial**

Paustenbach, D.J. Date: 1988. Title: The Risk Assessment of Environmental and Human Hazards. Corporate Author: . Pub: John Wiley and Sons Inc., New York, NY; 1600 pp. Abstract: A complete handbook for conducting risk assessments for environmental and occupational health hazards. This casebook, the first of its kind, presents 22 case studies, including many of the most important and thorough risk assessments ever conducted. It describes state-of-the-art approaches to assessing the low-dose response, estimating exposure, and evaluating the risks to birds and fish. It also serves as a how-to-text, as well as a reference for developing high-quality environmental and human health risk assessments. Diverse hazards are covered, such as waste sites; contaminated air, soil, and water; consumer products; and indoor air. All assessments are fully documented and referenced.

### **ECOLOGICAL/DOD**

Tate, D.J.; Jones, M.; Schulz, T.; Guo, X.; Fordham, C.L.; Ober, R.; Swalko, M. Date: 1992. Title: Innovative Probabilistic Assessment of Ecological Risk on a Federal Facility. Corporate Author: Ebasco Environmental, Lakewood, CO; Terra Technologies, Golden, CO; U.S. Army, Commerce City, CO; U.S. Army, Aurora, CO. Pub: CONF-9204110; Proceedings of the 1992 Hazardous Materials Control Research Institute Federal Environmental Restoration Conference and Exhibition, Vienna, VA, April 15-17, 1992. Hazardous Materials Control Resources Institute, Greenbelt, MD, 472 pp.; (pp. 147-152) Abstract: This paper presents an overview of an innovative probabilistic approach to ecological risk assessment (ERA) as applied to the onsite area of Rocky Mountain Arsenal (RMA). This 27-square-mile site contains multiple trophic levels in both aquatic and terrestrial ecosystems and is being considered for National Wildlife Refuge status in Congress. Therefore, ecological considerations are of particular importance in the assessment of risk and development of remediation goals at this site. The ERA will provide information for establishment of cleanup goals protective of wildlife on RMA. This ERA approach uses a computerized food web model that is most applicable to bioaccumulative contaminants of concern (COCs). It is tailored to site-specific ecological concerns and builds on the 1989 U.S. Environmental Protection Agency guidance for ERAs. Literature data to develop probabilistic and fixed parameter values provide input to a model that uses Latin Hypercube Sampling to estimate terrestrial and aquatic biomagnification factor (BMF)

distributions. BMF distributions are then calibrated and validated with site-specific contaminant data. At RMA, almost 2000 biota samples representing numerous trophic levels in food webs for five sink species were the basis for calibration and validation of the model. When a BMF distribution is divided into a maximum allowable tissue concentration (developed from literature values), a distribution of probabilistic biota criterion (PBC) is generated. PBCs are then used to quantify risks to biota in the various trophic levels and food webs. Contaminant-specific PBCs are compared to the concentrations of each COC in soil and water to identify exceedances. Finally, exceedances are summed to identify areas where the additive risk for all COCs indicates potential ecological endangerment.

## **ECOLOGICAL/DOE**

Cornaby, B.W.; Daniels, K.L.; Hadden, C.T.; Mitz, S.V.; Rogers, W.J.; Page, D.G. Date: 1992, March. Title: Ecological Risk Assessments and Remedial Investigations of Populations, Communities, and Ecosystems Along East Fork Poplar Creek, Oak Ridge, TN. Corporate Author: Science Applications International Corporation, Oak Ridge, TN; U.S. Department of Energy, Oak Ridge Operations Office, Oak Ridge, TN. Pub: CONF-920851 (Vol. 1); Spectrum '92: Nuclear and Hazardous Waste Management, Proceedings of an International Topical Meeting, Boise, ID, August 23-27, 1992, Vol. 1, 848 pp.; (pp. 815-818) Abstract: Mercury and other contaminants released from the Oak Ridge Y-12 Plant have contaminated nearly 15 miles of the East Fork Poplar Creek (EFPC) system. The creek originates inside the Y-12 Plant boundary and receives runoff and process waters at a rate of approximately 5 million gallons per day. It runs through the city of Oak Ridge and empties into a tributary of the Clinch River, which is part of the Tennessee Valley system of lakes and rivers. Land uses and ecosystems along EFPC include small businesses, residential and agricultural areas, wetlands, forest plantations, and successional forest ecosystems. Contaminants released from the Y-12 plant are predominantly particulate-bound and have therefore accumulated in alluvial deposits downstream from the Y-12 Plant. Contamination is believed to be confined to the floodplain and stream channel. Contamination of the aquatic biota with mercury and polychlorinated biphenyls (PCBs) has been documented since the early 1980s. A remedial investigation assessed the nature and extent of contamination for 188 constituents, including radionuclides, metals, volatile and semivolatile organic compounds, pesticides, and PCBs in surface water, creek sediments, floodplain soils, and

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groundwater. The horizontal and vertical distribution of contaminants was determined in soils and sediments at many locations along the creek. Mercury was found to be the major contaminant in all abiotic media. Soils and sediments in ecosystems near the Y-12 Plant have the highest concentrations of mercury (up to 2400 mg kg[E-1]), and contamination decreases with lateral distance from the stream. In 1991, biota were surveyed and/or sampled at one reference site and six locations along EFPC. These seven sites comprise the sampling locations for the ecological risk assessment. Ecological risk assessment is done in accordance with Comprehensive Environmental Response, Compensation and Liability Act regulatory guidance and is incorporated into the U.S. Environmental Protection Agency-approved activities of hazard identification, exposure assessment, effects assessment, and risk characterization. The approach also integrates the requirements for the Natural Resource Damage Assessment and the National Environmental Policy Act. The effects assessment emphasized effects observed in field samples and not merely laboratory dose-response data extrapolated to the field. A weight-of-evidence approach was used, consisting of several parts. There must be a reasonable dose-response relationship between contaminants and the observed effect, contaminants must be spatially and temporally associated with the effect, and the link between the contaminant and the effect must have consistency of association and must be biologically plausible. When these and related weight-of-evidence considerations are all present, and especially when they occur in field-observed sequences of response(s), then the likelihood of occurrence of an ecological effect is high. The weight-of-evidence approach used population patterns, community trophic relationships, and body-burden data for fish, benthos, crayfish, and periphyton in the aquatic system for small mammals, birds, earthworms, arthropods, and vegetation in the terrestrial system. Body-burden data for many metals, polycyclic aromatic hydrocarbons (PAHs), pesticides, and PCBs were obtained for indicator species in the aquatic and terrestrial food webs to measure and estimate exposures to the next trophic level. These data will be used during the feasibility study to help develop and evaluated remedial action levels and cleanup alternatives that are consistent with the protection of populations, communities, and ecosystems, including wetlands and riparian zones, thereby satisfying integrated compliance requirements.

## **ECOLOGICAL/DOE**

Suter II, G.W.; Redfearn, A.; White, R.K.; Shaw, R.A. Date: 1992, July. Title: Approach and Strategy for Performing Ecological Risk Assessments for the Department of Energy Oak Ridge Field Office Environmental Restoration Program. Corporate Author: Oak Ridge National Laboratory, Oak Ridge, TN. Pub: ES/ER/TM-33; 24 pp. Abstract: This document is intended to supplement exiting U.S. Environmental Protection Agency (EPA) guidance for ecological risk assessment at hazardous waste sites by providing guidance that is more specific and more tailored to U.S. Department of Energy sites than the guidance available from the EPA. However, it is a conceptual strategy document and does not include specific guidance on data, assumptions, and models. That detailed guidance is under development and will be presented in subsequent documents. Ecological risk assessments are equal to human health risk assessments in regulatory importance and can use many of the same data and some of the same estimation methods. However, they also have peculiar data needs and methods. Ecological risk assessments begin with an initial scoping phase, termed hazard definition, that characterizes the sources, the potential environment, and the assessment endpoints. In the subsequent measurement and estimation phase, in which data are obtained concerning source of the endpoint biota to the contaminants and the effects of those exposures, assumptions and models are used to relate the data to the desired exposure and effects parameters. Finally, in an integration phase, termed risk characterization, the various exposure and effects estimates are combined to infer the existence, cause, magnitude, and extent of effects of contaminants on the ecological endpoints. This phase is much more complicated for ecological risk assessments than for human health assessments because more types of data are available. Ecological risk assessments estimate effects using laboratory toxicity test results, like human health assessments, but also use results of ambient toxicity tests and biological surveys.

## **ECOLOGICAL/EPA**

Norton, S.B.; Rodier, D.J.; Gentile, J.H.; van der Schalie, W. Date: 1992, October. Title: EPA's Framework for Ecological Risk Assessment. Corporate Author: U.S. Environmental Protection Agency, Washington, DC. Pub: CONF-921029; Waste Management and Environmental Restoration, Proceedings of the Eighth Annual DOE Model Conference, Oak Ridge, TN, October 18-22, 1992, 228 pp.; (6 pp.) Abstract: The U.S. Environmental Protection Agency (EPA) has

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an increasing interest in using ecological risk assessments as a basis for environmental decisions. This increased emphasis is illustrated by a recent report by the EPA Science Advisory Board. Among their recommendations, the board suggested that EPA (1) target its environmental protection efforts on the basis of opportunities for the greatest risk reduction; (2) attach as much importance to reducing ecological risk as it does to reducing human health risk; and (3) improve the data and analytical methodologies that support the assessment, comparison, and reduction of different environmental risks. This article summarizes the recently published EPA Framework for Ecological Risk Assessment (1992) that describes the basic elements of ecological risk assessment. In addition, the article discusses several of the scientific issues that have been highlighted through the development of the framework report.

### **EXAMPLE/Commercial**

Bernard, H.; Bixler, B.; Lamont, D.; Masters, H.; Rollo, J.; Sanning, D.; Snyder, H.J., Jr.; Tusa, W.K. Date: 1982. Title: Abandoned Site Risk Assessment Modeling and Sensitivity Analysis. Corporate Author: TRC Environmental Consultants, East Hartford, CT. Pub: Management of Uncontrolled Hazardous Waste Sites, Proceedings of a Conference, Washington, DC, November 29-December 1, 1982; (pp. 396-398).

### **EXAMPLE/DOD**

Bernhardt, D.E. Date: 1992. Title: Depleted Uranium Cleanup Criteria and Associated Risks. Corporate Author: Rogers and Associates Engineering Corporation, Salt Lake City, UT. Pub: CONF-920617; Proceedings of the 37th Annual Meeting of the Health Physics Society, Columbus, OH, June 21-25, 1992; (13 pp.) Abstract: Depleted uranium (DU), a by-product from uranium enrichment, is used extensively for armor-piercing munitions by the military and as a catalyst in industry, and has also been used in various Department of Energy activities. Manufacturing and testing of the DU munitions and use of DU catalysts have resulted in residual contamination at DU facilities. This paper focuses on criteria that have been applied related to private party actions, however it also has application to government actions. Private party cleanup projects have been performed by Rogers and Associates for DU contamination at manufacturing sites in Tennessee and California that were based on criteria accepted under Agreement State licenses. The criteria for these projects were based on site-specific radiological pathways assessments and on the Nuclear

Regulatory Agency technical position (SECY-81-756) that was published in the Federal Register 46/205:52061 (October 23, 1981). The base criterion has been 1.3 Bq/g (35 pCi/g) of total uranium. This visual presentation addresses (1) the past and present DU cleanup criteria; (2) sampling techniques for implementing the criteria; (3) related criteria based on NUREG/CR-5512, "Residual Radioactive Contamination from Decommissioning;" and (4) an independent pathways risk assessment for cleanup criteria for DU. Several options for cleanup criteria are given.

### **EXAMPLE/DOD**

Tate, D.J.; Jones, M.; Schulz, T.; Guo, X.; Fordham, C.L.; Ober, R.; Swalko, M. Date: 1992. Title: Innovative Probabilistic Assessment of Ecological Risk on a Federal Facility. Corporate Author: Ebasco Environmental, Lakewood, CO; Terra Technologies, Golden, CO; U.S. Army, Commerce City, CO; U.S. Army, Aurora, CO. Pub: CONF-9204110; Proceedings of the 1992 Hazardous Materials Control Research Institute Federal Environmental Restoration Conference and Exhibition, Vienna, VA, April 15-17, 1992. Hazardous Materials Control Resources Institute, Greenbelt, MD, 472 pp.; (pp. 147-152) Abstract: This paper presents an overview of an innovative probabilistic approach to ecological risk assessment (ERA) as applied to the onsite area of Rocky Mountain Arsenal (RMA). This 27-square-mile site contains multiple trophic levels in both aquatic and terrestrial ecosystems and is being considered for National Wildlife Refuge status in Congress. Therefore, ecological considerations are of particular importance in the assessment of risk and development of remediation goals at this site. The ERA will provide information for establishment of cleanup goals protective of wildlife on RMA. This ERA approach uses a computerized food web model that is most applicable to bioaccumulative contaminants of concern (COCs). It is tailored to site-specific ecological concerns and builds on the 1989 U.S. EPA guidance for ERAs. Literature data to develop probabilistic and fixed parameter values provide input to a model that uses Latin Hypercube Sampling to estimate terrestrial and aquatic biomagnification factor (BMF) distributions. BMF distributions are then calibrated and validated with site-specific contaminant data. At RMA, almost 2000 biota samples representing numerous trophic levels in food webs for five sink species were the basis for calibration and validation of the model. When a BMF distribution is divided into a maximum allowable tissue concentration (developed from literature values), a distribution of probabilistic biota criterion (PBC) is generated. PBCs are then used to quantify risks

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to biota in the various trophic levels and food webs. Contaminant-specific PBCs are compared to the concentrations of each COC in soil and water to identify exceedances. Finally, exceedances are summed to identify areas where the additive risk for all COCs indicates potential ecological endangerment.

#### **EXAMPLE/DOE**

Addison, S.J. Date: 1981. Title: Excess Cancer Risk Estimates from Exposure to Gamma and Radon Daughter Levels in Mesa County, Colorado. Corporate Author: Western Colorado Radiologic Associates; Grand Junction, CO. Pub: CONF-811049; Uranium Mill Tailings Management, Proceedings of the Fourth Symposium, Fort Collins, CO, October 26-27, 1981, 737 pp.; (pp. 169-179) Abstract: Mesa County, Colorado has been a location of concern regarding the carcinogenic effect of chronic exposure to uranium mill tailings. This study utilizes a recent comprehensive report on health effects of low-level radiation to determine individual risks of excess cancer in the Mesa County population. Risks from radiation levels throughout the county are considered, with emphasis placed on sites included in the mill tailings removal project. Evidence indicates only a few, if any, cancers would be induced by the county's increased gamma levels, and these would probably not be discernable at a statistically significant level. However, elevated levels of alpha emitters, which cause irradiation of the bronchial epithelium, could conceivably increase an individual's chance of lung cancer.

#### **EXAMPLE/DOE**

Armstrong, A.Q.; Layton, D.W.; Rutz, E.E. Date: 1994. Title: Risk Assessment Applications for Determining Cleanup Limits for Uranium in Treated and Untreated Soils. Corporate Author: Oak Ridge National Laboratory, Oak Ridge, TN; Lawrence Livermore National Laboratory, Livermore, CA; University of Cincinnati, Cincinnati, OH. Pub: CONF-940225; Waste Management '94: Proceedings of a Conference, Tucson, AZ, February 27-March 3, 1994; (11 pp.) Abstract: Uranium-contaminated soils are present at various locations across the United States where uranium was processed for nuclear fuels or atomic weapons. Important issues relative to such contamination include the assessment of potential health risks associated with human exposures to the residual uranium and the determination of safe levels of uranium in soils that have been treated by a given technology. This paper discusses various risk assessment considerations that must be dealt with when developing

cleanup limits for uranium in treated and untreated soils. Key issues addressed include alternative land use scenarios, potential exposure pathways, characterization of the bioavailability of uranium compounds in food and water, a brief overview of health risks associated with uranium and its daughter products as well as a summary of considerations for development of risk-based cleanup limits for uranium in soils.

#### **EXAMPLE/DOE**

Avci, H.I.; Biwer, B.M.; Blunt, D.L. Date: 1992, November. Title: Off-Site Population Radiological Dose and Risk Assessment for Potential Airborne Emissions from the Weldon Spring Site. Corporate Author: Argonne National Laboratory, Environmental Assessment and Information Sciences Division, Argonne, IL. Pub: ANL/EAIS/TM-78; 26 pp. Abstract: Radiological doses and health risks to the population around the Weldon Spring site from potential airborne emissions during remedial action at the chemical plant area of the site have been assessed with the Clean Air Act Assessment Package-1988 computer code. Two treatment options are being considered for waste produced by site cleanup activities: chemical stabilization/solidification and vitrification. Over the entire cleanup period of 7 years, the collective dose received by the people who live within 80 km (50 mi) of the site (about 3 million persons) is estimated to be about 34 person-rem for the chemical stabilization/solidification option and 32 person-rem for the vitrification option. By comparison, the same population is expected to receive about  $6 \times 10^6$  (E+6) person-rem from natural background radiation during that time. If only the population within a reasonable radius of impact is considered (about 10,700 persons live within 5 km of the site), the remedial action activities are estimated to result in about 5 person-rem over the entire cleanup period; the same population is expected to receive about 20,000 person-rem from natural background radiation during that time. Because the doses are low, no cancers or genetic effects are expected to occur among the population around the Weldon Spring site as a result of exposures resulting from potential radioactive releases to the atmosphere during remediation of the chemical plant area.

#### **EXAMPLE/DOE**

Bair, W.J. Date: 1983, February. Title: Former Nuclear Site Risk Estimation. Corporate Author: Pacific Northwest Laboratory,

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Richland, WA. Pub: PNL-4600 (Part 5); Pacific Northwest Laboratory Annual Report for 1982 to the DOE Office of the Assistant Secretary for Environmental Protection, Safety and Emergency Preparedness - Part 5: Environmental and Occupational Protection, Assessment, and Engineering; (p. 13) Abstract: During FY 1982, the project was initiated to estimate health effects at formerly utilized MED/AEC nuclear sites or inactive uranium mill tailing sites. This activity complements radiological survey programs that are also sponsored by the Office of Operational Safety. During FY 1982, the general outlines of the methodology to be used in health effects estimation were developed, and initial estimates were calculated for twelve vicinity properties in the Salt Lake City area.

