Radiation Safety Guide

2022

The Division of Radiation Safety, a component of the Office of Research Services, Office of the Director, National Institutes of Health

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Preface

The Radiation Safety Guide has long been used as official guidance for those working with ionizing radiation at the National Institutes of Health (NIH). Historically the guide was revised every few years as regulations and policies changed over time, the last being in 1998. When the earliest version of the Radiation Safety website came out around 2000, the Radiation Safety Guide was presumed to be present in an on-line form throughout the various web pages. Instead of revising the guide as a sole document every few years, the web pages were updated as things changed over time. After a number of years operating this way, the Division of Radiation Safety (DRS) is bringing back the Radiation Safety Guide as a standalone guide that can be referenced for relevant policies all in one document for those who would prefer that over navigating web pages to find information.

Scope

DRS provides oversight for the use of radioactive materials or ionizing radiation producing devices at NIH. DRS does not have purview over any of the following (contact the Division of Occupational Health and Safety instead) technologies at NIH: magnets or MRI, lasers, microwaves, ultraviolet, infrared, EMF or ultrasound.

DRS provides its oversight of ionizing radiation activities for the following locations: main NIH campus in Bethesda; Poolesville Animal Center; Integrated Research Facility (IRF) at Ft. Detrick in Frederick; The NIA facilities in Baltimore; a few small leased labs in the Rockville area. DRS does **not** provide any oversight whatsoever for the following NIH-affiliated areas, and each has its own separate radiation safety program: NCI Research Facilities in Frederick; Research Triangle Park NC; Rocky Mountain Lab in Hamilton MT; Indian Health Service in Phoenix AZ

Authority to Use Ionizing Radiation

Radioactive Materials

The vast majority of radioactive material in use at NIH is governed by the Nuclear Regulatory Commission (NRC). The NRC has many regulations covering the possession, use and disposal of radioactive material. They provide active oversight of NIH through the issuance of specific licenses covering NIH activities and they conduct comprehensive unannounced inspections. DRS ensures that regulations and license commitments are followed at all times by NIH personnel. The DRS Director is also the NIH Radiation Safety Officer (RSO) who must meet specific NRC qualifications. Additionally, the RSO is specifically named on NRC licenses and has been explicitly given the authority by the Deputy Director of Intramural Research to maintain the radiation safety program at NIH, including the ability to stop any activity at NIH that the RSO believes jeopardizes the safety of NIH staff, patients or visitors, or stop any activity that will cause NIH to be in violation of NRC requirements.

All radiation workers have the right to contact the NRC directly with a concern regarding radiation safety at NIH. There are postings in numerous locations, including any lab authorized to store or use radioactive materials that go into more detail about the rights and responsibilities of radiation workers, including how to contact the NRC. While DRS hopes someone with a concern would contact DRS first to address an issue, DRS recognizes and supports the right for workers to contact the NRC directly. Note that trained radiation workers also have a responsibility to follow all radiation safety requirements.

Instruments/Equipment with Radioactive Sources Built-in

There are instruments and equipment that contain sealed sources of radioactive materials that are integral to the function of the device. Common examples at NIH include Liquid Scintillation Counters (LSC), gas chromatographs and explosive sniffers. These devices are not covered by NIH's specific NRC licenses but are instead covered under 10 CFR 31 directly as "Generally Licensed Devices." NIH researchers can purchase these directly from a vendor and they do not come through Building 21 for receipt or inspection. However, there are some regulations regarding their use that DRS must ensure are followed. Therefore, DRS requests that anyone acquiring a generally licensed device notify DRS once they receive it. Some of these devices require leak testing of the sources on a specified frequency and they cannot be taken apart for repair unless specifically licensed by the NRC to do so. Additionally, disposal of the device has requirements and anyone disposing of a generally licensed device should do so with the coordination of DRS. For LSCs specifically, see the section on radiological clearances.

Note that modern smoke detectors are exempt from general license device requirements. Also note that by NIH Policy, radioactive tritium (H-3) exit signs are prohibited on campus.

Radiation Producing Devices

Devices that produce radiation as a part of how they operate are not regulated by the NRC. Ordinarily the state would regulate these devices, but since NIH is a federal facility the State of Maryland has no jurisdiction over its operations. Therefore, the Occupational Safety and Health Administration (OSHA) is the regulatory authority over these devices (mostly x-ray units). DRS does strive to follow state regulations when these devices are inspected for safety.

"Source Material"

Chemicals that contain (naturally) radioactive uranyl or thoriated compounds (often used in microscopy applications) are defined by the NRC as "source material" and can be obtained without DRS involvement from commercial suppliers. However, there are possession limits (1.5 kg per lab) and these materials must be disposed as radioactive waste. DRS does conduct an annual contamination survey in spaces that use source material.

Guiding philosophy and enforcement

DRS provides its oversight with the goal of ALARA heavily emphasized. ALARA means **A**s **L**ow **A**s **R**easonably **A**chievable. It means that contamination and exposures shall be kept as low as reasonably possible given the circumstances involved (lab setup limitations and economic considerations are the usual limiting factors). It means that just being under the limits is not enough. Note, though, that generally speaking it is not possible to reduce someone's exposure to absolutely zero when working with ionizing radiation. However, for most NIH staff exposure can be reduced to less than 1% of the limits. NRC Regulatory Guide 8.29 discusses risks from occupational radiation exposure.

DRS is obligated to comply with all regulations and licenses involving ionizing radiation. Violations of policies by radiation workers can result in enforcement which is usually an official memo from DRS describing the violation(s) and a request from the recipient to describe corrective actions. Some violations may require targeted refresher training for lab staff involved in an infraction. Egregious or repeated violations can also result in a radiation worker appearing before the Radiation Safety Committee to explain their actions and how they will comply in the future. Although rare, the Committee may choose to suspend a radiation worker's use of ionizing radiation for any length of time including permanently.

In the course of conducting work involving ionizing radiation, never falsify anything or intentionally mislead DRS or NRC inspectors. The penalties for falsifying are steep and can include termination from employment. Note the NRC can also impose monetary fines on individuals and prevent violators from working with radioactive materials *anywhere* in the United States for up to 5 years. If you make a mistake or fail to comply with a DRS requirement, just say so and implement corrective actions to prevent recurrence. Covering up non-compliance will jeopardize your career and can impact NIH's ability to have radioactive materials.

Radiation Safety Committee

The Radiation Safety Committee (RSC) has existed in one form or another back to the late 1940s at NIH when it was first chartered by the NIH Director. Its primary function is to serve as an advisory body to DRS and NIH on all matters related to ionizing radiation. NRC regulations mandate the composition of some of the committee members – a chair, a member of NIH Management, members who are proficient in specific medical modalities of the use of radiation/radioactivity in human patients. The NRC also mandates some of the activities of the RSC such as the approval of Clinical Authorized Users for human administration of radiation/radioactivity; approval of laboratory Authorized Users; approval of certain uses of radioactive materials; approval of changes in DRS policies or the addition of new facilities that work with non-trivial amounts of radioactivity.

Getting Started with Radioactivity

Anyone 18 years of age or older wishing to work with radioactive material must register with DRS. The registration page will ask what types of radioactive materials and what kind of work will be done with them. DRS will then send the new user a link to the required baseline training modules that are completed on-line. All users get a set of modules that cover basic aspects of working with ionizing radiation at NIH, including topics mandated by 10 CFR 19.12. Specialty users of radioactivity will get additional modules tailored to those specialties. Once all training is completed and the accompanying test is passed, the new user is considered an Individual User (IU) and will be allowed to work with radioactive materials under the supervision of an Authorized User (AU). There are limitations to the amount and types of radioactivity allowed through the basic training course (RSL - Radiation Safety in the Lab). See the section on the Activity Control System regarding these limitations.

Any former NIH Radiation Worker who has returned to NIH can resume working with radioactive materials as before, provided the period of absence was under 4 years. Absences greater than 4 years will require going through the initial training regimen again.

If someone under the age of 18 will be present in a lab posted for radioactivity, there are specific training requirements whether the individual will be working with radioactive materials or not. See the section on minors for details on what to do for persons under 18 in the labs.

Becoming Responsible for Radioactive Materials

IUs must work under the supervision of a responsible AU. If an IU wishes to become an AU, the IU must complete an additional on-line set of training modules (RSAU – Radiation Safety for Authorized Users) and also complete an in-person practical demonstration designed to ensure the IU has sufficient knowledge and skills to become responsible for radioactive materials at NIH. The IU would then take a written exam. Upon passing the IU would need to formally apply for AU status, which is reviewed by DRS and the RSC.

After an AU is formally approved, he/she may order radioactivity as prescribed in the Activity Control System and be listed as the responsible individual for radioactive labs and other IUs.

AUs who leave NIH and later return do not have to start the Authorization process over other than re-submitting an application. However, if the absence was more than 4 years the RSL would have to be completed again. Additionally, any AU-specific training refreshers conducted during the absence would need to be completed.

Other DRS Training Programs

DRS runs several training programs at NIH. The most common are the RSL and RSAU courses described earlier for individual users and authorized users respectively.

DRS provides refresher training for various populations at the NIH. Some groups, such as radiotherapy nurses and oncology staff who use sealed sources within human subjects are required to receive annual training per 10 CFR 35. These trainings are largely in-person sessions conducted by DRS staff. Further, some groups receive in-person annual refresher training per DRS policy by virtue of their job, such as police, firefighters and high activity radiochemists.

Additionally, anyone who receives 100 mrem or more whole body exposure during the year is required by NRC License commitment to receive a refresher training specific to their work. This training can be in-person or in an electronic format.

Further, on a periodic basis (every 2-3 years on average), refresher training for all radiation workers or just all Authorized Users is administered electronically. Also included in these types of refresher training are groups working with radioactive animal housing or housekeeping staff.

Regardless of situation, all staff who are offered refresher training must complete the training by the specified deadline or will be suspended from their ability to work with ionizing radiation.

Administering Radioactivity to Human Subjects

Separately from an AU for radioactivity, there is a process to become authorized to administer radioactive materials in human subjects. These can be diagnostic or therapeutic administrations. Anyone wishing to work as a Clinical Authorized User (CAU) in this manner must apply through the Executive Secretary of the RSC. Note that a CAU wishing to order radioactive materials for non-human purposes must separately become an AU.

Activity Control System

There are limitations to how much radioactive material an AU may possess at any one time. This has been governed by DRS via the Activity Control System (ACS) since 2003. When an AU is first authorized, he/she is allowed a baseline amount (ceiling) of basic life science radionuclides ("The Basic Set"), based on completing the RSAU training course. If a lab wishes to use a nuclide not in the Basic Set, DRS must be contacted. An Area Health Physicist (AHP) will evaluate the lab to ensure it is sufficiently set up to use the requested materials – ability to survey for contamination, waste set-up, work area set-up, dosimetry considerations and adequate shielding are among the items that will be evaluated. If the AHP agrees the lab can handle the nuclide, the AU will be given a default ceiling for that radionuclide.

