



ASTSWMO's mission is to enhance and promote effective State and Territorial waste management programs and affect national waste management policies.

A Regulator's Guide to the Cleanup of Radiological Constituents at Department of Defense Facilities

FINAL

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Federal Facilities Research Center**

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I. INTRODUCTION

State and Territorial (henceforth, collectively referred to as States) Federal Facilities Managers typically manage the closure and cleanup of military facilities. These Managers look for common contaminants of concern (COCs), such as solvents, asbestos, lead and munitions, and generally have a background in the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the Resource Conservation and Recovery Act (RCRA). However, it is possible that military activities have resulted in radiological contamination, and these regulators may not have training in health physics or radiation protection.

This Guide is to serve as an introductory resource to State Federal Facilities Managers in evaluating the possibility for radioactive contamination to be present at a military facility. If radioactive contamination is suspected, State Managers are encouraged to coordinate with their radiation control program or a health physics consultant in characterizing this possibility and assessing any radiological data that is produced in environmental investigations. Contact information for state radiation control programs, certified health physicists and other resources can be located online at the following organizations:

- Conference of Radiation Control Program Directors (CRCPD)
<http://www.crcpd.org/Map/map.html>
- Health Physics Society (HPS)
<http://www.hps.org/>
- Interstate Technology & Regulatory Council (ITRC) – Radionuclides Team
<http://www.itrcweb.org/Documents/RAD-1.pdf>
- Nuclear Regulatory Commission (NRC)
<http://nrc-stp.ornl.gov/>
- Organization of Agreement States (OAS)
<http://www.agreementstates.org/>

II. RADIATION BASICS

Atoms are made up of three primary particles: protons, neutrons, and electrons. The protons and neutrons (nucleons) are present in the nucleus and are held together by strong nuclear forces. The electrons can be said to orbit the nucleus. Electrons are held in orbit by the relatively weak chemical binding energy.

The number of protons and electrons in an atom identify the element. The number of neutrons present in the nucleus identifies a particular isotope of that element. For example, the simplest element, hydrogen, has one proton and one electron and is identified by the symbol H-1, where the “1” indicates the total number of nucleons (mass number). If a neutron is added to the nucleus, an isotope of hydrogen is formed, H-2, known as deuterium. The “2” indicating two nucleons are present; one proton and one neutron. If yet another neutron is added, another isotope is formed: H-3, or tritium. The nucleus contains one proton and 2 neutrons. Isotopes or radionuclides are identified by their mass number, atomic number and chemical symbol.

When there are too many neutrons in a nucleus, the nucleus will have too much energy to remain stable. The excess energy will be released from the nucleus until it is stable. This release of energy from the nucleus is called nuclear radiation, commonly referred to as radioactivity.

Radioactivity

An unstable or radioactive nucleus will release excess energy by emitting particles or electromagnetic radiation. The common forms of radiation that may be emitted include alpha (α) particles, beta (β) particles, and gamma (γ) radiation or photons. Additional forms of nuclear radiation, though less common, include the emission of protons, neutrons, and the spontaneous fission of the nucleus. Nuclei that produce nuclear radiation are considered radioactive. Nearly all radionuclides found in the environment decay by the following mechanisms

Alpha (α) Decay:

The emission of a Helium-4 (He-4) nucleus from the nucleus of a radioactive element is known as alpha decay. An alpha particle therefore consists of two neutrons and two protons. An alpha particle is relatively massive (1836 to 1) compared to a beta particle and it has a +2 charge which causes it to attract electrons. Alpha particles do not travel far in air and are stopped by the dead external layers of skin, thus preventing damage to healthy tissue. Internal exposure to alpha particles can be very damaging to internal organs due to their high kinetic energy and mass. Alpha decay is common of radionuclides with 83 (i.e. Bismuth) or greater protons. Alpha particles are emitted with a characteristic energy and can be used to identify a parent radionuclide. The linear range is very short and the controls of the laboratory are necessary to do alpha spectroscopy successfully.

An example of alpha decay:

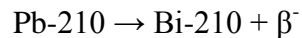


Uranium-238 (U-238) emits an alpha particle transforming the nucleus to a Thorium-234 (Th-234) nucleus. The U-238 also emits associated photons.

Beta (β) Decay

A beta particle may be emitted when a nucleus has too many neutrons or protons. A beta particle is formed when a neutron or a proton transforms into the other. Associated gamma radiation or photons may also be emitted with the beta particle. Beta particles are highly energized electrons or positrons (positively charged electrons) that travel a short distance in air. Some beta particles have enough energy to penetrate the skin, and have been known to cause burns. The eyes may be particularly sensitive to beta radiation. Internal exposure from beta particles can cause damage to internal organs of the body. One cannot use beta radiation to identify radioisotopes with spectroscopy. Radionuclides that only produce Beta radiation (pure beta emitters) have to be chemically identified before they can be quantified.

An example of beta decay:

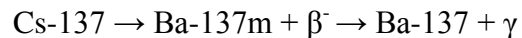


Lead (Pb) is changed to the new element Bismuth (Bi) because one neutron transforms to a proton. The Pb-210 also emits associated photons.

Gamma (γ) Decay

The release of a photon or gamma ray changes the energy state of a nucleus from a high energy to a lower energy. The number of nucleons remains unchanged. A photon is electromagnetic radiation and can travel great distances in air. Gamma rays are very penetrating and can be damaging to internal organs from outside the body. Gamma photons are characteristic and can be used to identify radionuclides. For example, if a soil sample contains several gamma nuclides, one analysis can identify each nuclide in the sample. Field gamma spectroscopy combined with GPS tracking software can be used to map the distribution of gamma emitting radionuclides associated with surfaces and top soils.

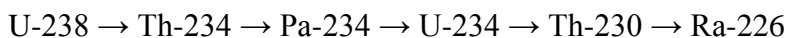
An example of gamma decay:



Cs-137 beta decays to Ba-137m (Ba-137 metastable). Ba-137m then transitions to stable Ba-137 by emitting a gamma photon from the nucleus.

Decay Chains

A radioactive nucleus (radionuclide) may go through many steps or decay modes until the nucleus becomes stable. This series of steps is called a decay chain. A partial decay chain for U-238 is shown below.



The first radionuclide in the chain is called the “parent” the subsequent radionuclides are considered progeny or “daughters” of the parent. In the example above, U-238 is considered the parent of Th-234 → Pa-234 → U-234 → Th-230 → Ra-226, which are progeny or daughters of U-238. The progeny may be stable or radioactive. A resultant stable progeny is the end of the decay chain. Radiochemists use both parent and progeny characteristic radiation to identify and quantify radionuclides. Furthermore, spectroscopy instrumentation incorporates computer libraries of alpha or gamma emission energies to do this automatically. A decay chain is simply a string of progeny. Each progeny radionuclide in a chain has a unique half-life and radiation signature that may also be helpful in identifying the ultimate parent. Fission products and accelerator products have short decay chains. Heavy radionuclides (alpha emitters) like uranium and plutonium have long decay chains. For example U-238 has a decay chain with 14 progeny ending with stable Pb-206.