### **EXAMPLE/DOE**

Barnthouse, L.W.; Bascietto, J.J.; Joseph, T.J.; Bilyard, G.R. Date: 1992, October. Title: A Survey of Ecological Risk Assessment at DOE Facilities. Corporate Author: Oak Ridge National Laboratory, Environmental Sciences Division, Oak Ridge, TN; U.S. Department of Energy, Washington, DC; U.S. Department of Energy, Oak Ridge Operations Office, Oak Ridge, TN; Pacific Northwest Laboratory, Richland, WA. Pub: CONF-921029; Waste Management and Environmental Restoration, Proceedings of the Eighth Annual DOE Model Conference, Oak Ridge, TN, October 18-22, 1992, 228 pp.; (6 pp.) Abstract: A Risk-Based Standards Working Group sponsored by the U.S. Department of Energy (DOE) is studying standard setting and remedial action based on realistic estimates of human health and ecological risks. Little technical guidance has been provided by state and local regulatory bodies about how ecological risk assessments should be performed or what constitutes an adequate assessment. The Superfund Guidance Manual put out by the U.S. Environmental Protection Agency (EPA) in 1989 is targeted at project managers rather than at technical staff. EPA's "Framework for Ecological Risk Assessment" (1992) provides basic definitions and principles for ecological risk assessment, but gives no concrete technical guidance. To develop guidance in this area, the Working Group conducted a survey between March and September 1992 of ecological risk assessment activities at ten major DOE facilities. The survey objectives were to (1) identify new approaches now being used by DOE staff and contractors; (2) record successes and failures of these approaches; (3) identify new technical developments with the potential for general application to many DOE facilities; and (4) identify major data needs, data resources, and methodological deficiencies. This paper describes the survey results.

**EXAMPLE/DOE**

Bascietto, J.J. Date: 1992, October. Title: Development of Ecological Risk Assessment - An Historical Perspective. Corporate Author: U.S. Department of Energy, Office of Environmental Guidance, Washington, DC. Pub: CONF-921029; Waste Management and Environmental Restoration, Proceedings of the Eighth Annual DOE Model Conference, Oak Ridge, TN, October 18-22, 1992, 228 pp.; (8 pp.) Abstract: This paper gives the history of the U.S. Environmental Protection Agency's (EPA's) effort to develop a regulatory framework for ecological risk, beginning in the 1980s. This effort arose from the EPA's difficulty in establishing the proper level of ecological risk for the cancellation of two pesticides (diazinon and carbamate carbofuran). Diazinon, which was canceled first in 1990 after a six-year special review by the EPA, was less widely used and less toxic than carbamate carbofuran, which was canceled in 1991 after another six-year special review. EPA's 1992 framework for ecologic risk was the first published consensus document on generic ecological risk assessment principles, and is expected to form the basis for all future EPA ecological risk assessments. Current EPA regulatory framework, based on early ecological risk assessment efforts, is given in another paper in this same conference session.

**EXAMPLE/DOE**

Biggerstaff, R.L. Date: 1994, June 30. Title: Qualitative Risk Assessment for the 100-KR-4 Groundwater Operable Unit. Corporate Author: Westinghouse Hanford Company, Richland, WA. Pub: WHC-SD-EN-RA-010; 81 pp. Abstract: This report provides the qualitative risk assessment (QRA) for the 100-KR-4 groundwater operable unit at the U.S. Department of Energy's (DOE) Hanford Site in southeastern Washington State. The extent of the groundwater beneath the 100 K Area is defined in the Remedial Investigation/Feasibility Study Work Plan for the 100-KR-4 Operable Unit (DOE-RL 1992a). The QRA is an evaluation of risk using a limited amount of data and a predefined set of human and environmental exposure scenarios and is not intended to replace or be a substitute for a baseline risk assessment.

**EXAMPLE/DOE**

Brice, D.A.; Archer, J.A.; Greer, J.K. Date: 1990. Title: Establishment of Alternate Clean Up Goals for a RCRA Facility

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Utilizing Numerical Analysis of Transport Pathways to Evaluate Risk to Human and Environmental Receptors. Corporate Author: Geraghty and Miller, Inc., Oak Ridge, TN; Oak Ridge National Laboratory, Oak Ridge, TN. Pub: CONF-9005149; Aquifer Restoration, Groundwater Monitoring, and Geophysical Methods, Proceedings of the Fourth National Outdoor Action Conference, Las Vegas, NV, May 14-17, 1990, 1333 pp.; (pp. 919-934) Abstract: Achievable cleanup goals were developed for a Resource Conservation and Recovery Act interim status disposal unit and associated Solid Waste Management Units collectively referred to as the S-3 Waste Management Area (S-3 WMA). The unit, now closed and capped, was an unlined disposal pond located at the Oak Ridge Y-12 Plant in Oak Ridge, Tennessee. The area is geologically complex, typified by steeply dipping sedimentary strata of diverse lithology and hydraulic properties. Groundwater was identified as the primary transport pathway because it links the source area to potential points of exposure along the creeks. The transport of four constituents representative of the types of constituents disposed at the ponds during the thirty-three years of use were modeled. Exposure scenarios were developed based upon current conditions for both human and environmental receptors. Plant workers conducting routine sampling or studies of the groundwater or surface water were identified as the most sensitive human receptors. Aquatic biota are the most sensitive environmental receptors. Transport simulations showed that the concentration of these constituents would be naturally attenuated by a factor of 10 or more between the source and the nearest point of exposure. Alternate concentration limits (ACLs) were based on attenuation and allowable levels at the point of exposure. Proposed ACLs have been submitted by the U.S. Department of Energy to the state of Tennessee and the U.S. Environmental Protection Agency for approval.

#### **EXAMPLE/DOE**

Cox, N.D.; Atwood, C.L. 1988. Probabilistic Risk Assessment for Greater Confinement Disposal. Oct. 1988. EG and G Idaho, Inc., Idaho Falls, ID Contract number - DOE AC08-89NV10630 Report number DOE/NV/10630-4 (NOTE - Portions of this document are illegible in microfiche products) Abstract: Risks arising from two aspects of disposing radioactive waste at the Nevada Test Site (NTS) are analyzed in this report. The first aspect concerns occupational exposures received during handling and disposal of high-specific-activity low-level waste (HSA-LLW) in augured boreholes used to ensure greater confinement. The second aspect concerns the threat to the public from waste after disposal in

augured boreholes. The risk assessment for HSA-LLW confirms that procedures for, and operations of, future augured borehole disposal sites will provide a safe and effective way to dispose of this type of waste. Augured borehole disposal operations are conducted at minimal, or near minimal, occupational radiation levels for site personnel. Contingency plans to recover from equipment failure are well thought out and, if executed as planned, will keep personnel radiation exposures within tolerable limits. The risk to the public from waste that has been disposed in augured boreholes was identified as a result of tritium seepage from disposal packages. The resulting committed dose equivalents were calculated using conservative assumptions. If one new hole is filled each year, the annual dose equivalent to an individual living full-time near the disposal site is on the order of 0.2 mrem, well below the regulatory limit of 25 mrem. The annual dose equivalent to an average individual is much smaller, approximately 0.001 mrem. The probability of a harmful health effect to either individual is negligible compared to other risks that are encountered in everyday life. 21 refs., 4 figs., 13 tabs.

#### **EXAMPLE/DOE**

Devgun, J.S. Date: 1990a, April. Title: Radioactive Risk Assessment for Radioactive Contamination at a Landfill Site. Corporate Author: Argonne National Laboratory, Argonne, IL. Pub: CONF-9004181 (Vol. 1); Remedial Action Under the Environmental Restoration and Waste Management Five-Year Plan, Proceedings of the Department of Energy Remedial Action Program Conference, Albuquerque, NM, April 16-19, 1990, Vol. 1, 656 pp.; (pp. 355-366) Abstract: A limited-scope preliminary assessment of radiological risk has been conducted for a landfill site at the Seaway Industrial Park in Tonawanda, New York, where radioactive residues resulting from past uranium ore processing operations of the Manhattan Engineering District are present. Potential radiation doses to an individual under different scenarios have been predicted using the RESRAD computer code. The assessment provides useful input to the remedial action planning for the site that is currently underway. The results of this preliminary analysis show that the current conditions case for Area A of the landfill site does not meet DOE radiation protection criterion of less than 100 mrem/yr dose to an individual member of the public. After the erosion of the thin cover on Area A in about 150 years, the dose to an individual in the resident/farmer scenario is more than two times the dose limit; for the industrial worker scenario, the dose is about three quarters of the dose limit. Given DOE commitment to as low as reasonably achievable

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potential dose levels, letting the current conditions remain "as is" in Area A is not a viable alternative in the long term.

#### **EXAMPLE/DOE**

Devgun, J.S. Date: 1990b. Title: Radiological Risk Assessment of a Radioactively Contaminated Site. Corporate Author: Argonne National Laboratory, Argonne, IL. Pub: CONF-900210 (Vol. 1); Waste Management '90: Working Towards a Cleaner Environment - Waste Processing, Transportation, Storage and Disposal, Technical Programs and Public Education - Overview and General Waste Management, R.G. Post (ed.), Proceedings of a Conference, Tucson, AZ, Feb. 25-Mar. 1, 1990, Vol. 1, 813 pp.; (pp. 513-518) Abstract: A limited-scope preliminary assessment of radiological risk has been conducted at a radioactively contaminated site located in the southeastern part of the city of Oak Ridge, Tennessee. The Elza Gate site was used by the Manhattan Engineering District in the early 1940s as a storage area for uranium ore and ore-processing residues. Five warehouses with concrete pad floors were used for storing such materials. None of the original structures remain, but the concrete pads upon which the warehouses were built are still in place. The site is currently being developed for use as an industrial park. The radiological risk assessment is based on the available preliminary radiological characterization data for the site and will provide useful input to the remedial action planning for the site.

#### **EXAMPLE/DOE**

Doctor, P.G.; Eslinger, P.W.; Elwood, D.M.; Engel, D.W.; Freshley, M.D.; Liebetrau, A.M.; Reimus, P.W.; Strenge, D.L.; Tanner, J.E.; Van Luik, A.E. Date: 1992, May. Title: An Example of Postclosure Risk Assessment Using the Potential Yucca Mountain Site. Corporate Author: Pacific Northwest Laboratory, Richland, WA. Pub: PNL-8081; 299 pp. Abstract: The risk analysis described in this document was performed for the U.S. Department of Energy's Office of Civilian Radioactive Waste Management over a 2-year time period ending in June 1988. The objective of Pacific Northwest Laboratory's (PNL's) task was to demonstrate an integrated, though preliminary, modeling approach for estimating the postclosure risk associated with a geologic repository for the disposal of high-level nuclear waste. The modeling study used published characterization data for the proposed candidate site at Yucca Mountain, Nevada, along with existing models and computer codes available at that time. Some of the site data and conceptual models reported in the Site

Characterization Plan published in December 1988, however, were not yet available when PNL conducted the modeling studies.

#### **EXAMPLE/DOE**

Duke, C.S.; Martin, J.F.; Gray, S.I. Date: 1991. Title: Ecological Risk Assessment for the DOE Fernald Facility. Corporate Author: Advanced Sciences, Inc., Idaho Falls, ID. Pub: CONF-910270 (Vol. 2); Waste Management '91: Working Towards a Cleaner Environment, R.G. Post (ed.), Proceedings of the Symposium, Tucson, AZ, February 24-28, 1991, Vol. 2, 815 pp.; (pp. 149-156) Abstract: Ecological risk assessment is an integral part of the CERCLA process for remediating hazardous waste sites, and of NEPA requirements for evaluating the environmental impacts of major federal actions. Ecological risk assessments in NEPA impact analyses and CERCLA Baseline Risk Assessments can serve in turn as the bases for CERCLA-required Preliminary Natural Resources Surveys and Natural Resources Damage Assessments (PNRS/NRDA). These documents attempt to directly assess the value of lost or damaged natural resources as the basis for a court award of monetary damages against the responsible parties. PNRS/NRDA is a significant issue for hazardous waste sites under the control of government agencies, because they are the designated trustees for the natural resources at their facilities. A variety of studies support ecological risk assessment for a CERCLA/NEPA investigation being conducted at the Department of Energy's Feed Materials Production Center (FMPC) near Fernald, Ohio. These include radionuclide analyses of vegetation and aquatic organisms; threatened and endangered species surveys; toxicity tests of soils, sediments, and effluent; wetlands delineation; and surveys of aquatic invertebrate communities. Preliminary results suggest that the FMPC does not have a major ecological impact on the surrounding area, that wetlands are limited in extent, and that endangered species are not present. The breadth of ecological studies at Fernald, a 1050 acre site without extensive wetlands or critical habitats, illustrates the potential importance of ecological risk assessment and PNRS/NRDA to larger and more complex sites.

#### **EXAMPLE/DOE**

Duke, C.S.; Meyers-Schone, L.; Glum, S.R.; Quaid, W. Date: 1991, September. Title: An Assessment of Baseline Ecological Risks at the Fernald Environmental Management Project, Fernald, Ohio. Corporate Author: Advanced Sciences, Inc., Ross, OH. Pub: CONF-910981; Environmental Remediation '91: Cleaning Up the Environment for the

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21st Century, D.E. Wood (ed.), Proceedings of a Conference, Pasco, WA, September 8-11, 1991, 970 pp.; (pp. 861-869) Abstract: The Fernald Environmental Management Project (FEMP), formerly the Feed Materials Production Center (FMPC), is a Department of Energy (DOE) facility located near Cincinnati, Ohio, which produced pure uranium metals from the early 1950s until 1989. DOE is currently conducting a Remedial Investigation/Feasibility Study (RI/FS) under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), in order to remediate environmental impacts at the site. DOE is also preparing an environmental impact statement under the National Environmental Protection Act (NEPA) to evaluate environmental impacts of proposed remedial actions. Both CERCLA and NEPA require evaluation of ecological risks of baseline conditions and proposed remedial actions. A preliminary assessment of ecological risks examined the potential effects of FEMP contaminants in one operable unit (OU) at the site: OU5, Environmental Media. Radionuclides of potential concern in OU5 soils include uranium, cesium, radium, strontium, technetium, and thorium. Chemicals detected in terrestrial organisms include aluminum, arsenic, barium, cadmium, lead, mercury, vanadium, and zinc, as well as radionuclides. Chemicals of potential concern in surface water include a variety of metals as well as uranium and technetium. Radionuclides in OU5 do not appear to pose a hazard to terrestrial organisms. Estimated radiation doses to aquatic organisms continually exposed to the maximum uranium concentrations observed in on-property drainages ranged from 40 to 4000 rad per year. However, off-property radionuclide concentrations are very low, and it is unlikely that organisms in streams adjacent to the FEMP are exposed to toxic levels. Maximum arsenic levels in vegetation collected from the FEMP are consistent with values reported in the literature to be toxic to certain plants. However, signs of stress have not been observed in vegetation on, or adjacent to, the FEMP. Similarly, arsenic levels in plants and animals collected from the FEMP could be toxic to terrestrial mammals under worst-case conditions, but toxicity has not been observed in the field. Current and planned sampling of soils will clarify whether nonradioactive constituents constitute a hazard to terrestrial organisms at the FEMP. The maximum concentrations of aluminum observed in OU5 surface waters are comparable to those reported to cause chronic-to-acute effects in aquatic organisms. However, macroinvertebrate communities in streams adjacent to the FEMP do not exhibit any adverse effects of exposure to FEMP constituents. This preliminary assessment suggests that present ecological risks of the FEMP are low and likely to be associated primarily with nonradiological effects. However, long-term

ecological risks could be substantial if containment systems fail or wastes are penetrated by plants or burrowing animals.

#### **EXAMPLE/DOE**

Ebinger, M.H.; Hansen, W.R. Date: 1994, April 29. Title: Depleted Uranium Human Health Risk Assessment, Jefferson Proving Ground, Indiana. Corporate Author: Los Alamos National Laboratory, Los Alamos, NM. Pub: LA-UR-94-1809; 77 pp. Abstract: The risk to human health from fragments of depleted uranium (DU) at Jefferson Proving Ground (JPG) was estimated using two types of ecosystem pathway models. A steady-state, model of the JPG area was developed to examine the effects of DU in soils, water, and vegetation on deer that were hunted and consumed by humans. The RESRAD code was also used to estimate the effects of farming the impact area and consuming the products derived from the farm. The steady-state model showed that minimal doses to humans are expected from consumption of deer that inhabit the impact area. Median values for doses to humans range from about 1 mrem (plus or minus 2.4) to 0.04 mrem (plus or minus 0.13) and translate to less than  $1 \times 10(E+[-6])$  detriments (excess cancers) in the population. Monte Carlo simulation of the steady-state model was used to derive the probability distributions from which the median values were drawn. Sensitivity analyses of the steady-state model showed that the amount of DU in airborne dust and, therefore, the amount of DU on the vegetation surface, controlled the amount of DU ingested by deer and by humans. Human doses from the RESRAD estimates ranged from less than 1 mrem/y to about 6.5 mrem/y in a hunting scenario and subsistence farming scenario, respectively. The human doses exceeded the 100 mrem/y dose limit when drinking water for the farming scenario was obtained from the on-site aquifer that was presumably contaminated with DU. The two farming scenarios were unrealistic land uses because the additional risk to humans due to unexploded ordnance in the impact area was not figured into the risk estimate. The doses estimated with RESRAD translated to less than  $1 \times 10(E+[-6])$  detriments to about  $1 \times 10(E+[-3])$  detriments. The higher risks were associated only with the farming scenario in which drinking water was obtained on-site.

