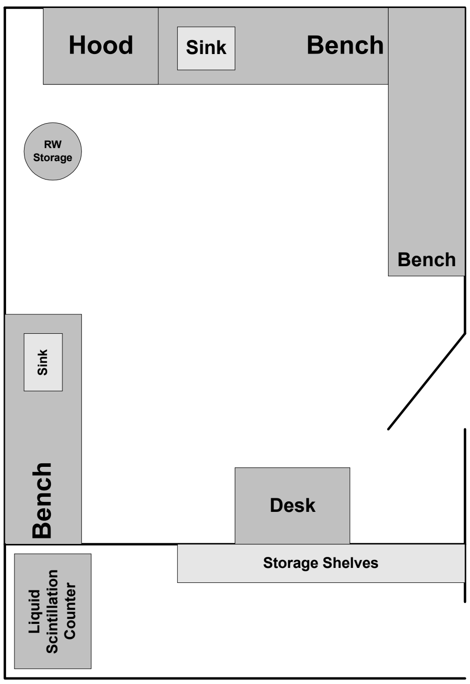
CHAPTER 9 - RADIOISOTOPE LABORATORY

Introduction: Proper use of equipment, techniques and procedures allow the use of radioisotopes with minimal exposure to you and without extensive contamination of facilities and equipment. This chapter discusses the components of a sound radiation protection program for your radioisotope laboratory.

Laboratory: For this discussion, we will assume that you have been assigned to work in the laboratory shown in the drawing. Before it was converted to radioisotope use, it was a conventional chemical laboratory with an adjacent storage room. The URI Radiation Safety Committee has licensed it as a Radioisotope Laboratory. When it was licensed it had adequate ventilation, a working fume hood, and polished, easily cleaned non-absorbing surfaces.



The adjacent storage room was also licensed as a counting laboratory. When it was licensed it had adequate ventilation and easily cleaned non-absorbing surfaces. It has been equipped with a liquid scintillation counter.

Samples are drawn in the hood and prepared on the adjacent bench. Radioactive wastes are collected in the container adjacent to the fume hood. Contaminated glassware is washed in the sink next to the fume hood. Counting samples are prepared on the bench on the right side of the laboratory and taken to the count room for counting. The remaining bench, sink and desk are used for non-radioactive work.

Hood: Before beginning your work, check the hood to ensure that it is working properly. Fume hoods should have ventilation rates between 100 to 125 linear feet per minute at 15 inches sash height. The Radiation Safety Office checks flow rates. Fume hoods should be rechecked annually.

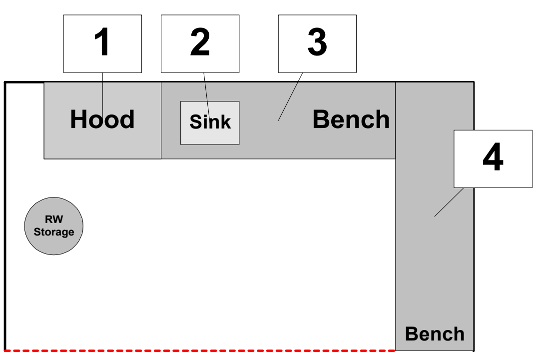
Marking: All radioactive materials use areas, equipment and storage containers must be marked the radiation symbol. Failure to mark radioactive materials with the radiation symbol is the most common cause of the spread of contamination. Check to ensure that the entrances to the radioisotope laboratory and count room have been posted with a "Caution – Radioactive Materials" sign.

Proper Attire: The routine use of proper laboratory attire can prevent contamination of your skin or personal clothing. Proper attire is required if there is a possibility of contamination (such as when handling or in the vicinity of someone handling radioactive materials). You should wear the following whenever you are handling radioactive materials:

1. A laboratory coat with sleeves long enough to cover the arms to the wrists, and long enough to cover the torso to the thighs should be worn. You should wear it with the closures fastened.
2. Eye protection should be worn to protect the eyes from splashes of radioactive and other hazardous materials.
3. Closed-toed shoes, long pants or a long dress should be worn to protect the feet and legs from splashes.
4. Disposable gloves should be worn to protect the skin of the hands and wrists from contamination. Gloves are most effective if two pairs are worn at a time, with the outer pair changed frequently.