Ceilings are decay-corrected in real time. If a lab needs more than the default ceiling for a nuclide, the AHP can evaluate the lab to ensure the higher amount of radioactivity can be worked with safely and in compliance with policies. The AHP can raise the ceiling up to a maximum amount specified by policy. The ceiling thresholds for common nuclides at NIH can be found in this table.

If a lab needs more than the maximum ceiling for a radionuclide (even for the Basic set), then a DRS Protocol is required. DRS Protocols are written agreements between the lab and DRS that indicate what kind of radioactive work will be performed and what radiation safety precautions and procedures will apply. The AHP will verify the lab meets the protocol requirements and will conduct periodic oversight of the work once the protocol is approved by the RSC. Protocols must be renewed every 2 years.

There are some situations that always require a DRS Protocol:

- volatile radioactive materials
- any alpha emitter (does not include natural uranyl or thoriated compounds)
- receiving unprocessed cyclotron targets

A few endeavors are exempt from the DRS lab protocol process:

- sealed sources
- human use of radioactivity
- experiments conducted in the Bldg. 21 Hot Lab Facility
- experiments conducted in a lab with DRS physically present (meant to be one-offs)

If a lab believes a DRS protocol will be required, it should contact DRS for a consultation on what needs to be included in their protocol application.

Working with Radioactive Animals

Anyone wishing to administer radioactive materials to animals must follow the process of their institute's Animal Care and Use Committee (ACUC) which requires an Animal Study Proposal (ASP) for the work. The ACUC evaluates the ASP for appropriateness in a number of issues surrounding animal welfare. If there is radiation or radioactive material involved, the ASP is forwarded to DRS for review. DRS has a standard set of requirements for working with radioactive animals. If necessary for specific ASPs, DRS may impose additional requirements, including submittal of a regular DRS Protocol if that criteria is met.

Obtaining Radioactive Material

Any Authorized User (AU) may order and receive radioactive materials. To do so, the AU must submit an 88-1 form which will tell DRS the nuclide and amount, chemical form, the intended users of the material and where the material needs to be delivered. This is done solely electronically through the AU Portal. Separately the AU must procure the material from a vendor through their own institute's procedures for buying chemicals. The institute order **MUST** indicate the address below is the receiving address for the radioactive package and make sure the AU's name and DRS number are listed as the clearance name/number.

Division of Radiation Safety

National Institutes of Health

Bldg. 21, Room 107

21 Wilson Drive

Bethesda, MD 20892-6780

All packages of radioactive material **MUST** be delivered to Building 21 for NRC regulated surveys and inspections. After inspection, DRS will deliver the radioactive material to the location indicated on the 88-1 form. The delivery will include a Utilization/Disposal form (U/D sheet). When radioactivity is aliquoted out of the source vial, the user must document this on the U/D sheet. If a user needs to aliquot material but was not listed on the U/D sheet initially, the AU may handwrite the user's name with the pre-printed ones and sign their full name to indicate permission to use the material was granted. Be sure to only allow users to be added to a U/D sheet who have completed the RSL training. Once the material is used up or the source vial is sent to radwaste, the U/D sheet must be closed out and a copy returned to DRS. If no users were added to the U/D sheet, simply closeout the item on the AU Portal. If a user was added to the U/D sheet, please send a copy to DRS by Fax (301-480-9708) or by campus mail (21/116).

DRS will also specifically alert the lab if contamination was found on the outer surfaces of the source vial during the receipt inspection so that the lab can take precautions to prevent the spread of contamination when opening/using the package.

If a radioactive package arrives at Building 21 and there is no accompanying 88-1 for it, DRS will contact the AU and hold the package until an 88-1 is submitted. If the package causes the AU to exceed their ceiling (see the section on the Activity Control System), the package will be held until the ceiling is raised by the AHP; the AU disposes of other items of that nuclide; or a DRS Protocol is in place to receive the nuclide at that amount.

IMPORTANT – if you receive a radioactive package from someone not in DRS (commercial carrier such as FedEx or UPS), do not open the package! Immediately notify DRS who will retrieve the package and conduct the required inspections and surveys. The regulations require these steps within 3 hours of receiving the package! One important clue that the package did not come to Building 21 first as required will be that there is no U/D sheet accompanying it.

Once you receive a radioactive package it must not be left unattended and must immediately be taken to a proper storage location within a posted space. Once the package is opened, survey the outer packages for contamination (wearing lab coat and gloves) and fully deface any radioactive labeling prior to disposing in the regular trash. If there are discrepancies with the order, notify DRS. If you suspect the inner packaging container is contaminated, or you receive a message from DRS that we found it contaminated, take great care to avoid spreading contamination once you access the inner packaging items. If the material comes in a more durable container (e.g. an ammo can) that is meant to be returned to the vendor at a later time, ensure that container is contamination-free before letting it leave the laboratory.

Transfers of Radioactive Material

If a lab wants to give some or all of a source vial to another AU, the **receiving** AU must go onto the AU Portal and complete an 88-1 form. List the first AU as the supplier and clearly indicate the amount being transferred. This procedure is also required if receiving material from a lab group that takes raw radioactive materials and labels them to compounds as a service to other labs who do not want to do this work themselves.

If a lab receives radioactive materials from the NIH Cyclotron directly, it MUST document the receipt of this radioactive material via an 88-1 form on the AU Portal in a timely manner after receiving the material. Fill out the form per usual but list NIH Cyclotron as the supplier. The NIH Cyclotron is NOT responsible for documenting this transfer…they are only responsible for ensuring they give radioactive materials only to labs who have been cleared by DRS to have them.

Obtaining and Working with Radiation-Producing Devices

Labs can purchase radiation-producing devices without going through DRS. However, once such a device is received, DRS must be contacted to register the unit to get an initial inspection and placement on an annual inspection schedule. **NOTE** – open beam devices (fluoro, CT, etc.) require a DRS shielding evaluation of the room where they will reside. This should be done **prior to acquiring** the unit to prevent delays or expensive retrofitting of a space with shielding.

Note that DRS no longer tracks Electron Microscopes and notifying DRS of their existence is not necessary unless the shielding integrity of the unit is in question. However, electron microscopes do often utilize uranyl or thoriated compounds (source material) which are radioactive from naturally occurring elements. DRS **does** need to know about the existence of these chemicals as there are some regulations regarding their possession and disposal.

DRS has training modules for both self-shielded and open beam machines. All users of radiation-producing devices require training appropriate for the type of machine being used. When a registering user indicates one of these kinds of machines will be used, the correct training module will be included.

Dosimetry is not required for self-shielded machines. Dosimetry is usually required for open beam machines.

Working with shielded units is straightforward – do not defeat safety interlocks or other features designed to prevent direct exposure to any part of the body. Contact DRS for an evaluation if the unit becomes damaged and/or the integrity of its shielding is in question.

When working with open beam x-ray units, it is important to observe several work practices to prevent unnecessary and potentially appreciable exposure:

- Wear lead aprons and organ shields if working in close proximity of the beam
- Always wear dosimetry assigned to you when working with open beam units
- Try to stay 6 feet from the beam if possible
- If you have to hold a patient/animal during a procedure, wear leaded gloves
- Use the lowest settings on the unit that will produce a useful result; use image hold on units that have this feature
- In general, practices that reduce the exposure to the patient will also reduce occupational worker exposure

Notify DRS if any radiation producing device is relocated – a shielding evaluation may be required. Consult the refresher training module for a fuller discussion of open beam x-ray units.

Security of Radioactive Materials

All radioactive materials must be used or stored in spaces that have been posted for this purpose by DRS. Radioactive items are not allowed to be used or stored in corridors except for the following two situations:

- Film cassettes may be stored in a locked container labeled as containing radioactive film cassettes
- Liquid Scintillation and Gamma Counters may be used in non-posted areas, provided the counting vials are removed and placed in a posted space following their analysis. It is OK for samples to be queued up inside the counter prior to counting.
- Locked storage of **DRS-approved** quantities of radiolabeled gels, tissues, cells, or reference standards contained on slides or in imaging cassettes.

Note that some NIH buildings do not allow corridor storage of any kind. The exceptions above are not meant to circumvent building-wide prohibitions on corridor usage.

The security of radioactive materials at NIH is very important. All radioactive materials (includes waste, any contaminated item and used LSC/gamma vials) must be locked up or attended by lab staff at all times. It is permissible to lock these materials up within a room as opposed to locking the room itself.

Additionally, since 2001 all **source vials must be locked up within the room** even if the door is locked when unoccupied. This can be done by locking the freezer, etc. If the lab needs to leave the freezer unlocked, the source vial can be placed in a locked box within the freezer and that box must be tethered to the freezer. DRS can provide guidance on whether an intended security arrangement is compliant with this policy.

DRS conducts periodic security sweeps of buildings and issues enforcement citations to AUs whose radioactive material or waste can be accessed when no lab staff is present. The contractor who performs the sweeps will restore a lab to a secured configuration if they are able to access radioactive materials. In the event a lab cannot be restored to a secure configuration, the contractor, in consultation with DRS Management, will attempt to relocate source vials to another posted room or confiscate them and bring them to Building 21 for appropriate temperature storage until the non-compliant lab is able to store materials properly.

Lab staff should be cognizant of unknown persons entering their areas and challenge them regarding their entry. Legitimate visitors should be briefed on areas of the lab to avoid due to radioactive materials or other occupational hazards.

Dose Monitoring for Radiation Workers

Since 1997, DRS has directly applied the 10 CFR 20 criteria for wearing dosimetry. Workers who have a reasonable potential to exceed 10% of the NRC exposure limits will be issued dosimetry. Each worker upon completing training submits a Dosimeter Evaluation Form that describes the intended use of ionizing radiation at NIH. DRS then determines if the worker meets the criteria for whole body or ring dosimetry. Note that dosimetry is never required for work with these nuclides, regardless of the amount: H-3, C-14, P-33, S-35, Ca-45, Fe-55, I-125 or I-129.

If you are issued dosimetry, you need to wear it whenever conducting work with ionizing radiation. Only wear **your** dosimeter! Never take your dosimeter home or wear it anywhere outside of NIH. Store dosimeters away from sources of radiation and away from heat sources (like a car) which could damage the dosimeter. Dosimeters are exchanged on a frequency commensurate with the potential amount of exposure. It is essential that dosimetry be promptly exchanged when replacements arrive so that your dose amount will be known and applied to your record. Notify DRS immediately if you lose a dosimeter or if you believe you were exposed to a potentially large amount of radiation (with or without a dosimeter present).