#### **EXAMPLE/DOE**

Fingleton, D.J.; MacDonell, M.M.; Haroun, L.A.; Ozkaynak, H.; Butler, D.A.; Xue, J. Date: 1991, September. Title: Assessing Exposures and Risks in Heterogeneously Contaminated Areas: A Simulation Approach. Corporate Author: Argonne National Laboratory,

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Argonne, IL; Harvard University, Cambridge, MA. Pub: CONF-910981; Environmental Remediation '91: Cleaning Up the Environment for the 21st Century, D.E. Wood (ed.), Proceedings of a Conference, Pasco, WA, September 8-11, 1991, 970 pp.; (pp. 871-876) Abstract: The U.S. Department of Energy (DOE) is responsible for cleanup activities at a number of facilities under its Environmental Restoration and Waste Management Program (EM), including the Weldon Spring Site in Missouri. The major goals of the EM program are (1) to eliminate potential hazards to human health and the environment that come from contamination at these sites and (2) to make surplus real property available for other uses. The assessment of baseline health risks and ecological impacts that may come from a contaminated site is an important component of the remedial investigation/feasibility study (RI/FS) process, which is required at all Superfund sites. This paper describes one phase of the baseline assessment through the example of the characterization of human health risks associated with exposure to chemical contaminants in air and on interior building surfaces in a contaminated structure on the Weldon Spring Site. The model combines data on human activity patterns in a particular microenvironment within a building, a 60 meter by 110 meter one-story cinderblock structure, with data on contaminant concentrations in that microenvironment to calculate personal exposure profiles and risks within the building. The results of the building assessment are presented as probability distribution functions and cumulative distribution functions, which show the variability and uncertainty in the risk estimates.

#### **EXAMPLE/DOE**

Friant, S.L. Date: 1992, October. Title: Ecological Risk Assessment for Radionuclides - A Case Study. Corporate Author: Pacific Northwest Laboratory, Richland, WA. Pub: CONF-921029; Waste Management and Environmental Restoration, Proceedings of the Eighth Annual DOE Model Conference, Oak Ridge, TN, October 18-22, 1992, 228 pp.; (6 pp.) Abstract: Since 1943, production activities at the Hanford Site have entailed the discharge of effluents to the Columbia River, which runs through the northern portion of the site and borders it on the east. DOE Order 5400.5, the one published standard for the protection of ecological resources from exposure to radioactive material, stipulates that the interim dose limit for native aquatic organisms "shall not exceed 1 rad per day from exposure to the radioactive material in liquid wastes discharged to natural waterways." This study was undertaken to determine whether the ecological risk paradigm for hazardous chemicals developed by

the Environmental Protection Agency is applicable to organism exposure to radionuclides. The paper is a brief description of the assessment.

#### **EXAMPLE/DOE**

Haroun, L.A.; Peterson, J.M.; MacDonell, M.M.; Fingleton, D.J.; McCracken, S.H. Date: 1990, April. Title: Risk Assessment at the Weldon Spring Site: Lessons Learned. Corporate Author: Argonne National Laboratory, Argonne, IL. Pub: CONF-9004181 (Vol. 1); Remedial Action Under the Environmental Restoration and Waste Management Five-Year Plan, Proceedings of the Department of Energy Remedial Action Program Conference, Albuquerque, NM, April 16-19, 1990, Vol. 1, 656 pp.; (pp. 331-354) Abstract: Several health-risk assessments have been prepared for the Weldon Spring Site Remedial Action Project, including (1) the quarry and site water treatment plant engineering evaluation/cost analyses; (2) the quarry baseline risk evaluation; (3) the quarry feasibility study; (4) the site baseline risk assessment; and (5) the site feasibility study. This presentation covers five general topics: (a) specific health risk assessments for the Weldon Spring Site, including their scope and methodology; (b) objectives of the health risk assessment; (c) lessons learned to date; (d) emerging issues in health risk assessment for U.S. Department of Energy Superfund sites; and (e) an ecological assessment.

#### **EXAMPLE/DOE**

Hook, L.A.; Gentry, M.J.; Shaakir-Ali, J.A.; Faulkner, M.A. Date: 1992, June. Title: Development of an Integrated Data Base for the Screening-Level Risk Assessment for the Clinch River Resource Conservation and Recovery Act Facility Investigation. Corporate Author: Science Applications International Corporation, Oak Ridge, TN; Oak Ridge National Laboratory, Oak Ridge, TN. Pub: CONF-9002111; Data Analysis and Interpretation for Environmental Surveillance, Proceedings of a Conference, Lexington, KY, February 5-7, 1990, 149 pp.; (pp. 35-36) Abstract: The Oak Ridge Reservation (ORR) includes three U.S. Department of Energy (DOE) facilities where radioactive and hazardous substances have been handled since 1942. Surface waters beyond the boundary of the ORR, including portions of the Clinch and Tennessee rivers, have received contaminants as a result of past operations and waste management practices. Thus, the U.S. Environmental Protection Agency (EPA), under the provisions of the Resource Conservation and Recovery Act (RCRA), requires that a Clinch River RCRA Facility Investigation

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(CRRFI) be conducted. The CRRFI is being implemented in a phased approach to (1) define the nature and extent of off-site contamination, (2) quantify risk to human health and the environment, and (3) identify and evaluate the remedial action alternatives. One of the first tasks was to perform screening-level risk analyses for human and aquatic organism exposure pathways, based on existing data. Thus, there was a need to identify, compile, and integrate selected data into a single consistent data base for use by the investigators performing the risk assessments. The data required were recent maximum and mean values of water quality parameters and of contaminant concentrations in sediment, water, fish, and other biota (e.g., vegetation). The study area was divided into manageable units or reaches for the risk assessment, based on proximity to known contaminant release points from DOE facilities and other potential sources of pollution in the area. The major sources of data included Oak Ridge Task Force results, DOE ORR Environmental Surveillance Reports, results of several intensive sediment sampling activities, and Tennessee Valley Authority data retrieved from the EPA's STORET system. No one study or program had sufficient data to meet the risk assessment requirements for any given reach. The structured process by which data files were quality checked and manipulated into a common SAS data base structure are discussed.

### **EXAMPLE/DOE**

JEG. 1993a, September. Title: Baseline Risk Assessment of Groundwater Contamination at the Uranium Mill Tailings Site Near Shiprock, New Mexico. Corporate Author: Jacobs Engineering Group, Inc., Albuquerque, NM. Pub: DOE/AL/62350-48D; 171 pp. Abstract: This report evaluates potential impact to public health or the environment resulting from groundwater contamination at the former uranium mill processing site near Shiprock, New Mexico. The tailings and other contaminated material at this site were placed in a disposal cell on the site in 1986 by the U.S. Department of Energy's (DOE) Uranium Mill Tailings Remedial Action (UMTRA) Project. Currently, the UMTRA Project is evaluating groundwater contamination. This risk assessment is the first document specific to this site for the Groundwater Project. This risk assessment follows the approach outlined by the U.S. Environmental Protection Agency (EPA). The first step is to evaluate groundwater data collected from monitor wells at the site. Evaluation of these data showed that the main contaminants in the floodplain groundwater are arsenic, magnesium, manganese, nitrate, sodium, sulfate, and uranium. The complete list of contaminants associated with the

terrace groundwater could not be determined due to the lack of the background groundwater quality data. However, uranium, nitrate, and sulfate are evaluated since these chemicals are clearly associated with uranium processing and are highly elevated compared to regional waters. It also could not be determined if the groundwater occurring in the terrace is a usable water resource, since it appears to have originated largely from past milling operations. The next step in the risk assessment is to estimate how much of these contaminants people would be exposed to if a drinking well were installed in the contaminated groundwater or if there were exposure to surface expressions of contaminated water. Potential exposures to surface water include incidental contact with contaminated water or sediments by children playing on the floodplain and consumption of meat and milk from domestic animals grazed and watered on the floodplain.

#### **EXAMPLE/DOE**

JEG. 1993b, September. Title: Baseline Risk Assessment for Groundwater Contamination at the Uranium Mill Tailings Site Near Monument Valley, Arizona. Corporate Author: Jacobs Engineering Group, Inc., Albuquerque, NM. Pub: DOE/AL/62350-43D; 127 pp. Abstract: This baseline risk assessment evaluates potential impact to public health or the environment resulting from groundwater contamination at the former uranium mill processing site near Monument Valley, Arizona. The tailings and other contaminated material at this site are being relocated and stabilized in a disposal cell at Mexican Hat, Utah, through the U.S. Department of Energy (DOE) Uranium Mill Tailings Remedial Action (UMTRA) Project. The tailings removal is planned for completion by spring 1994. After the tailings are removed, groundwater contamination at the site will continue to be evaluated. This risk assessment is the first document specific to this site for the Groundwater Project. It will be used to assist in determining what remedial action is needed for contaminated groundwater at the site.

#### **EXAMPLE/DOE**

Kluesner, D.; Nawar, M.; Mauro, J.J. Date: 1992, March. Title: Baseline Risk Assessment of the Maxey Flats Disposal Site. Corporate Author: U.S. Environmental Protection Agency, Region IV, Atlanta, GA; U.S. Environmental Protection Agency, Office of Radiation Programs, Washington, DC; Cohen (S.) and Associates, Inc., McLean, VA . Pub: CONF-920307 (Vol. 2); Waste Management '92: Working Towards a Cleaner Environment, R.G. Post (ed.), Proceedings

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of a Symposium, Tucson, AZ, March 1-5, 1992, Vol. 2, 820 pp.; (pp. 1435-1440) Abstract: The Maxey Flats Disposal Site (MFDS), located in Morehead, Kentucky, operated as a low-level radioactive waste disposal site from 1963 to 1977, when operations ceased due to the determination that leachate was migrating through the subsurface geology. In 1986, the site was listed on the National Priorities List to be addressed under the Superfund program. On April 1, 1991, the Maxey Flats Steering Committee file with U.S. Environmental Protection Agency (EPA) Region IV the MFDS Feasibility Study (FS) in accordance with the Administrative Order by Consent (USEPA Docket No. 87-08-C) entered into by the EPA and consenting members of the steering committee. During the preparation of the FS, a number of technical and regulatory issues were raised and resolved with regard to the Applicable or Relevant and Appropriate Requirements (ARARs) for the site and the performance of a Baseline Risk Assessment. Accordingly, the MFDS docket establishes EPA precedence that may be applicable to other Superfund sites contaminated with radioactive materials. The purpose of this paper is to (1) describe EPA requirements regarding ARARs pertaining to the remediation of the MFDS, and (2) to summarize the radiation exposure scenarios and assumptions used by the EPA to evaluate the baseline risks associated with the MFDS. It is intended that the regulatory interpretations and experience gained in preparing the MFDS remedial investigation/feasibility study reports will help to facilitate the remediation of other Superfund sites containing radioactive materials.

#### **EXAMPLE/DOE**

Marks, S.; Cross, F.T.; Denham, D.H.; Kennedy, W.E.; Stenner, R.D. Date: 1985, August. Title: Risk Assessment in the DOE Assurance Program for Remedial Action. Corporate Author: Pacific Northwest Laboratory, Richland, WA. Pub: PNL-5541; 98 pp. Abstract: This report provides information obtained during performance of several risk assessment tasks in support of the Assurance Program for Remedial Action (ARPA) sponsored by the DOE's Office of Operational Safety. It presents a method for the estimation of projected health effects at properties in the vicinity of uranium mill tailings piles due to transported tailings or emissions from the piles. Because radon and radon daughter exposure is identified as the principal factor contributing to health effects at such properties, the basis for estimating lung cancer risk as a result of such exposure is discussed in detail. Modeling of health risk due to a secondary pathway, ingestion of contaminated, home-grown food products, is also discussed since it is a potentially important

additional source of exposure in certain geographic locations. Risk assessment methods used in various mill tailings reports are reviewed. The protocols for radiological surveys conducted in DOE-sponsored remedial action programs are critically reviewed with respect to their relevance to the needs of health risk estimation. The relevance of risk assessment to the ARPA program is discussed briefly.

#### **EXAMPLE/DOE**

Morris, S.C.; Rowe, M.D.; Holtzman, S.; Meinhold, A.F. Date: 1993, May. Title: National Radiation Exposures and Risks Caused by Implementing EPA's Proposed Revised National Primary Drinking Water Regulations. Corporate Author: Brookhaven National Laboratory, Upton, NY. Pub: BNL-49162; 53 pp. Abstract: This report estimates risks to workers and the public associated with treatment processes and associated waste products mandated under proposed regulations of radium, radon, and uranium in drinking water. Three scenarios were examined: (1) all wastes flushed to the sanitary sewer; (2) all wastes disposed on land; (3) similar to (2) but radon removal by granulated activated carbon rather than packed tower aeration. Risks considered included accidental injury and cancer. Worker risks for both scenarios I and II were estimated to be 0.025 and 0.01 deaths per year of operation for radium-226 and radium-228, respectively. Worker risks for uranium were estimated to be 0.13 deaths/year of operation for scenario I and 0.5 deaths/year of operation for scenario II. Worker risks for radon removal were estimated to be 1.7 deaths/year of operation for scenario I and 2.2 deaths/year of operation for scenario II. Risks to the public for scenarios I and II for radium-226 were  $4 \times 10^{-4}$  and for radium-228 were  $9 \times 10^{-5}$  deaths/year of operation. Risks to the public for scenarios I and II for uranium were  $7.3 \times 10^{-2}$  and  $2 \times 10^{-4}$ , respectively. Risks to the public for scenario I and II for radon were 24 deaths/year of operation and for scenario III were nil. Public risks were quantified only for people exposed during a year of operation. For example, effects of public exposures in future years via groundwater contamination associated with landfill of treatment waste were not considered.

#### **EXAMPLE/DOE**

Oezkaynak, H.; Xue, J.; Butler, D.A.; Haroun, L.A.; MacDonell, M.M.; Fingleton, D.J. Date: 1991. Title: Addressing Data Heterogeneity: Lessons Learned from a Multimedia Risk Assessment. Corporate Author: Harvard University, Cambridge, MA; Argonne

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National Laboratory, Argonne, IL. Pub: ANL/CP-71902; CONF-910659; Proceedings of the 84th Annual Air and Waste Management Association Meeting and Exhibition, Vancouver, British Columbia, Canada, June 16-21, 1991; (27 pp.) Abstract: Cleanup activities are being conducted by the U.S. DOE at a former chemical plant site, the Weldon Spring Site (inactive for more than 20 years). The Army produced nitroaromatic explosives at the 220-acre site during the 1940s, and radioactive materials of the uranium and thorium series were processed there by DOE's predecessor agency during the 1950s and 1960s. Chemical and radioactive contaminants are present in soil, surface water, sediment, and groundwater at the site as a result of both past releases and disposal activities and subsequent contaminant migration. Samples have been collected from these media over a number of years under both DOE's environmental monitoring program and the site characterization program of the Superfund process. Results of samples analyses are compiled in a computerized data base, and these data are being evaluated for potential exposure pathways currently present at the site or that may be present in the future, in order to estimate possible adverse impacts to human health and the environment in the absence of cleanup. This paper discusses the methodology used to address associated tasks and the lessons learned during the assessment process. Statistical issues and recommended future directions for dealing with technical aspects of this project and with similar multimedia risk assessment projects are addressed in the final discussion.

#### **EXAMPLE/DOE**

Regens, J.L.; White, L.; Albers, B.J.; Purdy, C. Date: 1994. Title: Geomatic Techniques for Assessing Ecological and Health Risk at U.S. Department of Energy Facilities. Corporate Author: Tulane University Medical Center, New Orleans, LA; U.S. Department of Energy, Washington, DC. Pub: Report; 6 pp. Abstract: Hazardous substances, including radionuclides, heavy metals, and chlorinated hydrocarbons, pose unique challenges in terms of environmental restoration and waste management, especially in aquatic environments. When stored, used or disposed of improperly, hazardous materials can contaminate an array of environmental receptors ranging from soils, sediments, groundwater, to surface water. Depending on the specific hazardous substance and site attributes, assessing ecological and health risk as a basis for environmental restoration and waste management can be a complex, problematic activity. This is particularly true for the major Defense Programs facilities managed by the U.S. Department of

Energy (DOE). The Environmental Restoration program of DOE was initiated in 1987 to consolidate and coordinate those regulatory activities designed to identify and remediate sites at installations contaminated with radioactive, chemical or mixed wastes. To supply the tools necessary for defining, describing and characterizing the nature of contaminants within the DOE complex and identifying alternative post-remediation land use options, DOE has implemented a program for the research and development of spatial data technologies to aid in assessing ecological and health risk.

### **EXAMPLE/DOE**

USDOE. 1987. Environmental Analysis of Closure Options for Waste Sites at the Savannah River Plant. Savannah River Lab., Aiken, SC. U.S. Department of Energy, Washington, DC. Conference proceeding - Annual low-level radioactive waste management program conference, Denver, CO, USA, 25 Aug 1987. Abstract- Previously acceptable waste management practices (e.g., the use of unlined seepage basins) for discarding of wastes from nuclear materials production has resulted in occasional cases of groundwater contamination beneath some disposal sites, mainly in water-table aquifers. Groundwater contaminants include volatile organic compounds, heavy metals, radionuclides, and other chemicals. The closure of active and inactive waste sites that have received hazardous and/or low-level radioactive materials at the Savannah River Plant (SRP) is planned as part of an overall program to protect groundwater quality. DOE developed and submitted to Congress a groundwater protection plan for SRP. This initial plan and subsequent revisions provide the basis for closure of SRP waste sites to comply with applicable groundwater protection requirements. An environmental analysis of the closure options for the criteria waste sites that have received hazardous and/or low-level radioactive wastes was conducted to provide technical support. The several parts of this environmental analysis include description of geohydrologic conditions; determination of waste inventories; definition of closure options; modeling of environmental pathways; assessment of risk; and analysis of project costs. Each of these components of the overall analysis is described in turn in the following paragraphs. Production operations at SRP have generated a variety of solid, hazardous, and low-level radioactive waste materials. Several locations onplant have been used as waste disposal sites for solid and liquid wastes. Seventy-six individual waste sites at 45 distinct geographical locations on SRP have received hazardous, low-level radioactive, or mixed wastes. These waste sites can be

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categorized into 26 groupings according to the function of the waste disposed. 15 refs., 6 figs., 5 tabs.