A more detailed explanation with examples can be found at:

U.S. Environmental Protection Agency (EPA) Radiation Protection – Decay Chains
http://www.epa.gov/radiation/understand/chain.html#u_decay

Half-Lives

Individual nuclei decay at different rates. The time it takes for one half of the nuclei to decay is called a half-life. Half-lives of different radionuclides can vary from very short times on the order of microseconds (1×10^{-6} sec or millionths of a second) to billions of years. The shorter the half-life the faster the radionuclide decays away. A radionuclide with a long half-life will take a long time to decay away. A rule of thumb that can be used is that after 7 to 10 half-lives a radionuclide will have essentially decayed away, as long as a parent nuclide is not present. A few examples of half-lives are shown below.

<u>Isotope</u>	<u>Half-life</u>
U-238	4.49×10^9 years
Rn-222 (radon-222)	3.825 days
Po-214 (polonium-214)	1.4×10^{-4} seconds or 0.00014 seconds

One mole of a short half-life radionuclide will be more radioactive than one mole of a longer half-life radionuclide. Indeed, a function of half-life called the “decay constant” is used to calculate radioactivity.

Equilibrium

Secular equilibrium is reached when progeny in a decay chain reach the same level of radioactivity as the parent. Knowing this is useful in understanding and quantifying

radionuclides. As a rule of thumb, it takes seven to ten half-lives for a progeny to reach equilibrium with the parent. Referring back to U-238 as an example, the first progeny, Th-234 has a half life of 21 days, and the second progeny, protactinium-234(Pa-234) has a half life of 1 minute. After 10 half lives of Th-234 or about 210 days, it and Pa-234 both will be in secular equilibrium with processed U-238. The characteristic radiation of the progeny therefore can be used to help quantify the parent which by itself is difficult to quantify. Differences in mobility between progeny and parent in the media of concern may result in disequilibrium in the environment.

The presence or absence of secular equilibrium can have important inferences in the environment. For example, if uranium isotopes and progeny are approximately in secular equilibrium, one might infer that the material (e.g. ore, dark shales) originated from the native environment. However, if progeny are missing, one might suspect that the material has been processed. Even low levels of radioactivity might be anomalous to the natural background. At uranium milling sites, one would expect most of the uranium to be processed out and missing, but not progeny, especially radium.

Computer models can consider secular equilibrium, mobility, and decay as they relate to specified site parameters.

III. UNITS FOR THE MEASUREMENT OF RADIOACTIVITY

Activity

Unlike common chemical measurements that are based on mass, radioactivity measurements are based on the “activity” of a substance. The activity of a substance is a measure of how often a particle or photon is emitted from the substance. Each time a nucleus emits a particle or photon, the nucleus has decayed or disintegrated. The rate (disintegrations per unit time) at which nuclei decay is how radiation is measured. Specifically, one decay each second is a Becquerel (Bq). The U.S. customary unit for activity is the Curie (Ci). There are 3.7×10^{10} decays each second in a Curie. The Curie is derived from the activity of 1 gram of radium-226 (Ra-226). A useful conversion between SI units and U.S. Customary units is:

$$1 \text{ Ci} = 3.7 \times 10^{10} \text{ Bq}$$

Environmental samples are typically reported as activity in a unit mass or activity in a unit volume. Soil and sediment samples may be reported as pCi/gram, where a pCi = 1×10^{-12} Ci. (a millionth of a millionth Ci). Liquid samples may be reported as pCi/L and air samples may be reported as pCi/m³. Another useful conversion is:

$$1 \text{ Bq} = 27.027 \text{ pCi}$$

Exposure

Another way to describe radioactivity is to consider the amount of energy emitted by the nucleus in the form of gamma or x-rays (photons) and its ability to ionize air. The roentgen (R) is a unit that quantifies the amount of radiation energy in the air from photons. The roentgen is a measure of exposure to photons. Many radiation field instruments provide readings in roentgen units or roentgens per hour (R/hr).

Dose

The amount of emitted energy actually absorbed or deposited in tissue ,or other material, is called the radiation absorbed dose (rad). The units commonly used to quantify this dose are the rad (U.S. Customary) and the gray (Gy, SI units). The rad and Gy are measures of energy absorbed per unit mass of material. The relationship between rad and Gy is:

$$1 \text{ Gy} = 100 \text{ rad}$$

When radiation collides with living cells, a number of potential outcomes are possible. Some of these outcomes include no damage to the cell, death to the cell, and damage to the cell. Damage to a living cell depends on the amount of energy transmitted to the cell. The amount of energy transmitted to a cell depends on the type and energy of the radiation. Different types of radiation produce different effects and different levels of damage to cells. An alpha particle will interact more intensely and transfer energy over a shorter distance within a cell than a photon with the same energy. The alpha particle is more “effective” at producing biological damage than the

photon, even though the total amount of energy transferred is identical overall. The same amount of absorbed dose from different types of radiation will have different biological effects.

The Dose Equivalent (DE) is an expression of dose in terms of its biological effect. Appropriate weighting factors can be applied to the absorbed dose reflecting the different relative biological effects (RBE) to find the equivalent dose. The dose equivalent is expressed in units of rems (Roentgen Equivalent Man) or sieverts (Sv). The dose equivalent in rems is the radiation dose in rads multiplied by a weighting factor, which is an assessment of the relative biological effectiveness of that particular type and energy of radiation. Alpha particles have a weighting factor as high as 20, so that one rad is equivalent to 20 rems. For Photons the quality factor is so that one rad and one rem are equivalent for gamma and x-rays. The conversion from sieverts to rem is:

$$1 \text{ Sv} = 100 \text{ rem}$$

Risk

Carcinogenic slope factors are used to assess risk from radionuclides just like for other chemicals. The EPA's electronic calculator provides preliminary remediation goals for radionuclides. Per EPA policy, the calculator provides concentrations in both activity and mass units. EPA's recommended models for CERCLA sites are as follows: risk from radionuclides in soil and water (PRG), risk from radionuclides inside buildings (BRPG), risk from radionuclides on hard outside surfaces (SPRG), and complying with dose based ARARs (DCC). These calculators represent EPA's newest guidance and replace Risk Assessment Guidance for Superfund (RAGS) chapter 10 of Part A and chapter 4 of RAGS part B. Radiological risk should be considered cumulative to chemical risk. EPA's current site characterization methodology is found at:

“Soil Screen Guidance for Radionuclides”

<http://www.epa.gov/superfund/health/contaminants/radiation/radssg.htm>

One common radionuclide, uranium, has an acute chemical toxicity that is a concern for the ingestion pathway. If a site has uranium, this potential hazard should be noted and evaluated. The chemical toxicity of uranium can drive its risk as much as its carcinogenicity.

