STUDENT SUMMER INTERNISHIP TECHNICAL REPORT

Contrast of Cultures in Interagency Radiological Management Involving Human Health Reference Dose and Risk

DOE-FIU SCIENCE & TECHNOLOGY WORKFORCE DEVELOPMENT PROGRAM

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ABSTRACT

Humans can be exposed to radiation via several pathways. Much of the dialogue between the US Environmental Protection Agency (USEPA) and the US Department of Energy Office of Environmental Management (DOE-EM) fails to maintain consistency in interagency communication by not finding a middle ground in the dose-risk classification and decision making for radionuclides. Presented in this report, DOE-EM has decided to initiate a proposal that specifically touches assessment and decision making for CERCLA site-specific conditions.

DOE-EM's safety performance assessment initiated goals to reduce the exposure by radioactive and chemical materials. Under CERCLA, the radionuclide risk levels should be set to satisfy the $10^{-4}\ to\ 10^{-6}$ risk range noted in the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). It is important to steer the fundamental purpose of the guidelines, allowing the health risks to exposed individuals and populations to be limited. However, when EPA/DOE guidelines were analyzed, acceptable dose-risk level quantification criteria appeared inconsistent.

Key Facts:

- Ionizing radiation is a type of energy released by atoms in the form of electromagnetic particles or waves.
- Humans are currently being exposed to natural sources of ionizing radiation, such as vegetation, medicine, soil, water, as well as man-made sources (x-rays and medical devices).
- Ionizing radiation has many benefits, which are used in medicine, industry, agriculture and research.
- Low doses of ionizing radiation can increase the risk of longer term effects such as cancer.

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LIST OF ACCRONYMS AND ABBREVIATIONS

EPA	Environmental Protection Agency
DOE	Department of Energy
DOE-EM	Department of Energy – Office of Environmental Management
HLW	High Level Waste
LLW	Low Level Waste
ERA	Ecological Risk Assessment
NPL	National Priorities List
IAEA	International Atomic Energy Agency
TENORM	Technologically enhanced naturally occurring radioactive materials
ALARA	As Low As Reasonably Achievable

1. INTRODUCTION

Human exposure to radiation can occur via many pathways. Currently, radionuclide and chemical substances are frequently used in research, medical and military fields. Radiological assessment has reached a critical point where different agencies provide little specific decision-making strategies for assessment of radionuclide dose-response equivalent factors. During many round-circle seminars held at the Nuclear Regulatory Commission (NRC) and the US Environmental Protection Agency (EPA), discussion was subjected to a general concern in regards to finding solutions regarding radiation risk factors. The foremost foundation of the world is surrounded by naturally suited radionuclides in the bedrock, water and cosmic rays. Many studies suggest that exposures to radionuclides resulting from occupational hazards to some degree are subjected to regulatory control. Other agencies, including the International Atomic Energy Agency (IAEA), have led many initiatives to control the safety of workers exposed to radionuclides. It is important to establish a basis for the development of laboratory and occupational safety criteria, and for transporting various kinds and quantities of radionuclides.

Over the duration of Juan Morales' 2018 summer internship at DOE EM, he worked alongside the Director of Regulatory Compliance, Dr. Robert Seifertand maintained an open approach to understanding compliance, environmental orders and technical reports.

This aim of this report was to analyze regulatory and advisory organizations in regards to radionuclide dose risk assessment at the Office of Regulatory Compliance 4.31. The integration of occupational and pubic exposure to such technologically enhanced naturally occurring radioactive materials (TENORM) by DOE-EM, EPA and other regulatory advisory organizations was the subject of this study. By evaluating human exposure to radioactive materials, DOE EM will consider safety measures expressing cleanup standard doses in terms of dose, risk or concentration limits.

2. EXECUTIVE SUMMARY

This research work has been supported by the DOE-FIU Science and Technology Workforce Initiative, an innovative program developed by the US Department of Energy's Office of Environmental Management (DOE-EM) and Florida International University's Applied Research Center (FIU- ARC). During the summer of 2018, a DOE Fellow intern, Juan Morales, spent 10 weeks doing a summer internship at the U.S. Department of Energy's Office of Environmental Management in Washington D.C. under the supervision and guidance of Dr. Robert Seifert, Director of Regulatory Compliance (4.31). The intern's project was initiated on June 4th, 2018,, and continued through August 10th, 2018 with the objective of supporting ongoing projects under DOE-EM office 4.31.