Radioisotopes: Safety summaries for individual radioisotopes are provided in the Appendix.

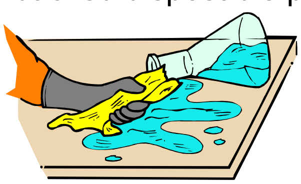
Contamination: In any radioisotope laboratory, you should separate work areas into potentially contaminated and uncontaminated areas and maintain a clear distinction between the two areas. In this example, the hood and adjacent bench and sink areas have been set aside as potentially contaminated areas. The reminder of the radioisotope laboratory and the count room are maintained as uncontaminated areas.



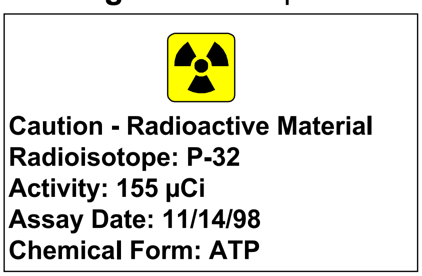
The potentially contaminated area includes (1) the hood, (2) the "hot" sink, (3) the "hot" bench, (4) the counting sample preparation area, and the adjacent floor areas. These areas are basic radioisotope work areas. Except for counting samples, radioactive materials are exclusively stored and handled within this area. Restricting the use of radioactive materials to these areas minimizes the spread of contamination within the laboratory, minimizes radiological control requirements, and allows other activities to occur in the non-contaminated areas.

There are two types of radioactive contamination – fixed and removable. Removable contamination is contamination deposited on the surface of structures, areas, objects or personnel that can readily be picked up or wiped up by physical or mechanical means during the course of a survey or during decontamination efforts. Fixed contamination is contamination adhering to the surface of structures, areas, objects or personnel not readily picked up or wiped up by physical or mechanical means during the course of a survey or during decontamination efforts.

Bench Coverings and Containment Trays: You should cover the bench and other work areas with absorbent coverings to confine contamination. Use plastic backed disposable paper taped in place with the plastic side down. You should also place trays lined with plastic-backed absorbent material in the hood, on the "hot" bench and counting sample preparation area, and under the radioactive waste container. These shallow trays contain spilled radioactive materials. Label the trays and absorbent materials with "Caution – Radioactive Materials" stickers or tape. Replace the covering whenever it becomes damaged (worn, soiled, or torn) or contaminated.



Labeling: Each sample vial or other radioactive materials bearing container should be labeled with the radiation symbol, name of the radioisotope, its activity, when the activity was determined and the chemical form of the material. Unlabeled sample containers have been removed from radioisotope laboratories. Failure to label radioactive waste containers has led to radioactive materials being picked up by janitors and thrown into the trash.



Double Containment: If you are storing radioactive materials bearing liquids, you should use secondary containers of sufficient volume to contain all of the liquid should a spill occur.

Liquid Waste Storage Cans: These cans should be used to store liquid radioactive waste bottles. The cans are available through laboratory equipment suppliers.

Transport Containers: These containers are usually deep plastic trays with snap fitting lids. The containers are used to double contain radioactive materials being transported between laboratories.

Disposable Items: You should use disposable plastic pipette tips, petri dishes, centrifuge tubes, etc. This routine practice prevents the need for decontamination of glassware.

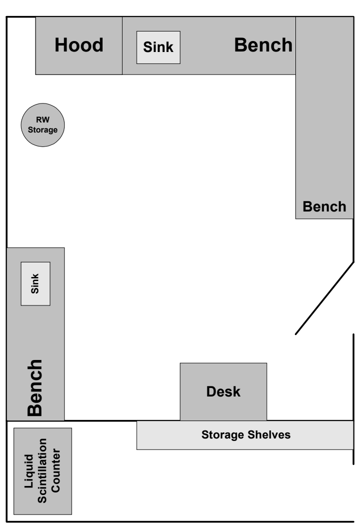
Appropriate Handling Tools: Handling tools serve dual purposes, reducing hand contamination while reducing extremity dose (includes tweezers, forceps, tongs, and shielded containers).