Resources for assessing risk from radionuclides are provided by the following:

- –EPA Preliminary Remediation Goals for Radionuclides
<http://epa-prgs.ornl.gov/radionuclides/>
- U.S. EPA - “Risk Assessment Guidance for Superfund”
<http://www.epa.gov/oswer/riskassessment/ragsa/index.htm>
- U.S. EPA - “Radiation Risk Assessment at CERCLA Sites: Q & A”
<http://www.epa.gov/superfund/health/contaminants/radiation/pdfs/riskqa.pdf>
- U.S. EPA – “Superfund Radiation Risk Assessment and How You Can Help: An Overview”

<http://www.epa.gov/superfund/health/contaminants/radiation/radvideo.htm>

Supplemental Computer Models for Risk and Dose Assessment

Dose and risk from contaminated environmental media can be calculated with computer models or codes. Specific activities for individual radionuclides are entered into these models along with site specific geophysical parameters. One of the most widely used and accepted computer models is the U.S. Department of Energy's (DOE's) Residual Radiation, or ResRads. ResRads can also provide output in terms of risk. Another model used by the Department of Defense (DOD) for all environmental contaminants for risk assessment is the U.S. Army Corps of Engineers' (USACE's) Adaptive Risk Assessment Modeling System (ARAMS). Both of these models include uncertainty analysis. DOE and DOD offer training for use of these models respectively.

- DOE, Argonne National Laboratory – ResRads
<http://web.ead.anl.gov/resrad/home2/>
- USACE – ARAMS
<http://el.ercd.usace.army.mil/arams/>

Radiation Detectors

Most radiation emitted from the nucleus can be classified as ionizing radiation. The particles and photons have enough energy to remove orbiting electrons from atoms. This produces positively charged ions and electrons. Radiation detectors are designed to measure this ionization and produce useable output. Modern radiation detectors can be very sensitive and can measure very small amounts of radioactivity. They may also be very complicated devices, requiring computers and other associated equipment to perform correctly.

Radiation detection devices have two primary purposes, to determine the field dose or to determine the amount of radioactivity present. It is important to recognize that the same dose rate or same radioactivity can produce different readings in different detectors. This is due to many factors that include the geometry, energy response, and active detector area.

Some common radiation detection devices are described below:

Geiger Counter: A common detector that may be most familiar to the public is the Geiger-Mueller (GM) counter, or simply the Geiger counter. It uses a gas-filled tube and high voltage to detect the ionization caused by the incoming radiation. The counter can detect alpha, beta, and gamma radiation although it cannot distinguish between them. A GM detector is often the first instrument used for detection of surface contamination on personnel and property.

Scintillation Detectors give off light when radiation interacts with them. The light is converted to electrical pulses that are processed by electronics and computers. Examples are sodium iodide (NaI) and bismuth germanate (BGO). These materials are used for radiation monitoring, in research, and in medical imaging equipment.

Solid State Photon Detectors use semiconductors such as silicon and germanium cooled to extremely low temperatures for precise measurements of X-ray and gamma-ray energies and intensities. Silicon detectors are good for low energy photons. Germanium detectors can be used to measure photons over a wide range of energies from several kilo electron volts (keV) to a few mega electron volts (MeV). Such detectors have applications in environmental radiation and trace element measurements.

The types of detectors described above can be configured for field use or laboratory use with varying detection sensitivity. Such electronic instruments can have libraries to identify specific radionuclides based on their gamma energy. Typically laboratory detectors have greater detection sensitivity than field detectors.

IV. BACKGROUND RADIATION

Ionizing radiation from natural sources such as the earth's crust, cosmic rays from outer space, and trace amounts of radioactivity in the body are present all the time. This type of radiation is called natural background radiation. The natural sources in the earth's crust include uranium and thorium and their decay products, and potassium-40 (K-40). These radionuclides, which are in the ground, lead to exposure from gamma rays, beta particles, and alpha particles. The presence of these radionuclides in soil can vary over a range of concentrations and exposure rates, and is highly dependant on the bedrock material found in a given area.

Cosmic rays are extremely energetic particles from the sun, stars and other events from the far reaches of space. Reactions in the upper atmosphere with these energetic particles produce lower energy particles. The earth's atmosphere absorbs many of these particles as they travel toward the surface of the earth. Since the atmosphere absorbs these particles exposure to cosmic rays is greater at higher elevations than at sea level.

Naturally occurring radionuclides are present in food and air. Through ingestion and inhalation they are also present in the human body in trace amounts. Some of these radionuclides include tritium (H-3), carbon-14 (C-14), and K-40.

Some man-made sources may also be considered as background radiation. These sources are considered background because they are globally distributed. Nuclear weapons tests and use, nuclear accidents, and nuclear reactors have contributed to the presence of certain radionuclides in environmental samples. Man-made sources that should be considered include cesium-137 (Cs-137), strontium-90 (Sr-90), krypton-85 (Kr-85), C-14, H-3, and isotopes of plutonium (Pu).

Background radiation to the average person is about 360 millirem per year or about 1 millirem per day. This is a useful analogy when explaining radiation to the public. Background radiation comes from natural uranium daughters in soil (radon), K-40 in soil, food and in our bodies, and cosmic rays (about 250 to 300 millirems per year). The rest comes from medical diagnostics, radiopharmaceuticals, and consumer products.

The following resources provide additional information on background radiation:

- Eisenbud, Merril and Thomas F. Gessell. *Environmental Radioactivity From Natural Industrial and Military Sources*. 4th ed. San Francisco, CA: Morgan Kaufmann Publishers, 1997
- U.S. EPA – Natural Radiation
<http://www.epa.gov/radtown/natural.html>

V. RADIONUCLIDES OF CONCERN AT DOD SITES

Like other environmental investigations, the key in knowing what to look for is often found in the operational history of the site. For example, if it is known that the facility maintained aircraft, then one might look for radium-226 (Ra-226) contamination in the landfill, as radium was used for luminescent dials in aircraft instrumentation. Similarly, modern military compasses and gun sights use tritium (H-3) to create the self-luminescent device. However, it should also be noted that radioactive contamination may be found at unexpected places that are not indicated by process knowledge.

In addition to letting historical operations guide your investigation, simple observation is helpful. Radiological signage is an obvious indicator. Other, more subtle keys, like thicker walls may indicate shielding for previous radionuclide usage. Sheet lead incorporated into walls may also indicate potential radioactive or x-ray source use. One must also consider that radiological contamination may have been painted over.

If radiological contamination is known or suspected at a site, an investigation should be performed by someone knowledgeable and experienced with the use of radioactive materials in the military, and detection methodologies for the characterization, assessment and cleanup of these materials. A military installation's Radiation Safety Officer (RSO), military branch's radiologic protection organization, and/or the Defense Reutilization Marketing Offices (DRMO) are good sources of information on the historic use of radioactive materials at the facility. A DRMO is responsible for the disposal of all surplus materials and should have removed radioactive instruments, sources, or components as part of the demilitarization process. The table below lists activities that should trigger an investigative thought process, and lists radionuclides that are associated with that activity.

