

ARGONNE NATIONAL LABORATORY RELEVANT EXPERIENCE AND PUBLICATIONS RELATED TO TECHNOLOGICALLY ENHANCED NATURALLY OCCURRING RADIOACTIVE MATERIAL RISK ASSESSMENT

RELEVANT EXPERIENCE

Scientists at the U.S. Department of Energy's Argonne National Laboratory (ANL) have conducted risk assessment studies related to Technologically Enhanced Naturally Occurring Radioactive Material (TENORM) for over 20 years. Sample lists of studies conducted by ANL scientists and their publications are given below.

In addition to specific TENORM studies, Argonne scientists also developed the computational tools that are used in the conducting these types risk assessments. The tools developed by Argonne staff are used not only by the Argonne staff, but also by scientists and engineers throughout the United States and abroad. For example, the RESRAD code developed by Argonne, is an internationally recognized preeminent computational tool used, by, among others, the U.S. Department of Energy and the U.S. Nuclear Regulatory Commission for cleanup of radiologically contaminated sites and for disposal of radioactive wastes. Another risk assessment code used to estimate the doses to workers and the general public, TSD-DOSE, was also developed by Argonne staff. In addition, Argonne staff members have extensive experience with management and risk analysis for all kinds of radioactive materials, including low-level wastes, that would be relevant to the assessment of risks associated with the management and disposal of TENORM wastes.

TENORM RELATED STUDIES CONDUCTED BY ARGONNE STAFF

NORM Overview Study (Dec. 1991 – Dec. 1992). As NORM became an issue of increasing concern and cost for the petroleum industry, Argonne was tasked by the U.S. Department of Energy (DOE) to prepare an overview document summarizing the origin of NORM in petroleum industry wastes, how NORM was regulated at that time, existing information about the geographic distribution of NORM, what management and disposal options were either being used by the industry or presented feasible alternatives, and available information regarding risk associated with petroleum industry NORM.

Overview of NORM Disposal and Treatment Alternatives (Jan. 1992 – Aug. 1993). Argonne was tasked by DOE to prepare a report summarizing regulations applicable to disposal of petroleum industry NORM; current NORM disposal options; and prospective NORM treatment, disposal, and mitigation alternatives.

NORM Disposal Dose Assessment (Mar. 1994 – Sept. 1996). This study, funded by DOE, assessed potential radiological doses associated with a variety of NORM management and disposal alternatives, including equipment cleaning activities, NORM storage activities, landspreading, underground injection and subsurface disposal, and smelting of contaminated

equipment. In addition, the report presented information regarding the characterization of NORM wastes and previous NORM research studies.

Support to NORM Technology Demonstration Project (Oct. 1996 – July 1998). The DOE funded a NORM treatment and disposal technology demonstration project, which entailed the development and evaluation of a portable technology to dissolve radium from solid NORM wastes and dispose of the radioactive waste by underground injection. Argonne supported this project by conducting an assessment of (1) the potential environmental impacts associated with the demonstration project and (2) the potential radiological risks to workers and the public associated with the new technology. As part of this study, Argonne prepared an environmental impact assessment and published a bibliography of NORM-related publications.

Dose Assessment of NORM Disposal by Landspreading (Nov. 1996 – Sept. 1998). This study, which was funded by DOE, built upon the assessment of landspreading conducted in an earlier study to provide a more detailed assessment of the potential doses associated with disposing of petroleum industry NORM by landspreading.

Assessment of NORM Disposal in Salt Caverns (Sept. 1997 – Aug. 1998). This study assessed the technical feasibility of disposing of NORM wastes by injection into salt caverns and the potential radiological risks to workers and the public associated with this activity. This study was funded by DOE.

Risk Assessment of NORM Disposal in Nonhazardous Landfills (Dec. 1997 – Sept. 1999). This study assessed the potential radiological risk to workers and the public associated with the disposal of petroleum industry NORM wastes in landfills designed to receive nonhazardous wastes. Specifically, the study evaluated whether a Michigan state policy allowing limited disposal of radium-bearing wastes in these types of landfills was adequately protective of human health. In addition, the study included a cost comparison of several NORM disposal alternatives, including downhole encapsulation, underground injection, landspreading, disposal in a landfill licensed to receive radioactive wastes, and disposal in a nonhazardous landfill. This study was funded by the DOE and the American Petroleum Institute.

Demonstration of Streamlined Approaches to Characterizing NORM-Contaminated Sites (July 1998 – present). DOE funded a demonstration of the Adaptive Sampling and Analysis Program (ASAP) approach to streamlined characterization of sites contaminated with petroleum industry NORM. The project entailed a demonstration at a pipe storage facility located in Michigan. Following completion of the demonstration project, DOE funded Argonne to conduct technology transfer activities to educate industry and regulators regarding the savings that can be realized through use of the ASAP approach. Argonne has offered two workshops on this topic and is considering other technology transfer opportunities.