Personal Habits: You should refrain from any eating, drinking, smoking and use of cosmetics in areas where radioactive materials are used or stored. Foodstuffs cannot be stored in refrigerators or freezers used for radioactive materials storage. The best practice is to isolate food storage areas from radioactive materials storage and use areas. Separate the areas by physical barriers.

Surveys: A survey is an evaluation of the hazards due to the presence of radiation and/or radioactivity under a given set of circumstances. Users shall perform contamination surveys and document the results in appropriate units for all areas where radioactive materials are used or stored under their supervision. Radioactive contamination is deposition of radioactive material in any place where it is not desired, and particularly in any place where its presence may be harmful. The harm caused may be excessive exposure to personnel or damage to the validity of an experiment or a procedure.

Frequency: Weekly surveys should be performed in all laboratories using or otherwise handling over 250 µCi of any isotope at any one time. Post-experiment surveys may be used instead of weekly surveys should quantities greater than 250 µCi be used infrequently. Where less than 250 µCi are used or handled at any one time monthly surveys should be completed. Weekly and monthly surveys require both direct meter probes with an appropriate, calibrated survey meter and wipe tests performed for removable contamination.

Survey Procedure: Laboratory surveys require the use of a calibrated survey meter with an appropriate detector as well as a wipe test for removable contamination. Wipe tests are to be counted using either liquid scintillation counting (H-3, C-14, P-32, S-35, etc.,) or gamma counting (Cr-51, Fe-59, I-125, etc.,) depending on the isotopes your laboratory utilizes. If you are not sure which technique is correct contact the Radiation Safety Office.

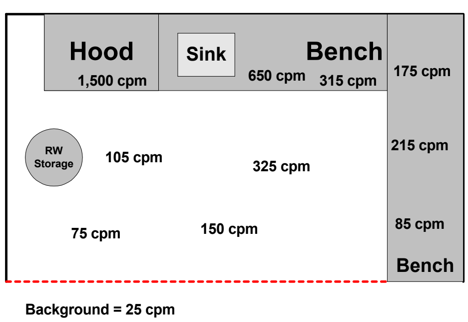


You should make a drawing of the survey region for indicating locations of meter surveys and wipe tests. You will need an appropriate meter with documentation indicating the calibration date and efficiency for isotopes of interest and the normal background reading. You will also need material for performing the wipe test such as cotton swabs, tissue or filter papers or pieces of linen, vials in which to place the wipes and tweezers to allow handling the wipes without cross-contaminating the samples.

When working with isotopes other than tritium, it is necessary to have a portable survey instrument on hand to monitor exposure levels and check for contamination. A thin-window Geiger-type survey meter is appropriate for work with beta emitters (including Carbon-14 and Sulfur-35). Iodine-125 monitoring requires use of an Iodine-125 specific scintillation-type detector.

With the exception of tritium, virtually all beta and gamma emitters can be "seen" with a Geiger-Mueller (GM) detector survey instrument. This instrument can be used to determine the rough location and gross nature of contamination. The appropriate method is to position the probe surface 1 to 2 cm. above the suspected surface and then slowly scan the area, listening for variation in the click rate. In general, the meter should be shielded from high background to check for equipment or personnel contamination. Bench or floor surfaces should be checked directly and by wiping, then monitoring the wipe.

When you are ready, you should survey the laboratory thoroughly with the portable meter, concentrating on regions were radioactive materials have been used. Do not overlook areas where technicians may inadvertently walk or items that they may touch. Hold the detector as close to the surface as possible without touching to avoid contaminating the detector. Move slowly and deliberately along lab benches, near selected floor regions, radioactive material work areas, all small equipment, sinks, refrigerators, telephones, light switches and doorknobs. Pay close attention to lab coats, waste areas and containers for both radioactive and ordinary trash.



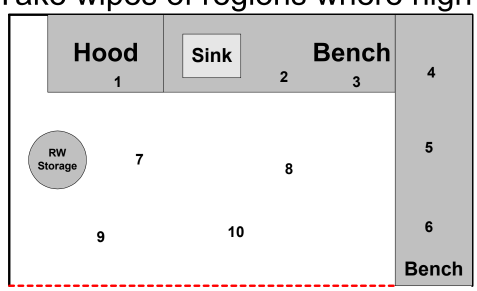
Record areas on the survey drawing that show counts 3 times background. Mark the location and give the highest count rate in the region and some description of the type of area--bench top, floor, etc. Indicate if the location is a radioactive material work area or if it was apparently contaminated inadvertently. Record areas and readings around all waste containers and radioactive materials storage areas.

