

**Appendix A**

**P-13152**

**RADIOLOGICAL DOSE AND RISK ASSESSMENT OF LANDFILL DISPOSAL OF  
TECHNOLOGICALLY ENHANCED, NATURALLY OCCURRING  
RADIOACTIVE MATERIALS (TENORM) IN NORTH DAKOTA**

Work proposed by:

Argonne National Laboratory  
Environmental Science Division  
9700 South Cass Avenue  
Lemont, IL 60439

Principal Investigators  
Karen P. Smith and Halil I. Avci

Submitted to:

Scott A. Radig  
Division of Waste Management  
North Dakota Department of Health  
918 E. Divide Avenue  
Bismarck, ND 58501  
(701) 328-5166  
sradig@nd.gov

October 2013

**P-13152**  
**Radiological Dose and Risk Assessment of Landfill Disposal of  
Technologically Enhanced, Naturally Occurring  
Radioactive Materials (TENORM) in North Dakota**

## **1.0 BACKGROUND**

Some oil and gas production and development activities can cause naturally occurring radioactive material (NORM) to accumulate in certain waste streams in concentrations above background. This material is often referred to as technologically enhanced NORM (TENORM). Waste streams that may have elevated TENORM levels include produced water, scale, and sludge. In the United States, the sources for these elevated TENORM levels are uranium-238 (U-238) and thorium-232 (Th-232), which are naturally present in the underground formations from which oil and gas are produced. The primary radioisotopes of concern in petroleum industry wastes are radium-226 (Ra-226) and radium-228 (Ra-228), which result from the radioactive decay of U-238 and Th-232, respectively, and their associated decay products. The primary radionuclide of concern for the gas industry is lead-210 (Pb-210), which forms a scale inside the pipes and equipment containing natural gas. Pb-210 is a decay product of the gaseous radon-222 (Rn-222), which results from the radioactive decay of Ra-226.

The staff in the Environmental Science (EVS) Division of Argonne National Laboratory (Argonne) has extensive expertise in the evaluation of TENORM disposal alternatives, including assessments of the health risk presented to workers and the general public. Over the past 20 years, the EVS staff has completed risk assessment studies for management and disposal of TENORM for the U.S. Department of Energy, the American Petroleum Institute, and several domestic and international oil companies; conducted numerous workshops; and published more than 40 reports and papers on the topic.

In addition to specific TENORM studies, Argonne scientists also developed some of the computational tools that are used to conduct the risk assessments. The tools developed by Argonne staff are used by scientists and engineers throughout the United States and abroad. For example, the RESRAD code developed by Argonne is an internationally recognized computational tool used by, among others, the U.S. Department of Energy and the U.S. Nuclear Regulatory Commission during projects aimed at cleanup of radiologically contaminated sites and disposal of radioactive wastes. Another risk assessment code used to estimate radiation doses to workers and the general public, TSD-DOSE, was also developed by Argonne staff. In addition, Argonne staff members have extensive experience in management and risk analysis for all kinds of radioactive materials, including the low-level radioactive waste that would be relevant to the assessment of risks associated with the management and disposal of TENORM wastes.

The State of North Dakota Department of Health (NDDH) is considering possible changes to North Dakota Solid Waste Management Rules regarding TENORM. The NDDH is planning to collect and evaluate a variety of information to ensure that any possible rule changes regarding handling and disposal of TENORM are protective of human health and the environment. As part

of this effort, NDDH has requested that Argonne conduct a radiological dose and risk assessment of landfill disposal of TENORM in North Dakota. This proposal was prepared in response to that request.

## **2.0 PROPOSED WORK**

On the basis of initial discussions with NDDH staff, Argonne proposes to prepare radiological dose and risk assessments of the disposal of TENORM wastes in engineered landfills located in North Dakota to support potential rulemaking activities. The work will include the following specific dose and risk analyses:

- Human health dose and risk associated with disposal of petroleum industry TENORM wastes in special waste and industrial waste landfills permitted in North Dakota, based on a generic location;
- Wastes containing concentrations of radionuclides, primarily Ra-226, Ra-228, and Pb-210, including non-liquid-bearing wastes, such as scales, dewatered sludge, filter socks, and other equipment; and
- Worker and general public receptors in exposure scenarios associated with well site operations, transportation, landfill operations, and future use of the landfill site.