#### **EXAMPLE/DOE**

USDOE. 1990, November. Title: Baseline Risk Assessment for Groundwater Contamination at the Uranium Mill Tailings Site, Gunnison, Colorado. Corporate Author: U.S. Department of Energy, Albuquerque Operations Office, Uranium Mill Tailings Remedial Action Project Office, Albuquerque, NM. Pub: DOE/UMTRA-050127-0000; 72 pp. Abstract: The Gunnison Baseline Risk Assessment for Groundwater Contamination at the Uranium Mill Tailings Site was performed to determine if long-term use of groundwater from domestic wells near the site has a potential for adverse health effects. The risk assessment was based on the results of sampling domestic wells during 1989-1990. A risk assessment evaluates health risks by comparing the amount of a contaminant taken in by a person with the amount of the contaminant that may be toxic. The Gunnison Risk Assessment used high intake values to estimate the maximum levels a person might be exposed to. The results of the risk assessment are divided into cancer (carcinogenic) risks and non-carcinogenic risks. Five key contaminants were evaluated for adverse health risks: uranium, manganese, lead, antimony, and cadmium. Due to the potential health risks and the unavoidable uncertainties associated with limited groundwater and toxicity data, it is prudent public health policy to provide a permanent alternate water supply. Additionally, providing a permanent alternate water supply is cost-effective compared to long-term routine monitoring.

#### **EXAMPLE/DOE**

USDOE. 1994a, April. Title: Baseline Risk Assessment of Groundwater Contamination at the Uranium Mill Tailings Site Near Gunnison, Colorado. Corporate Author: . Pub: DOE/AL/62350-57D-Rev.1; 157 pp. Abstract: This report evaluates potential impacts to public health or the environment resulting from groundwater contamination at the former uranium mill processing site. The tailings and other contaminated material at this site are being placed in an off-site disposal cell by the U.S. Department of Energy's (DOE's) Uranium Mill Tailings Remedial Action (UMTRA) Project. Currently, the UMTRA Project is evaluating groundwater contamination. This is the second risk assessment of groundwater contamination at this site. The first risk assessment was performed primarily to evaluate existing domestic wells to determine the potential for immediate human

health and environmental impacts. This risk assessment evaluates the most contaminated groundwater that flows beneath the processing site towards the Gunnison River. The monitor wells that have consistently shown the highest concentration of most contaminants are used in this risk assessment. This risk assessment will be used in conjunction with additional activities and documents to assist in determining what remedial action is needed for contaminated groundwater at the site after the tailings are relocated. This risk assessment follows an approach outlined by the U.S. Environmental Protection Agency (EPA). The first step is to evaluate groundwater data collected from monitor wells at the site. Evaluation of these data showed that the main contaminants in the groundwater are cadmium, cobalt, iron, manganese, sulfate, uranium, and some of the products of radioactive decay of uranium.

#### **EXAMPLE/DOE**

USDOE. 1994b, June. Title: Baseline Risk Assessment of Ground Water Contamination at the Uranium Mill Tailings Site Near Tuba City, Arizona. Corporate Author: . Pub: DOE/AL/62350-31F; 138 pp. Abstract: This document evaluates potential public health or environmental impacts resulting from ground water contamination at the former uranium mill site. The tailings and other contaminated material at this site were placed in a disposal cell on the site in 1990 by the DOE Uranium Mill Tailings Remedial Action (UMTRA) Project. The second phase of the UMTRA Project is to evaluate ground water contamination. This risk assessment is the first site-specific document under the Ground Water Project. It will help determine what remedial actions are necessary for contaminated ground water at the site.

#### **EXAMPLE/DOE**

USDOE. 1994c, April. Title: Baseline Risk Assessment of Ground Water Contamination at the Uranium Mill Tailings Site Near Shiprock, New Mexico. Corporate Author: . Pub: DOE/AL/62350-48F-Rev.1; 175 pp. Abstract: This baseline risk assessment at the former uranium mill tailings site near Shiprock, New Mexico, evaluates the potential impact to public health or the environment resulting from ground water contamination at the former uranium mill processing site. The tailings and other contaminated material at this site were placed in an on-site disposal cell in 1986 through the U.S. Department of Energy (DOE) Uranium Mill Tailings Remedial Action (UMTRA) Project. Currently, the UMTRA Project is evaluating ground water contamination. This risk

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assessment is the first document specific to this site for the Ground Water Project. There are no domestic or drinking water wells in the contaminated ground water of the two distinct ground water units: the contaminated ground water in the San Juan River floodplain alluvium below the site and the contaminated ground water in the terrace alluvium area where the disposal cell is located. Because no one is drinking the affected ground water, there are currently no health or environmental risks directly associated with the contaminated ground water. However, there is a potential for humans, domestic animals, and wildlife to be exposed to surface expressions of ground water in the seeps and pools in the area of the San Juan River floodplain below the site. For these reasons, this risk assessment evaluates potential exposure to contaminated surface water and seeps as well as potential future use of contaminated ground water.

#### **EXAMPLE/DOE**

USDOE/ORNL. 1992, September. Title: Preliminary Risk Assessment Report for Waste Area Grouping 1 at Oak Ridge National Laboratory, Oak Ridge, Tennessee. Corporate Author: Oak Ridge National Laboratory, Oak Ridge, TN. Pub: DOE/OR-1044&D1; ORNL/ER-132&D1; ORNL/ER/Sub/87-99053/60; 321 pp. Abstract: This Preliminary Risk Assessment Report (PRAR) presents the results of the preliminary human health evaluation (PHHE), preliminary environmental evaluation (EE), and hazard screening index (HSI) calculations for the Oak Ridge National Laboratory (ORNL) Waste Area Grouping (WAG) 1. The PHHE and EE analyze the risk to human health and the environment, respectively, from WAG 1 as a whole. The HSI prioritizes operable units on the basis of relative hazards to human health. The PRAR was prepared as part of the Phase 1 remedial investigation for WAG 1 under the ORNL Environmental Restoration program.

#### **EXAMPLE/DOE**

Yu, C.; Cheng, J.J.; Wallo III, A. Date: 1991, September. Title: Effect of Radon Dose on Cleanup Criteria and Using RESRAD for Chemical Risk Assessment. Corporate Author: Argonne National Laboratory, Environmental Assessment and Information Sciences Division, Argonne, IL. Pub: CONF-910981; Environmental Remediation '91: Cleaning Up the Environment for the 21st Century, D.E. Wood (ed.), Proceedings of a Conference, Pasco, WA, September 8-11, 1991, 970 pp.; (pp. 833-837) Abstract: The U.S. Department of Energy has used RESRAD, a pathway analysis program developed at

Argonne National Laboratory, in conjunction with the as-low-as-reasonably achievable (ALARA) principle to develop site-specific residual radioactive material guidelines (cleanup criteria) for radionuclides in soils at many sites. This study examines the effects of the radon pathway, recently added to the RESRAD program, on the calculation of uranium, radium, and thorium cleanup criteria. The results show that the derived uranium guidelines will not be affected by radon ingrowth considerations. The effect of radon on radium and thorium generic guidelines are more significant, but the model does indicate that at the generic soil limits used for radium and thorium, the indoor radon decay-product concentrations would be below the 0.02 working level standard. This study also examines the feasibility of applying RESRAD to chemical risk assessment. The results show that RESRAD can perform risk assessment of toxic chemicals after simple modifications. Expansion of the RESRAD database to include chemical compounds will increase its capability to handle chemical risk assessments.

#### **EXAMPLE/EPA**

Bernhardt, D.E.; Sandquist, G.M.; Bluck, W.V.; Jensen, L.; Meldgin, N. Date: 1987. Title: Remediation/Risk Assessment of Thorium Contaminated Sites in West Chicago. Corporate Author: Rogers & Associates Engineering Corporation, Salt Lake City, UT; CH2M Hill, Salt Lake City, UT; U.S. Environmental Protection Agency, Chicago, IL. Pub: CONF-870705; Proceedings of the Health Physics Society 32nd Annual Meeting, Salt Lake City, UT, July 5-9, 1987; Health Physics 52(Suppl. 1):S13 Abstract: Monazite ore processing operations were conducted at the Rare Earths Facility (REF) in West Chicago, Illinois, from the 1930's to 1973. The facility, which was owned and operated by several corporations, is presently owned by Kerr-McGee Chemical Corporation. Tens of thousands of cubic meters of radioactive waste materials from processing monazite ore were removed from the REF site and widely distributed to various locations in the West Chicago area. Studies and investigations have been conducted to identify these locations and determine the levels of contamination. The U.S. Environmental Protection Agency (EPA), the U.S. Nuclear Regulatory Commission (NRC), and the City of West Chicago studies have identified two major sites containing about 10,000 cubic meters each of thorium residuals; over 100 residential or commercial properties in West Chicago contaminated with the thorium residuals; a contaminated river and creek; and other contaminated properties in the West Chicago area. The two major sites are the West Chicago Sewage Treatment Plant and Reed-Keppler

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Park (West Chicago City park). The EPA placed these off-site contaminated areas on the proposed National Priorities List (NPL) for remediation. Subsequently, many of the sites have been remediated by Kerr-McGee. The paper focuses on the Remedial Investigation field studies and risk assessments performed by EPA, and mitigations performed by Kerr-McGee at the sites and the criteria for performing the actions.

### **EXAMPLE/EPA**

Morris, S.C.; Rowe, M.D.; Holtzman, S.; Meinhold, A.F. Date: 1993, May. Title: National Radiation Exposures and Risks Caused by Implementing EPA's Proposed Revised National Primary Drinking Water Regulations. Corporate Author: Brookhaven National Laboratory, Upton, NY. Pub: BNL-49162; 53 pp. Abstract: This report estimates the risks to workers and the public that are associated with the treatment processes and their associated waste products that would be mandated under proposed regulations of radium, radon, and uranium in drinking water. Three scenarios were examined: (1) all wastes flushed to the sanitary sewer; (2) all wastes disposed on land; (3) similar to (2) but radon removal by granulated activated carbon rather than packed tower aeration. Risks considered included accidental injury and cancer. Worker risks for both scenarios I and II were estimated to be 0.025 and 0.01 deaths per year of operation for radium-226 and radium-228, respectively. Worker risks for uranium were estimated to be 0.13 deaths/year of operation for scenario I and 0.5 deaths/year of operation for scenario II. Worker risks for radon removal were estimated to be 1.7 deaths/year of operation for scenario I and 2.2 deaths/year of operation for scenario II. Risks to the public for scenarios I and II for radium-226 were  $4 \times 10(E-4)$  and for radium-228 were  $9 \times 10(E-5)$  deaths/year of operation. Risks to the public for scenarios I and II for uranium were  $7.3 \times 10(E-2)$  and  $2 \times 10(E-4)$ , respectively. Risks to the public for scenario I and II for radon were 24 deaths/year of operation and for scenario III were nil. Public risks were quantified only for people exposed during a year of operation. For example, effects of public exposures in future years via groundwater contamination associated with landfill of treatment waste were not considered.

### **GENERAL/Commercial**

AWMA. 1989. Proceedings - 82nd A&WMA Annual Meeting. 1989. Air & Waste Management Assoc, Pittsburgh, PA. Conference Proceedings - 82nd A&WMA Annual Meeting Anaheim, CA. 1989 Jun 25-30 v 4 1989.

Publ by Air & Waste Management Assoc, Pittsburgh, PA. Abstract- This conference proceedings contain 69 papers presented at the Air and Waste Management Annual Meeting in June 1989. Topics covered include: Handling, Licencing, Minimizing, siting and development of hazardous and mixed waste, Atmospheric Emissions from accidental releases and their modelling and health hazards, emergency response, public awareness, risk communication programs and issues related to these communications, Risk Assessment and uncertainty analysis, Health risk assessment for specific chemicals, Transportation of Toxic and hazardous materials, Environmental Impairment Liability Insurance and issues related to it, Alternative fuels, and then impact on the environment, Air Pollution Analysis, measurement techniques and instrumentation.

### **GENERAL/Commercial**

CDM. 1985. Title: Application of Quantitative Risk Assessment to Remedial Measures Evaluation at Abandoned Sites. Corporate Author: Camp, Dresser and McGee, Boston, MA. Publication: Hazardous Wastes and Environmental Emergencies, Proceedings of a National Conference, Cincinnati, OH, May 14-16, 1985. (pp 234-238).

### **GENERAL/EPA**

ICF, Inc. 1986. Risk Assessment Information Directory. EPA Contract No. 69-01-7090.

### **GENERAL/Other**

FCCSET. 1992. Risk Assessment: A survey of characteristics, applications, and methods used by federal agencies for engineered systems. Federal Coordinating Council for Science, Engineering, and Technology. Ad Hoc Working Group on Risk Assessment. Nov. 1992.

### **METHODOLOGY/Commercial**

Dove, F.H.; Marshall, T.C.; Seiler, F.A. Date: 1991, September. Title: Baseline Risk Assessment Methodology for Mixed Waste. Corporate Author: International Technology Corporation, Albuquerque, NM. Pub: CONF-910981; Environmental Remediation '91: Cleaning Up the Environment for the 21st Century, D.E. Wood (ed.),

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Proceedings of a Conference, Pasco, WA, September 8-11, 1991, 970 pp.; (pp. 295-299) Abstract: The presence of mixed chemical and radioactive waste introduces several complex issues into a baseline risk assessment. A five-stage, serial methodology consistent with Department of Energy orders and Environmental Protection Agency regulations is available for the evaluation of risk at these disposal sites. The five stages are: (1) release scenario, (2) source term definition, (3) constituent transport, (4) exposure assessment, and (5) risk characterization. The model considers a variable level of detail (simple to complex) when determining risk, depending on the constituent concentration and exposure levels found. This approach minimizes the effort needed to determine constituent exposure by avoiding complicated models requiring detailed input and complex computation when that level of sophistication is not necessary. While many questions remain concerning the combined effects of radiation and chemicals on cancer, this paper proposes preliminary guidelines for the assessment of combined radiological and nonradiological risk.

#### **METHODOLOGY/Commercial**

Niemczyk, S.J. Date: 1987. Title: Estimation of the Risk from Residual Radioactivity. Corporate Author: Gull Associates, Washington, DC. Pub: CONF-871018; Decommissioning, G.A. Tarcza (ed.), Proceedings of the 1987 International Symposium, Pittsburgh, PA, October 4-8, 1987, Vol. 2, 705 pp.; (pp. V.89-V.103) Abstract: A new approach for estimating the potential radiation hazard from residual radioactivity at decontaminated sites and facilities has recently been developed to aid the U.S. Environmental Protection Agency's selection of decommissioning criteria for regulatory purposes. The approach is intended to generate conservatively realistic estimates of radiation doses to on-site residents from radioactivity both in the environment and in buildings. It does so using a comprehensive yet relatively simple set of physically-based, state-of-the-art risk-level environmental transport and exposure pathway models. The transport models have been interfaced to permit time-dependent, mechanistic consideration of radioactive transfers within and among the various environmental media. Radioactive decay and in-growth are explicitly accounted for. Doses in contaminated multiroom buildings are estimated using a set of unique transport and exposure models. The overall approach has been encoded in a computer code REUSEIT which runs on a personal computer.

#### **METHODOLOGY/DOE**

Blaylock, B.G.; Frank, M.L.; Hoffman, F.O.; Miller, P.D.; White, R.K.; Purucker, S.T.; Redfearn, A. Date: 1992, October. Title: Human Health Risk Assessment Screening Approach for Evaluating Contaminants at Source Control and Integrator Operable Units. Corporate Author: Oak Ridge National Laboratory, Oak Ridge, TN; University of Tennessee, Knoxville, TN. Pub: CONF-930165; How Clean is Clean, Proceedings of the 1992 Water Federation Environment Specialty Conference, Washington, DC, January 13, 1993; (15 pp.) Abstract: A more streamlined approach is proposed for executing the remedial investigation/feasibility study process. This approach recognizes the uncertainties associated with the process, particularly regarding the derivation of human health risk estimates. The approach is tailored for early identification of sites and contaminants of immediate concern, early remediation of such sites, and early identification of low-risk sites that can be eliminated from further investigations. The purpose is to hasten the clean-up process, and do so in a cost-effective manner.

#### **METHODOLOGY/DOE**

Chu, M. S. Y. ; Rodricks, J. V. ; St. Hilaire, C. ; Bras, R. L. 1986. Risk Assessment and Ranking Methodologies for Hazardous Chemical Defense Waste: A State-of-the-ART Review and Evaluation. Task 1 Report. Sandia National Labs., Albuquerque, NM. U.S. Department of Energy, Washington, DC. Abstract- This report summarizes the work performed under Task 1 of the Risk Assessment Evaluation Task under the Hazardous Chemical Defense Waste Management Program of the Department of Energy (DOE). The objective of Task 1 was to identify, review, and evaluate the state-of-the-art tools and techniques available for ranking and evaluating disposal facilities. These tools were evaluated for their applicability to DOE's mixed hazardous chemical and radioactive waste sites. Various ranking methodologies were reviewed and three were evaluated in detail. Areas that were found to be deficient in each ranking methodology were presented in the report. Recommendations were given for the development of an improved ranking methodology for use on DOE's sites. A literature review was then performed on the various components of a risk assessment methodology. They include source term evaluation, geosphere transport models, exposure pathways models, dose effects models, and sensitivity/uncertainty techniques. A number of recommendations have been made in the report based on the review and evaluation for the development of a comprehensive risk assessment methodology in evaluating mixed waste disposal sites.