Wipe monitoring can be used with all radioisotopes, and is the only reliable method for quantitative determination of removable contamination levels. Contamination levels are normally expressed as dpm/100 sq. cm. of surface. The method involves wiping the surface with an absorbent medium (paper wipes) and then counting the wipes by Liquid Scintillation Counter (LSC) analysis. A background (uncontaminated) wipe is counted as a comparison control.

A LSC is a counter in which light flashes produced in a liquid scintillation solution by ionizing radiation are converted into electrical pulses by a photomultiplier tube. The number of light pulses produced and counted is proportional to the radioactivity in the solution.

When using lower-energy emitters (tritium, Carbon-14, Sulfur-35, or Iodine-125), surfaces should be checked with dry or damp pieces of filter paper or cotton swabs that are counted by liquid scintillation. You should examine floor in front of the work area, equipment (heaters, stirrers, tubing), and any items handled with work gloves during the experiment (faucet handles, drawer handles, etc.). If extensive or high-level surface contamination (1,000 times background) is detected, call the Radiation Safety Office.

Do a wipe test of the laboratory, concentrating on the areas indicated previously. Take wipes of regions where high counts were found with the survey meter.



Standard cotton swabs, chemical wipes or other cotton or tissue paper may be wetted with alcohol or distilled water to increase the "lifting" ability. Wipes should be taken in areas of 100 cm^2 since limits for radioactive contamination are specified for 100cm^2 areas. You may take wipes of broader areas initially but remember that for determination of the level of contamination smaller areas should be wiped. Record the locations of the wipe tests and the area wiped on the drawing.

Load wipes in the proper radioactivity counter. Record type of counter used and its efficiency. All wipe data should be recorded in disintegrations per minute (DPM) per 100 cm^2 or in μCi/100cm^2. Check all wipe tests and survey meter readings to insure no contamination limits are exceeded. It is good practice to decontaminate all regions where removable contamination exists, regardless of the level of contamination. After decontamination, 100cm^2 wipes should be taken in the contaminated area to insure no contamination remains. The survey documentation should include counting efficiencies, all survey data and the checks made to ensure that limits have not been exceeded for removable contamination or restricted area exposure rates. The Authorized User should review, date and sign the survey results.

Survey Instruments: If your laboratory is interested in purchasing a survey instrument, contact the Radiation Safety Office before selecting one. Our recommendations are based on experience with various brands and take into account ease of calibration, reliability, versatility, ruggedness, ease of servicing, and value. Instruments ordered out of catalogues may not meet your individual needs.

Radioactive Waste: The Radiation Safety Office routinely picks up the radioactive waste and manages its disposal. This discussion defines each of the waste types and describes the methods for accumulating, storing and preparing the waste for transfer to Radiation Safety.

Users should separate their radioactive wastes by radioisotope and type. Separation allows proper handling and helps reduce overall disposal costs.

Wastes are taken to radioactive storage areas managed by the Radiation Safety Office. Short-lived radioactive wastes may be held for decay, surveyed and released to other waste disposal methods. Long-lived radioactive wastes are retained for transfer to a licensed broker, processor and/or waste disposal site

Short-lived wastes include those wastes contaminated with Phosphorus-32, Phosphorus-33, Sulfur-35, Iodine-125, Iodine-131, Chromium-51, Gallium-67, Molybdenium-99, Technetium-99m, Indium-111, Thallium-201 or any other radioisotope with a physical half-life less than ninety (90) days. Long-lived wastes include wastes contaminated with Hydrogen-3, Carbon-14, Sodium-22, Calcium-45, Nickel-63, Zinc-65, Barium-133 or any other radioisotope with a physical half-life of ninety (90) days or more. If more than one radioisotope is present, you should consider the waste short-lived if all of the radioisotopes present have physical half-lives less than ninety days. If one or more radioisotopes present have half-lives of ninety days or more, consider the waste long-lived regardless of the half-lives of the other radioisotopes.