3. RESEARCH DESCRIPTION

DOE-EM REGULATORY COMPLIANCE (EM-4.31)

There are eight offices which play an interconnecting role under DOE EM Office of Regulatory and Policy Affairs (EM-4.0). For this, the Office of Environmental Management has great responsibility to be in compliance with their worksites. Coming from past legacy production of nuclear fuel, the efforts to decontaminate and dismantle former facilities comes at a cost. Today there are 16 sites to be remediated. Regulatory Compliance 4.31 tasks work under the ultimate effort to ensure the safety of the public and workers guided by hundreds of different contractors.

The Office of Regulatory Compliance (EM-4.31) documents, manages, updates and measures legal milestones ensuring international, contractor, tribal, federal, state and local programs which are to be completed with the ultimate effort under the regulations compliance.

It is important to recognize that DOE-EM is not a regulatory agency. However, it does self-regulate its own radioactive waste and is governed by a variety of statutes, legislation, regulations, directives and guidance. Many of the current compliance-related actions revolve around waste and material disposition that are governed by the National Environmental Policy Act, Environmental Impact Statement and the Comprehensive Environmental Response, Compensation and Liability Act Records of Decision (USDOE, 2018).

RADIATION BASICS

The discovery of radioactivity has led to many scientific advances. Using naturally fluorescent minerals has made our knowledge of radiation grow, and our understanding of radiation safety has changed since its discovery in the 19th century. For many years, radiation has provided many benefits and proven to be a fruitful form of energy.

There are two types of radiation, ionizing and non-ionizing, each existing in different forms with different effects. Non-ionizing radiation has enough energy to move atoms in a molecule around or cause them to vibrate, but not enough to remove electrons from atoms (Environmental U.S. Protection, 2000). On the other hand, ionizing radiation is radiation that carries enough energy to liberate electrons from atoms or molecules, thereby ionizing them. Each molecule is made of energetic subatomic particles, ions or atoms moving at high speeds, and electromagnetic waves on the high-energy end of the electromagnetic spectrum. There are several processes an atom can become ionized or non-ionized. For example, there are natural radioactive atoms made by natural processes. Naturally occurring radioactive materials such as potassium-40 and uranium-238 have existed since the earth formed (ATSDR, 1999).

At very high doses, ionizing radiation can cause illness or death. Any dose could possibly cause cancer after a several year delay. It is not known how many of the 1517 National Priorities List (NPL) sites identified by the EPA give off ionizing radiation above background levels (Goswald, 1999). Natural background radiation exposure ranges from 70 to 250 mrem per year. To some radiation managers, reducing total excess exposures from all sources much below 100 mrem/

year is deemed unnecessary and exceedingly difficult to monitor because it is within the natural variability of background levels (Tran, Locke, & Burke, 2000).

Hazard Identification

Alpha Particles are positively charged ions that are emitted from naturally occurring materials. In general, alpha particles have a very limited ability to penetrate other materials. Alpha particles are considered dangerous but can be blocked by a couple of inches of air or a simple sheet of paper. Humans can become at risk or potentially be in danger if alpha ions are inhaled or ingested.

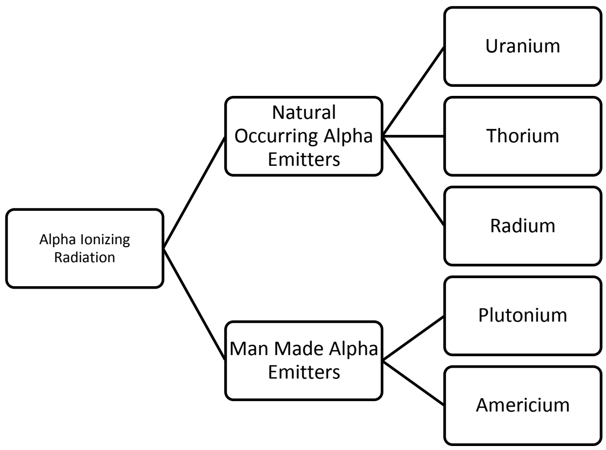

Figure 1. Comparison of natural vs. manufactured alpha emitters.

Beta Particles have similar properties when compared to electrons. In general, beta particles are lighter than alpha particles and have a greater ability to penetrate through materials and human skin. They are faster, stronger and can travel a few feet in the air. Some beta emitters are used in medical facilities for treating health issues such as eye disease.

A common form of beta emitter is found in nuclear fission and occurs in natural radioactive decay chains following one or more alpha-decays. Occupational hazards are closely monitored since beta particles are less ionizing than alpha ions.

Gamma particles are a packet of electromagnetic photons emitted by the nucleus of some radionuclides following radioactive decay. These particles are considered to be the most energetic photons in the electromagnetic spectrum. Research suggests that emission commonly occurs within a fraction of a second after radioactive decay, but sometimes it can take several hours.