NORM Disposal Cost Study (Oct. 1998). Argonne prepared a summary of costs associated with different NORM disposal options in use at the time of the study. Disposal methods summarized in the assessment included commercial underground injection, underground injection at company-owned wells, and disposal in a landfill licensed to receive radioactive wastes.

Support to the Interstate Oil and Gas Compact Commission's NORM Subcommittee (Oct. 1998 – Oct. 2000). DOE funded Argonne to participate in the NORM Subcommittee of the Interstate Oil and Gas Compact Commission (IOGCC). The IOGCC is an organization made of up state governor's and state agencies that oversee regulation of petroleum industry activities. The NORM subcommittee was formed to support the IOGCC's efforts to keep industry and regulators well informed on NORM issues. Argonne supported the committee's development of a pamphlet providing basic information about petroleum industry NORM and a report providing an overview of (1) literature studies evaluating NORM disposal options and associated risk and (2) state regulations applicable to NORM.

Development of the NORM Technology Connection Web Site (July 1999 – present). The DOE funded Argonne to develop a Web site providing streamlined access to current information about (1) companies providing NORM-related services to the petroleum industry and (2) regulation of NORM in the United States. The Web site was completed and transferred to the Interstate Oil and Gas Compact Commission (IOGCC) in Jan. 2001. The site was transferred back to Argonne and it is now hosted and maintained by Argonne, although not fully funded.

Evaluation of Proposed Rule Change to Mississippi NORM Regulations (Oct. 1999). The Mississippi State Oil and Gas Board hired Argonne to evaluate a proposed change to the state's NORM regulations on the basis of previously conducted risk assessments.

NORM Site Closure Project for Major Oil Company (June – July 2000). Argonne provided support to a major oil company in their efforts to negotiate a risk-based closure plan for a NORM-contaminated site. The work entailed radiological risk assessments of several potential future use scenarios for the property, using site specific data. Ultimately, the risk assessment supported closing the property without remediating the site for NORM.

NORM Disposal Analysis and Strategic Support to Two Major Foreign Oil Companies (2003 - 2010). Argonne provided technical analysis support to one major oil company in the Middle East for disposal of its NORM wastes in engineered landfills and in deep injection wells. The work involved conducting the analyses, preparing a draft and a final report, and presenting the results of the study to company management on location. Argonne also provided strategic support to another major oil company in the Middle East to assist the company in developing its NORM management strategy by conducting a workshop on location with the company personnel and in-country regulators.

NORM PUBLICATIONS

Full Reports

Radiological Risk and Cost Assessment of Naturally Occurring Radioactive Materials (NORM) Disposal Alternatives, prepared for a confidential client, (Smith et al. 2005).

An Assessment of the Disposal of Petroleum Industry NORM in Nonhazardous Landfills, DOE/BC/W-31-109-ENG-38-8 (OSTI ID: 13061), prepared for U.S. Department of Energy, National Petroleum Technology Office, Tulsa, Okla. (Smith et al. 1999).

The Application of Adaptive Sampling and Analysis Program (ASAP) Techniques to NORM Sites, DOE/BC/W-31-109-ENG-38-9 (OSTI ID: 14169), prepared for U.S. Department of Energy, National Petroleum Technology Office, Tulsa, Okla. (October 1999). (Johnson et al. 1999).

Potential Radiological Doses Associated with the Disposal of Petroleum Industry NORM Via Landspreading, DOE/BC/W-31-109-ENG-38-5 (DE9800550), prepared by Argonne National Laboratory for U.S. Department of Energy, National Petroleum Technology Office, Tulsa, Okla. (Smith et al. 1998)

Disposal of NORM-Contaminated Oil Field Wastes in Salt Caverns, prepared for U.S. Department of Energy, National Petroleum Technology Office, Tulsa, Okla. (Veil et al.1998).

Bibliography of Reports, Papers, and Presentations on Naturally Occurring Radioactive Material (NORM) in Petroleum Industry Wastes, DOE/BC/W-31-109-Eng-38-1, U.S. Department of Energy, National Petroleum Technology Office, Tulsa, Oklahoma (Smith et al. 1997).

Risk Assessment for Bench-Scale Phase of NORM Treatment and Disposal Demonstration Project, prepared for U.S. Department of Energy, National Petroleum Technology Office, Tulsa, Oklahoma (Blunt et al. 1997).