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### **METHODOLOGY/DOE**

Davis, M.; Avci, H.I.; Picel, K.; Janke, R.J. Date: 1993. Title: Strategy for Assessing Risks Associated with Remediation of the Former Production Area at Fernald. Corporate Author: Argonne National Laboratory, Argonne, IL; U.S. Department of Energy, Fernald Area Office, Cincinnati, OH. Pub: ANL/EAIS/CP-79748; CONF-931095 (Vol. 1); ER '93: Meeting the Challenge, Proceedings of the U.S. Department of Energy Environmental Remediation Conference, Augusta, GA, October 24-28, 1993, Vol. 1, 727 pp.; (pp. 489-492) Abstract: The strategy for assessing the risks associated with the remediation of the former Production Area at the Fernald Environmental Management Project is discussed. The general approach to risk assessment is strongly influenced by a number of factors related to the nature of the site and to management proposals that have been made concerning the site. How these factors affect the approach to assessing baseline risks, to assessing risks associated with remedial activity, and to establishing cleanup criteria are examined.

### **METHODOLOGY/DOE**

Devgun, J.S. Date: 1991. Title: Role of Risk Assessment in Remediation of Contaminated Sites. Corporate Author: Argonne National Laboratory, Chemical Technology Division, Argonne, IL. Pub: ANL/CP-72892; CONF-9106239; Proceedings of the Eleventh International Association for Impact Assessment Annual Meeting, Champaign, IL, June 7-11, 1991; (8 pp.) Abstract: Even though risk assessment is an essential consideration in remediation projects involving radioactive or hazardous waste sites, its role is often unclear and it is not fully utilized in the decision-making process. Risk assessment is an integral part of the remediation process and should play an important role from beginning to end, i.e., from planning stages to verification survey after the cleanup. A conceptual model with complete pathways of exposure and based on site-specific conditions is key to a successful risk assessment. A baseline comparison with existing standards determines, along with other factors, whether a site requires remediation. Risk assessment plays a role in setting priorities between sites and in setting cleanup standards for certain contaminants at a site. Matching the extensiveness and effectiveness of remediation to the degree of risk is important in the decision-making process. Often, the applicable technologies can be screened through risk assessment, and the potential remedial alternatives evaluated in terms of risk reduction. After a remedial

action is complete, its effectiveness can be judged via verification surveys, and any predicted future risk from residual concentrations of contaminants can be left at the site. This paper provides an overview of the risk-assessment process, its role in remediation projects, and the generic methodology for risk assessment.

## **METHODOLOGY/DOE**

Droppo Jr., J.G.; Strenge, D.L.; Buck, J.W. Date: 1991, September. Title: A Risk Computation Model for Environmental Restoration Activities. Corporate Author: Pacific Northwest Laboratory, Richland, WA. Pub: CONF-910981; Environmental Remediation '91: Cleaning Up the Environment for the 21st Century, D.E. Wood (ed.), Proceedings of a Conference, Pasco, WA, September 8-11, 1991, 970 pp.; (pp. 261-264) Abstract: A risk computation model useful in environmental restoration activities was developed for the U.S. Department of Energy. This model, the Multimedia Environmental Pollutant Assessment System (MEPAS), can be used to evaluate effects of potential exposures over a broad range of regulatory issues, including radioactive carcinogenic, nonradioactive carcinogenic, and noncarcinogenic effects. MEPAS integrates risk computation components. Release, transport, dispersion, deposition, exposure, and uptake computations are linked in a single system for evaluation of air, surface water, ground water, and overland flow transport. MEPAS uses standard computation approaches. Whenever available and appropriate, U.S. Environmental Protection Agency guidance and models were used to facilitate compatibility and acceptance. MEPAS is a computational tool that can be used at several phases of an environmental restoration effort. At a preliminary phase in problem characterization, potential problems can be prioritized. As more data become available, MEPAS can provide an estimate of baseline risks or evaluate environmental monitoring data. In the feasibility phase, MEPAS can compute risk from alternative remedies. However, MEPAS is not designed to replace a detailed risk assessment of the selected remedy. For major problems, it is appropriate to use a more detailed risk computation tool for a detailed, site-specific evaluation of the selected remedy.

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## **METHODOLOGY/DOE**

Dunning Jr., D.E.; Peterson, J.M. Date: 1993. Title: Comparison of Radiological Risk Assessment Methods for Environmental Restoration. Corporate Author: Argonne National Laboratory, Argonne, IL. Pub: ANL/EA/CP-78779; CONF-930746; Proceedings of the Health Physics Society 38th Annual Meeting, Atlanta, GA, July 11-15, 1993; (10 pp.) Abstract: Evaluation of risks to human health from exposure to ionizing radiation at radioactively contaminated sites is an integral part of the decision-making process for determining the need for remediation and selecting remedial actions that may be required. At sites regulated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), a target risk range of  $10(E-4)$  to  $10(E-6)$  incremental cancer incidence over a lifetime is specified by the U.S. Environmental Protection Agency (EPA) as generally acceptable, based on the reasonable maximum exposure to any individual under current and future land use scenarios. Two primary methods currently being used in conducting radiological risk assessments at CERCLA sites are compared in this analysis. Under the first method, the radiation dose equivalent (i.e., Sv or rem) to the receptors of interest over the appropriate period of exposure is estimated and multiplied by a risk factor (cancer risk/Sv). Alternatively, incremental cancer risk can be estimated by combining the EPA's cancer slope factors (previously termed potency factors) for radionuclides with estimates of radionuclide intake by ingestion and inhalation, as well as radionuclide concentrations in soil that contribute to external dose. The comparison of the two methods has demonstrated that resulting estimates of lifetime incremental cancer risk under these different methods may differ significantly, even when all other exposure assumptions are held constant, with the magnitude of the discrepancy depending upon the dominant radionuclides and exposure pathways for the site. The basis for these discrepancies, the advantages and disadvantages of each method, and the significance of the discrepant results for environmental restoration decisions are presented.

## **METHODOLOGY/DOE**

Dwyer, R.L.; Starmer, R.J. Date: 1991, October. Title: Integration of Superfund Risk Concepts into Setting Cleanup Criteria at Mixed Waste Sites. Corporate Author: Environmental Resources Management, Inc., Annapolis, MD; ERM Program Management Company, McLean, VA. Pub: CONF-9110168; Waste Management and Environmental Restoration, Proceedings of the Seventh Annual DOE Model Conference, Oak Ridge,

TN, October 14-17, 1991; (18 pp.) Abstract: As U.S. Department of Energy facility remedial activities evolve to comply with the additional requirements of the National Contingency Plan under CERCLA, some obvious methodological conflicts have arisen. A major instance has to do with the disposition of mixed waste. Difficulties in integrating the differing dose-response methods of radiation health physics and conventional hazardous waste toxicology into mixed waste risk assessment, the current inability to identify and deal with synergistic effects among hazardous and radioactive contaminants, and the lack of defined cleanup standards for many contaminants, or even a simple and straightforward method to calculate them, all hinder the timely and comprehensive definition of cleanup levels for mixed waste wastes at numerous sites. This paper presents several approaches developed for chemical waste risk assessment under the Superfund program that can be adapted to address these mixed waste problems.

## **METHODOLOGY/DOE**

Fields, D.E. Date: 1986, February. Title: Evaluation of Doses and Risks from Different Decontamination and Decommissioning Strategies Using the PRESTO-2 Methodology. Corporate Author: Oak Ridge National Laboratory, Oak Ridge, TN. Pub: CONF-860203; Health Physics Considerations in Decontamination and Decommissioning, Proceedings of the Health Physics Society 19th Midyear Topical Symposium, Knoxville, TN, February 2-6, 1986, 594 pp.; (pp. 115-124) Abstract: The PRESTO-2 methodology may be applied to evaluate doses and health risks from a variety of decontamination and decommissioning activities. This methodology has been implemented in the form of a computer code that has been applied to several sites, and that has been extensively documented. Radionuclide inventories are specified as separate contamination sources either present on the ground surface, covered by non-radioactive soils but lying above the water table, suspended in the atmosphere, or dissolved in surface waters. Hydrologic transport mechanisms considered in the PRESTO-2 methodology include chemical exchange, ponding and overflow, surface water transport, groundwater transport, and pumping contaminated groundwater from wells. Varied scenarios of water usage are treated. Atmospheric inputs are based on both resuspension factor and resuspension rate approaches, with inhalation and immersion doses based on a Gaussian

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plume transport calculation. Site activities that are considered include land clearing, farming, and residing on the site. Exposure and dose calculations are derived from the U.S. Nuclear Regulatory Commission Regulatory Guide 1.109 approach, while risk calculations use a life-table approach developed for the U.S. Environmental Protection Agency (EPA). Internal dose conversion factors are taken from ICRP 26 and 30, while risk conversion factors are values suggested by EPA.

### **METHODOLOGY/DOE**

Gregory, P.O.; Jones, G.A. Date: 1986. Title: Risk Assessment and Reliability for Low-Level Radioactive Waste Disposal. Corporate Author: Morrison-Knudsen Engineers, Inc., San Francisco, CA. Pub: CONF-860317; Waste Management '86, Volume 3 - Low-Level Waste, R.G. Post (ed.), Proceedings of the Symposium on Waste Management, Tucson, AZ, March 2-6, 1986; (pp. 139-146) Abstract: The reliability of critical design features at low-level radioactive waste disposal facilities is a major concern in the licensing of these structures. To date, no systematic methodology has been adopted to evaluate the geotechnical reliability of Uranium Mill Tailings Remedial Action (UMTRA) disposal facilities currently being designed and/or constructed. This paper discusses and critiques the deterministic methods currently used to evaluate UMTRA reliability. Because deterministic methods may not be applicable in some cases because of the unusually long design life of UMTRA facilities, it is proposed that a probabilistic risk assessment-based methodology be used as a secondary method to aid in the evaluating of geotechnical reliability of critical items. Similar methodologies have proven successful in evaluating the reliability of a variety of conventional earth structures. In this paper, an "acceptable" level of risk for UMTRA facilities is developed, an evaluation method is presented, and two example applications of the proposed methodology are provided for a generic UMTRA disposal facility. The proposed technique is shown to be a simple method which might be used to aid in reliability evaluations on a selective basis. Finally, other possible applications and the limitations of the proposed methodology are discussed.

### **METHODOLOGY/DOE**

Hamilton, L.D.; Medeiros, W.H.; Meinhold, A.; Morris, S.C.; Moskowitz, P.D.; Nagy, J. Date: 1988, Sept. Title: Health Risk Analysis for Ingestion of Contaminants from Existing Groundwater Contamination at Selected UMTRA Project Sites. Corporate Author:

Brookhaven National Laboratory, Upton, NY. Pub: BNL-44772; 84 pp. Abstract: This study examines potential hazards to human health from the ingestion of chemicals in groundwater beneath and adjacent to four abandoned uranium mill tailings sites: Gunnison, Colorado; Lakeview, Oregon; Monument Valley, Arizona; and Riverton, Wyoming. Chemicals of concern in the groundwater near these sites include arsenic, cadmium, chromium, lead-210, molybdenum, nitrate, polonium-210, radium-226 and radium-228, selenium, sulfate, thorium-230, uranium, and vanadium. Hazards to health were evaluated by implementing the method outlined in the Environmental Protection Agency (EPA) Superfund Public Health Evaluation Manual. Conservative assumptions in the method and the effect of these on the risk estimates and EPA's indexes of harm are discussed. Because the method has a number of built-in conservatisms, the estimated risks and indexes only indicate sites and chemicals requiring further analysis. The chemicals and sites identified as presenting risk in this first screening step should be investigated in more detail. Necessary steps are given. Sites and chemicals identified as harmless in this initial screening can be eliminated from further consideration.

#### **METHODOLOGY/DOE**

Hassig, N.L.; Gilbert, R.O.; Pulsipher, B.A. Date: 1991, September. Title: A Framework for Evaluating Innovative Statistical and Risk Assessment Tools to Solve Environmental Restoration Problems. Corporate Author: Pacific Northwest Laboratory, Richland, WA. Pub: CONF-910981; Environmental Remediation '91: Cleaning Up the Environment for the 21st Century, D.E. Wood (ed.), Proceedings of a Conference, Pasco, WA, September 8-11, 1991, 970 pp.; (pp. 271-275) Abstract: Environmental restoration activities at the U.S. Department of Energy (DOE) Hanford Site face complex problems due to a history of varied past contaminant disposal practices. Data collection and analysis required for site characterization, pathway modeling, and remediation-method selection decisions must deal with inherent uncertainties and unique problems associated with the restoration. This paper presents a framework for selecting appropriate statistical and risk assessment methods that can be applied to the restoration problem. Using an example, it follows the selection process from option identification to statistical tools identification and selection. The paper makes several points. Pathway modelers and risk assessors often refer to statistical methods but do not include tools selection in the early planning phases of a project. Statistical tools selection and development are problem-specific and often site-specific. The right tool,

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applied correctly, can minimize sampling costs, get as much information as possible out of existing data, provide consistency and defensibility for the results, and give structure and quantitative measures to decision risks and uncertainties. A framework for selecting and applying the right tools consists of developing an options matrix for evaluating a set of potential remediation options. Knowing these options and setting objectives for the quality of the data to be collected, a statistical tools matrix for tools selection can be developed. Applying the tools and iterating through the steps in the framework allows the remediation project manager to make a decision, at a quantifiable risk level, and be able to statistically defend the decision.

### **METHODOLOGY/DOE**

Hoffman, F.O.; Hammonds, J.S. Date: 1992, October. Title: Introductory Guide to Uncertainty Analysis in Environmental and Health Risk Assessment. Environmental Restoration Program. Corporate Author: Oak Ridge National Laboratory, Oak Ridge, TN. Pub: ES/ER/TM-35; 34 pp. Abstract: To compensate for the potential for overly conservative estimates of risk using standard U.S. Environmental Protection Agency methods, an uncertainty analysis should be performed as an integral part of each risk assessment. Uncertainty analyses allow one to obtain quantitative results in the form of confidence intervals which will aid in decision making and will provide guidance for the acquisition of additional data. To perform an uncertainty analysis, one must frequently rely on subjective judgment in the absence of data to estimate the range and a probability distribution describing the extent of uncertainty about a true but unknown value for each parameter of interest. This information is formulated from professional judgment based on an extensive review of literature, analysis of the data, and interviews with experts. Various analytical and numerical techniques are available to allow statistical propagation of the uncertainty in the model parameters to a statement of uncertainty in the risk to a potentially exposed individual. Although analytical methods may be straightforward for relatively simple models, they rapidly become complicated for more involved risk assessments. Because of the tedious efforts required to mathematically derive analytical approaches to propagate uncertainty in complicated risk assessments, numerical methods such as Monte Carlo simulation should be employed. The primary objective of this report is to provide an introductory guide for performing uncertainty analysis in risk assessments being performed for Superfund sites.

## **METHODOLOGY/DOE**

JEG. 1988, October. Title: Weldon Spring Site Remedial Action Project: Baseline Risk Assessment Protocol Document. Corporate Author: Jacobs Engineering Group, Inc., St. Charles, MO. Pub: DOE/OR/21548-047; 22 pp. Abstract: The Weldon Spring Site (WSS) is a former explosives manufacture and uranium feed materials processing plant, currently controlled by the U.S. Department of Energy (DOE). The Weldon Spring Site comprises two separate areas: (1) the raffinate pits and chemical plant (approximately 220 acres), and (2) the quarry. Although the two areas are considered to be one site for compliance purposes, a separate risk evaluation is being prepared for the quarry. This document does not address the quarry. The U.S. Environmental Protection Agency (EPA) has placed the Weldon Spring Site on the National Priorities List. A Baseline Risk Assessment is required for compliance with the Comprehensive Environmental Response, Compensation, and Liability Act. The purpose the Baseline Risk Assessment is to assess the potential risks to public health and the environment in the absence of remedial action. This Protocol document explains how the Baseline Risk Assessment for the raffinate pits and chemical plant area will be conducted. Specifically, the Protocol document: (1) provides EPA risk assessment guidelines appropriate for the Weldon Spring Site; (2) identifies the site-specific data to be used in the analysis; (3) provides a preliminary list of indicator contaminants; (4) identifies populations near the site; (5) identifies general exposure pathways; (6) describes how Applicable or Relevant and Appropriate Requirements (ARARs) will be identified; and (7) provides the framework for presenting the potential risks due to radiological and chemical contaminant exposures.

## **METHODOLOGY/DOE**

Joseph, T.J. Date: 1992, October. Title: Components and Complexity of an Ecorisk Paradigm. Corporate Author: U.S. Department of Energy, Oak Ridge Operations Office, Oak Ridge, TN. Pub: CONF-921029; Waste Management and Environmental Restoration, Proceedings of the Eighth Annual DOE Model Conference, Oak Ridge, TN, October 18-22, 1992, 228 pp.; (5 pp.) Abstract: This paper is an overview of ecological risk assessment that is intended to open the conference session on ecological risk with a look at the initial thought process. The subject of risk assessment began with the worker and moved gradually to include the public, only recently moving into ecology. The specific assessment variables and

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endpoints for worker risk assessment are more or less straightforward; those for public health risk assessment required new and more complex science and technology because the variables became more difficult to identify, track, and quantify. The continuum of assessment variables is an inverted pyramid which expands in all directions from the very specific point stressor and on to the worker, the public, or the environment or ecosystem (nonhuman species); the temporal and spatial scales within it widen greatly. The ecological risk "paradigm" should show clearly the architecture of risk imposed or inflicted upon all physical and biological components of an ecosystem. The paradigm should establish the most efficient architecture of risk to develop a roadmap to ecological risk that moves the assessor by the most direct route and results in quality science.