Cesium-137

- Measure and control the fluids in numerous industrial processess
- Investigate subterranean strata in oil wells
- Measure soil density
- Ensure proper fill levels for packages of food, drugs and other products

Cobalt-60

Technetium-99

- Diagnostic uses for brain, bone, live, spleen and kidney imaging
- Short half-life/ does not remain in body for long time

Americium-241

- Fluid level gauges
- Fluid density gauges
- Thickness gauges
- Aircraft fuel gauges

Figure 2. Commonly used gamma emitters (ARPANSA, 2018).

DEFINITION OF TOXICITY

The IAEA describes toxicity as having no definition when it comes to radionuclides. Toxicity is the ability of a chemical molecule or compound to produce injury once it reaches a susceptible site in or on the body. Toxicity hazard is the probability that injury may be caused by the manner in which the substance is used (IAEA, 1963). Most forms of radiation emit some primary basic physiochemical effects of excitation and ionization within the biological material they have penetrated and differ only in the spatial distribution and harmfulness of their effects.

It is well established that above certain doses, radiation induces cancer. Ionizing radiation is a multistage complex cellular phenomenon involving several cellular and molecular events (Prasad, 2017).

DOE-EM SAFETY STANDARDS

The DOE-EM mission has changed from nuclear materials production to site specific remediation policy for protecting employees, visitors, the public and the environment. DOE-EM maintains personnel exposure to radiation and radioactive materials at a level that is *As Low As Reasonably Achievable* (ALARA). Radiation exposure of the work force and public is controlled such that exposures are below regulatory limits and that no exposure is without an overall benefit (SRS, 2016).

Workers may get exposed to chronic daily radiation doses (including cosmic and natural exposure) for which the risks are very small. Research suggests that the effects can be manifested in the future children of the worker. The exposed individual may develop cancer-like symptoms due to chronic radiation doses; although compared to the natural occurrence of cancer, the risk is small. DOE-EM uses millirems to express an employee's radiation exposure.

Table 1. Average Annual Radiation Dose

Natural background source		Manmade Source	
Radon in Homes	231 mrem/year	Medical use	300 mrem/year
Cosmic	31 mrem/year	Consumer products (tobacco)	12 mrem/year
Human Body	31 mrem/year	Domestic (Airplane trip)	3 mrem/year
Terrestrial from rocks	19 mrem/year		

The general public receives about 620 millirem a year from natural background and manmade sources of radiation. Literature suggests that due to technology advancements in medical use, the radiation dose exposure has nearly doubled. In conclusion, the development of radiation standards for radionuclides requires several guidelines but most important is the assessment of dose-response.

DOE has established the Administrative Control Level of 2000 mrem/year for workers' activities. However, the administrative worker holds a threshold of 100 mrem/year.

HUMAN HEALTH EFFECTS

The moderate to low dose response effects are correlated with adverse biological effects associated with ionizing radiation exposures. The most common effect is carcinogenesis, mutagenesis and teratogenesis. It is important to acknowledge that the EPA has written a *Human Health Evaluation Manual.* The manual suggests that cancer risk appears to be a sufficient basis for assessing radiation-related human health risks at contaminated sites, although non-carcinogenic effects may be considered (USEPA, 1996). DOE trains their workers to be aware of exposure, especially if you are pregnant. Because the developing embryo is highly vulnerable to ionic rays, high doses may increase the likelihood of the child having slower mental growth, low birth weight or childhood cancer.

Exposure Routes

Ionizing radiation can come from internal and external exposure pathways. *Internal exposure* to ionizing radiation occurs when radionuclides get inhaled, ingested or otherwise enters the bloodstream. Internal exposure finds closure when the particle is eliminated from the body naturally or with treatment (WHO, 2016).

External exposure may occur when airborne particles become deposited on the skin or clothes. This type of exposure can be removed by washing off.