Waste Minimization: The Radiation Safety Office recommends the use of short-lived isotopes wherever possible. Short-lived isotopes can be decayed, surveyed and their wastes released from restrictions due to their radioactivity. You should maintain adequate records to support disposal. To minimize the generation of possible mixed wastes users should avoid hazardous chemicals[1] in their tracer studies

Waste Retention: Collect and retain radioactive wastes in receptacles marked: "Radioactive Waste – Do Not Discard." Liquid wastes may be collected and retained in heavy plastic carboys with a capacity of five gallons or less or discharged to the sanitary sewer using proper techniques. Liquid scintillation counting cocktails should be retained in the counting vials. Dry wastes should be retained in strong tight containers such as drums.

Determining Radioactive Waste Activities: The method uses a materials balance approach and assumes that the radioactivity will be confined to the solid, liquid and liquid scintillation wastes generated during the work. The first step is to determine the total activity (TA) used in your experiment(s). Next you determine the activity in your liquid waste (LW)

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[1] Chemicals subject to the Resource Conservation and Recovery Act and/or the Toxic Substances Control Act.

1. Take a sample of your liquid jug
2. Count it on a Liquid Scintillation Counter
3. Convert counts per minute (cpm) in the sample to μCi in the container [cpm/ml ÷ efficiency = dpm/ml; dpm/ml x number of mls = dpm/container; dpm/container ÷ 2.22E6 = μCi/container]

Then you estimate the activity from vial counts for your liquid scintillation vials (LSV).

In the final step, you determine the activity in your solid waste (SW)

$$SW = TA - LW - LSV$$

Animal Waste: Animal waste includes radioactively contaminated animal carcasses, tissue samples, excreta, blood, and bedding. It does not include microscopic tissue sections or slides. Exempted radioactive animal waste is animal waste containing only Hydrogen-3 (H-3) and/or Carbon-14 (C-14) at a concentration of less than 0.05 μCi/gram, averaged over the entire mass of the animal waste. Non-exempted radioactive animal waste includes all radioactive animal waste that does not qualify as exempted on the basis of H-3 and C-14 concentrations.

1. Separate animal wastes into long-lived and short-lived wastes.
2. Separate long-lived animal wastes into exempted and non-exempted subcategories on the basis of the H-3 and C-14 concentrations.
3. Separate short-lived animal wastes by radioisotope.
4. Place animal waste into a heavy-duty Ziploc bag and seal.
5. Place the heavy-duty Ziploc bag containing the waste into a second heavy-duty Ziploc bag ("double-bagged") and seal.
6. Attach a "Caution – Radioactive Materials" label to the exterior of the outer bag.
7. Keep the bagged animal waste frozen (at $–20^0$ C).

Scintillation Waste: This waste consists of liquid scintillation cocktails (including dissolved and suspended samples) and associated containers such as counting vials. Counting vials containing 0.05 μCi or less of H-3 or C-14 per gram are exempt by regulation. Counting cocktails shall never be poured into the sewer.

1. Be sure that the lids on each vial are tightly sealed.
2. Separate the counting vials into long-lived and short-lived wastes.
3. Separate long-lived counting vials into exempted and non-exempted subcategories on the basis of the H-3 and C-14 concentrations.
4. Separate short-lived counting vials by radioisotope.
5. Place the vials into a large heavy-duty Ziploc bag and seal.
6. Place the first Ziploc bag into a second Ziploc bag ("double-bagged") and seal.

7. Attach a “Caution – Radioactive Materials” label to the outer bag and list the radioisotope(s) present.
8. Keep the bagged vials separated by radioisotope.

High-activity waste: This waste type consists of stock vials with remaining activity and high concentration solutions (≥ 100 µCi/ml). Empty or decayed stock vials are ordinary solid radioactive wastes.

1. Retain each high-activity stock vial in the plastic or lead pig in which it came.
2. Be sure the lids are tightly sealed.
3. Separate high-activity stock vials by radioisotope.
4. Place the plastic or lead pig containing the high-activity stock vial into a heavy-duty Ziploc bag and seal.
5. Place the bagged stock vial into a second heavy-duty Ziploc bag and seal.
6. Attach a “Caution – Radioactive Materials” label to the outer bag.
7. List the radioisotope, its activity and the date on the outer bag.
8. Place the bagged stock vials in a separate cardboard or plastic container for pick up.