#### **METHODOLOGY/DOE**

Kennedy, W. E. ; Aaberg, R. L. 1991. Dose and risk assessment for intrusion into mixed waste disposal sites. Battelle Pacific Northwest Labs., Richland, WA. Conference proceeding - Hanford symposium on health and the environment: current topics in occupational health (30th), Richland, WA (United States), 29 Oct - 1 Nov 1991. Sponsored by Department of Energy, Washington, DC. Abstract: Sites previously used for disposal of radioactive and hazardous chemical materials have resulted in situations that pose a potential threat to humans from inadvertent intrusion. An example generic scenario analysis was developed to demonstrate the evaluation of potential exposure to either cleanup workers or members of the public who intrude into buried waste containing both radioactive and hazardous chemical contaminants. The example scenarios consist of a collection of exposure routes (or pathways) with specific modeling assumptions for well-drilling and for excavation to construct buildings. These scenarios are used to describe conceptually some potential patterns of activity by non-protected human beings during intrusion into mixed-waste disposal sites. The dose from exposure to radioactive materials is calculated using the GENII software system and converted to risk by using factors from ICRP Publication 60. The hazard assessment for nonradioactive materials is performed using recent guidelines from the US Environmental Protection Agency (EPA). The example results are in the form of cancer risk for carcinogens and radiation exposure.

## **METHODOLOGY/DOE**

Labieniec, P.A.; Dzombak, D.A.; Siegrist, R.L. Date: 1993. Title: Risk Implications of Approaches to Setting Soil Remediation Goals. Corporate Author: Carnegie-Mellon University, Pittsburgh, PA; Oak Ridge National Laboratory, Oak Ridge, TN. Pub: CONF-930165; How Clean Is Clean, Proceedings of the 1992 Water Federation Environment Specialty Conference, Washington, DC, January 10-13, 1993; (11 pp.) Abstract: A framework has been developed to evaluate and compare the carcinogenic risk implications of two approaches to establishing soil remediation goals at hazardous waste contaminated sites. The approaches considered are: (1) site-specific risk assessment to achieve a specified level of carcinogenic risk; and (2) the use of uniform, concentration-based soil quality guidelines. Uncertainty in site-specific risk assessments and variability in site conditions when a uniform approach is used are taken into account. For each approach, cumulative distribution functions representing the regional variability in risk across sites are developed using a soil risk model. The two approaches are then compared based on these distributions. This paper describes the evaluation framework and presents some preliminary results of ongoing research to apply the framework to sites contaminated with trichloroethylene. Preliminary work in applying the framework to sites contaminated with polychlorinated biphenyls is also described.

## **METHODOLOGY/DOE**

MacDonell, M.M.; Haroun, L.A.; Peterson, J.M.; Blunt, D.A.; Fingleton, D.J.; Picel, M.H. Date: 1991, September. Title: Strategy for Integrated CERCLA/NEPA Risk Assessments. Corporate Author: Argonne National Laboratory, Environmental Assessment and Information Sciences Division, Argonne, IL. Pub: CONF-910981; Environmental Remediation '91: Cleaning Up the Environment for the 21st Century, D.E. Wood (ed.), Proceedings of a Conference, Pasco, WA, September 8-11, 1991, 970 pp.; (pp. 853-860) Abstract: The U.S. Department of Energy (DOE) has established a policy whereby, for remedial actions, the procedural and documentary requirements of the National Environmental Policy Act (NEPA) are integrated with those of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended. However, the objectives of risk assessment under NEPA and CERCLA differ somewhat. Until its recent application to contaminated sites, NEPA analysis has typically been applied to impacts from actions at clean sites (e.g., for construction activities), and a somewhat loosely

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structured process has historically been used to estimate relative risks for NEPA. Decisions such as cleanup levels were not made on the basis of risk estimates, and therefore tended to be conservative and not detailed. In contrast, risk estimates for Superfund (CERCLA) sites are used to focus the decision-making process for those sites and support national prioritization for cleanup. The U.S. EPA has developed a detailed framework for preparing baseline health-risk assessments for these sites. The purpose of this paper is to discuss the issues relating to integrating CERCLA and NEPA approaches into the risk assessments prepared for a DOE remedial action project at the Weldon Spring Site near St. Charles, Missouri. These issues are grouped into three basic categories: general assumptions for the impact evaluation, data management, and presentation of the methodology and results. This paper is not intended to represent DOE policy and guidance, nor does it represent the only approach that can be used for integrated risk assessments. It discusses the process that was used for the Weldon Springs project, articulating the issues that were encountered and how they were addressed.

#### **METHODOLOGY/DOE**

Mahaffey, J.A.; Doctor, P.G.; Buschbom, R.L.; Glantz, C.S.; Daling, P.M.; Sever, L.E.; Vargo Jr., G.J.; Strachan, D.M.; Pajunen, A.L.; Hoyt, R.C.; Ludowise, J.D. Date: 1993, June. Title: Strategic Analysis Study-Based Approach to Integrated Risk Assessment: Occupational Health Risks from Environmental Restoration and Waste Management Activities at Hanford. Corporate Author: Pacific Northwest Laboratory, Richland, WA; Westinghouse Hanford Company, Richland, WA. Pub: PNL-8598; 86 pp. Abstract: The goal of environmental restoration and waste management activities is to reduce public health risks or to delay risks to the future when new technology will be available for improved cleanup solutions. Actions to remediate the wastes on the Hanford Site will entail risks to workers, the public, and the environment that do not currently exist. In some circumstances, remediation activities will create new exposure pathways that are not present without cleanup activities. In addition, cleanup actions will redistribute existing health risks over time and space, and will likely shift health risks to cleanup workers in the short term. This report describes an approach to occupational risk assessment based on the Hanford Strategic Analysis Study and illustrates the approach by comparing worker risks for two options for remediation of N/K fuels, a subcategory of unprocessed irradiated fuels at Hanford.

## **METHODOLOGY/DOE**

Marron, B.; Johnson, J. 1993. A method for comparative assessment of chemical and radionuclide risks. Transactions of the American Nuclear Society Vol. 68 Jun 1993 pp. 32-33. Abstract- A single, equivalent method has been developed for estimating the radiological and the chemical risks via the air pathway for the operational phase management of transuranic mixed waste at the Waste Isolation Pilot Plant (WIPP) facility. Although the proposed method uses the standard four-step risk assessment process developed by the U.S. EPA, the method is unique because it permits the direct comparison of radiological and chemical risks. Typically, such comparisons are unreasonable because of the differences in the risk assessment methodologies. The proposed method establishes data requirements, source terms, exposure scenarios, dispersion models, and risk characterizations that are equivalent for both radionuclides and chemicals. Variables are defined by probability density functions, and stochastic modeling is used to estimate the overall uncertainty in the risk characterization.

## **METHODOLOGY/DOE**

Miller, P.D.; McGinn, C.W.; Purucker, S.T.; White, R.K. Date: 1994, August. Title: Defining the Role of Risk Assessment in the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Remedial Investigation Process at the DOE-OR. Corporate Author: Oak Ridge National Laboratory, Health and Safety Research Division, Oak Ridge, TN. Pub: ES/ER/TM-58; 45 pp. Abstract: The risk assessment that will be implemented on the Oak Ridge Reservation has been standardized to ensure consistency and technical defensibility in all risk assessment activities and is presented in this document. The strategy emphasizes using existing environmental data in screening risk analyses to aid in identifying chemicals of potential concern, operable units that could pursue a no further investigation determination, and operable units that may warrant early response actions. The screening risk analyses include a comparison of measured chemical concentrations to preliminary remediation goals, performing a most likely exposure and integration point assessment, and performing a screening ecological risk assessment. This document focuses heavily on the screening risk analyses and relies on existing EPA risk assessment guidance to provide specific details on conducting baseline risk assessments. However, the document does contain a section on the

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baseline risk assessment process that details the exposure pathways to be evaluated on the Oak Ridge Reservation.

## **METHODOLOGY/DOE**

Nix, D.W.; Immel, J.W. Date: 1992, March. Title: Development of Exposure Scenarios for CERCLA Risk Assessments at the Savannah River Site. Corporate Author: Westinghouse Savannah River Company, Aiken, SC; University of Tennessee, Knoxville, TN. Pub: CONF-920307 (Vol. 1); Waste Management '92: Working Towards a Cleaner Environment, R.G. Post (ed.), Proceedings of a Symposium, Tucson, AZ, March 1-5, 1992, Vol. 1, 994 pp.; (pp. 515-518) Abstract: Environmental restoration (ER) activities at the Savannah River Site (SRS) begin with the characterization of inactive hazardous, radioactive and mixed waste disposal areas by a combined Resource Conservation and Recovery Act (RCRA) facility investigation (RFI)/Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) remedial investigation (RI) followed by evaluation of remedial alternatives in a RCRA corrective measures study (CMS)/CERCLA feasibility study (FS). A CERCLA baseline risk assessment (BRA) is performed during the RFI/RI characterization to determine if there are any potential risks to human health or the environment from the waste unit. If it is determined that there is need for remedial action, a risk evaluation of remedial alternatives (RERA) is performed as part of the CMS/FS to provide a basis for selecting a remedy that is protective of human health and the environment. The SRS has numerous waste units to evaluate in the RFI/RI and CMS/FS programs and, in order to provide a consistent approach, four standard exposure scenarios were developed for exposure assessments to be used in human health risk assessments. The standard exposure scenarios are divided into two temporal categories: (a) current land use in the BRA, and (b) future land use in the RERA. The current land use scenarios consist of the evaluation of human health risk for industrial exposure (of a worker not involved in waste unit characterization or remediation), a trespasser, a hypothetical current on-site resident, and an off-site resident. The future land use scenario considers exposure to an on-site resident following termination of institutional control in the absence of any remedial action (no action alternative), as well as evaluating potential remedial alternatives against the four scenarios from the BRA. A critical facet in the development of a BRA or RERA is the scoping of exposure scenarios that reflect actual conditions of a waste unit, rather than using factors such as the U.S. Environmental Protection Agency standard default exposure scenarios (OSWER Directive

9285.6-03) that are based on upper-bound exposures that tend to reflect worst case conditions. The use of site-specific information for developing risk assessment exposure scenarios will result in a realistic estimate of reasonable maximum exposure for SRS waste units.

## **METHODOLOGY/DOE**

Pavlou, S.; Waite, D.; Maheras, S.; Robinson, S. 1990. Finding a compromise between chemical and radiological risk assessment methods for mixed waste sites. Paper 5 In: Proceedings of DOE model conference on waste management and environmental restoration. 6th Annual Department of Energy model conference on waste management and environmental restoration. Oak Ridge, TN. 29 Oct - 2 Nov 1990. Abstract- The purpose of this paper is to (1) outline the fundamental similarities and differences between the presently accepted radiological and chemical risk assessment methods, (2) examine the significant differences in analytical results and decision making that can result if either is used to the exclusion of the other and (3) to suggest a hybrid method that utilizes the strong points of each to arrive at a balanced contaminant impact data base for decision making. The approach taken to facilitate these comparisons is to quantitatively assess the collective risk at a simplified site, contaminated with a short list of chemicals and radionuclides. The site is assessed first using exclusively the suggested Superfund toxic chemical methodology for both chemicals and radionuclides, followed by the same analysis using accepted radiological methods for both contaminant categories. Both the methods and the results of these calculations are compared and contrasted. Logical mitigation decisions that might result from each set of calculations are examined. The same site is finally analyzed using a method that incorporates the best of both of the previously used methods and the results are analyzed on the basis of the decision-making utility of the results. Conclusions are drawn relative to several topics of prime importance. These are: acceptable risk bases, key assumptions, statistical inputs, prioritizing contaminants, environmental models, cumulative risk, and risk assessments for non-human receptors.

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## **METHODOLOGY/DOE**

Picel, M.H.; Peterson, J.M. Date: 1990, April. Title: Strategies for Conducting Baseline Risk Assessments at FUSRAP Sites. Corporate Author: Argonne National Laboratory, Argonne, IL. Pub: CONF-9004181 (Vol. 1); Remedial Action Under the Environmental Restoration and Waste Management Five-Year Plan, Proceedings of the Department of Energy Remedial Action Program Conference, Albuquerque, NM, April 16-19, 1990, Vol. 1, 656 pp.; (pp. 367-391) Abstract: The main objectives of the Formerly Utilized Sites Remedial Action Program (FUSRAP) are to identify and evaluate radiological conditions at sites formerly utilized by Manhattan District/Atomic Energy Commission programs and to control and manage this contamination so that these sites can be certified for use without radiological restrictions to the extent practicable. There are currently 31 FUSRAP sites, several of which are on the National Priorities List (NPL). A remedial investigation/feasibility study (RI/FS) will be prepared for each of the NPL sites. FUSRAP risk assessments will address both human health and ecological risks and will carry out separate but parallel assessments for both chemical and radiological risks. The risk assessments activities within the RI/FS process consist of two components: (1) the Baseline Risk Assessment (BRA), which occurs during the RI, and (2) the risk assessment, which is performed during the FS to compare risk associated with each remedial alternative being considered. BRAs for FUSRAP sites will be prepared as stand-alone documents or will be folded into the RI report as a chapter, depending on the complexity of the assessment. BRAs at FUSRAP sites serve to analyze potential current and future adverse health effects caused by hazardous substance releases from a given site in the absence of actions to control or mitigate such releases. In addition, BRAs may aid in the prioritization of remedial actions and the development of cleanup criteria. As delineated by the Environmental Protection Agency, there are four basic steps to conducting risk assessment for a site under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA): (a) identification of the contaminants of concern, (b) exposure assessment, (c) toxicity assessment, and (d) risk characterization. This presentation explores FUSRAP guidelines for compliance with CERCLA BRAs.

## **METHODOLOGY/DOE**

Ramsey, B.A.; Thatcher, B.K. Date: 1993, March. Title: Use of Risk Assessment/Management Methodologies in Natural Resource Trusteeship. Corporate Author: Systematic Management Services,

Germantown, MD; U.S. Department of Energy, Rocky Flats Field Office, Golden, CO. Pub: CONF-930205 (Vol. 1); Waste Management '93: Working Towards a Cleaner Environment, R.G. Post (ed.), Proceedings of a Symposium, Tucson, AZ, February 28-March 4, 1993, Vol. 1, 967 pp.; (pp. 629-632) Abstract: Under section 107(f)(2) of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and Executive Order 12580, the Department of Energy (DOE) is taking the responsibilities of Natural Resource Trustee at DOE sites throughout the United States. CERCLA and the National Contingency Plan (NCP), Subpart G, authorize the designated trustees to assess damages for injury to, destruction of, or loss of natural resources on lands managed or protected by the trustees. DOE therefore has a dual role to act as Primary Natural Resource Trustee for its lands and facilities and to act as CERCLA lead response agency for cleanups on its lands. Damages assessed by other trustees, such as the Department of Interior and U.S. Fish and Wildlife Service, for damage to threatened and endangered species are enforceable against the DOE. Since the Environmental Protection Agency (EPA) in March 1989 issued guidance for the preparation of ecological risk assessments at CERCLA sites, several regulatory developments have occurred which indicate that ecological risks increasingly may drive decisions on environmental protection and remediation. The developments include (1) revision of the NCP to explicitly require ecological evaluations; (2) the July 1989 court order requiring the scope be expanded of the damages that can be recovered under a Natural Resource Damage Assessment (NRDA); (3) the Resource Conservation and Recovery Act (RCRA) corrective action proposed requirement for ecological risk considerations; and (4) EPA publication of the "Framework for Ecological Risk Assessment" in February 1992. DOE must conduct risk assessments in a cost-effective manner and must be proactive in meeting its responsibilities as a resource trustee. In addition, monies budgeted for remedial and corrective actions must be at least partially based on risk management principles. To meet these needs, the DOE Rocky Flats Office has developed a concept for a comprehensive, site-wide risk assessment (CSWRA) that will be a primary tool. The purpose of the CSWRA is to provide the Rocky Flats Office with a fundamental management tool to support its continuing efforts at the Rocky Flats Plant. The CSWRA will be a living document, updated from its initial descriptive analysis to be increasingly quantitative as data from monitoring, the Rocky Flats Interagency Agreement, and other projects become available.

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SAI. 1979, September. Title: Draft Preliminary Risk Assessment of the Weldon Spring Rock Quarry. Corporate Author: Science Applications, Inc., Oak Ridge, TN. Pub: SAI-OR-79-135-01; 92 pp. Abstract: The Weldon Spring quarry is an abandoned rock quarry located between Missouri State Route 94 and Femme Osage Creek, about 25 miles west of St. Louis, Missouri. For over twenty years the quarry has been utilized as a dump site, first for TNT contaminated rubble and low level radioactive material. The first usage for disposal of radioactive waste occurred in 1959 under the auspices of the U.S. Atomic Energy Commission. The site and the characterization of the drummed and uncontained waste are discussed in detail in Chapter 2 of this report. The ultimate objective of risk assessment activities for the Weldon Spring quarry is to develop an estimate of the public risk and the attendant uncertainties in that estimate. These parameters provide one of the major inputs to decision making. The study reported in this document supports this objective but it is not intended to meet this total objective. Rather the present effort provides a preliminary and scoping evaluation of this risk. This allows a preliminary "ball-park" estimation of risk and establishes the basis for a definitive risk assessment of the Weldon Spring quarry. The specific results of the project necessary to support the objectives include the following items: (1) Risk Estimation - An estimate of the range of risk to the public of the Weldon Spring quarry in its current configuration results from this analysis. This estimate is only representative of the general range in which the hazard could be expected to occur, and is in no way a definitive risk assessment; (2) Methodology - A major result of the project is the development of the preliminary methodology for performance of a complete risk assessment; and (3) Identification of Areas for Further Work. Synthesis of available data and methodology identify areas in which limiting ignorance exists. This includes identification of the areas in which more specific data are needed, and those areas in which methodology developments are necessary.