Radionuclides Associated with Military Activities

Activity / Occurrence	Radionuclide	Where to Look
Laboratory	Radium-226 (Ra-226)/ beryllium or plutonium-238 / beryllium neutron sources; cesium-137 (Cs-137), cobalt-60 (Co-60) or strontium-90 (Sr-90) calibration sources; tritium (H-3) or carbon-14 (C-14) tracers	Laboratories, benches and chemical storage, landfills
Hospital / Infirmary	Sr-90 (eye applicator), iridium-192, Ra-226, Cs-137 or Co-60 (sealed sources); Co-57 calibration / flood sources	Landfill, sewer lines (may have been lost and accidentally flushed), old incinerator
Firing Ranges	Depleted uranium (DU), (aluminum pistons may indicate use of DU)	Firing ranges, look for oxidized metal fragments of yellow color

Activity / Occurrence	Radionuclide	Where to Look
Burial sites	Ra-226, Sr-90, DU	Old disposal pits, stand-pipes and landfills
Armor plates (e.g for tanks), penetrators and aircraft counterweights	DU	Vehicle / aircraft assembly or maintenance areas, ordinance storage, landfills
Sand Blasting	Technologically Enhanced Naturally Occurring Radioactive Material (TENORM)	Paint or metal sand blasting areas, landfill disposal of blasting waste
Welding rods	Thorium-232 (Th-232)	Slag piles, floors of repair shops, scrap metal recycle areas
Manufacture, use, repair or replacement of pre-1970 self-luminescent instrument gauges and dashboard dials, watches, clocks, compasses and gun sights	Ra-226	Landfills, equipment surplus, scrap parts and solvent dumping areas
Self-luminescent exit signs in buildings, watches, compasses, gunners quadrants, aim device, gun sights	H-3	In standing buildings, landfills with building rubble, artillery equipment
Smoke detectors	Americium-241 and Ra-226	In standing buildings, maintenance shops and landfills
Aircraft parts	Magnesium / Th-232 alloys	Assembly and maintenance facilities, landfills
Radar and other electron tubes	Ra-226, Co-60, Cs-137, nickle-63, krypton-85, Promethium-147 and H-3	Instrument and electronic maintenance shops, landfills
Deck markers	Sr-90, Ra-226	Surplus equipment storage, landfills
Arsenals	DU	Machine shops, ordinance storage and testing, landfills
Gas Chromatographs	Ni-63, H-3	Surplus equipment storage, landfills
Vehicle or aircraft maintenance	Ra-226, DU and magnesium-thorium (MgTh)	Repair areas in buildings
Airborne and soil contamination	Ra-226, DU	Roofs, gutters, downspout and outfalls

The U.S. EPA provides additional information on radionuclides that may be present at Superfund sites:

- U.S. EPA – Common Radionuclides Found at Superfund Sites
<http://epa.gov/superfund/health/contaminants/radiation/nuclides.htm>

Several examples of finding radionuclides at military facilities have been noted in the past. At one Air Force base, radium dials/gauges were found disposed of inside a 12" to 24" steel/metal pipe. The pipe was embedded in place, similar to a well casing. The top of the pipe was sealed either by a screw on or welded cap. At an ammunition plant, test firing of depleted uranium (DU) rounds resulted in a cleanup of mixed waste (lead and uranium) that had to address both U.S. EPA and NRC standards. Lastly, at a site associated with the early development of fuel for the Nuclear Navy, high enriched uranium (HEU) was found in waste (rags, cuttings, protective clothing, etc.) buried in trenches on site. This particular site was operating under a NRC (initially Atomic Energy Commission) license, and ceased waste burial practices in the early to mid-1970's. There was no signage associated with these trenches and very little documentation of inventory, placement or location of the trenches.

Examples of radionuclide-containing materials that may be found at military facilities during environmental remediation are presented below:



Military Deck Markers: Radium-226



Military Compass: Tritium



Penetrator Bullet: Depleted Uranium

VI. SITE CHARACTERIZATION AND MEASUREMENT

Once you have determined that you should be looking for radionuclides at a DOD facility, there are several issues regarding sampling and measurement that should be considered. A data quality objective (DQO) process generally follows this sequence:

Step 1. State the Problem. Define the problem that necessitates the study; identify the planning team, examine budget, schedule.

Step 2. Identify the Goal of the Study. State how environmental data will be used in meeting objectives and solving the problem, identify study questions, define alternative outcomes.

Step 3. Identify Information Inputs. Identify data & information needed to answer study questions.

Step 4. Define the Boundaries of the Study Specify the target population and characteristics of interest, define spatial and temporal limits, scale of inference.

Step 5. Develop the Analytic Approach. Define the parameter of interest, specify the type of inference, and develop the logic for drawing conclusions from findings.

Step 6. Specify Performance or Acceptance Criteria. Specify probability limits for false rejection and false acceptance decision errors. Develop performance criteria for new data being collected or acceptable criteria for existing data being considered for use.

Step 7. Develop the Plan for Obtaining Data. Select the resource-effective sampling and analysis plan that meets the performance criteria.

The U.S. EPA has developed guidance for systematic planning using the DQO process.

Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) is a widely accepted survey and verification approach that is useful in identifying, characterizing, and surveying radioactive contamination in buildings and shallow soil. It should be used as the standard default methodology in these situations. MARSSIM is a graded approach in that not all areas of the site will have the same potential for residual contamination, thus, not all areas require the same level of survey. As regulators you should review and approve all survey plans. EPA does not recommend any particular methodology. It is critical to use the DQO process to identify data gaps that may be inherent to a method.

In response to the success of MARSSIM, Kentucky, California, and several federal agencies developed a supplement document: the Multi-Agency Radiological Laboratory Analytical Protocols Manual (MARLAP). MARLAP provides uniform guidance for the planning, implementation, and assessment phases of projects that require the laboratory analysis of radionuclides. In addition, the Multi-Agency Radiation Survey and Assessment of Materials and Equipment Manual (MARSAME), also a supplement to MARSSIM, has recently been released by the U.S. EPA, DOD, DOE, and NRC. MARSAME provides information on planning, conducting, evaluating, and documenting environmental radiological surveys to determine proper disposition of radioactive materials and equipment. Prior to MARSAME, the NRC

Regulation Guide 1.86, “Termination of Operating Licenses for Nuclear Reactors,” was typically used as the standard for surveying material and equipment for release.