Argonne's analyses will assume design and operations criteria established for North Dakota permitted landfills. Sensitivity analyses will be conducted to evaluate key design elements (e.g., radon emanation rate, thickness of landfill cover, depth to wastes in landfill, performance of leachate collection systems). NDDH can use the results of those analyses to inform rulemaking regarding TENORM landfill disposal. Radiological dose and risk will be estimated on a per-picrocurie-per-gram (pCi/g) basis to support decisions regarding landfill acceptance criteria. On the basis of the results of this study and previous Argonne studies, a discussion will be included in the draft and final reports concerning the possibility of disposal of small volumes of TENORM wastes that are not detected and are inadvertently disposed in a North Dakota municipal solid waste landfill.

Argonne's work has been divided into five separate tasks; each is described below.

### **2.1 Task 1: Detailed Study Design**

To provide a basis for work conducted under this proposal, Argonne will prepare a Detailed Study Design. This document will define the scope and methodology of the dose and risk assessments and include a detailed list of data requirements. The main objective of the Detailed Study Design is to ensure that the risk assessments provide the information needed to support NDDH decisions about TENORM waste disposal in permitted landfills in North Dakota.

The Detailed Study Design will include the following specific elements:

- Identification of the required outcomes of the risk analyses;

- Identification of uncertainty and sensitivity analyses that will be conducted;
- Descriptions of the engineered landfill design and operations requirements and of any pretreatment activities that will be conducted prior to waste disposal;
- Description of the radiological risk assessment scenarios (e.g., receptors, operational and future use scenarios, exposure pathways);
- Identification of models to be used to conduct risk assessments; and
- Identification of data needs.

A draft of the Detailed Study Design will be provided to NDDH for review, and a final will be prepared incorporating NDDH comments, as appropriate. If necessary, based on the final Detailed Study Design, the scope, budget, and schedule for subsequent tasks will be revised.

## **2.2 Task 2: Data Collection and Verification**

On the basis of the data requirements identified in the Detailed Study Design, Argonne will work with NDDH to collect and verify data for use in the risk assessments. The data collection and verification task is one of the most critical; the better the data, the more useful and accurate the results will be. For this reason, Argonne anticipates that the data collection and verification process will be iterative and could potentially continue throughout the detailed analysis tasks discussed below.

Although Argonne may determine that other data are needed, the types of data that will likely be collected and verified include the following:

- Characteristics of the generic landfill sites (e.g., meteorological data, population distribution, geo-hydrological data [depth, thickness, permeability, etc.], usable aquifers [depth and other characteristics], general geology, seismicity, and any other data that might be pertinent to subsurface migration of TENORM radionuclides);
- Waste characterization data (e.g., quantities, physical form, and radionuclide concentrations of existing stockpiles and newly generated wastes);
- Potential treatment options for the wastes, either at the point of generation or at the disposal site;
- Characteristics of waste packages used for waste transportation, interim storage, and disposal (e.g., bulk [no package], drums, boxes, supersacks);
- Transportation data (e.g., distance, number of shipments, crew size, transportation route, average population density along the route); and
- Locations of potential groundwater receptors, including water wells, seeps, springs, streams, etc.

When specific data are not available for key parameters, Argonne will identify appropriate assumed values to be used in the analyses. Ranges will also be estimated for those input parameters that will be evaluated in the sensitivity analyses. These values and ranges will be submitted to NDDH for review and concurrence.

### **2.3 Task 3: Radiological Dose and Risk Assessment**

Radiological doses to workers and members of the public will be estimated by using a suite of existing computer codes developed at Argonne for radiological assessment. Potential risks associated with the estimated radiological doses will be calculated by using risk factors recommended by the International Commission on Radiological Protection. The assessment will consider (1) well site operations, (2) transportation of TENORM to the landfill sites, (3) disposal of TENORM wastes in permitted landfills, (4) consumption and use of TENORM-contaminated groundwater, and (5) future use of the landfill sites following closure. Both worker and general public receptors will be considered.

The dose and risk assessments will assume generic locations in North Dakota, and sensitivity analyses will be conducted on location-related parameters to support evaluation of landfill locations. The assessment will also evaluate transportation of wastes from points of generation to landfill locations, but it will not be based on specific routes.