## **METHODOLOGY/DOE**

Shevenell, L.A.; Hoffman, F.O.; MacIntosh, D.L. Date: 1992, March. Title: Risk Assessment Calculations Using MEPAS, an Accepted Screening Methodology, and an Uncertainty Analysis for the Reranking of Waste Area Groupings at Oak Ridge National Laboratory, Oak Ridge, Tennessee. Environmental Restoration Program. Corporate Author: Oak Ridge National Laboratory, Oak Ridge, TN. Pub: ORNL/ER-53; 70 pp. Abstract: The Waste Area Groupings (WAGs) at the

Oak Ridge National Laboratory (ORNL) were reranked with respect to on- and off-site human health risks using two different methods. Risks associated with selected contaminants from each WAG for occupants of WAG 2 or an off-site area were calculated using a modified formulation of the Multimedia Environmental Pollutant Assessment System (MEPAS) and a method suitable for screening, referred to as the ORNL/ESD method (the method developed by the Environmental Sciences Division at ORNL) in this report. Each method resulted in a different ranking of the WAGs. Rankings from the two methods are compared in this report. All risk assessment calculations, except the original MEPAS calculations, indicated that three Waste Area Groupings - WAG 1; WAGs 2, 6, and 7 (combined as one WAG); and WAG 4 - pose the greatest potential threat to human health. However, the overall rankings of the WAGs using constant parameter values in the different methods were inconclusive because uncertainty in parameter values can change the calculated risk associated with particular pathways, and hence, the final rankings. Uncertainty analysis using uncertainties about all model parameters were used to reduce biases associated with parameter selection and to more reliably rank waste sites according to potential risks associated with site contaminants. Uncertainty analysis indicates that the WAGs should be considered for further investigation, or remediation, in the following order: (1) WAG 1; (2) WAGs 2, 6, and 7 (combined) and WAG 4; (3) WAGs 3, 5, and 9; and (4) WAG 8.

## **METHODOLOGY/DOE**

Sims, L.M.; Temesny, A.; Leidle, J.M. Date: 1991. Title: Chemical and Radiological Risk Assessment Techniques. Corporate Author: Bechtel Environmental, Inc., Oak Ridge, TN. Pub: CONF-910270 (Vol. 2); Waste Management '91: Working Towards a Cleaner Environment, R.G. Post (ed.), Proceedings of the Symposium, Tucson, AZ, February 24-28, 1991, Vol. 2, 815 pp.; (pp. 137-142) Abstract: This paper presents techniques for conducting an exposure assessment at a Superfund site. The exposure assessment is potentially the most controversial aspect of risk assessment, requiring decision-making that is based on subjective assumptions, which invites closer scrutiny by regulators. The exposure assessment receives this scrutiny because it is used to identify exposure pathways and to estimate contaminant concentrations to which potential receptors could be exposed. The exposure assessment has three parts: (1) characterizing the exposure setting; (2) identifying exposure pathways; and (3) quantifying the exposure. The first component of the assessment includes analyses of contaminant and receptor

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characteristics that are used to identify potential exposure pathways for three periods of institutional control. Exposure concentrations are determined from a combination of characterization data, disposal inventory data, and environmental fate and transport modeling data. Specific intake values are then calculated for each of the identified pathways using the exposure concentrations and other pathway-specific intake variables.

#### **METHODOLOGY/DOE**

Stephenson, D.E.; King, C.M.; Looney, B.B.; Holmes, W.G.; Gordon, D.E. Date: 1985. Title: Factors for Assessment of Human Health Risk Associated with Remedial Action at Hazardous Waste Sites. Corporate Author: Savannah River Laboratory, Aiken, SC; Anderson Hospital and Tumor Institute, Houston, TX. Pub: DP-MS-85-129; CONF-851235; Proceedings of an American Geophysical Union Fall Meeting, San Francisco, CA, December 9, 1985; (17 pp.) Abstract: A risk assessment strategy that is cost effective and minimized human health risks was developed for closure of hazardous waste sites at the Savannah River Plant. The strategy consists of (1) site characterization, (2) contaminant transport modeling, and (3) determination of relative merits of alternative remedial actions according to the degree of health protection they provide.

#### **METHODOLOGY/DOE**

Suter II, G.W.; Redfearn, A.; White, R.K.; Shaw, R.A. Date: 1992, July. Title: Approach and Strategy for Performing Ecological Risk Assessments for the Department of Energy Oak Ridge Field Office Environmental Restoration Program. Corporate Author: Oak Ridge National Laboratory, Oak Ridge, TN. Pub: ES/ER/TM-33; 24 pp. Abstract: This document is intended to supplement existing U.S. Environmental Protection Agency (EPA) guidance for ecological risk assessment at hazardous waste sites by providing guidance that is more specific and more tailored to U.S. Department of Energy sites than the guidance available from the EPA. However, it is a conceptual strategy document and does not include specific guidance on data, assumptions, and models. That detailed guidance is under development and will be presented in subsequent documents. Ecological risk assessments are equal to human health risk assessments in regulatory importance and can use many of the same data and some of the same estimation methods. However, they also have peculiar data needs and methods. Ecological risk assessments begin with an initial scoping phase, termed hazard definition, that characterizes the sources, the potential environment, and the

assessment endpoints. In the subsequent measurement and estimation phase, in which data are obtained concerning source of the endpoint biota to the contaminants and the effects of those exposures, assumptions and models are used to relate the data to the desired exposure and effects parameters. Finally, in an integration phase, termed risk characterization, the various exposure and effects estimates are combined to infer the existence, cause, magnitude, and extent of effects of contaminants on the ecological endpoints. This phase is much more complicated for ecological risk assessments than for human health assessments because more types of data are available. Ecological risk assessments estimate effects using laboratory toxicity test results, like human health assessments, but also use results of ambient toxicity tests and biological surveys.

## **METHODOLOGY/DOE**

Temeshy, A.; Liedle, J.M.; Sims, L.M.; Efird, C.R. Date: 1992. Title: Estimating Risk at a Superfund Site Contaminated with Radiological and Chemical Wastes. Corporate Author: Bechtel National, Inc., Oak Ridge, TN. Pub: Superfund Risk Assessment in Soil Contamination Studies, Proceedings of a Symposium, New Orleans, LA, January 30-31, 1991; ASTM Special Technical Publication 1158:231-244 Abstract: This paper describes the methods and results for estimating carcinogenic and noncarcinogenic effects at a Superfund site that is radiologically and chemically contaminated. Risk to receptors from disposal of waste in soil and resulting contamination of groundwater, air, surface water, and sediment is quantified. Specific risk assessment components which are addressed are the exposure assessment, toxicity assessment, and the resulting risk characterization. In the exposure assessment, potential exposure pathways are identified using waste disposal inventory information for soil and modeled information for other media. Models are used to calculate future radionuclide concentrations in groundwater, soil, surface water and air. Chemical exposure concentrations are quantified using site characterization data. Models are used to determine concentrations of chemicals in surface water and in air. Toxicity parameters used to quantify the dose-response relationship associated with the carcinogenic contaminants are slope factors, and with noncarcinogenic contaminants are reference doses. In the risk characterization step, results from the exposure assessment and toxicity assessment are summarized and integrated into quantitative risk estimates for carcinogens and hazard indices for noncarcinogens. Calculated risks for carcinogenic contaminants are

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compared with EPA's target risk range. At Waste Area Grouping 6, the risk from radionuclides and chemicals for an on-WAG homesteader exceeds EPA's target risk range. Hazard indices are compared to unity for noncarcinogenic contaminants. At WAG 6, the total pathway hazard index for the on-WAG homesteader exceeds unity.

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USDOE. 1992, May. Title: Risk Assessment Guidance Document for the UMTRA Project Groundwater Remediation Phase. Corporate Author: U.S. Department of Energy, Albuquerque Operations Office, Uranium Mill Tailings Remedial Action Project Office, Albuquerque, NM. Pub: DOE/UMTRA-400680-0000; 50 pp. Abstract: The purpose of the groundwater remedial activities at the Uranium Mill Tailings Remedial Action (UMTRA) sites is to reduce, control, or eliminate risks to human health and the environment. This is in accordance with Subpart B of 40 CFR 192. According to this regulation, the need for groundwater restoration is based upon U.S. Environmental Protection Agency (EPA)-defined groundwater cleanup standards and must be consistent with the National Environmental Policy Act process. Risk assessments will be used in the UMTRA Groundwater Program to aid in the evaluation of sites. Risk assessments are conducted for four purposes: (1) preliminary risk assessments are used in prioritizing sites, scope data collection, and determine if a site presents immediate health risks; (2) baseline risk assessments provide a comprehensive integration and interpretation of demographic, geographic, physical, chemical, and biological factors at a site to determine the extent of actual or potential harm; (3) risk evaluation of remedial alternatives is performed to evaluate risks to humans or the environment associated with the various remedial strategies; and (4) after remediation, an evaluation of residual risks is conducted. The information gathered for each of these risk evaluations is used to determine the need for subsequent evaluation. Several sites may be eliminated after a preliminary risk assessment if there is no current or future threat to humans or the environment. Likewise, much of the data from a baseline risk assessment can be used to support alternate concentration limits or supplemental standards demonstrations, or identify sensitive habitats or receptors that may be of concern in selecting a remedy.

## **METHODOLOGY/DOE**

Whelan, G.; Steelman, B. L. 1984. Development of Improved Risk Assessment Tools for Prioritizing Hazardous and Radioactive-Mixed Waste Disposal Sites. Battelle Pacific Northwest Labs., Richland, WA. Conference proceeding - DOE environmental protection information meeting, Albuquerque, NM, USA, 6 Nov 1984. U.S. Department of Energy, Washington, DC. Abstract: It is the intent of all environmental regulations to minimize the risks to man and his environment that arise from a regulated activity. Because lower levels of risk are generally accompanied by higher environmental control costs, optimum management is achieved by balancing risks and costs. Currently, the US Environmental Protection Agency employs the Hazard Ranking System (HRS) to evaluate the environmental risks associated with inactive hazardous waste sites for the purpose of establishing the National Priorities List. Recently, investigators modified the HRS to more realistically evaluate the risks posed by radioactive waste constituents. Although results from applying the modified HRS will be useful for comparing the priority of DOE sites to non-DOE sites, the methodology is still overly subjective. To provide DOE with a better management tool for prioritizing funding allocations for further site investigations and possible remediations, Pacific Northwest Laboratory is developing a more objective, scientifically based, risk assessment methodology called the Remedial Action Priority System (RAPS). This methodology will be developed using empirically, analytically, and semianalytically based mathematical algorithms to predict the potential for contaminant migration from a site to receptors of concern using pathways analyses. Four major pathways for contaminant migration will be considered in the RAPS methodology: groundwater, overland, surface water, and atmospheric. Using the predictions of contaminant transport, simplified exposure assessments will be performed for receptors of interest. The risks associated with the sites will then be calculated relative to other sites for each pathway and for all pathways together. The RAPS methodology will require minimum user knowledge of risk assessment and the least possible amount of input data, and is being designed to operate on a personal computer. 17 refs, 3 figs, 1 table.

#### **METHODOLOGY/DOE**

Whelan, G.; Strenge, D.L.; Steelman, B.L.; Hawley, K.A. Date: 1985. Title: Development of the Remedial Action Priority System: An Improved Risk Assessment Tool for Prioritizing Hazardous and Radioactive-Mixed Waste Disposal Sites. Corporate Author: Pacific Northwest Laboratory, Richland, WA. Pub: Management of Uncontrolled Hazardous Waste Sites, Proceedings of the Sixth National

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Conference, Washington, DC, November 4, 1985. Hazardous Materials Control Research Institute, Silver Spring, MD; (pp. 432-437) Abstract: The Remedial Action Priority System (RAPS) represents a methodology that prioritizes inactive hazardous and radioactive mixed-waste disposal sites in a scientific and objective manner based on limited site information. This methodology is intended to bridge the technology gap that exists between the initial site evaluation using the Hazard Ranking System (HRS) and the time-consuming process of actual field site characterization, assessment and remediation efforts. The HRS was designed as an initial screening tool to discriminate between hazardous waste sites that do not and those that are likely to pose significant problems to human health, safety and/or the environment. The HRS is used by the U.S. Environmental Protection Agency to identify sites for nomination to the National Priorities List (NPL). Because the HRS is not designed to evaluate sites containing radionuclides, a modified Hazard Ranking System (mHRS) addressing both hazardous and radioactive mixed wastes was developed by Pacific Northwest Laboratory (PNL) for the U.S. Department of Energy (DOE). Neither the HRS nor the mHRS was designed to prioritize sites that are nominated to the NPL according to their potential risks. To provide DOE with a better management tool for prioritizing funding and human resource allocations for further investigations and possible remediations at its inactive waste sites, PNL is developing the risk assessment methodology called RAPS. Use of RAPS will help DOE ensure that those sites posing the highest potential risk are addressed first.

#### **METHODOLOGY/DOE**

White, R.K.; Redfearn, A.; Shaw, R.A.; King, A.D.; Swindle Jr., D.W. Date: 1992. Title: Impacts of the Use of Institutional Controls on Risk Assessments for Department of Energy Facilities. Corporate Author: Oak Ridge National Laboratory, Oak Ridge, TN. Pub: CONF-920851 (Vol. 1); Spectrum '92: Nuclear and Hazardous Waste Management, Proceedings of an International Topical Meeting, Boise, ID, August 23-27, 1992, Vol. 1, 848 pp.; (pp. 37-43); CONF-9209165; Proceedings of the 65th Annual Conference of the Water Environment Federation, New Orleans, LA, September 23, 1992; (10 pp.) Abstract: This paper summarizes some of the major issues related to the use of institutional controls at hazardous waste sites that are now under the auspices of the Department of Energy Field Office, Oak Ridge/Environmental Restoration Division (DOE-OR/ERD). The impacts that assumptions regarding institutional controls have on the results and interpretation of the risk

assessment, both in the Remedial Investigation (RI) and the Feasibility Study (FS), are addressed. The approaches and assumptions relating to institutional controls focus on the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), since it is the regulatory driver for hazardous waste sites at DOE facilities. In order to provide a contrast to approaches adopted under CERCLA, the Resource Conservation and Recovery Act and radiation regulatory authorities are briefly outlined. To demonstrate the implications of the use of institutional controls at DOE facilities, the approaches and results of a recent baseline risk assessment for Solid Waste Storage Area 6 at Oak Ridge National Laboratory are summarized.

#### **METHODOLOGY/DOE**

Zentner, M.D. Date: 1992, November. Title: Comparison of Reactor and Nonreactor Risk Assessment Approaches. Corporate Author: Westinghouse Hanford Company, Richland, WA. Pub: WHC-SA-1560; CONF-930116; Probabilistic Safety Assessment, Proceedings of an International Topical Meeting, Clearwater Beach, FL, January 27-29, 1993; (8 pp.) Abstract: The Risk Assessment Technology Group, Westinghouse Hanford Company (WHC), has participated in a number of full and partial reactor risk assessments of facilities such as the N Reactor, Fast Flux Test Facility, Washington Public Power Supply System No. 1, SP-100 Ground Test Facility, and the Savannah River K Reactor. As the mission of the Hanford Site has changed from special nuclear material production to environmental cleanup, the emphasis for performing risk assessments has shifted from evaluating the risk from operation of reactors to that from nonreactor facilities such as: waste storage tanks; waste treatment facilities such as Grout and the Hanford Waste Vitrification Plant; and waste processing facilities such as the 242-A evaporator. Additionally, risk assessment techniques are being used to support transportation safety studies, engineering design studies, safety analysis report development, and environmental remediation efforts. There are many opportunities for constructive use of risk assessment methodology in a wide variety of areas. This paper describes the state-of-the-art risk assessment at the Hanford Site, shows how the techniques are evolving, and compares reactor and nonreactor approaches.

#### **METHODOLOGY/EPA**

Bascietto, J.J. Date: 1992, October. Title: Development of Ecological Risk Assessment - An Historical Perspective. Corporate

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Author: U.S. Department of Energy, Office of Environmental Guidance, Washington, DC. Pub: CONF-921029; Waste Management and Environmental Restoration, Proceedings of the Eighth Annual DOE Model Conference, Oak Ridge, TN, October 18-22, 1992, 228 pp.; (8 pp.) Abstract: This paper gives the history of the U.S. Environmental Protection Agency's (EPA's) effort to develop a regulatory framework for ecological risk, beginning in the 1980s. This effort arose from the EPA's difficulty in establishing the proper level of ecological risk for the cancellation of two pesticides (diazinon and carbamate carbofuran). Diazinon, which was canceled first in 1990 after a six-year special review by the EPA, was less widely used and less toxic than carbamate carbofuran, which was canceled in 1991 after another six-year special review. EPA's 1992 framework for ecologic risk was the first published consensus document on generic ecological risk assessment principles, and is expected to form the basis for all future EPA ecological risk assessments. The current EPA regulatory framework, which is based on these early ecological risk assessment efforts, is given in another paper in this same conference session.

#### **METHODOLOGY/EPA**

Hamilton, L.D.; Medeiros, W.H.; Meinhold, A.; Morris, S.C.; Moskowitz, P.D.; Nagy, J. Date: 1988, Sept. Title: Health Risk Analysis for Ingestion of Contaminants from Existing Groundwater Contamination at Selected UMTRA Project Sites. Corporate Author: Brookhaven National Laboratory, Upton, NY. Pub: BNL-44772; 84 pp. Abstract: This study examines potential hazards to human health from ingestion of chemicals in groundwater beneath and adjacent to four abandoned uranium mill tailings sites: Gunnison, CO; Lakeview, OR; Monument Valley, AZ; and Riverton, WY. Chemicals of concern in groundwater near the sites include arsenic, cadmium, chromium, lead-210, molybdenum, nitrate, polonium-210, radium-226 and radium-228, selenium, sulfate, thorium-230, uranium, and vanadium. Hazards to health were evaluated by implementing the method outlined in the EPA Superfund Public Health Evaluation Manual. Because the method has a number of built-in conservatisms, the estimated risks and indexes only indicate sites and chemicals requiring further analysis. The chemicals and sites identified as presenting risk in this first screening step should be investigated in more detail. Necessary steps are given. Sites and chemicals identified as harmless in this initial screening can be eliminated from further consideration.