Final Environmental Assessment of Proposed Field Demonstrations of a Naturally Occurring Radioactive Material (NORM) Treatment and Disposal Technology, prepared for U.S. Department of Energy, National Petroleum Technology Office, Tulsa, Okla. (Smith et al.1997).

Radiological Dose Assessment Related to Management of Naturally Occurring Radioactive Materials Generated by the Petroleum Industry, ANL/EAD-2, Argonne National Laboratory, Argonne, Ill. (Smith et al. 1996).

Disposal and Treatment Technologies for Naturally Occurring Radioactive Materials (NORM) Produced by the Petroleum Industry, prepared for prepared for U.S. Department of Energy, Office of Domestic and International Energy Policy, Washington, D.C. (Smith 1993).

An Overview of Naturally Occurring Radioactive Materials (NORM) in the Petroleum Industry, ANL/EAIS-7, Argonne National Laboratory, Argonne, Ill. (Smith 1992).

Related Papers/Abstracts

- “An Analytical Model for Simulating Step-Function Injection in a Radial Geometry,” *Mathematical Geology*, Vol. 33, No. 2 (Tomasko et al. 2001).
- “The NORM Technology Connection Web Site: Streamlined Access to NORM-Related Service Company and Regulatory Information,” in proc. of the 7th International Petroleum Environmental Conference, sponsored by the Integrated Petroleum Environmental Consortium, University of Tulsa and others, Albuquerque, N.M. (Smith et al. 2000).
- “Assessing the Disposal of Wastes Containing NORM in Nonhazardous Waste Landfills,” in proc. of the 6th International Petroleum Environmental Conference, sponsored by the University of Tulsa and others, Houston, Tex. (Smith et al. 1999).
- “Issues Related to Setting Exemption Levels for Oil and Gas NORM,” in proc. of the 6th International Petroleum Environmental Conference, sponsored by the University of Tulsa and others, Houston, Tex. (Blunt et al. 1999).
- “Feasibility of Re-Melting NORM-Contaminated Scrap Metal,” in proc. of the 6th International Petroleum Environmental Conference, sponsored by the University of Tulsa and others, Houston, Tex. (Winters and Smith 1999).
- “Adaptive Sampling and Analysis Programs for NORM-Contaminated Soils,” in proc. of the 6th International Petroleum Environmental Conference, sponsored by the University of Tulsa and others, Houston, Tex. (Johnson et al. 1999).
- “Adaptive Sampling and Analysis Programs for NORM Contaminated Soils,” abstract presented at the 15th Annual International Conference on Contaminated Soils and Water, University of Massachusetts, Amherst, Mass., (Johnson et al. 1999).
- “A Risk-Based Approach To Subsurface NORM Disposal,” in Proc. of the ASCE 26th Annual Water Resources Planning and Management Conference, Tempe, Ariz., June 6-9 (Williams et al. 1999).
- “Disposal of Oilfield Wastes and NORM Wastes into Salt Caverns,” in Proc. of the ASCE 26th Annual Water Resources Planning and Management Conference, Tempe, Ariz., June 6-9 (Veil 1999).
- “Disposal of Naturally Occurring Radioactive Materials in a Municipal Landfill: Can Natural Attenuation be Trusted,” in Proc. of the ASCE 26th Annual Water Resources Planning and Management Conference, Tempe, Ariz., June 6-9 (Williams et al. 1999).
- “Natural Attenuation of Naturally Occurring Radioactive Materials Disposed of by Deep Injection,” in Proc. of the ASCE 26th Annual Water Resources Planning and Management Conference, Tempe, Ariz., June 6-9 (Williams et al. 1999).
- “NORM-Disposal Options, Costs Vary,” *Oil and Gas Journal*, V97:1: 37-43 (Jan. 4) (Veil and Smith 1999).
- “Radiological Dose Assessment of the Disposal of NORM Wastes Via Landspreading,” in Proc. of the 5th International Petroleum Environmental Conference, sponsored by the University of Tulsa and others, Albuquerque, NM, October 20-23 (Smith et al. 1998).