All applicable exposure pathways of concern (e.g., external irradiation; inhalation of particulates and radon progeny; and ingestion of soil, plants, meat, milk, and water) will be considered, as applicable, for each scenario. For those scenarios involving potential exposure to TENORM-contaminated groundwater, doses to the public will be estimated by using the results of the groundwater transport modeling described in Subtask 3.5.

For each scenario modeled, sensitivity analyses will be conducted for those parameters that are likely to have the greatest impact on the dose calculations. The analyses will consider different values for these parameters to define how sensitive the dose calculations are to changing conditions and to identify design, operational, and location requirements needed to keep potential risks at acceptable levels.

The following sections describe five subtasks of the radiological risk assessments. Assumptions regarding the approach and scope of these tasks have been made to support the schedule and budget projections; these assumptions will be confirmed and/or revised as needed pending completion of the Detailed Study Design.

#### **2.3.1 Subtask 3.1 Dose and Risk Assessment Related to Well Site Operations**

Potential radiological doses to workers at the well sites where the TENORM is generated will be estimated. The dose assessments will be performed for workers who are likely to experience the highest radiation doses (e.g., tank cleaning workers, scale house workers, and drilling crew). Scenarios will be developed on the basis of typical operations and TENORM characteristics at

the well sites. Worker doses will be estimated per unit time of operation. The computer code TSD-DOSE, which was developed at Argonne, will be used to estimate the doses. Scenarios to be analyzed and exposure parameters to be used will be established during Task 1 and will be based on input provided by NDDH.

Potential radiological doses to the general public living in the vicinity of well sites will also be estimated using the CAP88 PC computer code developed by the U.S. Environmental Protection Agency or the GENII code developed by Pacific Northwest National Laboratory. Typical airborne emissions of radionuclides originating from the operations at the oil and gas production facilities will be used. The data used to estimate the public doses will be provided by NDDH.

### **2.3.2 Subtask 3.2: Dose and Risk Assessment Related to Transportation**

The assessment will estimate the potential radiological doses to workers and members of the general public associated with overland transportation of TENORM from production facilities to generic landfill sites by truck. Radiological doses from both routine and accident conditions will be evaluated. Argonne proposes to use the RADTRAN computer code, developed by Sandia National Laboratories, and the RISKIND computer code, developed by Argonne, in the analysis. Specifically, radiological doses to the driver of the vehicle, persons living along the transportation corridor, persons traveling along the transportation corridor, persons at truck stops during refueling operations, and a person living near the entrance of the disposal facility will be estimated.

Average values for population density; travel fractions in rural, suburban, and urban zones; and accident rates for North Dakota will be used in the assessment, provided these values are available. In the absence of accident rate data, consequence analyses will be performed at representative locations along the transportation routes (e.g., in high-population areas). The exact nature of transportation calculations to be performed will be determined during preparation of the Detailed Study Design.

One of the parameters that has a strong influence on the consequence analyses results is the type of packaging used to transport the waste. The analyses will address packages that represent the package types that may be used in North Dakota, including bulk transport (no packaging), industrial type packages (e.g., wood or metal boxes), and what are referred to as Type A packages in U.S. Department of Transportation regulations (e.g., 55-gallon drums).

### **2.3.3 Subtask 3.3: Dose and Risk Assessment of TENORM Landfill Operations**

The assessment will investigate the potential radiological doses and associated risks to individuals working at a TENORM disposal landfill and members of the public living near the landfill during operations. Radiological doses will be estimated for several different disposal operations, including (1) receiving and handling of TENORM waste containers, (2) interim storage of the TENORM wastes prior to disposal, and (3) disposal of the TENORM wastes in the

landfill and operation of landfill components (e.g., leachate collection system). If pretreatment activities are identified by NDDH, they will also be evaluated.

Argonne proposes to use the TSD-DOSE computer code, developed by Argonne, in the analysis. Transport of the TENORM within the landfill to the leachate collection system will be modeled using the U.S. Environmental Protection Agency's HELP (Hydrologic Evaluation of Landfill Performance) model. All applicable exposure pathways of concern will be considered to the extent that they are applicable for each scenario.