Copies of all guidance materials and additional information on the topics discussed above can be located at the following websites:

- *Guidance on Systematic Planning Using the Data Quality Objectives (DQO) Process (EPA QA/G-4)*
<http://www.epa.gov/QUALITY/qs-docs/g4-final.pdf>
- *Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)*
<http://www.epa.gov/rpdweb00/marssim/obtain.html>
- *Multi-Agency Radiological Laboratory Analytical Protocols Manual (MARLAP)*
<http://www.epa.gov/rpdweb00/marlap/manual.html>
- *Multi-Agency Radiation Survey and Assessment of Materials and Equipment Manual (MARSAME)*
<http://www.epa.gov/rpdweb00/marssim/marsame.html>
- *NRC Regulation Guide 1.86 – “Termination of Operating Licenses for Nuclear Reactors”*
<http://www.nrc.gov/reading-rm/doc-collections/reg-guides/power-reactors/active/01-086/01-086.pdf>
- Additional information on MARSSIM:
www.marssim.com
<http://www.epa.gov/radiation/marssim/>

Establishing background can be an issue on sites, both for naturally occurring radioisotopes, and for anthropogenic isotopes that we as regulators would consider “background” but the public would not. It is important to discriminate contamination originating from the responsible party from background ubiquitous distributions of radioisotopes, such as fallout and primordial radionuclides. Radioactive contamination is typically the result of a release during the production or use of radionuclides. The radionuclides of interest are identified with the site as a source of radioactive contamination. Make this clear in the DQO and in professional and public information.

The measurement of gross alpha and gross beta is common on sites because it is relatively simple and inexpensive. However, it is important that these results are properly interpreted. The responsible party might try to screen out environmental media entirely based on gross counts. This should be validated by isotopic analysis for an agreeable number of quality assurance (QA) samples. It could be that specific radionuclides such as tritium might be present that would not contribute to gross beta counts. Gross counts might not find the fringe of an unknown source term where isotopic analysis would.

Considering limitations, gross counts can be used for screening groundwater that is suspected of being impacted by radioactive contamination. The probability of missing particular radionuclides must be considered in the DOQs. This screening method assumes that the

groundwater is a potential source of drinking water. The screening process is based on U.S. EPA Drinking Water Maximum Contaminant Level (MCL) guidance for radionuclides in groundwater. The primary analytical method for this screening is by gross alpha/beta counting via gas proportional counter (EPA method 900.0). If the gross alpha results exceed 5 pCi/L, then the sample shall be analyzed for isotopic radium (Ra-226/Ra-228) constituents. If the gross alpha results exceed 15 pCi/L, then the sample shall be analyzed for isotopic uranium (U-238/U-235/U-234) constituents. If the initial analytical results (gross alpha) are not explained by the isotopic radium or uranium and daughters results, then perform alpha spectroscopy to determine other potential contaminants. Should the gross beta results exceed 50 pCi/L, then the sample shall be analyzed for strontium-90, or, if strontium is not a COC, another potential beta emitter suggested by the historical site assessment. The sample shall be analyzed for tritium and compared to the tritium MCL of 20,000 pCi/L, most likely by liquid scintillation counting.

Information on groundwater sampling can be found at:

U.S. EPA - <http://www.epa.gov/safewater/radionuclides/regulation.html>

Additional testing can be determined based on screening results, site history and knowledge. The site investigation process can be iterative. The sampling plan and data objectives should recognize the probability of developing additional concerns and questions. The resolution is based on additional statistical sampling, site research, and refinement of remediation alternatives. Biased sampling can be used in an educated manner but cannot be used to prove a negative. The “If it isn’t here, it isn’t anywhere” statement cannot be statistically validated. It may be possible to obtain specific manufactures documentation on site related radioactive materials and prove a positive however.

The following resources contain additional guidance and training for measuring radionuclides.

- ITRC – *Real Time Measurement of Radionuclides in Soil: Technology and Case Studies*
Guidance: http://www.itrcweb.org/Documents/RAD_4Web.pdf
Training: http://www.clu-in.org/conf/itrc/radsrealtime_102808/
- U.S. EPA – Soil Screening Guidance for Radionuclides (Current Site Characterization Methodology)
<http://www.epa.gov/superfund/health/contaminants/radiation/radssg.htm>

VII. REGULATORY FRAMEWORK

The cleanup of DOD sites is usually performed under CERCLA or RCRA authority (or both). When radionuclides are present, it is possible that the Atomic Energy Act (AEA) might also come into play, either through the NRC or through a State's radiation control program. Oftentimes, the NRC relinquishes their authority under the AEA, and the State becomes an Agreement State (AS) to implement an equivalent program. However, States cannot license federal facilities that are under exclusive federal sovereignty, such as a Formerly Utilized Sites Remedial Action Program (FUSRAP) site that has been transferred to private ownership.

Generally, if the radioactive material on a federal site is licensed by NRC, it is highly unlikely that NRC will relinquish its authority to regulate. It should be determined whether the site obtained any radioactive materials licenses from NRC or the AS. If so, it is likely that there will be an extra regulatory cleanup hurdle, as the site will need to be decommissioned in accordance with the NRC's license termination rules (10CFR20.1401-20.1406). In other cases, the license may have already been terminated in the past. Such license records will contain valuable information about what radionuclides were present, where they were used, how license was terminated, and where the materials were disposed. In addition, there may be new licensing requirements if radioactive materials remain on the property and/or if the residual dose after the cleanup exceeds NRC's 25 millirem per year standard.

There are both federal and State drinking water standards for alpha radiation, beta radiation, tritium, uranium and radium, which may apply to radiological site cleanups. Soil Applicable, or Relevant and Appropriate Requirements (ARARs) may also be considered from the Uranium Mill Tailing Regulations (40 CFR Part 192); for example, the 5 pCi/g cleanup standard for Radium-226 in the first 6 inches of surface soil. State Managers should consult EPA guidance on the use of these standards as appropriate.

For additional information:

- U.S. EPA – “*Use of Uranium Drinking Water Standards under 40 CFR 141 and 40 CFR 192 as Remediation Goals for Groundwater at CERCLA Sites*”
http://www.epa.gov/superfund/health/contaminants/radiation/pdfs/9283_1_14.pdf
- U.S. EPA – “*Clarification of the Role of Applicable, or Relevant and Appropriate Requirements in Establishing Preliminary Remediation Goals Under CERCLA*”
<http://www.epa.gov/superfund/health/contaminants/radiation/pdfs/aras.pdf>

VIII. CLEANUP

Integration of EPA and NRC / Agreement State (AS) Approaches

If a DOD contractor has operated on a property under an NRC or AS license, and the license has or will be terminated, the Memorandum of Understanding (MOU) between NRC and EPA should be reviewed and the respective endpoints, approaches, and methods reconciled. This is especially relevant when evaluating groundwater because EPA has specific dose limits for groundwater, whereas NRC does not. Under the MOU, NRC headquarters determines when EPA is to be consulted. States should be observant to the consultation. The MOU can be found at: <http://www.epa.gov/superfund/health/contaminants/radiation/mou.htm>.

NRC uses radiation dose to assess cleanup endpoints, while EPA uses risk to assess endpoints. EPA cleanup endpoints under CERCLA tend to be a little more conservative than NRC endpoints. Following the MOU principles should help reduce conflict between the two approaches. Given the uncertainty in dose assessment and risk assessment, the practical differences are often minor. It is suggested, however, that the formal public participation process of CERCLA be used to help assure community acceptance.

