VII. Radiological Constituents

State and Territorial (States) Federal Facilities Managers typically manage the closure and cleanup of military facilities. These Managers look for common BRAC contaminants of concern (COCs), such as solvents, asbestos, lead and munitions, and generally have a background in CERLCA and RCRA. However, it is possible that military activities have resulted in radiological contamination, and these regulators do not have training in health physics or radiation protection.

This chapter provides an introductory resource to State Federal Facilities Managers in evaluating the potential for radioactive contamination to be present at a BRAC site. If radioactive contamination is suspected, State Managers are encouraged to coordinate with their radiation control program or a health physics consultant in characterizing this potential 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 found at the following web sites:

- Contact information for State radiation control programs:
  http://nrc-stp.ornl.gov/asdirectory.html
- Conference of Radiation Control Program Directors:
  http://www.crcpd.org/
- Health Physics Society:
  http://www.hps.org/
- American Academy of Health Physics:
  http://www.hps1.org/aahp/
  http://www.hps1.org/aahp/members/members.htm

Radiation Basics

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. Nuclei that produce nuclear radiation are considered radioactive.

An alpha particle is relatively massive compared to a beta particle and it has a +2 charge, which causes it to strongly interact with electrons as it passes thru matter. Alpha particles do not travel far in air and are stopped by the dead external layers of skin causing no damage to the skin. Internal exposure to alpha particles can be very damaging to internal organs due to their high kinetic energy and its deposition in a short range. Beta particles are highly energized electrons with a single negative (-1) charge, or positrons (+1), that travel a short distance in air. Some beta particles have enough energy to penetrate the live thickness of skin, and if sufficient activity is present, can cause acute damage. Beta radiation can affect the lens of the eye causing cataracts at very high doses. Internal exposure from beta particles can cause damage to internal organs of the body. Gamma rays are very penetrating and can be damaging to internal organs from outside the body.

A radioactive nucleus (radionuclide) may go through a single to many steps or decay transitions until the nucleus reaches stability. This series of steps is called a decay chain. Individual nuclei decay at different rates. The time it takes for one half of a given population of 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 more radioactive the material, and faster the radionuclide decays away. A radionuclide with a long half-life will take a long time to decay away, but will be less radioactive.

Unlike common chemical measurements that are based on mass or chemical reactivity, measurements of radioactivity are based on detection of radiations emitted from a substance (e.g., water, soil, air filter, etc.). The "activity" of a particular media is a measure of how often a particle or photon is emitted from the substance per unit time. Each time a nucleus emits a particle or photon, the nucleus has decayed or disintegrated. The rate (disintegrations in a unit of time) at which nuclei decay is how radioactivity or activity is measured. In the U.S. it is often customary to still use the old unit for activity, the curie (Ci).

The international or "SI" unit of radioactivity is the becquerel (Bq), which is equal to a single disintegration per second (dps). There are 3.7×10^{10} dps (or Bq) in a curie. Activity of sources is typically stated in micro- or millicuries, μCi or mCi respectively. Environmental samples are often reported as activity in a unit mass or activity in a unit volume. Soil and sediment samples may be reported as picocuries per gram (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/m^3.

Radionuclides of Concern at BRAC 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 you know the base maintained aircraft, you might look for radium-226 contamination in the landfill, as radium was used for luminescent dials in aircraft instrumentation. Similarly, modern military compasses and gun sights use hydrogen-3 (or tritium) to create the self-luminescent device.

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. The military base'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.

Activity / Occurrence	Radionuclide	Where to Look
Laboratory	Radium-226 / beryllium or plutonium-238 / beryllium neutron sources, cesium-137, cobalt-60 or strontium-90 calibration sources, tritium or carbon-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
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	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	Tritium	In standing buildings, landfills with building rubble, artillery equipment

Activity / Occurrence	Radionuclide	Where to Look
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 tritium	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, tritium	Surplus equipment storage, landfills
Vehicle or aircraft maintenance	Ra-226, DU and MgTh	Repair areas in buildings
Airborne and soil contamination	Ra-226, DU	Roofs, gutters, downspout and outfalls

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 EPA and Nuclear Regulatory Commission (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 AEC) 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.

In addition to letting historical operations guide your investigation, simple observation is also helpful. Radiological signage is an obvious indicator, Other, more subtle keys, like shielded walls in certain rooms may indicate previous radionuclide usage, as the thicker walls provide shielding from radiation exposure. Sheet lead incorporated into walls may indicate potential radioactive or x-ray source use. If unbound radioactive materials were used in facilities, one must also consider radiological contamination may have been painted over.

Regulatory Framework

The cleanup of BRAC sites is usually performed under CERCLA or RCRA authority (or both). When radionuclides are preset, 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. 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 of. 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 reg's (40 CFR Part 192); for example, the 5 pCi/g cleanup standard for Ra-226 in the first 6 inches of surface soil. State Managers should consult EPA guidance on the use of these standards as appropriate.

Integration of EPA and NRC - Agreement State Approaches

If a DOD contractor has operated on a BRAC property under an NRC or AS license and the license has or will be terminated, the MOU between NRC and EPA (found at http://www.epa.gov/superfund/health/contaminants/radiation/mou.htm) 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.

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 BRAC sites is that the DOD is the responsible party that hires contractors to characterize and remediate the site. Once the contracts are written and 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, and 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 U or Th series present when looking of elevated U or Th). 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.

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 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. Reg Guide 1.86 provides generally acceptable criteria for release of surface contaminated facilities and equipment. Regarding general survey methods and how to approach complex decommissioning sites, the Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) (NRC's NUREG-1575) should be reviewed and considered for applicability.

See the NRC's reference library for both Reg Guide 1.86 and the MARSSIM manual.
http://www.nrc.gov/reading-rm/doc-collections/reg-guides/power-reactors/active/
http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1575/