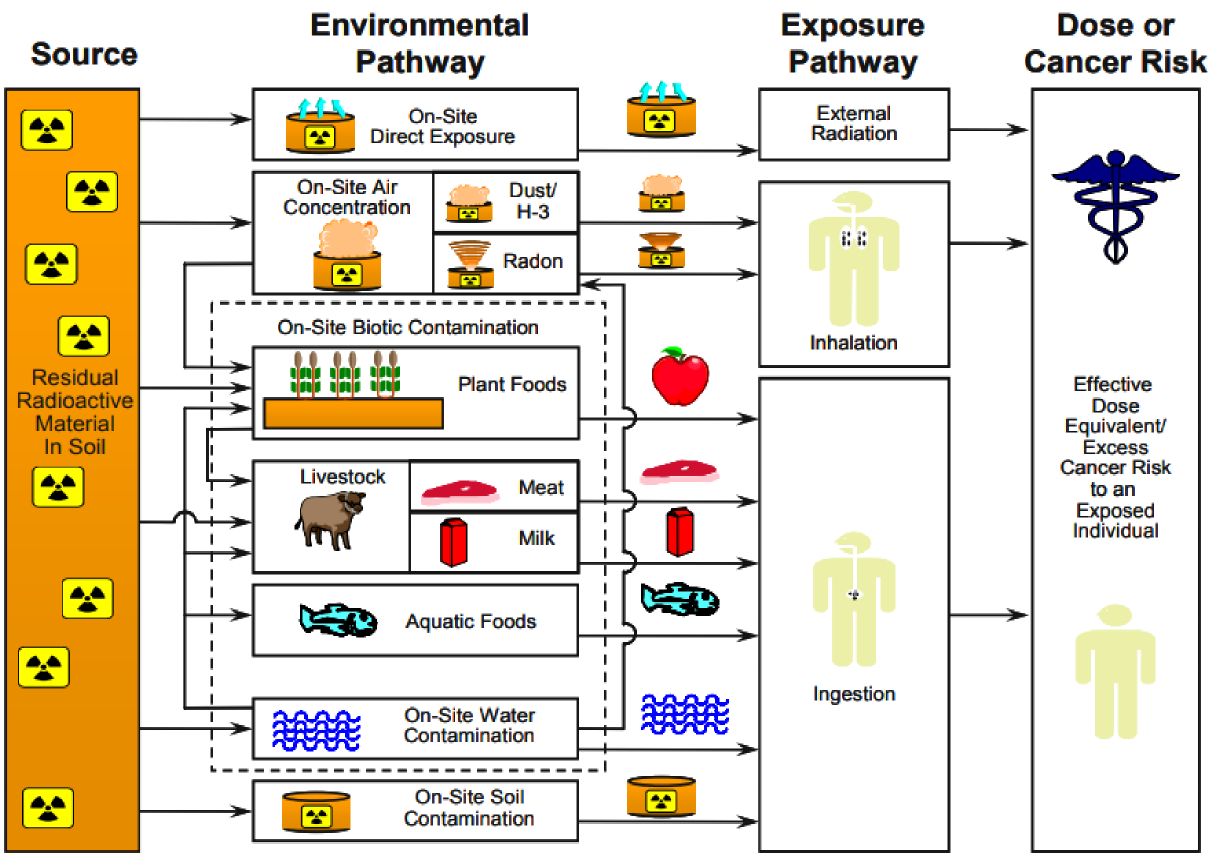

Figure 3. Exposure pathways associated to radionuclide dose-modeling (Avila, 2005).

INTERAGENCY RADIONUCLIDE ASSESSMENT

The assessment of radioactive contamination between agencies overlaps in:

1. Source assessment - identifies and evaluates the potential hazard.
2. Exposure assessment - determines the risk agent and the level of exposure.
3. Effects assessment - links the exposure levels to the extent of adverse effects.
4. Risk characterization - compiles the results of the above assessments and quantifies to estimate a risk level.