#### **2.3.4 Subtask 3.4: Dose and Risk Assessment of Future Use of the Disposal Facility Property**

Potential radiological doses to members of the general public who make use of the landfill sites at some point in the future following landfill closure will be evaluated. Four future use scenarios will likely be analyzed to estimate radiological doses and risks to the general public resulting from activities on the property after closure: residential use, agricultural use, industrial/commercial use, and recreational use/continued monitoring. The final list of scenarios to be analyzed and the exposure pathways assumed to be active under each scenario will be determined during preparation of the Detailed Study Design (Task 1). Argonne proposes to use its RESRAD family of computer codes to estimate the doses to the receptors under future use scenarios. The only exception will be the groundwater pathway, for which the results of the groundwater transport modeling described for Subtask 3.5 will be used. Previous studies conducted by Argonne have demonstrated that the risks associated with future use scenarios are the public's primary concern regarding management and disposal of TENORM. As a result, a considerable part of the effort proposed for this study will be spent developing and evaluating these scenarios.

#### **2.3.5 Subtask 3.5: TENORM Groundwater Transport Modeling**

Several of the risk assessment scenarios described above assume that, in some instances, members of the general public may be exposed to contaminated groundwater. If contaminated groundwater provides the primary source of household and drinking water, an individual may be exposed to TENORM through water consumption or bathing. If contaminated groundwater is used for agricultural purposes, an individual may be exposed to TENORM through consumption of crops grown on irrigated lands or animals watered with groundwater. Potential radiological doses to the public associated with the exposure to TENORM-contaminated groundwater will be estimated by using the results of the groundwater transport modeling conducted in this task.

To support the risk assessments for specific scenarios, a suite of numerical and analytical models will be used to estimate the potential TENORM concentrations in groundwater resulting from the various disposal alternatives included in this study. Various landfill system failure scenarios will be considered for each alternative, as appropriate.

## **2.4 Task 4: Draft and Final Report**

A draft project report will be prepared to present the results of the dose and risk assessments and proposed waste acceptance criteria. This report will provide descriptions of the methodologies, data and assumptions, and sensitivity analyses. It will be sufficiently detailed to support evaluation of the results and replication of analyses by others. The draft report will be provided to NDDH for review and comment. A final report will be prepared incorporating NDDH comments, as appropriate.

## **2.5 Task 5: Final Presentation (Optional Task)**

At the discretion of NDDH, Argonne staff would travel to North Dakota to present results to NDDH staff and management and, if appropriate, at a public meeting. If conducted, this task will also consist of providing detailed technical responses to questions from NDDH regarding the study.

## **3.0 PROPOSED SCHEDULE AND BUDGET**

Table 1 shows a tentative schedule and budget for each task described in this proposal. As indicated in Table 1, Argonne estimates that approximately 7 months will be required for delivery of a draft report. Although delivery of a final report is contingent, in part, on NDDH's review, it is estimated that it will take an additional 2 to 3 months. Table 2 presents Argonne's proposed budget by cost component (e.g., effort, other direct costs, general and administrative charges).

The cost estimates in Tables 1 and 2 are based on the assumption that the work will begin in November 2013 and will be completed by September 2014.

Task 5, although included in the cost estimates, is optional and will be conducted at the discretion of NDDH. If exercised, this option would allow Argonne staff to travel to North Dakota to present the results of the study to NDDH staff and management. During the same trip, Argonne staff could also attend and present at a public meeting, if deemed appropriate by NDDH.

The cost estimates represent fully loaded costs, including all applicable technical and administrative costs. The estimates do not include the 3% fee that the U.S. Department of Energy normally charges non-DOE customers; this fee is waived for State agencies. As a not-for-profit organization, Argonne conducts business on a cost-recovery basis; however, any money not spent by Argonne in the course of a project will be reimbursed to the customer. In addition, money can be reallocated between tasks at the discretion of the customer, depending upon the project needs.