- “Modeling the Transport of NORM Within and Beneath an RCRA Class D Landfill,” in Proc. of the 5th International Petroleum Environmental Conference, sponsored by the University of Tulsa and others, Albuquerque, NM, October 20-23, (Williams et al. 1998).
- “Human Health Risk Analyses for Disposing of NORM in Salt Caverns,” in Proc. of the 5th International Petroleum Environmental Conference, sponsored by the University of Tulsa and others, Albuquerque, NM, October 20-23 (Tomasko et al. 1998).
- “Options and Cost for Disposal of NORM Waste,” in Proc. of the 5th International Petroleum Environmental Conference, sponsored by the University of Tulsa and others, Albuquerque, NM, October 20-23 (Veil 1998).
- “Data Collection Methodologies Associated with Onsite Treatment and Injection of Oilfield NORM,” abstract and poster, presented at the Health Physics Society Annual Meeting, Minneapolis, Minn., July 12-16, (Arnish et al. 1998).
- “Methodologies for Evaluating Radiological Doses Associated with Disposal of NORM Wastes in a Nonhazardous Landfill,” abstract and poster, presented at the Health Physics Society Annual Meeting, Minneapolis, Minn., July 12-16 (Arnish et al. 1998).
- “Evaluation of Subsurface Radium Transport and Potential Radiological Doses Related to Injection of NORM,” in Proc. of the SPE International Conference on Health, Safety and Environment in Oil and Gas Exploration and Production, sponsored by the Society of Petroleum Engineers, Caracas, Venezuela, June 7-10 (Williams et al. 1998).
- “Disposal of NORM Wastes in Salt Caverns,” in Proc. of the 1998 SPE International Conference on Health, Safety and Environment in Oil and Gas Exploration and Production, sponsored by the Society of Petroleum Engineers, Caracas, Venezuela, June 7-10 (Veil et al. 1998).
- “Disposal of NORM-Contaminated Oil Field Wastes in Salt Caverns – Legality, Technical Feasibility, Economics, and Risk,” in Proc. of the Solution Mining Research Institute Spring Meeting, New Orleans, Louisiana, April 19-22, (Veil et al. 1998).
- “Risk Assessment Related to Management of NORM Generated by the Petroleum Industry,” presented at the 1998 Annual Society of Environmental Toxicology and Chemistry Conference, Argonne National Laboratory, Argonne Illinois, April (Arnish et al. 1998).
- “Radiological Dose Assessment of NORM Disposal in Class II Wells,” in Proc. of the 4th International Petroleum Environmental Conference, sponsored by the University of Tulsa, U.S. Department of Energy, and others, San Antonio, Texas, September 9-12 (Smith et al. 1997).
- “An Analytical Model for Radial Injection of NORM with a Step-Function Source,” in Proc. of the 4th International Petroleum Environmental Conference, sponsored by the University of Tulsa, U.S. Department of Energy, and others, San Antonio, Texas, September 9-12 (Williams et al. 1997).
- “Groundwater Risk from the Disposal of NORM by Underground Injection,” abstract presented at the American Society of Civil Engineers 24th Annual Water Resources Planning and Management Conference, Houston, Texas, April 6-9 (Williams et al. 1997).

- “Modeling of NORM Injection in a Layered Geologic System,” in Proc. of the Naturally Occurring Radioactive Material Conference: Forum on NORM Management and Control, American Petroleum Institute and Gas Research Institute, Houston, Texas, October (Williams et al. 1995).
- “Modeling and Risk Assessment of Underground Injection of Naturally Occurring Radioactive Materials (NORM),” in *Environmental Issues and Solutions in Exploration, Production and Refining*, Proc. of the Second International Petroleum Environmental Conference, sponsored by the U.S. Department of Energy and others, New Orleans, La., Sept. 25-27 (Williams, et al. 1995).
- “Dose Assessment for Management Alternatives for NORM-Contaminated Equipment Within the Petroleum Industry,” in *Beneficial Reuse '95, The Third Annual Conference on the Recycle and Reuse of Radioactive Scrap Metal*, sponsored by the Energy, Environment, and Resources Center, University of Tennessee and the Center for Risk Management, Oak Ridge National Laboratory, Knoxville, Tenn., July 31-Aug. 3 (Blunt and Smith 1995).
- “Scrap Metal Management Issues Associated with Naturally Occurring Radioactive Material,” in *Beneficial Reuse '95, The Third Annual Conference on the Recycle and Reuse of Radioactive Scrap Metal*, sponsored by the Energy, Environment, and Resources Center, University of Tennessee and the Center for Risk Management, Oak Ridge National Laboratory, Knoxville, Tenn., July 31-Aug. 3 (Smith and Blunt 1995).
- “Radiological Dose Assessment Related to Management of Naturally Occurring Radioactive Materials Generated by the Petroleum Industry,” SPE Paper 29712, in Proc. of the SPE/EPA Exploration and Production Environmental Conference 95, sponsored by the Society of Petroleum Engineers and the U.S. Environmental Protection Agency, Houston, Texas, March 27-29, pp. 231-238 (Smith et al. 1995).
- “Problems Associated With the Management of Naturally Occurring Radioactive Material (NORM),” abstract published in *Proc. of the AAPG 1994 Annual Convention*, sponsored by American Association of Petroleum Geologists, Denver, Colo., June 12-15 (Smith 1994).