Some workers will be issued both a chest dosimeter and a collar dosimeter. Be sure to always wear the correct dosimeter in the correct location. Finger rings are marked L and R and should be worn with the label facing inward on the finger with the highest potential for exposure. If you are an x-ray user and are issued one dosimeter, wear it at the collar level outside any lead apron. If an x-ray user receives two dosimeters, the second one should be worn underneath the lead apron.

DRS will provide dosimetry results annually to anyone who had dosimetry during the year. Separately, a worker may request their exposure in writing (DOSIMETRY@mail.nih.gov) while either a current or former employee and DRS will provide this information within 30 days as required by 10 CFR 19.13.

DRS tracks users' cumulative dose totals over the course of a calendar year. Should a worker exceed 10% of any dose limit, an ALARA investigation is triggered. Reaching 30% and 50% also trigger additional investigations. DRS discusses the exposures with the worker and evaluates whether there are measures that can be taken to reduce exposure - additional shielding, remote handling devices and sharing the workload are common techniques. For some workers at NIH the workload is such that reaching 10% is a normal outcome over the course of the year. In these cases, DRS ensures that nothing unusual is going on and that engineering controls are in place that can reasonably be applied. The 30% and 50% investigations are usually more involved and may involve a worker's AU and/or supervisor. Any worker reaching 70% of any limit during the year will be prohibited from performing further work involving ionizing radiation for the remainder of the calendar year. DRS is obligated to prevent workers from exceeding the regulatory limits.

The dose limits depend on who regulates the activity. Staff who only work with radioactive materials are subject to the NRC limits. Staff who only work with x-ray equipment are subject to OSHA limits. Staff who work in both arenas are held to both sets of limits by DRS policy and the NRC has jurisdiction over all occupational exposure if ANY of it comes from NRC regulated activities.

Dose limits observed at NIH:

Location or circumstance	NRC – 10 CFR 20.1201	OSHA – 29 CFR 1910.1096
Whole Body (DDE)	5,000 mrem/yr	1,250 mrem/qtr
Lens of the Eye (LDE)	15,000 mrem/yr	1,250 mrem/qtr
Extremities (SDE)	50,000 mrem/yr	18,750 mrem/qtr
Skin (SDE)	50,000 mrem/yr	7,500 mrem/qtr
Organs	50,000 mrem/yr	1,250 mrem/qtr
Declared Pregnant Worker	500 mrem/gestation period	N/A
Persons under 18 years old	10% of the above limits	10% of the above limits
Members of the Public	100 mrem/yr **and** no more than 2 mrem in any one hour	N/A

Internal Dose Monitoring (Bioassay)

DRS has the ability to conduct internal monitoring of staff who may have internalized radioactive materials. The two main ways bioassay is conducted at NIH are urinalysis and body scanning. The method employed depends upon the decay characteristics of the specific nuclide and/or the biological characteristics of the element/compound itself.

Most workers at NIH do not require routine bioassays but instead might be required to undergo one if involved in a contamination event or otherwise believe radioactive materials have gotten inside the body.

Urinalysis can be a single sample or a 24-hour collection. DRS then analyzes the urine for radioactivity (and nothing else). For body scanning, the worker would come to Building 21 and a sensitive detector would be placed in front of the appropriate part of the clothed worker (thyroid, lung, gut, etc.).

If air sampling was performed in conjunction with a procedure that precipitates bioassay, the concentration of the air sample can also be used to estimate internal dose.

For bioassays with detectable radioactivity, DRS calculates an estimated internal exposure plus an equivalent whole body dose value that results from internalization of radioactivity, using the NRC tables for Annual Limit on Intake (ALI). As a part of that process the worker might be required to continue a bioassay schedule to determine or verify the rate of elimination from the body via the combination of radiological decay and biological elimination. DRS will investigate the cause of internalization of radioactive materials so that measures can be put into place to prevent recurrence.

Declared Pregnancy and Breastfeeding Programs

An embryo/fetus can be more sensitive to radiation than an adult (highly dependent on the stage of pregnancy). Per NRC Regulatory Guide 8.13, DRS has a Declared Pregnancy policy in place. Any pregnant worker can voluntarily be evaluated for the potential of internal/external exposure as part of their job duties. The Authorized User or supervisor will be a part of the discussion. DRS will recommend if any changes in duties are needed to prevent the embryo/fetus from exceeding the regulatory limit of 500 mrem for the pregnancy. DRS will prohibit working with radioiodines for declared pregnant workers to prevent a damaging thyroid dose to the fetus. Other duties that may result in restrictions include open-beam x-rays (fluoro/CT) or work involving hot cells. It is also recommended that any dose is evenly spread out over the pregnancy. DRS will issue a dosimeter specifically to track this exposure.

The pregnant worker must declare formally in writing for the dose limits and monitoring to apply. This can be done by campus mail (mark an envelope 'confidential') to Building. 21, Room 116 or by giving the declaration to a DRS Health Physicist directly. You can choose to fax it to 301-496-3544 but confidentiality cannot be guaranteed. DRS will contact the worker within 2 business days to arrange a consultation.

Note that the Declared Pregnancy status is completely voluntary and a woman who chooses to participate can withdraw at any time. Undeclared pregnant workers are not subject to the 500 mrem dose limit.

Similar to the Declared Pregnancy program, DRS also offers a Declared Breastfeeding program. Some chemical compounds or radionuclides can transfer to breast milk if ingested by the mother. For any breastfeeding mother who declares, the consultation would evaluate the potential for the infant to receive 100 mrem. DRS may recommend declared mothers refrain from certain kinds of work with open-form radioactive materials and have the mother undergo periodic bioassay to ensure uptakes of radioactive material have not occurred. The potential for uptake is greatest for volatile forms of radioiodine, as well as potentially volatile forms of H-3, S-35, Br-76 and At-211.

The Declared Breastfeeding program works administratively exactly the same as the Declared Pregnancy program.

Minors in Posted Spaces

If someone under the age of 18 is going to be in a location posted for radioactive materials, but not working with them, he/she must complete the Radiation Safety Orientation training.

If someone who is 16 or 17 wishes to work with radioactive materials or ionizing radiation-producing machines, they must apply for specific permission from the RSO. There are restrictions on what a minor is allowed to do, per RSC directive in 2001:

- No one under the age of 16 may work with ionizing radiation

- The minor must complete the Radiation Safety in the Lab (RSL) course and also the lab safety course conducted by the Division of Occupational Health and Safety (DOHS)
- The minor must complete and submit an application to DRS for permission to work with ionizing radiation, which includes parental consent and an affirmation by an adult in the lab who will be present 100% of the time during any radiation work conducted by the minor
- The minor may not directly handle source vials or work with protocol quantities

Working with Radioactive Materials

General Practices

Any room/space that has radioactive materials stored (including waste) or the materials are being manipulated must be posted by Radiation Safety. DRS will evaluate whether the room is set up sufficiently to use the intended radionuclides – waste containers, monitoring capability, shielding if needed.

Eating, drinking and smoking are all prohibited in a posted area, or in an adjacent area that is not separated from the posted area by full height walls and has separate ventilation. This policy is consistent with that of the Division of Occupational Health and Safety for working with chemical or biological materials.

Anyone working with radioactive material must wear at a minimum a lab coat and gloves. Additional protective clothing may be specified in a DRS Protocol. Open-toe shoes are not permitted while working with radioactive material.

Areas/benches where radioactive work is taking place should be covered with absorbent paper or equivalent to prevent the spread of contamination. All items that are expected to become contaminated or come into direct contact with the radioactivity should be labeled in advance of the work with Caution Radioactive Material (CRAM) tape. Items that are radioactive in some way that are not waste must remain labeled to include nuclide, estimated activity, date and a radiation level if it is significantly above background.

Where practical, work should occur within a fume hood, especially if thawing out a frozen source vial containing H-3 or S-35. Note for procedures involving aerosols or inherently volatile work (e.g. halogens like radioiodine) DRS will mandate that the work be conducted in a working fume hood.

Internal Hazards

There are four main ways radioactivity can end up inside your body – ingestion, inhalation, absorption and puncture. The methods to prevent these pathways from being available include wearing protective clothing (PPE), engineering practices such as hoods or ventilation controls, and prohibitions on eating, etc. within the lab. In a few labs it is necessary to employ further controls such as fully enclosed boxes and air monitoring.

NEVER pipette by mouth…

External Hazards

An external hazard means that radiation can impact living cells from sources outside the body. At NIH this would be gamma radiation or high-energy beta radiation. The principles to minimize exposure from external sources are:

- Time – limit the time handling radioactive materials. Do practice runs of procedures without the radioactivity so that you will be efficient when using the radioactivity.
- Distance – keep the sources of radiation in locations not near work areas when not using them. Use remote handling tools when practical while working with radioactive materials…even having them a couple feet away from your body makes an appreciable difference in the dose rate when compared to having the source up close due to the inverse square law nature of radiation intensity over distances.
- Shielding – using appropriate materials in between you and the source to attenuate the incoming radiation

Laboratories should conduct radioactive work in a way such that dose rates within the lab do not exceed 2 mrem/hr or cause a dose rate in an unrestricted area to exceed 0.5 mrem/hr. Shielding may be required for source storage or waste collection areas to maintain dose levels ALARA. Note that labs working with many mCi of radioactivity at a time may not feasibly be able to meet the 2 mrem/hr standard in localized areas of a laboratory during the radioactive work. In these rare cases DRS will work with the lab to have levels as low as can be reasonably achieved and may post the lab as a Radiation Area as defined in 10 CFR 20. In all cases, the dose rates in unrestricted areas must be maintained below 0.5 mrem/hr.

Monitoring for Contamination

Labs must have the ability to perform contamination monitoring for the radionuclide(s) in use. For high-energy beta emitters such as P-32, a Geiger-Mueller (GM) probe is required. DRS allows for either the end window or pancake style of GM meter, but recommends the pancake style for better detection efficiency. For low-energy emitters such as H-3 and C-14, the lab must be able to perform Liquid Scintillation counting for smear/swipe analysis. For low-energy photon emitters like I-125, a NaI scintillation probe is recommended or smear surveys can be performed.

Note that the lab **MUST** conduct a contamination survey any day that radioactive material is used. Unless otherwise directed by DRS, these daily surveys are not documented. You should monitor the work area, the floor below that area, the equipment used in the experiment, yourself and the traverse route to waste containers.

Hand-Held Meters

When using a hand-held instrument for monitoring, it is vital that you ensure the instrument is working properly prior to use by performing these steps:

- Battery check the instrument – most instruments have a setting called Bat Check or similar…the needle should deflect to the Bat OK area on the dial. Do not use the meter if it fails this test, even if it makes clicks

- Calibration date check – the instrument should have a sticker on it with a calibration date within the last year. If the date is greater than 1 year or there is no sticker at all, contact DRS
- Source check – the instrument has a check source attached to the side of it. The calibration sticker has the cpm value that source reads with the probe of the instrument. Put the probe on the source to ensure it deflects off the first scale. At least once a week you should adjust the scale when performing this check to ensure you get within ±20% of the value on the sticker.