**TABLE 1 Anticipated Schedule and Budget by Task<sup>1</sup>**

Task	Schedule (Duration of Task)	Schedule (Elapsed Time)	Estimated Cost (\$1,000) <sup>2</sup>
1. Detailed Study Design <sup>3</sup>	2 months	2 months	9.7
2. Data Collection and Verification <sup>4</sup>	1 month initially and throughout project	3 months	23.3
3. Radiological Dose and Risk Assessment	2 months	5 months	70.6
4. Draft and Final Project Reports <sup>5</sup>	2 months for draft and 1.5 months for final	7 months to draft and 10 months to final	64.1
5. Final Presentation <sup>6</sup> (Optional Task)			15.1
			Total: 182.8

<sup>1</sup> All analyses will assume standard design parameters for engineered landfills unless otherwise specified by NDDH. Argonne will not be responsible for developing detailed engineering designs.

<sup>2</sup> The estimated costs include all applicable technical and administrative costs. These cost estimates assume that the work will start in November 2013.

<sup>3</sup> Outcomes of Task 1 could result in a revised scope of work, schedule, and cost estimate for subsequent tasks. Argonne thus recommends that this task include one or more conference calls between Argonne staff and NDDH staff.

<sup>4</sup> Task 2 is initially estimated to take 1 month, but it is likely to continue through most of the project and will run concurrently with Task 3.

<sup>5</sup> The schedule for the final report will depend, in part, on the outcome of NDDH's review of the draft. It is assumed that the NDDH review will take 1.5 months and will not result in reanalysis and/or substantial rewrite of the draft report.

<sup>6</sup> This task is optional and will be conducted at the discretion of NDDH. Under this task, Argonne staff would travel to North Dakota to present results to NDDH staff and management; this trip could also include a presentation at a public meeting, if needed.

**TABLE 2 Estimated Costs by Cost Component for P-13152<sup>1</sup>**

Component	FY 2014 <sup>2</sup>	
	Person-Months	Cost (\$1,000)
<b>Direct Effort</b>		
Scientific Direct	5.4	106.7
Secretarial/Clerical Direct	0.5	5.2
<b>Total Effort</b>	<b>5.9</b>	<b>111.9</b>
<b>Other Direct Costs</b>		
Materials and Supplies		3.2
Technical Editing		10.2
Travel		3.0
<b>Total Other Direct Costs</b>		<b>16.4</b>
<b>Total Direct Cost</b>		<b>128.3</b>
<b>General and Administrative LDRD Indirect<sup>3</sup></b>		<b>54.5</b>
		7.8
<b>Total Argonne Cost</b>		<b>182.8</b>
<b>DOE Factor<sup>4</sup></b> <b>(total Argonne × 3%)</b>		0.0
<b>Federal Rate</b>		<b>182.8</b>

<sup>1</sup> Totals may be off due to rounding.

<sup>2</sup> It is assumed that all work will be completed in FY 2014.

<sup>3</sup> "LDRD Indirect" costs are a subset of the "General and Administrative" costs. They are shown separately for information purposes only.

<sup>4</sup> The U.S. Department of Energy does not charge the customary 3% fee to State agencies. Therefore, this fee is waived.

## **4.0 REQUIRED RESOURCES**

### **4.1 Resources to Be Provided by Argonne**

Argonne shall furnish all personnel, equipment, supervision, supplies, and incidentals, except those indicated as furnished by NDDH, to perform all work necessary for completion of the proposed work. The Argonne project managers will provide monthly status reports, including cost summaries, to NDDH's project manager.

### **4.2 Resources To Be Provided by NDDH**

NDDH shall furnish information needed by Argonne to support the risk analyses. If the requested data are unavailable, NDDH staff members shall engage in discussions with Argonne staff to define reasonable assumptions. In addition, NDDH shall participate in the review of all draft documents and provide comments to Argonne according to the agreed-upon timelines.

## **5.0 QUALITY ASSURANCE**

The purpose of the Argonne quality assurance (QA) program is to establish procedures for performing high-quality work on projects and to ensure that the planned procedures are being followed during the course of the work. QA procedures will be followed for all elements of this project. The Argonne QA program conforms to the good management practices specified in U.S. Department of Energy Order 414.1C ("Quality Assurance").

## **6.0 ARGONNE PROJECT MANAGEMENT**

Staff in Argonne's EVS Division will be responsible for completing the tasks described in this proposal. The principal investigators will be Karen P. Smith and Halil Avci. Ms. Smith and Dr. Avci have jointly managed past projects to evaluate TENORM management and disposal options.