Oversight of Radiation Cleanups

The paradigm presented for DOD sites is that the DOD is the responsible party that hires contractors to characterize and remediate the site. Once the contracts are written, work scopes identified, and work starts, DOD oversight will likely vary from one installation to another. Ideally, DOD should oversee the project competently or else hire a neutral oversight contractor to do it instead. This oversight should include basic sampling protocol and analysis, quality assurance, data handling quality assurance, proper statistical treatment, accurate reporting, and related items.

What remains for the State regulator is to assure that the administrative process and the Record of Decision (ROD) are performed in an informed manner compliant with environmental regulations. The State regulator should also perform enough fundamental oversight of sampling procedures and basic protocol to assure that DOD oversight is adequate in this regard. For example, the State could request the chain-of-custody records for a specific sampling event and trace the samples and data forward into reports.

The State could also review reported data, and back track to see if the data are valid and all chain-of-custody and quality assurance/quality control (QA/QC) procedures were followed back to the sampling event.

The State regulator's oversight is particularly relevant in that radiological analysis accuracy and precision is directly related to the sample matrix (i.e., smear wipe, soil, water or air sample) and prep, any needed radiochemistry and analytical method (e.g., alpha spec, fluorimetry, KPA or ICP-MS for uranium), and length of time the sample is counted on the detection instrument (e.g., alpha or gamma spec, proportional or liquid scintillation counter, etc.). If detection limits are unacceptably high, often the laboratory can make improvement, albeit at the expense to the

client, by lengthening count times. Sometimes other complications arise that confound laboratory analyses that are beyond control (e.g., natural uranium or thorium series present when looking for elevated uranium or thorium). QA records should be available for review upon request in any regard. The simple act of such a request can shore up a responsible party's approach, whether one actually reviews the QA package or not. Often a three party agreement between the State, DOD, and other federal agency can be developed to address all these issues.

Cleanup Levels

Radionuclides have two elements of toxicity (stochastic and non-stochastic); carcinogenicity (stochastic) represented as cancer risk via slope factor, and a radiation and chemical toxicity (non-stochastic) represented in a hazard index. In fact some radionuclides (such as uranium) generally present a greater risk from chemical toxicity than from radioactivity. EPA guidance recommends adding the radiation and chemical risks.

Two regulatory frameworks exist in statute and affiliated regulation that manage the health and safety aspects of ionizing radiation. The first framework is controlled by dose, as found in the radiation control programs of the NRC, as well as affiliated AS, the DOD, and the DOE, with authority derived from the AEA. This dose-based framework establishes cleanup levels at a site. A site will be considered acceptable for unrestricted use if the residual radioactivity that is distinguishable from background radiation results in a Total Effective Dose Equivalent (TEDE) to an average member of the critical group that does not exceed 25 mrem (0.25 mSv) per year, including that from groundwater sources of drinking water, and the residual radioactivity has been reduced to levels that are as low as reasonably achievable (ALARA). Determination of the levels which are ALARA must take into account consideration of any detriments, such as deaths from transportation accidents, expected to potentially result from decontamination and waste disposal.

The second framework is controlled by risk, as found in the radiation control program of the U.S. EPA, with authority derived from CERCLA and the National Contingency Plan (NCP). This risk based framework establishes cleanup levels at a site:

For systemic toxicants, acceptable exposure levels shall represent concentration levels to which the human population, including sensitive subgroups, may be exposed without adverse effects during a lifetime or part of a lifetime, incorporating an adequate margin of safety. (40 CFR Part 300.430(e)(2)(i)(A)(1))

For known or suspected carcinogens, acceptable exposure levels are generally concentration levels that represent an excess upper bound lifetime cancer risk to an individual of between 10^{-4} to 10^{-6} using information on the relationship between dose and response. The 10^{-6} risk level shall be used as the point of departure for determining remediation goals for alternatives when ARARs are not available or are not sufficiently protective because of the presence of multiple contaminants at a site or multiple pathways of exposure. (40 CFR Part 300.430(e)(2)(i)(A)(2)).

These two regulatory frameworks had the potential to result in the dual regulation of sites impacted by radioactive material, and the US Congress asked that the NRC and EPA take the lead in resolving the potential conflict caused by these regulatory frameworks. As a result of

congressional interest, the EPA and NRC developed the MOU, which clarifies when EPA consultation would be required during NRC decommissioning activities (site cleanups).

No similar MOU has been established for clarifying when NRC consultation would be required at CERCLA cleanups involving radioactive materials that may fall under NRC regulatory jurisdiction. However, in recent Base Realignment and Closure (BRAC)/CERCLA cleanups in California involving radioactive materials, the NRC has deferred their authority to the CERCLA process, finding it adequately protective, and the NRC, choosing not to actively participate, has only asked to remain informed of the CERCLA activities and process at the sites.

Both regulatory frameworks have provided screening levels for radionuclides in soils and building surfaces. Depending on the authorized lead regulatory agency and keeping in mind the MOU, either of these screening level methods may be used as appropriate to screen out potentially contaminated sites per common practice.

NRC screening levels can be found at: <http://www.nrc.gov/reading-rm/doc-collections/commission/secys/1998/secy1998-242/1998-242scy.html#ATTACHMENT%202>

EPA screening levels can be found at: <http://epa-prgs.ornl.gov/radionuclides/>

Regardless of the regulatory frameworks that would have ultimate authority over the site, if contaminant levels exceed screening levels, then cleanup levels would have to be developed on a case by case basis, dependent on site specific conditions and future anticipated use. The NRC development of these cleanup levels would normally be performed with a dose/risk modeling computer program such as the RESRAD family of codes (<http://web.ead.anl.gov/resrad/home2/>). Once the site transitions to EPA authority, the EPA electronic calculators for PRG, BPRG, SPRG, and DCCs are appropriate for risk characterization. Specific dose estimates may still be performed with ResRad on DOD sites.

Mobility of Radionuclides

As examples, some radionuclides can be grouped according to potential ground water mobility. A study performed by Argonne National Laboratory looked at 19 radionuclides. Of these, nine (H-3, C-14, Se-79, Sr-90, Tc-99, I-129, U-238, Np-237, and Am-241) were found to have the potential to reach groundwater and cause contamination; the remaining 10 (Co-60, Ni-63, Sb-125, Cs-137, Sm-151, Eu-152, Eu-154, Th-230, Th-232, and Pu-239) were considered less likely to cause groundwater contamination. Tc-99, I-129, C-14, and H-3 are particularly mobile with persistent half-lives.

Be aware that transport can be facilitated by physical and chemical site conditions. Analyze for all radionuclides as specified in the DQO process. Soil to groundwater models should be used.

Some chemical complexes are more mobile than others. For example, UO_2F_2 is probably the most mobile chemical form of uranium. However, it is unlikely to be found unless around a fluorination facility or a UF_4 or UF_6 spill.