Lead pigs are source vial enclosures that have lead integrated into them for use as shielding. If the lead pig is not contaminated, the user should deface all labels on the pig and place it in a heavy-duty Ziploc bag. Uncontaminated lead pigs will be recycled. If the lead pig is contaminated (either internally and/or externally):
1. Place it into a heavy-duty Ziploc bag and seal the bag;
2. Place the first bag into another heavy-duty Ziploc bag and seal it;
3. Label the outer bag with “Caution – Radioactive Materials”; and
4. Mark the isotope and date on the outer bag.

Keep the contaminated lead pigs separate from other dry wastes.

Sharps waste includes hypodermic needles, syringes (with or without the attached needle), scalpel blades and similar items. Items are classified as “Sharps” because they could cause a puncture wound or cut during handling. The user should:
1. Separate sharps waste from other waste;
2. Separate sharps waste by radioisotope (if more than one radioisotope is used in the laboratory;
3. Place sharps waste in a puncture resistant container;
4. Label the sharps waste container, “Caution – Radioactive Materials”; and
5. Mark the container, “Sharps Wastes.”

Liquid Waste may consist of a variety of chemical constituents, provided that the waste is a homogeneous solution. Although small amounts of non-soluble materials may be unavoidably present, liquid radioactive waste generally does not contain solid materials, (e.g., plastic pipette tips, micro-centrifuge tubes and/or precipitates).

Aqueous Liquid Waste is a radioactive liquid waste in which the waste materials are either dissolved in water or evenly distributed in a liquid that is mainly composed of water. Aqueous liquid wastes must have a pH between 7 and 9 and cannot be contaminated with toxic, flammable, poisonous or reactive materials. Users should:

1. Keep aqueous liquid wastes separate from other wastes and segregated by their radioisotope and chemical compositions;
2. Accumulate aqueous liquid wastes in heavy duty plastic carboys with screw top closures;
3. Keep the primary container tightly closed and stored in a secondary container when not being filled;
4. Label each container with "Caution- Radioactive Materials" and "Aqueous Liquid Waste;"
5. Mark each container to indicate the radioisotope present.
6. Hold short-lived aqueous wastes for decay;
7. Sample them; and
8. Discharge them to the sanitary sewer if the activity is statistically indistinguishable from background.

Aqueous wastes containing H-3 and/or C-14 with concentrations less than 0.05 µCi/ml may also be discharged to the sewer.

Non-aqueous Liquid Waste is a radioactive liquid waste in which the waste materials are either dissolved or evenly distributed in a non-aqueous solvent. Non-aqueous liquid wastes containing toxic, flammable, corrosive, poisonous or reactive materials are mixed wastes. Users should refrain from generating these wastes.

Solid Radioactive Waste consists of dry, radioactively contaminated materials. Typical solid radioactive waste may include paper, plastics, micro-centrifuge tubes, glassware, empty vials and/or gloves. Although small amounts of damp materials may be present, solid radioactive waste must not contain any free liquids.

Users should:

1. Separate all solid waste by radioisotope;
2. Accumulate solid wastes in drums or other containers lined with yellow plastic bags ("rad bags");

Records: Users should maintain an ongoing inventory of the waste as it is generated. The "Radioactive Waste Disposal Form" is designed to support the generation of the inventory. The form requests the recording of the date, radionuclide, activity and a brief waste description each time waste is added to the container. A separate form is maintained for each container in use.

When a container is transferred to the Radiation Safety Office for disposal, the form provides the necessary information for its proper disposal.

Isotope Summaries

Carbon-14 (C-14) is a radioisotope with a half-life of 5,730 years that emits only beta particles with a maximum energy of 0.156 MeV and an average energy of 0.049 MeV. The beta particles from C-14 travel a maximum of about 2 feet in air. The principal radiation safety issue in the routine use of C-14 is that it cannot be easily monitored during use. Special precautions are needed to keep the work environment clean. The regular use of wipe testing is the only way to insure that your work area is not contaminated. Contamination on the skin will not cause a significant dose to the skin; however, it could lead to the internal absorption of C-14. The annual limit of intake is 2 millicuries.