Prior to surveying, note the background level of the meter by turning it on in an area that should not have any radiation sources present. While surveying if you find 100 cpm *above background* and is repeatable, that is likely contamination and should be addressed.

When surveying with a hand-held instrument, move the probe slowly, no faster than 2 inches per second and keep the probe within ½" of the surface being measured. Be careful not to touch the surface with the probe, as it can be difficult to decontaminate a probe. Never cover the probe with plastic wrap or anything else as this prevents beta particles from reaching the probe.

If the general background from nearby radiation sources (i.e. waste or source storage areas) reaches 200 cpm on an instrument, you have to survey more slowly to find low-level contamination. You should consider shielding or moving those sources of radiation while surveying for contamination. If this is not feasible, you can do a smear survey in a high background area OR if you need to do a quick check of an area to ensure contamination from high-energy beta emitters is not present, take an area wipe with absorbent paper or a Kimwipe, move to a low background area and survey the wipe with the instrument probe.

If you are unsure of the radionuclide from contamination found with a pancake GM, there are some techniques to narrow down the possibilities. First, turn the probe over – if the count rate drops to essentially zero, it is a pure beta emitter. Second, place a thick card (index card works) between the probe window and the contamination – if the count rate drops noticeably, it is a low energy beta emitter.

Radiation Dose vs. Contamination

One thing to keep in mind when using a pancake probe is that it tells you **nothing** about the dose rate to the whole body. This is due to how the instrument works. If radiation interacts with a gas molecule within the detection chamber, it sets off an ionizing avalanche that creates an electrical pulse signal. The pulse size is the same no matter what the energy of the incident radiation was – if it can penetrate the detector window, it generates a pulse. The instrument is actually counting how frequently the pulses are occurring (thus a count rate). Since dose is defined as energy per mass of something (such as air or tissue), not being able to discern the energy makes it impossible to use the instrument for a dose rate measurement.

If a lab is concerned about the dose rate from their work, waste containers, source storage or from something nearby, DRS can visit and take dose rate measurements with an instrument meant for that purpose.

Liquid Scintillation Counting

Use smears or swipes that will dissolve in the LSC cocktail being used. Smear a reasonably sized area when conducting a smear survey; otherwise, the location of a contaminated smear might be hard to determine. Ensure your LSC is working by using a check source (internal or external radioactive standard). DRS recommends an annual calibration by the manufacturer. Include a blank smear with your set of smears as a background to ensure cross-contamination is not occurring. Be sure to apply a counting efficiency to any positive results (consult user manuals for the specific machine or contact DRS for estimates). Note that erroneous results can occur from chemiluminescence (chemical reactions in the cocktail instead of radiation). This can usually be counteracted by dark-adapting the samples for at least 30 minutes (store them inside the counter with the lid closed).

Selection of Monitoring Method

The chart below shows the recommended monitoring method for nuclides commonly used at NIH. If you are using something not in this chart you can contact your Area Health Physicist for guidance:

Nuclides	For personnel or check for gross lab contamination:	For verifying a lab is not contaminated at the lab limits (end of day or spill surveys)	Notes
H-3, Fe-55, Ni-63	smears	smears	Very low energy beta emitters that cannot be detected by hand-held instruments
C-11, N-13, F-18, P-32, Cl-36, Mn-51, Fe-59, Zn-65, Cu-64, Ga-68, Br-76, Y-86, Y-88, Sr-90, Tc-94m, I-131, Lu-177, Bi-205	Pancake GM probe	Pancake GM probe	High-energy beta or beta/gamma emitters
C-14, P-33, S-35, Ca-45, Cr-51[1], Mn-52[1], Zn-65[1], Ga-67, Se-75, Zr-89[1], I-124[1],	Pancake GM probe	smears	Low energy beta emitters
I-125, I-129	NaI probe or smears	smears	Very low energy x-ray/gammas
Tc-99m, In-111, I-123, Gd-153, Tl-201, Pb-203	Pancake GM probe or NaI probe	smears	Low energy x-ray/gammas
At-211, Pb-212, Bi-213, Ra-223, Ra-224, Ac-225, Ra-226, Th-227, Am-241	ZnS probe	ZnS probe	Alpha emitters; a pancake probe can be used if ZnS meter fails

[1] – **These nuclides emit energetic particles or gammas. However, the percentage of the time they decay this way is small. Thus, when these are detected by a hand-held instrument the contamination level is well above the lab limits.**

Contamination limits are in disintegrations per minute (dpm), whereas hand-held instruments read out in counts per minute (cpm). To get dpm from the cpm value, simply take the cpm and divide by the efficiency of the meter for that nuclide. P32 efficiencies are provided on the calibration sticker. Typical efficiencies are estimated below. For example, 1,000 cpm of P32 would be (divide by 0.25) 4,000 dpm while 1,000 cpm of C14 (divide by 0.05) would be 20,000 dpm.

Estimates of detector efficiencies for selected nuclides:

Nuclides	Detection Efficiency Estimates
H-3, Fe-55, Ni-63	not detectable
Cr-51, Zn-65, Ga-67, Tc-99m, In-111, Tl-201	1-2% (pancake GM)
C-14, P-33, S-35, Ca-45, Mn-52, Zr-89, I-124	5% (pancake GM)
Cu-64, Br-76, Y-86, Lu-177	10-15% (pancake GM)
I-125, I-129	15-20% (NaI probe)
F-18, Ga-68, Tc-94m	20% (pancake GM)
At-211, Pb-212, Bi-213, Ra-223, Ra-224, Ac-225, Ra-226, Th-227, Am-241	20% (ZnS probe)
C-11, N-13, P-32, Cl-36, Mn-51, Sr-90	25% (pancake GM)

The removable contamination limits in NIH laboratories are as follows:

	Beta/gamma emitters	Alpha emitters
Posted area	2,200 dpm/100 cm^2	220 dpm/100 cm^2
Unposted/Unrestricted areas	220 dpm/100 cm^2	22 dpm/100 cm^2

Non-removable contamination is evaluated by DRS on a case by case basis to determine whether further decontamination is necessary.

Shielding

If you are working with high-energy beta emitters, you must use plexiglass shielding (beta shield) to reduce your exposure. If you are using a gamma emitter, DRS will advise on a thickness of lead shielding recommended for keeping exposures ALARA. Never use lead for pure beta emitters like P-32, as doing so produces Bremsstrahlung x-ray radiation from beta particles interacting with dense materials. This creates an exposure hazard where there had been none with plexiglass. If you are working with a high-energy beta-gamma emitter, shield with the heavy plastic first, then lead closest to the worker.

Additional Requirements

If you are working under a DRS protocol or an Animal Study Proposal (ASP), there may be additional job-specific requirements imposed by DRS. Any additional requirement will be communicated to the lab as part of the approval process for these types of procedures.

Collaborating with Outside Entities

Researchers sometimes wish to collaborate with another institution with their research involving radioactive materials. This can involve wanting to send radioactive materials (raw materials, labeled cells, etc.) to another location. There are numerous Department of Transportation (DOT) regulations surrounding the shipment of radioactive materials on public highways. Therefore, DRS must be contacted to ship radioactive materials of any amount to a location outside the boundaries of the main campus, even if it is to another NIH-owned site. DRS will package the item in accordance with DOT requirements and ship it to the intended destination. Note that DRS requests 1 week notice for shipping radioactive items, as it is necessary to do some prep work in advance of the shipment, such as verifying the recipient is licensed to possess the radioactive material.

Radioactive Waste

Minimizing the amount of radioactive waste should be a goal of anyone working with radioactive materials to reduce disposal costs and environmental impact. However, some radioactive waste is inevitable. Some general requirements are delineated below. For more details on a particular type of radioactive waste, see the Radioactive Waste section of the DEP Waste Calendar.

Radioactive waste should be segregated in the following ways:

- Solid vs. Liquid – step cans with a plastic bag are provided for solid wastes and carboys are provided for liquid radioactive waste collections. Step cans should not be overflowing – schedule pickups to prevent this. Never fill the liquid waste carboys past the marked fill line. Except for washing skin contamination off, **NEVER** put liquid radioactive waste down any NIH sink.
- Half-life segregation – all radioactive waste with a half-life greater than 120 days should be kept separate from those with a half-life less than that. Labs may not “decay in storage” any radioactive waste, regardless of how short the half-life is. Have all radioactive waste collected by DRS, who will conduct proper and formalized decay in storage to meet regulatory guidelines for any waste that can be decayed in storage.
- Mixed waste vs. Regular Radwaste – any radioactive waste that contains another hazard (flammable, oxidizer, organic etc.) must be kept separate from radwaste with no other hazards. Consult the waste calendar to ensure your mixed waste is being collected properly based on what your lab is working with.

Radioactive waste containers should be located in a defined area of the lab, with the floor underneath lined with absorbent paper or equivalent. Liquid waste carboys should be inside a secondary spill container. Radioactive waste is subject to the DRS Security Policy and therefore must be locked up within the lab or else the lab door must be locked when unoccupied.

Take care when transferring waste from the work area to the waste container to avoid contaminating the traverse area or the exterior of waste containers.

Disposal Information

Anything that is contaminated with radioactive material that cannot be completely decontaminated must be picked up as radioactive waste. DRS collects radioactive waste on a standing schedule or through ad hoc pickups. Either can be arranged through the AU Portal or by calling 301-496-4451. Note that off-campus locations may only do standing pickups on a specific day of the week. All radioactive waste containers must be labeled with Caution Radioactive Material Tape/Labels and also have a Radioactive Waste Tag completed and attached.

Source Vial Disposal

Empty source vials may be disposed as dry radioactive waste. Unused or partially used vials should be placed in a small cardboard box with its own radioactive waste tag for pick up.

Medical Pathological Waste (MPW) Disposal

General MPW must be double bagged and packaged in MPW boxes. Label the boxes as radioactive material and include a radioactive waste tag, in addition to writing directly on the box the origin of the box.

If storing animal carcasses while awaiting pickup, the MPW boxes must be refrigerated if stored >4 hours and frozen if >24 hours.

Note that some animal facilities may have larger totes for marshalling MPW waste. These are intended for non-radioactive wastes, although the totes are surveyed externally for signs of radiation prior to being sent off campus.

Infectious Materials

Radioactive waste that also contains infectious agents must be inactivated biologically prior to pickup by the Radioactive Waste Service. Note that use of an autoclave on radioactive items has a specific procedure:

- Label the autoclave as radioactive prior to starting
- Two autoclavable bags must be used
- Add 50 mL water to the inner bag and seal each bag separately
- The bags shall be placed in a pan for transport and autoclaving
- Process for at least 60 minutes at 121 degrees C
- After cooling, label the bag(s) as radioactive and attach a radioactive waste tag
- Survey the interior of the autoclave with a portable detector (high energy beta or gamma nuclides) and smears (all cases)
- If the above survey finds no contamination, remove the label affixed in the first step

Sharps Disposal

Use the red puncture resistant containers for needles, syringes or anything sharp. Label the container as radioactive and include a radioactive waste tag.

LSC Vial Disposal

Separate out groups of vials by radionuclide (except H-3 and C-14 may be disposed together) and place in cardboard trays. The tray must be labeled as radioactive material (not each vial) and a radioactive waste tag is required.

Emergencies Involving Radioactive Materials

Despite the best intentions of everyone, accidents do happen in the laboratory involving radioactive materials. Following the proper course of actions following a contamination event will limit the spread of contamination and reduce the likelihood of appreciable exposures from the event.

A spill is simply radioactive material where it is not wanted. When a spill occurs or is discovered, the lab needs to take actions to determine its extent, minimize the spread, ensure others are aware in the lab of the contamination and to get the contamination cleaned up. You **MUST** notify DRS (see notification table below) if any of the following situations arise:

- Anyone is injured or contaminated with radioactive material
- Contamination is found outside posted spaces or in obvious unrestricted areas such as sinks or internal offices
- Greater than 1 mCi of activity is involved
- Greater than 1 liter of radioactive liquid is involved
- The spill area covers more than 10 ft^2 (not necessarily continuous)

DRS is happy to respond to contamination events that do not meet the above criteria.

How to contact DRS for emergencies involving radioactivity -

For fire or serious emergencies, call 911 on campus and 9-911 off-campus			
	On-campus	IRF at Frederick	All other off-campus
Normal working hours (7 a.m. to 5 p.m., Mon-Fri)	301-496-5774	301-631-7226 or 301-496-5774	301-496-5774
Off-hours	911	301-496-5685 and ask for radiation safety assistance	301-496-5685 and ask for radiation safety assistance

Spill Clean-up

In general, lab staff cleans inside their posted spaces and DRS cleans unrestricted areas.

NEVER ask housekeeping staff to assist cleaning radioactive spills and do not borrow their equipment.

When cleaning a spill, wear a lab coat, gloves and shoe covers/booties. Start at the outer edges of the spill and work inward. Minimize the amount of water added to the spill clean-up. Treat all cleaning materials as radioactive waste. Check your gloves and shoe covers for contamination regularly during clean-up operations, limit the movement of people and materials inside/outside the spill area and check all impacted lab staff carefully for contamination. Once you believe the spill is cleaned, monitor the spill area with a hand-held instrument (if appropriate for the nuclide) and follow-up with a smear survey to declare the area contamination free. If you find contamination with the meter that will not come up, notify DRS so that they can confirm the contamination is fixed and evaluate if any further actions (covering for decay, removing floor tile, etc.) are necessary.

During the clean-up be sure to let others in the area know there is a spill and to stay away from the area. Mark the area(s) as best you can.

Skin Contamination

If you find contamination on clothing or PPE, remove the top layer and survey underneath. Bag up any contaminated clothing for decay or disposal as radioactive waste.

If you find contamination on the skin, notify DRS immediately. It is important to get a quantified measurement with the instrument used. If the instrument reads higher than the highest scale you can try the following techniques to get a usable reading:

- Cover the probe with thick paper or plastic, but not so much that it blocks all the beta particles. Once you get a value on the instrument that is not off the highest scale, note what was used to shield the probe for that reading and DRS can figure out the true unshielded value
- If the lab has an exposure rate meter with a window, open the window and measure the skin. DRS can do an experiment later to quantify the amount of contamination

Do not unduly delay decontaminating the skin. Attempt to wash it off in the nearest sink. This is the only exception to the sink disposal prohibition. After wiping/washing, take a new measurement and document. Use gentle methods to remove skin contamination. Keep going until the contamination level no longer drops or if the skin begins to redden. If decontamination continues on damaged skin it could internalize the contamination which is usually a worse result that leaving it on the skin.

DRS may instruct the worker to wear something over any non-removable skin contamination to keep it contained should the contamination start to work its way off the skin. DRS will follow-up the day after to re-check the contamination to see if it is reducing at a faster rate than physical decay. Based on the initial measurements and subsequent follow-up, DRS will calculate an estimated skin dose from the contamination.

If the skin contamination is in the facial area DRS may request the worker undergo a bioassay to verify radioactivity was not inhaled/ingested. DRS may also do some basic field measurements that determine the likelihood of that occurring.

Eye contamination

Immediately flush the eyes with water and notify/report to OMS. Alert DRS who will report to OMS to monitor the contamination.

Medical Emergencies

Life-saving **ALWAYS** takes precedence over contamination issues. If something happens and you would normally dial 911 for emergency response, do that without regard to radiological contamination issues that might be present. Someone in the lab should additionally notify DRS who will perform monitoring of the lab and follow-up with first responders once the emergency is over.

If there is a minor injury involving radioactive material, notify DRS so that they can accompany the worker to OMS who will want to know the contamination status of anyone who visits their clinic.

Other Kinds of Emergencies

For floods or fires in a posted lab, notify DRS when safe to do so. DRS will conduct surveys of the affected area once first responders deem it physically safe to enter. Do not dispose of collected flood water (from a flood event or fire response) without DRS sampling it first.

Lost Material

If you believe a radioactive source vial has gone missing, conduct a thorough search in your lab. Check to see that it wasn't disposed as radioactive waste or in a non-radiological disposal outlet. Check other freezers and storage areas within the lab and check with staff in neighboring labs, as well as asking everyone who is listed on the U/D sheet if they know where it is. Once it is evident the source is missing, notify DRS immediately, as under some circumstances it is necessary to notify the NRC of lost material. DRS will come to the lab and attempt to locate the source vial in addition to verifying it was not picked up as radioactive waste and brought back to Building 21.

DRS Oversight Activities

DRS is obligated by NRC regulations and license commitments to ensure workers, patients and visitors are protected from unnecessary exposure. For workers, this means ensuring contamination and exposure limits are observed and work practices are utilized to minimize exposure from working with ionizing radiation.

Because NIH is a large program with regard to ionizing radiation, DRS relies on its Authorized Users to implement day-to-day oversight within the labs. For procedures that are novel or involve larger potential for exposure, DRS may observe procedures in the lab.

In general DRS conducts its oversight through its comprehensive survey and lab inspection program. While a lab using radioactive material must conduct a survey at least once a day it is used, DRS or its contractors will conduct an unannounced monthly evaluation of all posted rooms and will do a contamination survey regardless if any radioactive material was used during the month. Additionally, all posted spaces and adjacent corridors undergo a comprehensive inspection at least twice a year. In addition to conducting radiation and contamination surveys, a number of other radiation safety inspection items are evaluated, such as use of absorbent paper and PPE, radioactive waste management, radioactive material security and appropriate monitoring is being performed within the lab. The inspection also includes looking at records to ensure DRS requirements are being carried out. Minor findings may be corrected on the spot, with some infractions being followed up by an Area Health Physicist.

Labs with histories of non-compliance or who use larger quantities of high-energy radioactive materials undergo these comprehensive inspections more often.

Annually all AUs undergo a material inventory to reconcile DRS records with what is actually in the lab. Even AUs with no inventory will be visited to ensure source vials are not physically present that may have inadvertently been cleared from an AU's record. Additionally, several aspects of the AU's intersection with DRS will be reviewed to ensure our records are accurate. The AU Audit, a comprehensive look at AUs over the previous 2 years, was discontinued in 2020 and folded into the annual inventory for a much more streamlined process for both the AU and DRS.

Separately, sealed sources of radioactivity are inventoried every 6 months and tested for leakage by DRS in accordance with NRC requirements.

NRC Oversight Activities

As the regulator of most radioactive materials and the issuer of NIH's licenses to possess them, the NRC conducts oversight of how DRS implements and complies with all relevant regulations and license commitments. The NRC conducts unannounced routine inspections on a recurring frequency. During these inspections they immerse themselves in the NIH radiation safety programs. The NRC visits laboratories who use radioactive materials and talks with lab staff to see if they know DRS policies and general radiation safety principles. For procedures with more exposure potential they may observe a procedure or ask lab staff to demonstrate how they comply with policies. They also closely scrutinize DRS' recordkeeping and procedures.

The NRC may also conduct inspections after specific radiation safety incidents that have come to their attention either through DRS notifying them as required or if a radiation worker contacts them directly.

In all cases, if the NRC contacts or visits you, please cooperate with the inspector(s). Answer all questions truthfully to the best of your ability. If you do not know the answer then say so. The penalties for misleading the NRC are very steep, so always be straightforward, even if it means the answer might violate a policy or regulation.

All NRC inspections culminate in a written report that outlines any violations or findings that NIH should address. Severe or repeated violations can result in monetary fines to the NIH or restrictions on NIH's ability to possess radioactive material. Radiation workers have the right to see this inspection report, which is posted publicly in Building 21 or a copy can be requested.

Working with Radioactive Materials in Clinical Applications

The NIH has an extensive clinical program that includes using radioactive materials for diagnostic and therapeutic purposes. The NRC regulates how radioactive materials are used in these contexts in 10 CFR 35, in addition to license commitments.

For any human administration of radioactivity, there must be a Clinical Authorized User (CAU) who has been approved by the NIH RSC in accordance with 10 CFR 35. The CAU then has specific protocols for human administration approved by the RSC as well. The CAU is responsible for prescribing the radioactive dose for specific procedures and the radioactive material is delivered to an RSC-approved radiopharmacist who dispenses the correct amount of radioactivity for the administration. Note that for diagnostic procedures involving I-131 in an amount greater than 1.11 MBq (30 µCi) and **ALL** therapeutic doses of radioactive material, a **written directive** must be completed by the CAU. See the *Therapeutic Procedures* section below for details on the written directive.

Diagnostic Procedures

For diagnostic procedures, small amounts of radioactive material are administered to a patient. After a brief (up to an hour) uptake period, the patient is evaluated on a radiation scanner, then released to go home. The radionuclides used have half-lives ranging from 2 minutes up to a few days. Thus, some patients are still radioactive when they are released from the diagnostic clinic. The exposure hazard to anyone around them is low – NRC regulations require any patient with the potential to give 500 mrem dose to another person must be quarantined at the facility where the administration occurred. Patients who do not meet that standard are allowed to leave. Patients are given instructions on how to minimize exposure to others and to limit contamination in their homes. Radioactive contamination is possible from any form of excretion from the patient (urine, sweat, etc.) and the extent depends upon the radiochemical used and how the body processes it (the same as if the compound were non-radioactive). Pathology samples from diagnostic procedures contain trivial amounts of radioactivity and are not labeled as radioactive. DRS is generally not directly involved in diagnostic administrations, except for ones involving I-131.

Therapeutic Procedures

For therapeutic procedures, larger amounts of radioactive material are administered to a patient, or patients are exposed to high doses of radiation from a radioactive sealed source. DRS is heavily involved in the safety procedures that are followed by the nursing staff in caring for these patients and is frequently present during the administration of radiopharmaceuticals. As with diagnostic procedures, the CAU and the protocols involved are approved by the RSC. For new therapy applications, there must be extensive consultation with DRS well in advance (months) to ensure that NIH is licensed to conduct the intended radiotherapies. Therapies involving sealed sources or external radiation beams from a radioactive source may involve implementation of physical security requirements and significant radiation shielding is likely needed. Amendments to the NIH Broad Scope License generally take 2-6 months and require approval by the RSC and NIH Senior Management to proceed. Additionally, DRS will develop specific safety operating procedures that highly depend upon the specific radionuclide, the location of the therapies and whether the patient must be quarantined for some period of time.

All therapeutic procedures require a written directive. The written directive specifies the nuclide, the amount administered and the route of administration, in addition to other basic information. It must be signed by the CAU in advance of the administration. A written directive can be changed by the CAU as long as it is prior to administration of the radiopharmaceutical. In a medical emergency that threatens the life of the patient, this can be an oral change so long as a written change is done as soon as possible. For new therapies, DRS will work with the CAU on ensuring a written directive template and implementing procedures are in place that comply with 10 CFR 35.40 and 35.41. If an overdose/underdose occurs, the radioactivity was the wrong nuclide/drug, the administration was the wrong method or the wrong person was dosed, DRS must be notified immediately as it will be necessary to evaluate the potential dose consequences to the patient and NRC notification may be required.

If a patient received enough radioactivity to cause someone near them to receive 500 mrem dose if they were sent home, he/she must be quarantined until that is no longer true. Quarantine rooms are restricted for entry to only nursing staff involved in caring for the patient's medical needs. All nursing staff for quarantine therapies receive specific annual training in contamination and exposure control procedures. All objects within the quarantine room are monitored for contamination before release outside the room.

All pathology samples from therapeutic administrations must be labeled as radioactive for the benefit of the staff who process these samples and to ensure they are not inappropriately disposed as non-radioactive.

Once a patient is released from quarantine through DRS survey or other established method, he/she is given instructions on how to minimize contamination and radiation exposure to others. DRS must formally survey and release the quarantine room before general access can be restored.

Radiological Clearances

De-posting a Lab

If a lab no longer needs radioactive materials for storage or use, the Authorized User should initiate the DRS Clearance process. If the lab has not used or stored radioactive materials for 12 months or more, DRS will strongly suggest a clearance. Note that a lab can be reactivated with DRS within 48 hours if needed.

To clear a lab from radiation safety controls, the AU needs to have all radioactive waste and the waste containers moved to another lab that will remain posted or picked up by the Radioactive Waste Service. Any item labeled with Caution Radioactive Material tape must be surveyed by the lab and once shown non-contaminated, the tape must be removed. Alternatively, labeled items can be moved to a lab that will remain posted.

Once all radioactive items are gone, the AU shall conduct a smear survey of the lab to establish it is not contaminated. DRS will then come and conduct a more thorough survey that will take into account whether the lab is being renovated or gutted, and will consider the entire known radiological history of the space. A checklist for the process the AU needs to follow is available.

Note that *only DRS* can remove the door posting for radioactive materials.

Moving Your Lab to Another Building

If you are moving the lab to another building, follow the steps above to inactivate the old space. However, if source vials need to be moved, please contact DRS who will come to the lab, inventory the source vials, store them in Building 21 and deliver them to the new location once it is set up and posted. The lab may move labeled items to the new location (must be posted by DRS) and may move contaminated items (petri dishes, tubes, etc) so long as they are in *double containment* (bag in a box, etc.) to prevent contamination escaping during transit.

Minor Renovations

If a portion of the lab will undergo renovation or repair (e.g. sink replacement, shelf removal, etc.), contact DRS who will survey the portion of the lab involved and post a "partial clearance" sticker which explicitly indicates to construction staff what part of the lab is released for their work. Lab staff should not re-introduce radioactive items into the renovation area until the project is complete.

Clearance of Items and Equipment

Any item that was labeled as contaminated must be surveyed by the lab prior to removing labels and allowing the item to leave a posted space for repair, surplus, etc. This also includes equipment such as a freezer that was used to store radioactive items. Labs conduct these surveys themselves. However, in the case of equipment with complicated internals that were subject to radioactive liquid, it is best to contact DRS for advice on the best way to conduct a meaningful survey.

For releasing fume hoods that were used for volatile radioactivity, contact DRS to conduct a release survey.

For LSCs and gamma counters that have internal sources, DRS must be involved in the clearance process. If a counter is being moved off campus or surplussed, the internal source MUST be removed by a qualified service technician who will formally ship the source to wherever the counter is going. Once the source is removed, DRS will perform a contamination survey of the counter and put a clearance sticker on it. For moving an LSC within the main campus, the source does not have to be removed. However, it is recommended that the lead be removed by a qualified service technician to prevent shifting which can damage the internals of the counter or breach the internal source.

Surplussing radiation-producing devices (x-ray units) requires no DRS involvement other than notifying DRS the unit has been removed from service.

Generally Licensed devices (sniffers, gas chromatographs, etc.) can only be disposed through coordination with DRS to ensure all requirements of 10 CFR 31 are followed. Contact DRS for guidance on how to get rid of these kinds of items.

Housekeeping in a Posted Lab

DRS allows housekeeping in posted spaces. The AU must ensure by surveying that the floor is not contaminated prior to allowing mopping. Additionally, radwaste containers must be moved (plus survey where they were) out of the area being cleaned.

Non-radioactive trash may be removed by housekeeping without specific additional steps. It is very important that radioactive items/trash is never disposed in the regular trash.

Radiological Clearances for Major Renovations

For construction projects that involve substantial structural modifications to a room or series of rooms; gutting entire laboratories, wings of buildings or entire buildings; or converting lab buildings to office buildings, there is substantially more DRS involvement in the process.

Any construction project involving a space that involves or will involve a radiation safety interest gets routed through DRS for review as part of the design phase of the project. DRS then researches the radiological history of the affected spaces to determine how much DRS involvement is required at any stage of the project.

For spaces that DRS determines had a history with long-lived radioactive materials at any point in the past, DRS will conduct additional contamination surveys. Depending on the nature of the project this could be when the lab is emptied, when certain structures are removed, or both. DRS works with the Division of Environmental Protection (DEP) and the Project Officer for the project to make DRS requirements known and coordinate when the project needs to pause for DRS surveys.

DRS surveys generally are 100% surveys of the spaces. However, if the footprint of a project makes it impractical for DRS to conduct 100% surveys in a timely manner relative to the project schedule, the NRC permits a surveying scheme that employs a statistically defensible proportion of survey coverage. At NIH this is accomplished via a MARSSIM (Multi-Agency Radiation Survey and Site Investigation Manual) survey. A contractor (through DEP with DRS consultation) is hired at the expense of the project to perform the MARSSIM survey that will allow free release of the affected area. This survey is done in concert with other environmental clearances (mercury, asbestos, etc.) administered by DEP. Once a final report is produced by the survey contractor, DRS reviews it. For an off-campus space that will be relinquished from NIH control, this report **MUST** be reviewed by the NRC prior to allowing relinquishment. NRC review takes 90 days and they sometimes visit the site to do an independent inspection of the location and the survey process used. DRS recommends building a 6-month time frame for NRC review into any project that in the end will relinquish an off-campus space from NIH control.

For on-campus areas, the NRC reserves the right to inspect the clearance process and report before allowing renovations to begin. Traditionally they have only reviewed on-campus clearances during routine license inspections. However, for large scale renovations or entire building demolitions, the NRC may exercise this right in the future.

Construction and Commissioning New Facilities

New construction or renovation of NIH lab spaces may result in facilities that utilize radiation or radioactivity. Projects where this is clearly the point of the project get routed through DRS as part of the design phase. If the project results in labs working with radioactivity in traditional ways, DRS involvement is generally limited to formally posting the space for radioactive materials once DRS determines it is appropriate to do so.

For projects involving radiation producing devices or Positron Emission Tomography (PET) scanners (animal or human), contact DRS as soon as it is known these devices are part of the project. Shielding evaluations will need to be conducted on the spaces where these types of equipment will be housed.

For projects involving significant quantities of radioactive materials in use all at once (tens of mCi or more), contact DRS as soon as that is known. DRS will need to specify shielding requirements for any transfer lines or hot cells employed to handle large amounts of radioactive materials safely. There may also be exhaust effluent issues to consider. Note that in some cases it may be necessary to obtain RSC approval and/or an amendment to the NRC license.

It is crucial to contact DRS at the earliest stages of project conception to ensure the design will incorporate DRS' requirements. In addition to ensuring regulatory compliance, this prevents potentially delaying the project or incurring costly changes to a project in progress.

Once a new facility involving shielding is completed, DRS will formally commission a facility by taking dose measurements of the first use of the facility to verify shielding is correctly installed.

Appendix A

The Basic Physics of Radioactivity

Radioactivity is the property possessed by a subset of atoms which are unstable (related to neutron-proton ratio) and spontaneously emit various energetic particles in an attempt to reach stability.

For the purposes of radiation safety discussions, an atom has a nucleus containing neutrons and protons (the total of these constitute the atomic mass) and an orbiting cloud of electrons in energy shells. The number of protons dictates what element the atom is, while differing numbers of neutrons affect the stability of the overall atom. Atoms with the same number of protons but different numbers of neutrons are isotopes to one another. The term isotope is often used to mean radioactive but that is not technically accurate – radionuclide is the correct term.

Depending on the ratio of neutrons to protons, a radioactive atom can emit differing particles (called disintegration or decay). For radionuclides commonly used at NIH, the following emitted particles are possible:

- Alpha particles – more common among heavier and man-made nuclides, this is a particle made up of 2 neutrons and 2 protons. Alphas do not penetrate very far in material and are easily shielded by a piece of paper or even the dead layer of skin on the human body. When ingested, however, they are able to impart all of their energy into a small area (handful of cells at most) and are considered to be the most damaging when internalized
- Beta particles – more common among lighter elements, this is an electron being ejected out of the nucleus by virtue of a neutron splitting into a proton and an electron. Beta particles are emitted in a wide array of energies and the higher the energy the deeper it can penetrate materials such as plastics or live skin cells.
- Gamma or X-rays – these often accompany particle emission from atoms. Gamma rays originate in the nucleus whereas x-rays originate from electrons changing shell locations outside the atom. Both can penetrate large distances and can only be attenuated by dense materials.
- Positrons – in some lighter elements, positron decay can occur. A proton within the atom converts into a neutron and emits a positively charged electron. Once emitted it acts like a beta particle until it runs into an electron which annihilate one another and that produces two 511 keV gamma rays that are released 180 degrees from each other. Therefore, positron emitters are a gamma hazard even if gammas are not part of the atom's decay mechanism.

What the above 4 radiation types have in common is that they can ionize atoms they interact with after being emitted from a radioactive atom. Ionization is the process of knocking electrons out of the orbit of an atom. This does not normally make the impacted atom radioactive but instead causes it to behave differently from a chemical standpoint as its electrical charge has been changed. When inside a living cell this can disrupt cell function if enough atoms are ionized or if DNA is damaged.

Another emission from an atom that is possible (common in nuclear fission) but is only present at NIH during cyclotron operations is the neutron. Neutrons cannot directly ionize another atom but instead interact directly with a nucleus to lose its energy until a nucleus absorbs it entirely. Since this changes the neutron to proton ratio in that atom, it may become radioactive and emit any of the 4 radiation types described above. Because of this, neutrons are said to be indirectly ionizing.

Radioactive Decay

Each radionuclide has a unique half-life which is the amount of time it takes for half of the radioactive material to decay. This is a statistical property of a large quantity of radioactive atoms observed over time. The time it takes for any one radioactive atom is not predictable and can be any length of time. The half-life cannot be altered by any known means. Researchers need to take radiological decay into account when procuring radioactive materials for experiments. The amount of radioactivity at any time t is given by the following equation:

$$A = A_0 e^{-\lambda t}$$

Where A_0 is the original amount of material (or a dose rate) and λ is (ln 2/half-life)

Most radionuclides at NIH decay to a non-radioactive atom. Sometimes, though, the progeny (sometimes called daughter) is also radioactive. Depending on the half-lives of the two species of atoms, there are three scenarios possible:

- If the half-life of the parent is long compared to the progeny, secular equilibrium is reached, where the amount of radioactivity of the progeny is the same as the parent and appears to decay at the same half-life as the parent
- If the half-life of the parent is only slightly longer than the progeny, transient equilibrium is reached, where the activity of the progeny builds up to an amount greater than the parent, then decays at the rate of the parent
- If the half-life of the progeny is longer than the parent, no equilibrium is reached and the observed half-life of the progeny is constantly changing until all of the parent has decayed away, leaving the progeny to then decay at its own half-life

Researchers using gamma emitters in the second and third scenarios above have to be cognizant that the dose rate from their radioactivity may *increase* for a time before beginning to decline as one would expect with radioactivity. DRS is available to give more detailed information on any nuclides that behave this way.

Some radionuclides decay through a series of multiple radioactive elements (decay chain) and it gets very complicated to describe what is happening with each of the radionuclides within the chain after a period of time. A common example is household radon, which is in the middle of one of these decay chains. Despite having a half-life of 3.8 days, it is constantly being produced by radioactive parents above it in the chain and therefore never decays out unless the parents (uranium/radium in the ground) are physically removed. An air sample from a basement with radon decays away at the 3.8-day half-life because the uranium/radium sources are not in the air.

Amount of Radioactivity

The quantity of radioactive material is normally described in terms of how many decays/disintegrations are occurring over time. The traditional unit for this is the Curie (Ci) which is defined as 1 gram of Ra-226. 1 gram of Ra-226 (half-life 1600 years) has 3.7E10 decays per second. This is a large amount in terms of radioactivity, despite being a small amount of material in terms of its mass. Because every radionuclide has a different half-life or rate at which it is decaying, 1 Ci of any other nuclide would have a different mass than 1 gram. For example, 1 Ci of C-11 (20 min half-life) is 0.001 micrograms.

The SI unit for radioactivity is the Becquerel (Bq). 1 Bq = 1 disintegration per second (dps) = 60 dpm. Thus, the Bq is a very small unit.

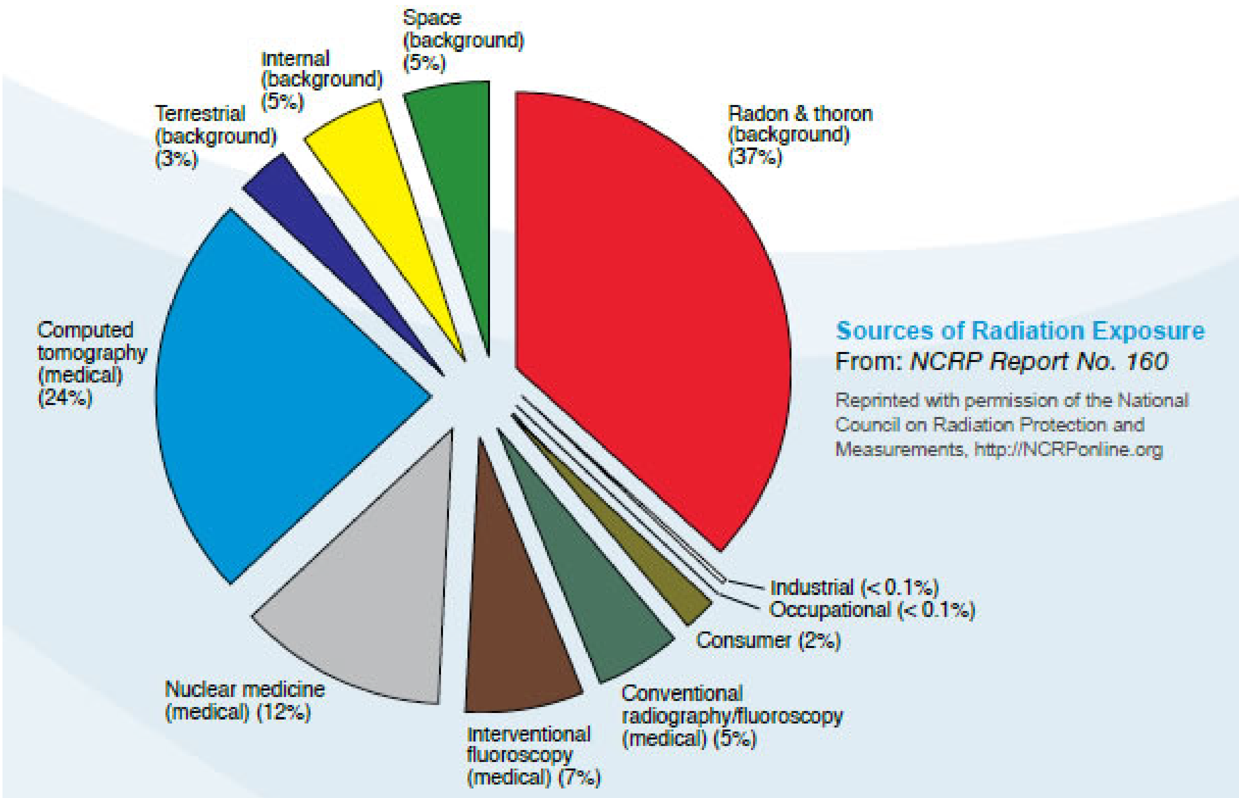
Because the regulations are still mostly using the old Curie-based units, DRS mostly operates with those as opposed to SI units. Typical radioactive benchwork involves microcurie or millicurie amounts. The NIH Cyclotron and associated radiochemists do use Curie amounts of radioactivity.

Background Radiation

Radiation is all around us. The sources of this radiation are naturally occurring – rocks in the earth and cosmic radiation from space contribute a consistent amount of radiation to any particular geographic location. Locations that have a higher concentration of uranium/radium in the ground or are higher in elevation receive more background radiation. For example, Denver CO (lots of granite and high elevation) has a higher background radiation dose rate than Miami FL (not much rock and at sea level). The average for the United States as a whole is roughly 1 mrem per day from background sources.

Regulatory authorities also consider medical radiation to be part of the background, since this source of radiation is not occupational in nature.

NCRP 160 has the most recent analysis of background radiation and combining the medical radiation with the natural background gives an average of 620 mrem per year. Note that this is a population statistic and any one individual's actual exposure from these sources can vary pretty widely. For example, if you have no medical radiation this year, your background exposure will be closer to the 1 mrem/day value. If you received a typical CT scan, your dose total for the year will be closer to 1500 mrem. Almost nobody receives the 620 mrem average value in a year.



Biological Effects of Radiation

The extent to which radiation causes biological effects is dependent upon broad factors such as how much dose was received and over what time frame it was received; age of the individual; radiosensitivity of the cells impacted; and overall health of the individual.

Biological effects from radiation are broadly categorized as being prompt (non-stochastic) and delayed (stochastic). Prompt effects have dose thresholds and are a result of receiving this threshold in a very short period of time. Examples of prompt effects are burns, hair loss, sterility and radiation sickness. For prompt effects, the higher the dose received – the worse the effect will be. The chart below shows some prompt effects and the doses required on average to observe them. Keep in mind that the occupational exposure limit is 5,000 mrem and that 99% of NIH workers do not reach 10% of the limit.

Biological effects at various doses are shown in the two tables below. These dose amounts would need to be received in a short period of time to cause the effect.

Dose (whole body)	Effect
5,000 mrem (occupational limit)	none
10,000 to 50,000 mrem	minor blood changes can be detected
50,000 to 100,000 mrem	blood changes plus appreciable risk of cancer increase
100,000 to 300,000 mrem	nausea/fatigue with drop in red blood cell production (moderate radiation sickness)
300,000 to 500,000 mrem	Nausea/vomiting/diarrhea quickly; 50% fatal with no treatment (severe radiation sickness)
500,000 to 1,200,000 mrem	Death likely even with treatment

Dose (localized)	Effect
300,000 mrem to skin	minor radiation burn threshold
1,000,000+ mrem to skin	major burn including ulceration and necrosis
500,000 mrem to scalp	temporary hair loss
1,000,000 mrem to scalp	permanent hair loss
20,000 to 500,000 mrem to reproductive organs	temporary sterility
500,000 to 1,000,000 mrem to reproductive organs	permanent sterility

The most common examples of delayed effects are cataracts and cancer. For delayed effects, there is no specific dose threshold, but rather the probability of the effect increases with the dose received. Additionally, the severity of the effect is not related to the amount of dose received. Occupational dose limits are designed to limit the increase of probability of these stochastic effects. Although the data is inconclusive for very low exposures, for regulatory purposes the NRC assumes that any exposure has some small increase in the risk for cancer (this mathematical theory is called Linear No-Threshold or LNT). This is the basis for the ALARA philosophy – to avoid exposure when practical to do so. The cancer statistic commonly cited (American Cancer Society) is that in a population of 10,000 people, 25% would be expected to die of cancer from all causes. If they all received 1,000 mrem over a career, then 5 extra people would be expected to die of cancer.