C-14 becomes incorporated into the carbon cycle. For example if C-14 is burned in waste or other wise oxidized it comes off as CO₂ and enters the biosphere through photosynthesis with several dose pathways to humans.

H-3 or tritium is hydrogen (H) with two neutrons and one proton in the nucleus instead of a proton alone. The chemistry for tritium is the same as hydrogen. If H-3 is oxidized, the product is tritiated water. One of the biggest sources of environmental tritium is the disposal of luminescent exit signs. When a sign breaks it releases many curies of tritium all at once creating a “slug” of contamination with high mobility. Tritium is also found in other luminescent items. The tritium can enter potable water supplies via streams and groundwater.

Technetium-99 (Tc-99) is a very mobile synthetic metal mostly associated with recycling of nuclear fuel. It is an inconvenient contaminant in fuel reprocessing. It has a propensity to escape confinement and travels far in groundwater. Its prevalence on DOD facilities is unknown, but if it is found, it can become a driver both from the clean-up standpoint and the disposal standpoint, since facilities typically have restrictive waste acceptance criteria for Tc-99. For all practical purposes the element did not exist on earth before the atomic age. A global residual of Tc-99 remains from atomic bomb testing. The half-life of Tc-99 is 213,000 years.

A description of other radionuclide chemistry and matrix effects in the environment can be found at:

- Understanding Variation in Partition Coefficient, K_d , Values
<http://www.epa.gov/radiation/cleanup/402-r-99-004.html#vol1>
- Argonne National Laboratory – “Assessing the Impact of Hazardous Constituents on the Mobilization, Transport, and Fate of Radionuclides in RCRA Waste Disposal Units”
<http://web.ead.anl.gov/resrad/documents/ANL-EAD-TM-93.pdf>
- DOE – “Bioremediation of Metals & Radionuclides: What It Is and How It Works?”
http://www.lbl.gov/NABIRarchive/generalinfo/03_NABIR_primer.pdf

Generally, the chemical properties of radioisotopes do not differ from stable isotopes of the same element, same atomic number, same number of protons and electrons (number of neutrons differ). Furthermore, it still holds true that chemical characteristics of the vertical groups of the periodic table are similar. For example, Calcium (Ca), Strontium (Sr), and Radium (Ra), are in the same column (Group) on the periodic table. We know that our bones are made of Ca, so it stands to reason that the radionuclides Sr-90 and Ra-226 are bone seekers because they are in the same column as Ca. This rule of thumb is weaker with the center columns and lower rows of elements that have various possible oxidation states, however.

Heavier atoms such as uranium with a complicated arrangement of electron shells that can take different valence states are hard to pigeon hole. Different chemical complexes have different environmental mobility. As mentioned above, UO₂F₂ is probably the most mobile chemical form of uranium. U₃O₈ is the oxide form of uranium found in nature and is not as mobile. Ingested uranium exhibits acute renal toxicity that dwarfs its radiotoxicity. Mobility and dose is

highly dependent on chemical form and matrix chemistry. Either high or low pHs can mobilize uranium. Uranium has approximately 17 daughters for each isotope. Each daughter has unique radiotoxicity and mobility characteristics. Computer models can be set to consider these factors conservatively.

IX. OVERALL CONSIDERATIONS ABOUT RADIATION CLEANUPS

In that all U.S. commercial radioactive waste disposal sites are licensed under AS programs, characterization plans and waste handling must accommodate the waste acceptance criteria (WAC) for the receiving disposal site. This includes meeting federal Department of Transportation regulations.

The disposal of very low activity contaminated waste in RCRA D or C facilities is potentially contentious. NRC, and compatible AS regulations, have provisions in 10 CFR Part 20, section 20.2002, where generators can do a dose assessment for “alternate” low-level radioactive (LLRW) disposal. If the public dose is below a few mrem per year, NRC or an AS may approve the alternate disposal. However, despite a risk analysis demonstrating protectiveness of public health and safety, the proposal may still encounter public resistance. Public participation and transparency on cleanup criteria and waste disposal approaches cannot be overemphasized. The public perception is that no level of radiation is safe, thus there is no safe level of residual radioactivity. Leaving buried radioactive waste in place on a site that will be reused raises similar issues. Long-term institutional controls may be needed in some cases.

The old AEC and NRC regulations allowed a licensee to dispose of certain amounts of low-level radioactive waste onsite until circa-1980. However, what is known and what is unknown from historical records is often blurred, and investigators are often left with having to perform robust statistical building and site sampling to reduce uncertainties. A rigorous data quality objective document should be cooperatively developed to ensure all parties are satisfied with the scheme to identify COCs and the acceptable sampling approach to quantify knowledge of residual activity. An example of acceptable knowledge is when the potentially responsible party (PRP) has records of particular radiological items used and disposed of onsite. If the PRP can provide records that disposed items are from a particular manufacturer, and can provide source term specifications, it may be possible to deterministically quantify the radioactivity and potential public dose if left in place. This approach, when possible, can cut sampling cost and provide a more confident statement for a ROD than a statistically driven sampling approach and dose / risk assessment. If source terms are known with certainty, a relatively small focused sampling plan might then be done to verify the information.

When performing small or large scale radiological cleanups, one is often concerned with buildings, equipment, and external environs (e.g., soil and ground water) that may be contaminated. This raises the issue of how to assess and deal with surface vs. volume contamination. NRC Regulation Guide 1.86 provides generally acceptable criteria for release of surface contaminated facilities and equipment at NRC or AS licensee facilities. Regarding general survey methods and how to approach complex decommissioning sites, the MARSSIM (NRC’s NUREG-1575) should be reviewed and considered for applicability. Remember, once a site is under EPA authority, the BPRG and SPRG EPA calculators are recommended.

- *Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)*
<http://www.epa.gov/rpdweb00/marssim/obtain.html>
- *NRC Regulation Guide 1.86 – “Termination of Operating Licenses for Nuclear Reactors”*
<http://www.nrc.gov/reading-rm/doc-collections/reg-guides/power-reactors/active/01-086/01-086.pdf>

APPENDIX A: REFERENCES

In addition to the resources provided throughout this guide, the following are excellent resources on a variety of topics that may be useful in the cleanup of radiological contaminated sites.

- Conference of Radiation Control Program Directors (CRCPD)
<http://www.crcpd.org/>

“CRCPD's mission is to promote consistency in addressing and resolving radiation protection issues, to encourage high standards of quality in radiation protection programs, and to provide leadership in radiation safety and education. CRCPD's primary goal is to assure that radiation exposure to individuals is kept to the lowest practical level, while not restricting its beneficial uses. CRCPD's primary membership is made up of radiation professionals in State and local government that regulate the use of radiation sources.”

- Health Physics Society (HPS)
<http://www.hps.org>
<http://radiationanswers.org>

“The HPS is a scientific organization of professionals who specialize in radiation safety. Its mission is to support its members in the practice of their profession and to promote excellence in the science and practice of radiation safety.”