Calcium-45 (Ca-45) is a radioisotope with a half-life of 162.7 days that emits only beta particles with a maximum energy of 0.254 MeV and an average energy of 0.076 MeV. The beta particles from Ca-45 travel a maximum of about 3 feet in air. The principal radiation safety issue in the routine use of Ca-45 is that it cannot be easily monitored during use. Special precautions are needed to keep the work environment clean. The regular use of wipe testing is the only way to insure that your work area is not contaminated. Contamination on the skin will not cause a significant dose to the skin; however, it could lead to the internal absorption of Ca-45. The annual limit of intake is 800 µCi by inhalation and 2 mCi by ingestion.

Chlorine-36 (Cl-36) is a radioisotope with a half-life of 300,000 years that emits beta particles with a maximum energy of 0.710 MeV and an average energy of 0.252 MeV. The beta particles from Cl-36 travel a maximum of about 8.5 feet in air. The principal radiation safety issue in the routine use of Cl-36 is that it can present a significant skin dose hazard. Special precautions are needed to prevent skin contamination with Cl-36 and keep the work environment clean. The regular use of a thin window Geiger-Mueller counter is the best way to insure that your work area is not contaminated. Contamination could lead to the internal absorption of Cl-36. The annual limit of intake is 2 mCi by inhalation and 2 mCi by ingestion.

Chromium-51 (Cr-51) is a radioisotope with a half-life of 27.7 days that emits photons with a maximum energy of 0.320 MeV. The major radiation safety concern associated with the use of Cr-51 is its radiation exposure from an unshielded vial. The dose rate at the surface of an unshielded vial containing 1 millicurie of Cr-51 is about 1,800 millirems per hour. The annual limits of intake are 50 millicuries for intakes by inhalation and 40 millicuries for intakes by ingestion.

Iron-59 (Fe-59) is a radioisotope with a half-life of 44.6 days that emits beta particles with energies of 0.466 MeV (53.1%) and 0.273 MeV (45.2%) and gamma photons with energies of 1.292 MeV (43.2%), 1.099 MeV (56.5%) and 0.192 MeV (3.1%). The major radiation safety concern associated with the use of Fe-59 is its radiation exposure from an unshielded vial. The dose rate at the surface of an unshielded vial containing 1 millicurie of Fe-59 is about 640 millirems per hour. The annual limits of intake are 300 µCi for intakes by inhalation and 800 µCi for intakes by ingestion.

Hydrogen-3 is commonly known as tritium. Tritium is a radioisotope with a half-life of 12.3 years that emits only beta particles with a maximum energy of 0.019 MeV and an average energy of 0.0057 MeV. The beta particles from tritium travel a maximum of 6 mm. in air. The principal radiation safety issue in the routine use of tritium is it cannot be easily monitored during use. Special precautions are needed to keep the work environment clean. The regular use of wipe testing is the only way to insure that your work area is not contaminated. Contamination on the skin will not cause a significant dose to the skin; however, it could lead to the internal absorption of tritium. Many tritium-labeled compounds can readily penetrate gloves and skin. The annual limit of intake is 80 millicuries in the form of water.

Iodine-125 (I-125) is a radioisotope with a half-life of 60 days that emits gamma rays with a maximum energy of 0.035 MeV. The major radiation safety concerns with using I-125 are radiation exposure in air over an unshielded vial and inhalation/ingestion. The dose rate at the opening of an unshielded vial containing 1 millicurie of I-125 can be 1,400 millirems per hour. The annual limits of intake are 60 µCi by inhalation and 40 µCi by ingestion. Sodium iodide is known to be volatile in air and readily absorbed by the thyroid gland if inhaled or absorbed internally. Uncapped vials of I-125 and laboratory contamination with I-125 may potentially lead to uptake in the thyroid gland and extra precautions are necessary beyond the normal operating procedures for other radioisotopes. The absorption of 1 microcurie of I-125 in the thyroid gland produces a thyroid dose of about 3.5 Rads.