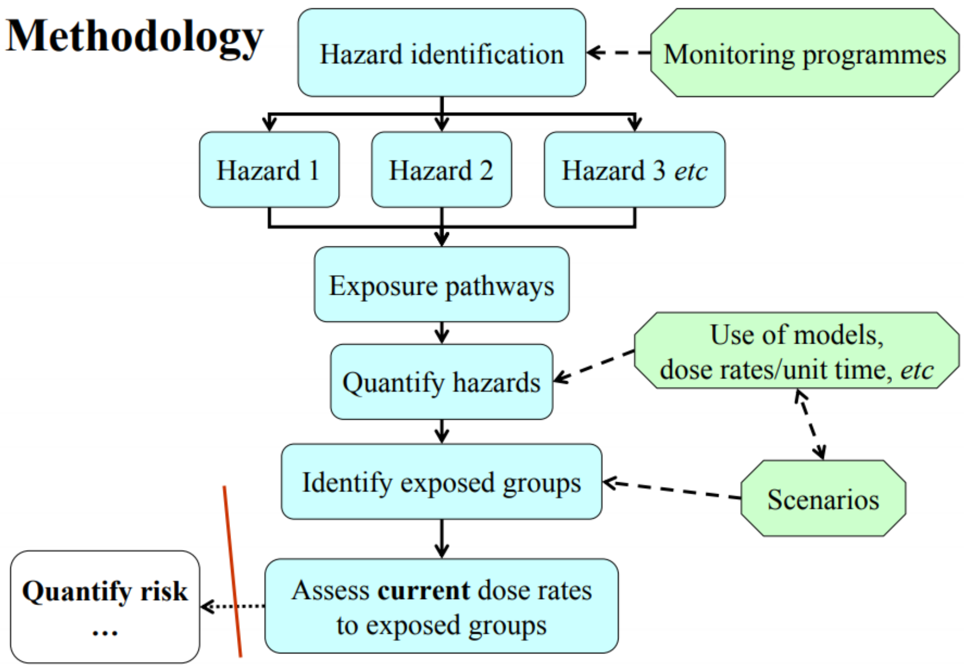

Figure 4. Key steps in conducting an exposure assessment for radionuclides.

Quantifying the risk in the models is the tricky part. Many integrate the radiological and chemical assessments, while others separate them.

EPA EXPOSURE MODELS

To facilitate the application of radiation protection regulations and recommendations, it is necessary in some cases to classify radionuclides into groups according to their radiotoxicity. There are various schemes which have evolved for classifying radioactive waste according to the physical and radiological properties that are of relevance to the particular facilities or circumstances in which radioactive waste is managed (IAEA, 2009). In addition, EPA holds the responsibility for establishing generally applicable standards for radionuclides.

EPA's Preliminary Remediation Goals (PRG) model is intended to serve as a calculator to determine minimal and acceptable exposure levels of radionuclides and chemicals. The general objective is to present a risk-based standardized human exposure guideline for commercial/industrial and agricultural land use exposures from soil, surface water and biota.

It is important to emphasize that the radionuclide assessment needs to become the top priority when using the tool. Information on the radionuclides that are present onsite, the specific contaminated area, land-use assumptions, and the exposure assumption behind the pathways of the individual exposure are necessary in order to develop site-specific PRGs. Modeled PRGs can be formulated using generic or site-specific exposure data for 1,255 radionuclides in the PRG tool. EPA's PRG tool can be downloaded at:
https://epa-prgs.ornl.gov/radionuclides/ (US EPA, 2018).

Regional Screening Levels (RSL)

The development of a risk screening tool gives the researcher the ability to calculate applicable dose standards for radionuclides. EPA in conjunction with the PRG model, developed a *Regional Screening Level (RSL)* tool for chemical contaminants at Superfund Sites. This has the power to combine standard equations for exposure iwith EPA toxicity data which allows researchers to conduct analyses for chemicals in the soil, water, and air.

The RSL tool can be found at https://epa-prgs.ornl.gov/cgi-bin/chemicals/csl_search (Regional Screening Levels (RSL) | Superfund Risk Assessment | US EPA, 2018).

Screening Levels	**(TR=1E-06 THQ=1.0)**	**(TR=1E-06 THQ=1.0)**	**(TR=1E-06 THQ=0.1)**	**(TR=1E-06 THQ=0.1)**
Summary Table	PDF	XLS	PDF	XLS
Resident Soil	PDF	XLS	PDF	XLS
Composite Worker Soil	PDF	XLS	PDF	XLS
Resident Air	PDF	XLS	PDF	XLS
Composite Worker Air	PDF	XLS	PDF	XLS
Resident Tapwater	PDF	XLS	PDF	XLS
Resident Soil to Groundwater	PDF	XLS	PDF	XLS
Composite Table (Every Table)	PDF	XLS	PDF	XLS

Figure 5. Regional Screening Levels (RSLs) - Generic Tab.

4. DISCUSSION

It should be noted that despite the strong foundation EPA has with the development of the PRG and RSL models, the DOE and NRC currently favor the top-down (ALARA) approach in their standard setting and risk management practices. EPA on the other hand, uses a bottom-up approach which is more consistent with their model methods. A careful analysis of the application of both risk management approaches is essential for establishment of a standardized methodology. Interagency dialogue needs to be improved in regards to interaction and mobilized coordination. Fostering the past two decades, risk-based environmental decision making has become the dominant public policy tool for managing a wide range of risks. Risk assessment should not be treated as a “one size fits all” regulatory straightjacket, nor should it be perceived as an approach to deregulating or relaxing current environmental standards for radiological risk (Tran et al., 2000). Perhaps the greatest challenge will be to coordinate collaborative efforts aimed at achieving interagency consensus on a standardized risk management approach, particularly when faced with strong historical and political influences.

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