#### **METHODOLOGY/EPA**

MacDonell, M.M.; Haroun, L.A.; Peterson, J.M.; Blunt, D.A.; Fingleton, D.J.; Picel, M.H. Date: 1991, September. Title: Strategy for Integrated CERCLA/NEPA Risk Assessments. Corporate Author: Argonne National Laboratory, Environmental Assessment and Information Sciences Division, Argonne, IL. Pub: CONF-910981; Environmental Remediation '91: Cleaning Up the Environment for the 21st Century, D.E. Wood (ed.), Proceedings of a Conference, Pasco, WA, September 8-11, 1991, 970 pp.; (pp. 853-860) Abstract: The U.S. Department of Energy (DOE) has established a policy whereby, for remedial actions, the procedural and documentational requirements of the National Environmental Policy Act (NEPA) are integrated with those of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended. However, the objectives of risk assessment under NEPA and CERCLA differ somewhat. Until its recent application to contaminated sites, NEPA analysis has typically been applied to impacts from actions at clean sites (e.g., for construction activities), and a somewhat loosely structured process has historically been used to estimate relative risks for NEPA. Decisions such as cleanup levels were not made on the basis of risk estimates, and therefore tended to be conservative and not detailed. In contrast, risk estimates for Superfund (CERCLA) sites are used to focus the decision-making process for those sites and support national prioritization for cleanup. The U.S. Environmental Protection Agency (EPA) has developed a detailed framework for preparing baseline health-risk assessments for these sites. The purpose of this paper is to discuss the issues relating to integrating the CERCLA and NEPA approaches into the risk assessments that have been prepared for a DOE remedial action project at the Weldon Spring Site near St. Charles, Missouri. These issues are grouped into three basic categories: general assumptions for the impact evaluation, data management, and presentation of the methodology and results. This paper is not intended to represent DOE policy and guidance, nor does it represent the only approach that can be used for integrated risk assessments. It merely discusses the process that was used for the Weldon Springs project, articulating the issues that were encountered and how they were addressed.

#### **METHODOLOGY/EPA**

Niemczyk, S.J. Date: 1988. Title: A New Approach for Estimating the Risk from Residual Radioactivity. Corporate Author: Gull Associates, Washington, DC. Pub: Proceedings of the Health Physics Society 33rd Annual Meeting, Boston, MA, July 4-8, 1988; (p. S7); Health Physics 54(Suppl. 1):S7 Abstract: To aid the U.S.

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Environmental Protection Agency's selection of decommissioning criteria for unrestricted release of cleaned-up sites and facilities, a new approach has been developed for estimating the potential hazard from residual radioactivity. That approach, intended to provide conservatively realistic estimates of radiation doses to individual residents from such radioactivity in the environment and in buildings, uses a comprehensive yet relatively simple set of physically-based, risk-level environmental transport and exposure pathway models. Doses are estimated for up to 10,000 years. Compared to other approaches which might be used for residual radioactivity, the new approach has several outstanding features. First, some of its models are less conservative than the comparable models in other approaches, thus reducing the likelihood of unwarranted over-estimation of certain doses. Second, the new approach includes models for estimating certain doses due to the neglect of contributions from "other" rooms (as happens in the one-room models typically used). Third, the approach's integrated set of transport and behavior models permits straightforward consideration of situations with significant movement of radioactivity within the environment and/or significant radioactive in-growth, thus helping to prevent overlooking of situations in which the largest potential doses occur at times long after the site's release. Fourth, the approach's extremely efficient solution techniques, combined with its comprehensive set of transport and behavior models, make consideration of a large variety of situations practical. And fifth, the approach has been implemented in a computer code which runs on a personal computer, making the approach accessible to a wide number of users. The new approach constitutes a significant first step toward a set of comprehensive relationships for providing radiation dose estimates for residual radioactivity at a variety of sites and facilities. As such it serves to fill a significant gap in the spectrum of available approaches.

#### **METHODOLOGY/EPA**

Norton, S.B.; Rodier, D.J.; Gentile, J.H.; van der Schalie, W. Date: 1992, October. Title: EPA's Framework for Ecological Risk Assessment. Corporate Author: U.S. Environmental Protection Agency, Washington, DC. Pub: CONF-921029; Waste Management and Environmental Restoration, Proceedings of the Eighth Annual DOE Model Conference, Oak Ridge, TN, October 18-22, 1992, 228 pp.; (6 pp.) Abstract: The U.S. Environmental Protection Agency (EPA) has an increasing interest in using ecological risk assessments as a basis for environmental decisions. This increased emphasis is

illustrated by a recent report by the EPA Science Advisory Board. Among their recommendations, the board suggested that EPA (1) target its environmental protection efforts on the basis of opportunities for the greatest risk reduction; (2) attach as much importance to reducing ecological risk as it does to reducing human health risk; and (3) improve the data and analytical methodologies that support the assessment, comparison, and reduction of different environmental risks. This article summarizes the recently published EPA Framework for Ecological Risk Assessment (1992) that describes the basic elements of ecological risk assessment. In addition, the article discusses several of the scientific issues that have been highlighted through the development of the framework report.

#### **METHODOLOGY/EPA**

USEPA. 1986. The risk assessment guidelines of 1986. EPA/600/8-87/045. U.S. Environmental Protection Agency. August, 1987.

#### **METHODOLOGY/EPA**

USEPA. 1989a. Risk Assessment Guidance for Superfund. Vol. 1: Human Health Evaluation Manual. EPA/540/1-89/002. U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, DC. OSWER Directive 9285.7-01A; 340 pp. Abstract: This document is part of the two-manual set titled Risk Assessment Guidance for Superfund. Volume I, the Human Health Evaluation Manual, provides guidance for health risk assessment at Superfund sites; Volume 2, the Environmental Evaluation Manual, provides guidance for ecological assessment at Superfund sites. The Environmental Protection Agency (EPA) Office of Emergency and Remedial Response developed a human health evaluation process as part of its remedial response program. The process of gathering and assessing human health risk information described in this manual is adapted from well-established chemical risk assessment principles and procedures (NAS 1983; CRS 1983; OSTP 1985). It is designed to be consistent with EPA's published risk assessment guidelines (EPA 1984; EPA 1986a-e; EPA 1988a; EPA 1989a) and other EPA-wide risk assessment policy. The Human Health Evaluation Manual replaces the Superfund Public Health Evaluation Manual (EPA 1986f). It incorporates new information and builds on several years of Superfund program experience in conducting risk assessments at hazardous waste sites. In addition, this manual and its companion Environmental Evaluation Manual (EPA 1989b) replace the EPA 1985 Endangerment Assessment Handbook, which is no longer to be used. The goal of the Superfund human health evaluation process is to

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provide a framework for developing the risk information necessary to decision making at remedial sites. Specific objectives are to (1) provide an analysis of baseline risks and help determine the need for action at sites; (2) provide a basis for determining levels of chemicals that can remain onsite and still be adequately protective of public health; (3) provide a basis for comparing potential health impacts of various remedial alternatives; and (4) provide a constituent process for evaluating and documenting public health threats at sites.

### **METHODOLOGY/EPA**

USEPA. 1989b. Risk Assessment Guidance for Superfund. Vol. 2: Environmental Evaluation Manual. EPA/540/1-89/001. U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, DC. 70 pp. Abstract: This document is part of the two-manual set titled Risk Assessment Guidance for Superfund. Volume I, the Human Health Evaluation Manual, provides guidance for health risk assessment at Superfund sites; Volume 2, the Environmental Evaluation Manual, provides guidance for ecological assessment at Superfund sites. Volume 2 primarily addresses remedial project managers and on-scene coordinators, who are responsible for ensuring a thorough evaluation of potential environmental effects at sites. It is not a detailed "how-to" guidance and does not provide "cookbook" approaches for evaluation. Instead, it identifies the kinds of help that on-scene coordinators and project managers are likely to need and where to find this help. Then it describes an overall framework for considering environmental effects. A detailed discussion of environmental evaluation methods can be found in Ecological Assessments of Hazardous Waste Sites: A Field and Laboratory Reference Document (EPA/600/3-89/013).

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USEPA. 1991, December. Title: Risk Assessment Guidance for Superfund - Volume 1: Human Health Evaluation Manual - Part B, Development of Risk-Based Preliminary Remediation Goals - Interim Report. Corporate Author: U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, DC. Pub: OSWER Directive 9285.7-01B; 66 pp. Abstract: The document is one of a three-part series. Part B provides guidance on using U.S. Environmental Protection Agency toxicity values and exposure information to derive risk-based preliminary remedial goals (PRG) for a Comprehensive Environmental Response, Compensation and

Liability Act (CERCLA) site. Initially developed at the scoping phase using readily available information, risk-based PRGs generally are modified based on site-specific data gathered during the remedial investigation/feasibility study. The guidance does not discuss the risk management decisions that are necessary at a CERCLA site. The potential users of Part B are those involved in the remedy selection and implementation process, including risk assessors, risk assessment reviewers, remedial project managers, and other decision-makers.

### **METHODOLOGY/EPA**

USEPA. 1992, May. Title: Guidance for Data Useability in Risk Assessment (Part B): Final Report. Corporate Author: U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, DC. Pub: PB-92-963362/XAB; OSWER Directive 9285.7-09B; 85 pp. Abstract: Part B of this report, Guidance for Data Useability in Risk Assessment, provides supplemental information regarding the useability of analytical data for performing a baseline risk assessment at sites with radioactivity. While Part A focuses primarily on chemical contamination, much of the information presented also applies to the risk assessment process for radioactive contamination. The guidance offered in Part B is intended as an overview of the key differences between chemical and radionuclide risk assessments, and not as a comprehensive, stand-alone document to assess the risks posed by radionuclide exposures. Part A of the guidance should be used side-by-side with this document.

### **METHODOLOGY/ICRP**

Devgun, J.S.; Devgun, M.E. Date: 1992. Title: Implications of Recent ICRP Recommendations for Risk Assessments for Radioactive Waste Disposal and Cleanup. Corporate Author: Argonne National Laboratory, Argonne, IL. Pub: ANL/CP-74093; CONF-920307; Waste Management '92, R.G. Post (ed.), Proceedings of a Conference, Tucson, AZ, March 1-5, 1992, Vol. 1, 994 pp.; (pp. 499-503) Abstract: The International Commission on Radiological Protection (ICRP) adopted a new set of recommendations in November 1990 which were issued as ICRP Publication No. 60 in March 1991. These recommendations incorporate new radiobiological information and outline a comprehensive system of radiological protection. This paper evaluates the implications of these new recommendations regarding risk assessments for radioactive waste disposal and remediation of radioactively contaminated sites.

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### **METHODOLOGY/International**

Murray, M.L.; Chambers, D.B.; Knapp, R.A.; Kaplan, S. Date: 1987, September. Title: Estimation of Long-Term Risk from Canadian Uranium Mill Tailings. Corporate Author: Senes Consultants Limited, Willowdale, Ontario, Canada. Pub: Risk Analysis 7(3):287-298  
Abstract: A methodology is presented for assessing the risk from Canadian uranium mill tailings piles. The methodology is based on the set of triplets concept and uses an event tree to identify various scenarios representing the performance of a pile over its 1,000-year design life. Compartment-type mathematical models are used to quantify the movement of hazardous substances through the environment. Numerical examples are given of both level 1 (straight probabilistic) and level 2 (probability of frequency) type analyses.

### **METHODOLOGY/International**

Murray, M.L.; Chambers, D.B.; Knapp, R.A.; Holmes, R.W. Date: 1986. Title: An Approach to Risk Assessment for Canadian Uranium Mill Tailings. Corporate Author: Senes Consultants, Willowdale, Ontario, Canada; Department of Energy, Mines and Resources, Ottawa, Ontario, Canada. Pub: CONF-8609486; Radioactive Waste Management, Proceedings of the Second International Conference, Winnipeg, Ontario, Canada, September 7-11, 1986, 821 pp.; (pp. 273-280)  
Abstract: Quantitative risk analysis provides a framework for considering the consequences of sequences of events (scenarios) in proportion to their likelihoods of occurrence. This paper considers risk as a "set of triplets" consisting of scenarios, the likelihoods of those scenarios occurring, and their consequences should they occur. Both the likelihood of an event (or scenario) occurring and its consequence may be uncertain quantities. The risk quantification method presented allows incorporation of these uncertainties. This paper discusses the concept of risk and demonstrates how the consequences of a number of scenarios involving naturally occurring events can be combined to estimate the overall risk arising from uranium mill tailings.

### **METHODOLOGY/NCRP**

NCRPM. 1989. Comparative carcinogenicity of ionizing radiation and chemicals. National Council on Radiation Protection and Measurements. Report No. 96.

## **METHODOLOGY/NRC**

USNRC. 1986a. Title: Scientific Basis for Risk Assessment and Management of Uranium Mill Tailings. Corporate Author: National Research Council, Uranium Mill Tailings Study Panel, Washington, DC. Pub: DOE/DP-93032-T1; 260 pp. Abstract: Uranium mill tailings are the finely ground sand-like material that is left after uranium is extracted from ore. As of early 1983, approximately 200 million metric tons of uranium mill tailings covering 1300 ha at 51 sites had accumulated in the United States. Most of these sites are in the arid Southwest. Uranium mill tailings present health and environmental concerns because of the residual radioactivity that they contain and because of a variety of other potential pollutants, such as chlorides, sulfates, and heavy metals. The milling process makes the radioactive and nonradioactive materials contained in the ore when it was mined much more mobile and also adds several potential contaminants to the tailings material during the milling process. Exposure routes of concern are release of the gas, Rn-222, airborne dust, and surface and groundwater contamination. In addition, the use of tailings as construction material or fill can lead to dangerously high levels of radon in associated buildings. At the request of the Department of Energy, a National Research Council study panel, convened by the Board on Radioactive Waste Management, has examined the scientific basis for risk assessment and management of uranium mill tailings and issued this final report containing a number of recommendations. Chapter 1 provides a brief introduction to the problem. Chapter 2 examines the processes of uranium extraction and the mechanisms by which radionuclides and toxic chemicals contained in the ore can enter the environment. Chapter 3 is largely devoted to a review of the evidence on health risks associated with radon and its decay products. Chapter 4 provides a consideration of conventional and possible new technical alternatives for tailings management. Chapter 5 explores a number of issues of comparative risk, provides a brief history of uranium mill tailings regulation, and concludes with a discussion of choices that must be made in mill tailing risk management.

## **METHODOLOGY/NRC**

USNRC. 1986b. Title: Scientific Basis for Risk Assessment and Management of Uranium Mill Tailings. Corporate Author: National Research Council, Uranium Mill Tailings Study Panel, Washington, DC. Pub: DOE/DP-93032-T2; 262 pp. Abstract: A National Research Council study panel, convened by the Board on Radioactive Waste

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Management, has examined the scientific basis for risk assessment and management of uranium mill tailings and issued this final report containing a number of recommendations. Chapter 1 provides a brief introduction to the problem. Chapter 2 examines the processes of uranium extraction and the mechanisms by which radionuclides and toxic chemicals contained in the ore can enter the environment. Chapter 3 is devoted to a review of the evidence on health risks associated with radon and its decay products. Chapter 4 provides a consideration of conventional and possible new technical alternatives for tailings management. Chapter 5 explores a number of issues of comparative risk, provides a brief history of uranium mill tailings regulation, and concludes with a discussion of choices that must be made in mill tailing risk management.

### **METHODOLOGY/Other**

Wartenberg, D., and R. Simon. 1995. Comment: Integrating epidemiologic data into risk assessment. American Journal of Public Health. 85(4):491-493. April, 1995.

### **UNCERTAINTY/Commercial**

Mendez Jr., W.M. Date: 1990. Title: Recent Developments in Health Risks Modeling Techniques Applied to Hazardous Waste Site Assessment and Remediation. Corporate Author: Ebasco Environmental, Inc., Arlington, VA. Pub: CONF-9010166; Waste Management and Environmental Restoration, Proceedings of the 1990 DOE Model Conference, Oak Ridge, TN, October 29-November 2, 1990, 343 pp.; (1 p.) Abstract: Remediation of hazardous and mixed-waste sites is often driven by assessments of human health risks posed by exposures to the hazardous substances released from these sites. The methods used to assess potential health risk involve, either implicitly or explicitly, models for pollutant releases, transport, human exposure and intake, and characterizing health effects. Because knowledge about pollutant fate and transport processes at most waste sites is quite limited and data costs are quite high, most of the models currently used to assess risk that are endorsed by regulatory agencies are quite simple. The models employ many simplifying assumptions about pollutant fate and distribution in the environment, human pollutant intake, and toxicologic responses to pollutant exposures. An important consequence of data scarcity and model simplification is that risk estimates are quite uncertain. Estimates of the magnitude uncertainty associated with risk assessment has been very difficult. A number of methods have been developed to address the issue of uncertainty in risk

assessment in a manner that realistically reflects uncertainty in model specification and data limitations. These methods include (1) definition of multiple exposure scenarios, (2) sensitivity analyses, and (3) explicit probabilistic modeling of uncertainty. Recent developments in this area will be discussed, along with their possible impacts on remediation programs and remaining obstacles to their wider use and acceptance by the scientific and regulatory communities.

### **USES/Commercial**

Anderson, P. Date: 1992. Title: Controlling Remediation Costs with Risk Assessment. Pub: ENSR Newsletter 2:8-9 Abstract: To control the costs and liabilities of hazardous waste site remediation, many companies are including risk assessment, used to estimate the size of a site's health effects and cleanup levels necessary to protect human health and the environment, in their strategic planning and management. Risk assessment affects cleanup costs through a series of procedures, including prioritization of the cleanup, the treatment technology, and the volume of material to be treated. Of special importance is the use of newer bioremediation technologies directly applicable to the new kinds of problems being encountered.