Radiation Answers, provided by the HPS, offers answers to many common questions about radiation, and includes several resources on radiation issues.

- Interstate Technology & Regulatory Council (ITRC) Radionuclides Team Homepage
http://www.itrcweb.org/teamresources_11.asp

The ITRC Radionuclides Team is “focused on facilitating decision making and cleanup of radioactively contaminated sites.” The Team Homepage includes five guidance documents, four Internet-based trainings, and other resources “to increase awareness and acceptance of technical successes and regulatory processes associated with radioactive contamination.”

- Organization of Agreement States (OAS)
<http://www.agreementstates.org/>

The OAS is a nonprofit, voluntary, scientific and professional society. Its members consist of state radiation control directors and staff from the 35 Agreement States (AS) responsible for implementing their respective AS programs. “The purpose of the OAS is to provide a mechanism for these Agreement States to work with each other and with the United States Nuclear Regulatory Commission (NRC) on regulatory issues associated with their respective agreements.”

- U.S. Army Corps of Engineers – Formerly Utilized Sites Remedial Action Program (FUSRAP)
http://www.environmental.usace.army.mil/prog_FUSRAP.htm

Homepage for the FUSRAP, with a general overview of the program and its policy.

- U.S. EPA – Radiation Protection Homepage
<http://www.epa.gov/radiation/index.html>

Homepage for the U.S. EPA Radiation Protection Program with links and references to several internal and external resources focused on a wide range of radiation issues. Links include access to various guidance and technical documents, fact sheets and reports.

- U.S. EPA Superfund Radiation Homepage
<http://www.epa.gov/superfund/health/contaminants/radiation/index.htm>

“Radiation guidances and reports that are used frequently by Superfund Remedial Project Managers.”

- U.S. EPA – RadTown USA
<http://www.epa.gov/radtown/index.html>

Introduction to radiation issues for the general public.

- U.S. Nuclear Regulatory Commission (NRC)
<http://www.nrc.gov/>

Homepage for the NRC with links and references to several internal and external resources focused on radiation issues. Links include access to various guidance and technical documents and reports.

APPENDIX B: FACILITY SURVEY FORM – EXAMPLE

**Tennessee Department of Environment and Conservation
DOE-Oversight Division
Radiological Monitoring and Oversight Program
Facility Survey Program**

Site:	Date(s) of Survey(s):	TDEC Staff:	Site Staff:
Facility Number:			
Year Built Date:	Operating: Shutdown:	Building Manager:	Program Area:

D & D Status:

Facility Location/Description/History/Equipment:

Location:

Building Description:

History:

Equipment:

Facility Drawings Available:

- | | | |
|---------------------------------------|------------------------------|-----------------------------|
| 1. Floor Plan available? | <input type="checkbox"/> Yes | <input type="checkbox"/> No |
| 2. Area Maps? | <input type="checkbox"/> Yes | <input type="checkbox"/> No |
| 3. Radiation survey map? | <input type="checkbox"/> Yes | <input type="checkbox"/> No |
| 4. Piping diagrams? | <input type="checkbox"/> Yes | <input type="checkbox"/> No |
| 5. Sink and Drain Survey? | <input type="checkbox"/> Yes | <input type="checkbox"/> No |
| 6. Hazardous Chemical Inventory list? | <input type="checkbox"/> Yes | <input type="checkbox"/> No |

Radiation Status of Facility:

Summary:

7. Contaminated areas in facility? Yes No
8. Contaminated equipment in facility? Yes No
9. Radioactive Material Storage Areas (RMSA)? Yes No
10. Hot cells and glove boxes in facility? Yes No
11. Radiation monitoring equipment available at exits? Yes No
12. Radioactive materials and equipment presently stored in facility? Yes No
13. Radioactive materials inventory list available? Yes No
14. Radioactive materials and equipment used in the facility? Yes No
15. Radiation Work Permit (RWP) required for entry? Yes No

Chemical Status of Facility:

16. Contaminated area(s) in facility? Yes No
17. Contaminated chemical process equipment in facility? Yes No
18. Chemical storage areas in facility? Yes No
19. Chemical inventory list available? Yes No
20. Hazardous or mixed waste permits required in facility? Yes No
21. PCBs present in facility? Yes No
22. Asbestos present in facility? Yes No

Health and Safety Restrictions in Facility:

23. Respirator area(s) in facility? Yes No
24. Special clothing requirement(s) for entry into facility? Yes No

Gloves, shoe scuffs, and RWPs are required.

25. Special hazard(s) in facility?
- a. *Physical Hazards* Yes No

b. *Chemical Hazards* Yes No

c. *Radiation Hazards* Yes No

d. *Biological Hazards* Yes No

26. Medical screening required for entry into specific areas? Yes No

27. Training required for entry into facility? Yes No

Water Sources and Wastewater Drains:

28. Open drains in facility? Yes No

29. Plugged drains in facility? Yes No

30. Are drains labeled for intended use? Yes No

31. Drain Identifications?

Oak Ridge City Sanitary Sewer Drains: Yes No

ORNL Sanitary Sewer Drains: Yes No

Other Sanitary Sewer Drains (septic tanks): Yes No

ORNL Process Wastewater Drains: Yes No

ORNL Storm Sewer Drains: Yes No

ORNL LLLW Radiological Drains: Yes No

32. Are there existing drain fields? Yes No

33. Water supplied to facility? Yes No

34. Are backflow prevention device(s) in place for drinking water system? Yes No

Outdoor Survey:

35. During survey of facility exterior, was there evidence of environmental release from any area (downspouts, roof runoff, or related outdoor indicators)? Yes No

Outdoor Chemical:

Outdoor Radiological:

Waste Containment in Tanks, Lines and Drums:

36. Process and LLLW lines associated with facility? Yes No
37. Are process related storage tanks associated with facility (interior/exterior)? Yes No
38. Concerns about liquid or sludge in sumps, canals, pools or drums? Yes No
39. Spill prevention measures in place for tanks, sumps, pools, canals and/or drums? Yes No

Potential for Environmental Release:

40. Does environmental release potential exist at the facility? Yes No
41. Are previous releases from the facility suspected? Yes No

Facility Structure:

42. Is power on in the facility? Yes No
43. Is facility secure (doors, locks, gates, badge reader)? Yes No
44. Are there housekeeping deficiencies? Yes No
45. Are the grounds well maintained? Yes No
46. Is there damage to floors, walls, windows, or doors? Yes No
47. Are evacuation routes posted? Yes No
48. Are exit lights operable? Yes No
49. Is lighting adequate? Yes No
50. Does a fire protection system exist at the facility? Yes No
51. Communications at facility during survey? Yes No
52. Is facility suitable for storage? Yes No

Follow up Actions:

Comments:

Individual(s) Interviewed:

Internal Routing:

RMO **WM** **ER** **EM/C**

References: