NORTHERN ILLINOIS UNIVERSITY

ENVIRONMENTAL HEALTH & SAFETY

Northern Illinois University
Radiation Safety Manual

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1. Introduction

This document provides basic information on the Radiation Protection program at Northern Illinois University. If there are any questions beyond the scope of this manual, contact the Radiation Safety Officer (RSO). It is the responsibility of the individual to maintain training requirements and to keep personal exposure As Low As Reasonably Achievable (ALARA).

University Radioactive Materials License

Radioactive material is used at Northern Illinois University under the NIU Radioactive Materials License granted by the Illinois Emergency Management Agency, Division of Nuclear Safety (IEMA). This document and the IEMA regulations governing use of radioactive material are located in the Dorland Building room 100. NIU is inspected annually by IEMA to ensure compliance with these regulations and license conditions.

Regulatory Chain

IEMA has direct authority over university activities involving radiation sources. The Radiation Safety Committee (RSC) meets quarterly and is responsible for formulating policies and procedures relating to the use of radioactive material or radiation-producing machines. The RSC also reviews and grants permission for uses of radiation sources on campus.

The Radiation Safety Officer (RSO) is responsible for implementation of these policies and procedures. Some of the services provided by the Radiation Safety Officer include user training, laboratory monitoring, personnel monitoring, package receipts, waste disposal, and emergency response.

The Authorized User is the faculty or staff member who has been granted authorization to use radioactive materials by the RSC. The Authorized User is responsible to ensure that all work performed under his or her permit complies with the terms of that permit, NIU Radiation Safety Procedures and IEMA regulations.

Training Requirements

Radiation Workers are the most important component of a successful radiation safety program. Therefore all users of Radioactive Material, Radiation Producing Machines (X-ray) and most individuals who work in a laboratory where Radioactive Materials is used are required to receive Radiation Safety Training. To meet the training requirement each radiation worker must receive initial training and again annually, not to exceed twelve months, as long as they remain active radiation workers. It is the radiation worker's responsibility to be aware and to maintain training requirements.

Radiation workers are responsible for knowing the terms of their Authorized User's permit as well as NIU Radiation Safety Procedures and IEMA regulations which apply to their work. Each worker is responsible for his or her own safety when using radioactive sources. It is also the responsibility of every individual to report any conditions which may cause or constitute a violation of regulation, policies, procedure, Authorized User Permit, or the University's license.

2. Radiation Protection Fundamentals

Sources of Ionizing Radiation

Sources of ionizing radiation may be either natural or man-made. Some examples of natural sources are naturally occurring uranium, radium, and thorium in soil; radon in air, potassium-40 and carbon-14 in plants and animals, and cosmic radiation from the sun. Examples of man-made radioactive sources would be radiopharmaceuticals and X-rays used in medical treatments, sources manufactured for use in research, and various radionuclides that form nuclear fallout. These sources combined are known as "background radiation" and give the average person in the United States 360 mRem per year of radiation exposure.

Radioactive sources are unstable and undergo **radioactive decay.** Radioactive decay is a process by which an unstable element releases energy in the form of gamma or X-ray energy or particles such as alphas, betas, or neutrons in order to transform into a stable element. These particles or rays interact with other atoms to create **ion pairs** (an electron and a positively charged nucleus). This is called **ionization** and can rupture bonds in DNA causing strand breaks and other damage.

Each radionuclide has own distinct **half-life**. A half-life is defined as the time it takes for a radioactive substance to lose 50% of its activity through radioactive decay. Activity of any radionuclide is reduced to less than 1% of its original activity after 7 half-lives and is effectively decayed away after ten half-lives.

Type of Ionizing Radiation

There are four major types of ionizing radiation which interact with matter in different ways.

1. Alpha Particles

Alpha particles are basically a helium nucleus – two neutrons and two protons. Due to their large mass and charge of +2, alphas travel only very short distances in air. They can be shielded with a piece of paper or the outer layer of skin. Alpha particles are not considered to be an external radiation hazard. When inhaled or ingested they deposit all their energy in a small area, which makes them the most hazardous type of radiation for internal exposure.

2. Beta Particles

Beta particles are actually high-speed electrons. Beta particles have the mass of an electron and a charge of -1, with a range in air of about 10 feet. Betas are ejected in a wide range of energies. Betas with energies above 70 Kev can penetrate the dead layer of skin and will deliver a dose to the live skin beneath. The lens of the eyes should be shielded with safety glasses when working with beta emitters such as H-3, C-14, P-32, and S-35.

Another hazard of beta emissions is "bremsstrahlung", or "braking radiation". This occurs when betas with energies greater than 1Mev (such as those emitted by P-32) interact with dense shielding material (such as lead) creating X-rays. In order to reduce the likelihood of bremsstrahlung radiation, beta emitters should **only** be shielded with low-density materials such as Plexiglass.

Beta particles are also an internal hazard due to their mass and charge. Care should be taken to reduce the likelihood of ingestion or inhalation.

3. Gamma and X-rays

Gamma and X-rays are pure energy. Since they have no mass or charge they expend their energy over the path of travel in air or human tissue. The range in air of gamma and X-rays is theoretically infinite. This makes gamma and X-radiation more an external hazard than an internal hazard. One notable exception to this is gamma radiation emitted from iodine-125. Since iodine collects in the thyroid, the low energy gamma emitted can intensely irradiate the thyroid tissue in a small area. Special precautions must be taken when using I-125 to prevent inhalation. Gamma emitters are best shielded with high-density material such a lead.

4. Neutrons

Neutron, like gamma and X-rays, are very penetration radiation. Neutrons are emitted from certain nuclei (notably Pu-238) after the absorption of high energy particles from another radionuclide such as Be-9. Neutrons are mainly an external hazard. When exposed to a neutron beam some materials may become activated and thus become a source of radiation. Low density materials such as paraffin, water, and plastic are used to shield neutrons.

There are no sources of neutron radiation at NIU.

Routes of Entry

The most common routes of entry for radionuclides into the body are by **inhalation, ingestion, or absorption. Inhalation** of radioactive materials is possible when using techniques which can cause radioactive material to become airborne. Lab procedures such a centrifugation and shaker baths may produce aerosols while certain isotopes of iodine can volatilize quickly. Therefore use of fume hoods is required. **Ingestion** is the most likely route for internal contamination. For this reason food and drink is not allowed in radioactive material work areas. Radioactive material may also enter the bloodstream directly via wounds or, in the case of H-3, by **absorption** through the skin. Risk of ingestion and absorption is significantly reduced by the use of gloves and lab coats.

External Exposure Control Techniques

There are three techniques by which an individual may reduce exposure from external sources of radiation. These are commonly termed together as “time, distance, and shielding.”

1. **Time** – the less time spent near a radiation source, the less exposure is received.

2. **Distance** – exposure rate from a source of radiation drops off exponentially the more distance achieved. The more distance between you and the source, the less exposure.

3. **Shielding** – the more shielding placed between an individual and the source of radiation, the less exposure. Plexiglas (C-14, P-32, S-35) and lead (I-135) shielding should be used whenever possible.

Units of Measurement

Radiation exposure is measured in units of rem or millirem (mrem). 1000 mrem equals 1 rem. Average exposure at NIU is less than 100 mrem per year.

Federal Exposure Limits

To prevent damage to an individual from exposure to ionizing radiation, limits are set for individual occupational exposure. These limits are derived from epidemiological and laboratory studies of the effects of ionizing radiation on the human body. The federal government outlines these limits for occupational exposure:

5 rem/yr to the whole body (head, trunk gonads, and major blood forming organs)

15 rem/yr to the lens of the eye

50 rem/yr to the extremities (arms below the elbow, legs below the knees)

The federal government has also set a limit of **500 mrem for the term of the pregnancy** for the developing fetus. The woman should notify the Radiation Safety Officer, in writing, of the pregnancy after which the dose to the fetus will be kept to no more than 500 mrem for the term of the pregnancy. If the woman chooses not to notify the RSO of her pregnancy the limit would be the same as an adult worker. Studies have shown that the fetus is more sensitive to the effects of radiation than an adult, especially 8 to 15 weeks post-conception. However, exposures to low levels of radiation present an extremely low risk when compared with the spontaneous rate of prenatal death and congenital malformation.

There is also a limit of **500 mrem/yr** for the general public. The general public is defined as minors and all persons who do not work with radioactive materials.

3. Biological Effects of Radiation

There are two types of exposures an individual could receive when working with radioactive sources. **Acute exposure** is defined as a large amount of radiation (rem) received in a short period of time, usually seconds. **Chronic exposure** refers to small amounts (mrem) received over an extended period of time. Exposure received occupationally at NIU is chronic exposure.

Cell radio-sensitivity plays an important role in determining the effect a dose of radiation will produce. Cells which are most radio-sensitive are rapidly developing, simple cells such as white blood cells, cells lining the small intestine, and cells present in the developing fetus. Complex cells such as those found in the central nervous system are less radio-sensitive.

As with use of any potentially hazardous material, proper planning and use of protective equipment will reduce risk when working with Radioactive Material or Radiation Producing Machines.

4. Instrumentation and Surveying

Radiation detecting instrumentation varies. At NIU the detectors most commonly used are **Geiger-Mueller (GM)** and **scintillation** detectors. The basic detection principle involves measuring the number of reactions produced in a detector via interaction with energy or particles emitted by radioactive material.

In order to reduce both internal and external exposure to lab personnel it is necessary to monitor labs frequently for radiation and contamination levels. This is accomplished by using two techniques, direct frisking and wipe testing. Direct frisking is accomplished by moving a detector slowly across the surface of the material to be monitored and watching for an increase in the count rate. Wipe testing is performed by wiping a small ($100cm^2$) area with a cotton swab or kimwipe and counting the activity on the wipe with either a GM detector or a scintillation counter.

GM detectors readily detect beta and gamma radiation in higher energy ranges. GM detectors are best used when monitoring for C-14, P-32, or S-35 contamination. GM detectors are not suited for monitoring for H-3 or Ni-63 contamination due to the low energy of the beta emitted. Monitoring for H-3 contamination is accomplished by using liquid scintillation. Special gamma counters which are more efficient for low-energy gamma are preferred when monitoring for I-125 contamination.

Laboratory survey instruments are calibrated yearly by the Radiation Safety Staff. Instruments which are past the calibration due date must not be used for documenting surveys.

5. Personnel Monitoring

Personnel monitoring is accomplished by using thermoluminescent dosimetry (TLDs) or bioassay. TLDs are small crystals encased in plastic which should be worn between the neck and the waist when working with high-energy beta or gamma emitters. When the crystals are exposed to heat in a special chamber they emit light which corresponds to the amount of radiation received by the wearer. Ring badges also include a TLD crystal and measure the amount of radiation received to the hands.

Should an individual work with significant amounts of radioactive materials or an intake is suspected, bioassay may be required. Bioassay is a process where the amount of radioactive material deposited in the body is measured and the exposure to the individual is calculated. This is done by either counting the thyroid directly (for iodine) or by counting urine samples (H-3 and other radionuclides).

Personnel monitoring records are kept in the Radiation Safety Office and reports are furnished yearly to the individuals monitored.

6. Identification of Radioactive Material Areas

All labs where radioactive material is used must be posted on the outer door with a “Caution-Radioactive Material” sign with the three-bladed, yellow and magenta radiation symbol.

Radioactive material labs are divided into **red, yellow** and **green zones.** These zones are clearly outlined with tape on the bench top surfaces or on the floor. Tape surrounding a red zone is 1” yellow and magenta tape with radiation symbols. Green and yellow 1” nylon tape is affixed to floors and cabinets by Radiation Safety personnel to outline the corresponding zones. These zones are discussed in detail in section nine (9) of this manual.

7. General Rules for the Safe Use of Radioactive Material

1. Wear lab coats or other protective clothing at all times in areas where radioactive material is used.
2. Wear disposable gloves at all times while handling radioactive material.
3. Monitor hands, shoes, clothing, and work surfaces with a low-level GM survey instrument (if appropriate for radionuclides in use) for contamination after each use of radioactive material or before leaving the restricted area.
4. Do not eat, drink, chew gum, smoke, or apply cosmetics in any area where radioactive material is stored or used.
5. Do not store food, drink, or personal items in any area where radioactive material is stored or used.
6. Secure all areas where radionuclides are used or stored when unattended. This may be accomplished by locking the laboratory door and/or the radioactive material storage area.
7. Wear whole-body personnel monitoring devices (TLDs) at all times while in areas where radioactive material is used or stored if required by license conditions. These must be worn at chest or waist level where the highest exposure is expected.
8. Finger TLD ring badges must be turned inward toward the material being handled.
9. Dispose of radioactive waste only in specially labeled receptacles.
10. Label and store radioactive materials correctly.
11. Never pipette by mouth.
12. Confine radioactive solutions in covered containers plainly identified and labeled with the name of the compound, radionuclide, date, activity, and radiation level if applicable.
13. Always transport radioactive material in shielded containers with sufficient absorbent material.
14. Use absorbent material on countertops where radioactive material is used.
15. Use suitable ventilation systems when handling gases or volatile material.

8. Waste Disposal

Dry Waste

It is the Authorized User's responsibility to notify Radiation Safety personnel for waste pick-up. At the time of pick-up the User should provide the signed inventory control forms with usage and estimated disposal amounts for liquid and dry waste listed.

1. Waste must be double bagged.
2. Sharp objects should be boxed or padded.
3. Biohazardous material must be treated to render the substance harmless before waste is picked up.
4. All radioactive labels must be removed or defaced prior to placing in waste.
5. Free standing liquid or liquid-filled containers must be decanted or absorbed before placing into dry waste.
6. Liquid waste containers must contain only aqueous waste, no chemicals which are not water soluble.
7. Hazardous chemical and biohazardous materials are unacceptable.

Sewer Disposal

Small (uCi) amounts of **aqueous** liquids (no solids, suspensions, or organics) may be disposed of via sanitary sewer.

1. Disposal must be done in a designated sink.
2. Exercise caution when pouring liquid so that adjacent areas are not splashed and inadvertently contaminated.
3. Thoroughly rinse the sink before, during, and after disposal (let water run for 15 minutes after disposal).
4. Disposal in excess of 200 uCi per week must receive approval by the RSO.
5. Solutions containing radioactive material must be diluted with water so that their concentration meets the amounts in the table below:

Radionuclide	**Maximum Concentration in uCi/gal**
H-3	378
C-14	75
S-35	7.5
I-125	0.15
P-32	1.9

6. Disposal of radionuclides not listed must receive prior approve from the RSO.
7. Generation of radioactive mixed waste (radioactive hazardous waste subject to RCRA) is unacceptable.

9. <u>Survey Procedures</u>

Whenever unsealed radioactive materials are handled it is possible to contaminate laboratory benches, floors, and equipment. Contamination is defined as radioactive material in an undesirable location. Undetected and unchecked it can result in personnel contamination (internal or external) and interfere with experiments being performed in the laboratory.

Surveys **must be performed and documented** each day that radioactive material is handled. The purpose of this document it to provide guidelines and techniques for laboratory personnel conducting laboratory contamination surveys.

A **<u>Red Zone</u>** is a dedicated radioactive material work area, usually a benchtop or a hood. Red Zone boundaries will be labeled clearly. Red Zones will contain shielding appropriate for the radionuclide in use. All portable radioactive materials in a Red Zone must be labeled.

A **<u>Yellow Zone</u>** is a "buffer area" surrounding a Red Zone. It is not designated a radioactive material work area but transient radioactive material work bay be performed in a Yellow Zone. Work areas in Yellow Zones must be surveyed at the end of these experiments. Contamination is indicated by direct frisk or wipe test results above action limits. Contaminated surfaces in Yellow Zones must be decontaminated and noted on the survey log. Contaminated equipment in Yellow Zones must either be decontaminated or labeled and placed in a Red Zone behind appropriate shielding. Radioactive material must <u>not</u> be left unattended in a yellow Zone.

A **<u>Green Zone</u>** is a designated "clean" area in which <u>no radioactive material is allowed</u>. Contamination in Green Zones is indicated by any reading above background levels. If contamination is detected in a Green Zone, decontaminate immediately and contact Radiation Safety.

There are two types of contamination surveys:

1. <u>Direct Frisking</u> – this method is preferred for work with P-32, S-35, C-14, and I-125. for P-32 and S-35, use a GM pancake or end-window probe. For I-125 use a NaI end window probe. Hold the probe ½ inch from the surface to be monitored and move it slowly (1/2 inch per second) back and forth, watching the meter face for an increase in count rate. Direct frisk surveys must be performed with the end cap <u>off</u>.

2. <u>Wet wipe Testing</u> – this method is preferred for with H-3. Dampen absorbent material (such as kimwipe, filter paper, or cotton swab) and wipe it over the surface to be monitored. Count in liquid scintillation counter.

3. <u>Dry Wipe Testing</u> (Smear) – this method is used for finding smearable or removable dry contamination. Wipe an area of approximately 100 cm^2 and count using a GM probe.

Areas should be monitored for contamination include (but are not limited to) benchtops and absorbent bench paper, floors, refrigerator/freezer handles, sinks, microfuges, shielding, and equipment that has been in contact with radioactive material.

<u>If you find results above these action amounts (Action Limits)</u>:

<u>Direct Frisk</u> – 100 counts per minute above background for S-35 and P-32 with a GM detector. 500 counts per minute above background for I-125 with a NaI detector.

<u>Wipe Test</u> – 220 disintegrations per minute – all radionuclides.

<u>Then</u>

Decontaminate the area in which the contamination was found with damp toweling or decon solution. If contamination is spread over a large area, call the Radiation Safety Officer at 753-1093 and follow the steps outlined in the Emergency Procedures under "Decontamination of laboratory and Work Areas." Monitor the area after each attempt. When follow-up survey indicates that contamination levers are below action limits, you must <u>document these results</u> on the survey log sheet.

Document your survey by recording survey results on the User Laboratory Survey Log.

1. Enter the date (include the year), print your name, and sign your initials. Indicate whether you performed a direct frisk or a wipe survey.
2. For the Red Zone column, enter the highest net counts per minute found and mark the location. Indicate any corrective actions taken in the comments section.
3. In the yellow Zone column, indicate whether net cpm exceeded Action Limits. If yes, indicate corrective action taken to decontaminate the area in the comments section. When the area has been decontaminated and net cpm are below action limits, initial the space by "Follow-up survey indicates net cpm below Action Limits."
4. In the Green Zone column, indicate corrective actions taken in the event of counts per minute found above background levels.

Log sheet will be reviewed periodically by the Radiation Safety officer.

10. Decontamination Procedures

In each of the instances below, notify the Radiation Safety Officer as soon a possible. Explain the extent and cause of the contamination and follow any special instruction in addition to the steps outlined below.

Decontamination of Laboratory and Work Areas

1. Put on protective clothing such as lab coat, gloves and shoe covers.
2. Survey the area to determine the extent of the contamination, and mark the contaminated area clearly with tape or rope.
3. Monitor workers and adjacent "clean" areas periodically during cleanup to ensure contamination is not being spread. Monitoring should be performed by a person not involved with the cleanup process to avoid cross contamination of the instrument.
4. Spilled radioactive material should be soaked up with absorbent paper, if liquid, and scooped up carefully with dampened paper if it is a dry material. Use long-handled tongs or forceps if possible when handling high-activity paper toweling.
5. Dampen the contaminated area with a soapy water solution.
6. Begin wiping from the outer edges of the affected area inward with dampened paper towels.
7. Resurvey the area and personnel frequently to determine the effectiveness of decontamination efforts. Personnel should be free of contamination before moving into uncontaminated areas.
8. Discard all toweling, gloves, and shoe covers in the radioactive waste container. Survey lab coats with GM probe for contamination. If contamination is found, bag these separately for washing or decay.
9. Once the affected area is determined to be free of contamination, perform a wipe test survey in the entire room to ensure no contamination was spread.
10. Record survey results.

Personnel Decontamination

Special care should be taken when decontaminating skin. Avoid using decontamination methods that could spread contamination or cause contamination to absorb into the body.

- DO NOT cause abrasion of the skin by scrubbing too hard. This could cause contamination to enter the bloodstream through breaks in the skin.
- DO NOT use highly alkaline soaps. These may cause fixation of the contaminant. Use a mild detergent.
- DO NOT use organic solvents such as alcohol. These may increase the skin's absorption of contaminants.
- DO NOT use hot water. This causes pores to open, trapping contamination in the skin. Use lukewarm water.

Survey the skin surface with a survey meter, preferably a detector with a thin-window GM tube probe. Make sure the skin is dry, as even a thin layer of water can shield some radiation and give erroneous results.

Skin and Hand Decontamination

1. Wet hands under lukewarm water. Lather gently with mild detergent.
2. Work lather into affected area for at least 3 minute, wetting frequently.
3. Rinse thoroughly with lukewarm water. Avoid contacting unaffected areas with potentially contaminated rinse water.
4. Dry skin with paper towels and resurvey. Toweling used to dry the skin should considered radioactive waste and disposed of accordingly.
5. Repeat steps 1-4 until survey shows no activity above background.
6. In the event of contamination distributed over the whole body, attend to any areas of localized high activity first. If resurvey still shows distributed contamination, a shower may be necessary.

Wound Decontamination

1. Wounds should be decontaminated under the supervision of a physician whenever possible.
2. Irrigate wounds profusely with lukewarm or tepid water.
3. Clean gently with a cotton swab, still under running water.
4. Gently lather the area with mild soap and water. Rinse well.
5. Dry and resurvey until the meter registers no activity above background.
6. Repeat steps 2-5 as necessary. If after several washings and rinsing, the wound still registers contamination on a survey meter, scrub gently with a soft brush under running water after lathering and rinsing, and continue with step 5.

11. Emergency Procedures

Significant Spills Constituting No Radiation Hazard to Personnel

1. Confine the spill immediately be covering it with paper towels or other absorbent material. If the spilled material is in powder form, cover it with dampened paper towels.
2. Warn personnel in the area that a spill has occurred and inform them which areas to avoid.
3. **Call the RSO at: 753-1093 (Office) 815-761-5316 (Cell)**
4. Monitor all individuals involved for contamination, especially their shoes, to prevent spreading contamination throughout the lab.
5. Contaminated articles of clothing should be removed as soon as practical and bagged for decontamination.
6. Visibly identify the suspected contaminated area (mark the floor with tape or string a rope around the area, etc.) and guard it to prevent inadvertent entry.
7. Keep the number of personnel involved in the clean-up to a minimum. All personnel should wear appropriate protective clothing (lab coat, gloves, etc.)
8. Perform decontamination under direction of the RSO or designee.
9. Begin cleaning with dampened paper towels or absorbent material working from the outer edges toward the center.
10. Resurvey and clean any area remaining above action levels.
11. Repeat the above action until surveys indicate that the area is below all action levels.
12. Bag all contaminated materials and dispose of a radioactive waste.

Major Spill Involving Radiation Hazard to Personnel

1. Without risking further hazard to yourself, control the spill if possible to prevent further spread of contamination.
2. Clear the area of all personnel
3. Retreat to a safe area. Block access to the spill area or close the room and lock the door.
4. **Call the RSO at 753-1093 (Office) 815-761-5316 (Cell).**
5. Seek medical attention for personnel injuries. First aid should take priority over the risk of personnel contamination.
6. Monitor individuals for contamination as soon as possible after medical attention has been given.
7. Control access to the area to avoid contamination of personnel. Anyone entering the spill area should be monitored for contamination and decontaminated before leaving the area.

   Anyone involved in decontamination of personnel should wear appropriate protective clothing (lab coats, gloves, etc.).

   Wash contaminated skin gently with mild soap and lukewarm water. Avoid irritation or abrasion of the skin surface.

   Special attention should be given to open wounds and contamination around the nose, mouth, and eyes. Rinse these areas for several minutes under lukewarm, running water.

   Remove contaminated articles of clothing and place them in plastic bags. Decontaminate when practical.

8. Decontamination of laboratory and work areas should only be attempted under direction of the RSO or designee.

Accidents Involving Airborne Radioactivity

1. Take action to stop the release of airborne radioactive material from the source, taking care to avoid breathing high concentration of the contaminant. DO NOT risk injury to perform this action.
2. Turn off all ventilation and hoods.
3. Evacuate all personnel from the area and secure access to the room. Make sure doors are closed and locked at all points of entry.
4. **Call the RSO at 753-1093 (Office) 815-761-5316 (Cell).**
5. Proceed as with any major spill (step 5 above)

RSO Emergency Contact:

Office: 753-1093
Cell: 815-761-5316