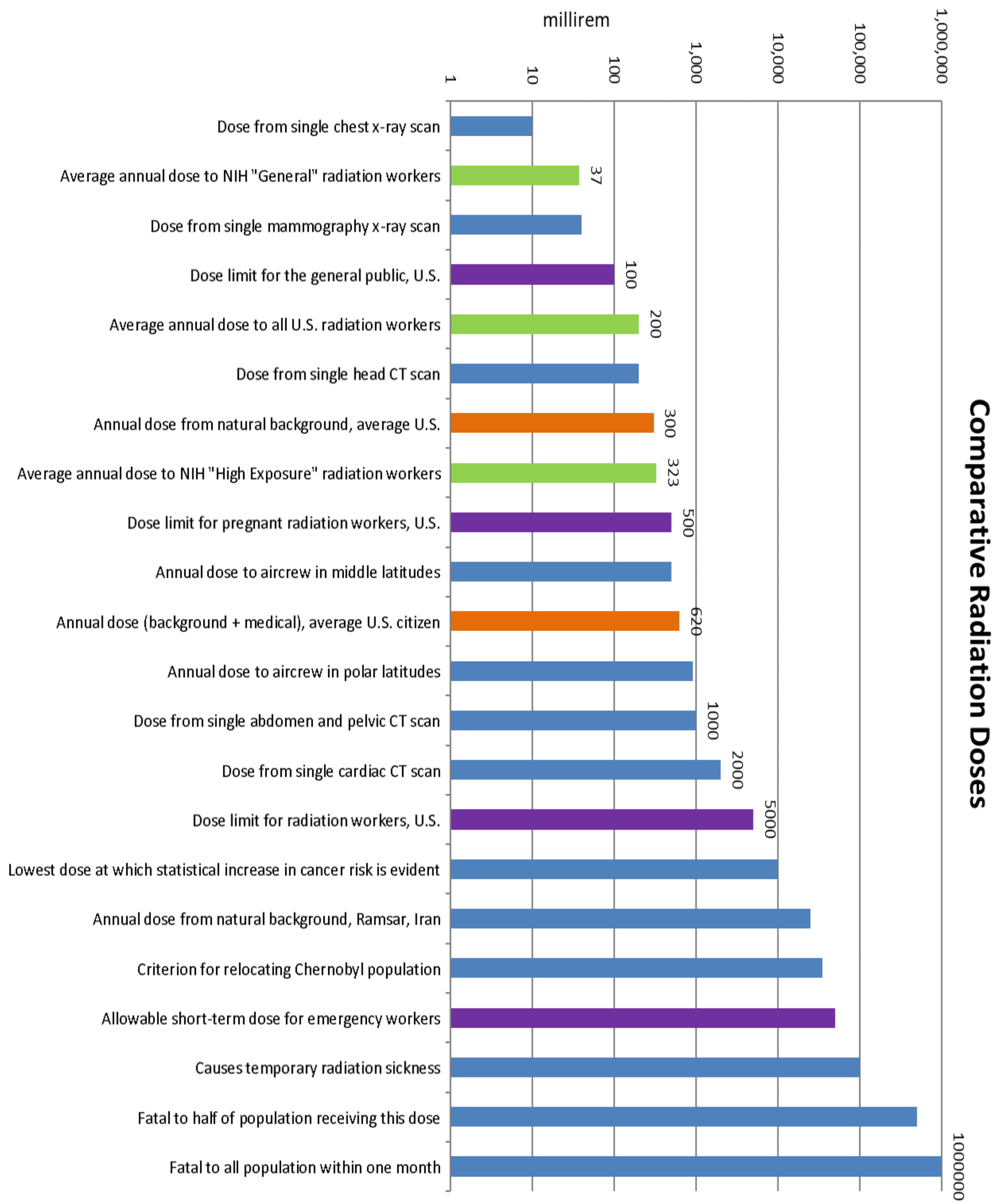
What does radiation actually do within the body? Since it ionizes atoms it interacts with, this changes the electrical charge and therefore how the atom/compound behaves chemically. This creates free radicals within cells which damage cell structures and cell function. Radiation can also break DNA strands in a cell nucleus. If the cell repair works correctly, then there is likely no lasting impact. If the cell repair is imperfect, then the cell may replicate with the wrong DNA sequence and cause a proliferation of incorrect cells which can be harmful. Another potential outcome is cell death at the time of the radiation interaction, which sounds bad but is actually a good outcome so long as it is not happening to too many cells all at once.

The human body has a good mechanism to repair radiation-induced damage. Because of this, therapeutic radiation can be given in higher amounts over a relatively short period of time instead of all at once which could kill a person.

A theoretical delayed effect is genetic – radiation damage to an individual resulting in genetic effects to that individual's offspring. However, this has never been observed in human populations.

Occupational Exposure in Context

The following table shows various activities and the radiation dose that results. Note that occupational exposures are on the low end of the table and that the table is logarithmic and not linear.



Orange represents U.S. background sources

Green represents occupational exposures

Purple represents regulatory limits

Blue represents other (mostly medical) exposures

Source for the non-NIH values: American Nuclear Society and World Nuclear Association

Appendix B

Glossary of Terms Related to Radiation Safety

ALARA: Acronym for ”As Low As Reasonably Achievable”, means making every reasonable effort to maintain exposures to ionizing radiation as far below the dose limits as practical, consistent with the purpose for which the licensed activity is undertaken, taking into account the state of technology, the economics of improvements in relation to state of technology, the economics of improvements in relation to benefits to the public health and safety, and other societal and socioeconomic considerations, and in relation to utilization of nuclear energy and licensed materials in the public interest.

ALI: Acronym for “Annual Limit on Intake”, which is the amount of a radionuclide taken internally that will result in an effective dose of 5,000 mrem (annual occupational limit). These values are prescribed in NRC Regulations – 10 CFR 20, Appendix B.

Bioassay: The determination of kinds, quantities or concentrations and, in some cases, the locations of radioactive material in the human body, whether by direct measurement or by analysis and evaluation of materials excreted or removed from the body.

Curie (Ci): The basic unit of activity. A quantity of any radionuclide that undergoes an average transformation rate of 37 billion transformations per second. One curie is the approximate activity of 1 gram of radium.

Cyclotron: A machine used to accelerate charged atomic particles to high energies by the application of electromagnetic forces. These particles then bombard suitable target materials to produce radioisotopes.

Dosimeter: A wearable detector for measuring and recording the total accumulated exposure to ionizing radiation.

Dpm: (disintegrations per minute) the number of atoms of a radioactive substance decaying (emitting ionizing radiation and changing to another substance) per minute.

Effective Dose: The whole body dose normalized to the radiological impact of a radiation exposure summed over specified tissues/organs exposed. Mathematically it is the product of the equivalent dose in a tissue and the weighting factor for that tissue, summed over all organs. Quantities are recommended by the International Commission on Radiological Protection (ICRP) 103. Tissue weighting factors recommended by ICRP 26 (1977), ICRP 60 (1991), and ICRP 103 (2007) differ in the tissues included and the numerical values of the respective factors.

Generally-Licensed Device: A device containing radioactive material which is typically used to detect, measure, or gauge the thickness, density, level, or chemical composition of various items, or to produce an ionized atmosphere. Examples of such devices are gas chromatographs, static elimination devices, lead paint analyzers, liquid scintillation counters, and ion mobility spectrometers.

Half-Life: The time in which half the atoms of a particular radioactive substance disintegrate to another nuclear form. Measured half-lives vary from millionths of a second to billions of years.

Hot Cell: A heavily shielded enclosure for highly radioactive materials. It may be used for their handling or processing by remote means or for their storage.

Hot Lab: A laboratory specifically designated for use of radioactive materials.

Isotopes: Radionuclides whose nuclei contain the same number of protons (therefore they are the same element), but differing numbers of neutrons.

Ionizing Radiation: Photons or particulate radiation with sufficient energy to break chemical bonds or ionize single atoms.

PET: (Positron Emission Tomography) A computerized radiographic technique that shows metabolic activity occurring in various body organs (e.g. heart or brain). In a PET study, a radioactive substance that emits positively charged electrons (positrons) is injected into or inhaled by the patient, in whom they combine with negatively charged electrons. The resulting gamma radiation is detected and converted into color-coded images.

Radiography: A method of non-destructive testing, using a source of radiation to examine many types of manufactured products (e.g., welds, pipes, concrete, machined parts, and metal components) in order to look for defects in their internal structure and verify their integrity.

Radionuclide: Materials that produce ionizing radiation, such as gamma rays, alpha particles, and beta particles.

Radioactive Material: Any material or combination of materials which spontaneously emits ionizing radiation.

Rem: One of the two standard units, along with the Sievert, used to measure the dose equivalent (or effective dose), an individual receives from a radiation exposure. This measured quantity combines the amount of energy (from any type of ionizing radiation that is deposited in human tissue) with the biological effects of the given type of radiation. One Sievert (Sv) equals 100 rem.

Scintillation: A scintillation detector, sometimes called a scintillator, is a device that emits light when ionizing radiation interacts with the detector. The light is converted into an electrical signal and recorded on a readout device. The amount of light is proportional to the amount of energy deposited, allowing energy discrimination if desired.

Sealed Source: Radioactive material permanently bonded or fixed in a capsule or matrix designed to prevent release or dispersal of the material under the most severe conditions likely to be encountered in normal use and handling.

Source Material: Compounds of uranium and/or thorium, including depleted uranium, that are not regulated by the NRC as byproduct material. Examples include uranyl acetate, uranyl nitrate, thorium nitrate, and thorium citrate. Uranyl acetate is commonly used as a staining technique in electron microscopy and is the most common form of source material at NIH. Though not subject to NRC license requirements, source material must still be disposed of as radioactive waste.

Appendix C

Resources Related to Radiation Safety

Division of Radiation Safety Contacts

- Main Phone Number – 301-496-5774
- Radioactive Waste Service – 301-496-4451
- Radioactive Packages/Shipment Office – 301-496-3277
- Radiation Safety Training Office – 301-496-2255
- Radiation Safety Committee Executive Secretary – 301-496-2253
- Radiation Safety Office at IRF Frederick – 301-631-7226
- DRS Fax – 301-496-3544 or 301-480-9708

Other Contacts

- Chemical Waste – 301-496-4710
- Division of Occupational Health and Safety – 301-496-2960
- NIH Directory Assistance – 301-496-4000

Radiation Safety Resources

- Nuclear Regulatory Commission website – www.nrc.gov
  - Notices, Instructions and Reports to Workers – 10 CFR 19
  - Standards for Protection Against Radiation – 10 CFR 20
  - Medical Use of Byproduct Material – 10 CFR 35
  - Regulatory Guides - Occupational
- OSHA Radiation Standards website – 29 CR 1910.1096