Iodine-131 (I-131) is a radioisotope with a half-life of 8.04 days that emits beta particles with a maximum energy of 0.606 MeV and gamma rays with a maximum energy of 0.364 MeV. The major radiation safety concerns with using I-131 are radiation exposures from an unshielded vial and inhalation/ingestion. The dose rate at the opening of an unshielded vial containing 1 millicurie of I-131 can be 2,200 millirems per hour. The annual limits of intake are 50 µCi by inhalation and 30 µCi by ingestion. Sodium iodide is known to be volatile in air and readily absorbed by the thyroid gland if inhaled or absorbed internally. Uncapped vials of I-131 and laboratory contamination with I-131 may potentially lead to uptake in the thyroid gland and extra precautions are necessary beyond the normal operating procedures for other radioisotopes. The absorption of 1 microcurie of I-131 in the thyroid gland produces a thyroid dose of about 5.3 Rads.

Sodium-24 (Na-24) is a radioisotope with a half-life of 15.02 hours. Na-24 emits beta particles with a maximum energy of 1.390 MeV, and gamma photons with energies of 1.369 MeV and 2.754 MeV.

The major radiation safety concern associated with the use of Na-24 is the radiation exposure from an unshielded vial. The dose rate at the surface of an unshielded vial containing 1 millicurie of Na-24 is about 18,400 millirems per hour.

The annual limits of intake are 5,000 μCi for intakes by inhalation and 4,000 μCi for intakes by ingestion.

Phosphorus-32 (P-32) is a radioisotope with a half-life of 14.3 days that emits beta particles with a maximum energy of 1.71 MeV. The beta particles travel a maximum of 20 feet in air. A drop of contamination containing 1 microcurie of P-32 on 1 cm^2 area of the skin produces an exposure of 2,000 millirems/hour. The dose rate at the opening of a vial containing 1 millicurie of P-32 can be as high as 26,000 millirems per hour.

Using orthophosphate can pose significant problems because of the large activity and high concentrations sometimes provided by suppliers. Experience has shown that laboratories using pre-labeled P-32 (dATP, etc.) in activities of 0.25 and 0.5 millicuries have had little or no safety problems. Using lower concentrations is very desirable in terms of routine handling. Most suppliers will provide lower concentrations if requested.

The annual limits of intake for P-32 are 900 μCi for inhalation intakes and 600 μCi for ingestion intakes.

Phosphorus-33 (P-33) is lower energy alternative to P-32 as a phosphorus tracer. P-33 is a radioisotope with a half-life of 25.4 days that emits only beta particles with a maximum energy of 0.249 MeV and an average energy of 0.083 MeV. The beta particles from P-33 travel a maximum of 46 cm in air. The major concern with using P-33 is that it cannot be easily monitored during use. Special precautions are needed to keep the work environment clean. The regular use of wipe testing is the only way to insure that your work area is not contaminated. Contamination on the skin will not cause a significant dose to the skin; however, it could lead to the internal absorption of P-33. The annual limits of intake are 8 millicuries for inhalation intakes and 6 millicuries for ingestion intakes.

Sulfur-35 (S-35) is a radioisotope with a half-life of 87.4 days that emits only beta particles with a maximum energy of 0.167 MeV and an average energy of 0.049 MeV. The beta particles from S-35 travel a maximum of 24 cm. in air. These properties are very similar to those of C-14.

S-35 is difficult to distinguish from C-14. If both radioisotopes are used in the same laboratory, they should be kept separate to allow S-35 wastes to be decayed in storage. If unknown contamination is found in a laboratory using both radioisotopes, it should be treated as C-14.

The major radiation safety concern in the routine use of S-35 is it cannot be easily monitored during use. Many Geiger Counters cannot detect the beta particles from S-35. Special precautions are needed to keep the work environment free of contamination. The regular use of wipe testing is the only way to insure that your work area is not contaminated.

Contamination on the skin will not cause a significant dose to the skin; however, it could lead to the internal absorption of S-35 if there are cuts in the skin. The annual limits of intake for S-35 are 20 millicuries for inhalation intakes and 10 millicuries for ingestion intakes.

Radiolysis of S-35 labeled amino acids may lead to the release of S-35 labeled volatile impurities. Delivery vials should always be opened in the hood. The addition of buffers (stabilizers) will reduce, but not eliminate, the evolution of S-35 labeled volatile impurities.