INTRODUCTION

In every laboratory where radioactive materials are utilized, it is necessary to maintain a policy of specific methods and procedures to develop and maintain safety practices.

The University of Texas operates under the Texas Department of Health, Bureau of Radiation Control, License number L00485. This license is a specific license with broad authorization. It allows the University of Texas the privilege of using large varieties of radioactive materials. Large amounts of activity are authorized and may then be used in many locations, with many procedures and users that change frequently. The broad license confers the authority upon the University to approve, manage and control the receipt, use and disposal of radioactive materials. In fact, the University acts to “police” itself under the authority given in a broad license.

The broad license has one feature which must always be remembered by each radioactive user: **there is only one license for the entire university, and any individual or action which jeopardizes the license endangers the permission of all researchers to utilize radioactive materials at UT.** If for any reasons, the license is suspended or terminated, no individual or sub-authorized user may use radioactive materials of any kind until the license is reinstated. Therefore, this license places significant responsibility on each individual who uses radioactive materials to conform with safe work practices, and to conduct and complete all required compliance duties, however large or small they may be.

The University of Texas Radiation Safety Committee (RSC) members are appointed by the President of the University and are given the responsibility to oversee the radiological health and safety at the University. Approval for use of radioactive materials, reviewing policy and campus radiation safety are some of the functions performed by the RSC. The Radiation Safety Officer acts as the delegated authority of the RSC in the day-to-day implementation of the use of radioactive materials and the Radiation Safety Program.

FOREWORD

This manual is prepared for individuals who use radioactive materials and assume certain responsibilities in their work. The individual worker is the “first line of defense” in the protection of people and the environment against undue risks of radiation exposure and/or contamination. Since the workers themselves, are the direct handlers of radioactive materials, the final responsibility lies with them for safety and compliance with regulations. For this reason, it is critical that they be aware of the risks, safe practices and requirements for the use of radioactive materials.

The university identifies an individual who uses radioactive material in the course of his/her employment or study with the term “radiation worker.” Radiation workers may be sub-authorized users, graduate students, undergraduate students, technicians, post-doctorates, visitors, or any individual who will handle radioactive materials. Upon completion of the training the radiation worker will be able to complete the following tasks.

1. Complete the radiation safety examination and pass with a score of 70% or better. The individual will be prohibited from handling radioactive material until this has occurred.
2. The radiation worker will be able to practice ALARA (As Low As Reasonably Achievable) in their work habits and to minimize the potential for exposures, contamination or release of radioactive materials.

IONIZING RADIATION THEORY

Ionizing radiation has the ability to remove electrons from the atoms, creating ions; hence, the term "ionizing radiation". The result of ionization is the production of negatively charged free electrons and positively charged atoms. There are four types of ionizing radiation involved that can be classified into groups: 1) photons, such as **gamma** and **x-rays**, and 2) particles, such as **beta** particles (positrons or electrons), **alpha** particles (similar to helium nuclei, 2 protons and 2 neutrons), and **neutrons** (particles with zero charge, electrically neutral). Photons are electromagnetic radiation having energy, but no mass or charge; whereas particles have typically mass and charge as well as energy. Neutrons have mass and energy, but no charge, and are typically produced by man with machines, such as cyclotrons. All types of ionizing radiation can remove electrons, but interact with matter in different ways.

Particles are more highly ionizing; excitation and ionization are the primary interaction with matter, and potential for ionization increases as mass and charge increase. The range in tissue (depth to which the radiation may penetrate) for particles decreases as mass and charge increase. Photons, because they have no mass or charge, are less ionizing but more penetrating in matter.

RADIATION UNITS

Two types of units are used for radiation, units of activity and units of exposure (dose). Units of activity quantify the amount of radiation emitted by a given radiation source. Units of exposure quantify the amount of radiation absorbed or deposited in a specific material by a radiation source.

In the world today, two sets of units exist. They are Special units (Curie, Roentgen, Rad and Rem) and the SI Units (Becquerel, Gray and Sievert). In the United States, the Special units are used. Therefore, in our discussions the units used will always be the Special units.

Units of Activity

The unit of activity for radiation is the Curie, abbreviated Ci. Most laboratory facilities use only millicurie (mCi, 0.001 Ci) or microcurie (μCi, 0.000001 Ci) amounts of radioactive materials. The microcurie is an amount of radioactive material emitting 2.22 X 10^6 disintegrations (particles or photons) per minute (DPM). Activity can be measured with an appropriate radiation detection instrument. Most of these measurements are made with a liquid scintillation counter or gamma well counter. These instruments detect a percentage of disintegrations and display in counts per minute (CPM).

Counts per minute (CPM) can be converted into DPM, then into μCi. First you must establish efficiency on the machine that you are using. To do this you must calibrate the instrument with a known source. (Note that lower energy radionuclides are detected with lower efficiencies than higher energy radionuclides.) To make the necessary conversion to microcurie units (μCi), the following formula must be used.

$$\mathbf{CPM/Efficiency = DPM}$$
$$\mathbf{DPM/2.22 \times 10^6 = \mu Ci}$$

Units of Exposure

The Roentgen, abbreviated as "R", is the unit for measuring the quantity of x-ray or gamma radiation. One Roentgen is equal to the quantity of gamma or x-radiation that will produce ions carrying a charge of 2.58 X 10^{-4} coulombs per kilogram of air. An exposure to one Roentgen of radiation with total absorption will yield 89.6 ergs of energy deposition per gram of air. If human tissue absorbs one Roentgen of radiation, 96 ergs of energy will be deposited per gram of tissue. (The SI units do not include the Roentgen, but simply use the amount of energy deposited in air as the descriptive term.)

The rad and rem are the two main radiation units used when assessing radiation exposure. The rad (radiation absorbed dose), is the unit of absorbed dose, and refers to the energy deposition by any type of radiation in any type of material. (The SI unit for absorbed dose is the Gray; it is defined as being equal to 100 rads. 1Gy = 100 rads) One rad equals 100 ergs of energy deposition per gram of absorber.

The rem is the unit of human exposure and is a dose equivalent (DE). (The SI unit for human exposure is the Sievert, which is defined as equal to 100 rem. 1Sv = 100 rem) It takes into account the biological effectiveness of different types of radiation. The target organ is important when assessing radiation dose and a modifying factor is used in radiation protection to correct for the relative biological effectiveness (RBE or quality factor). Also, the chemical form of the radioactive material producing the dose is of critical importance in assessing internal doses, because different chemicals bind with different cell and/or organ receptor sites.

- Quality Factors (QF) are used to relate the relative biological effectiveness (RBE) of different types of radiation. Rad (or R) x QF = Rem. Some typical quality factors are: 1 for beta, gamma, x-rays, 10 for neutrons, and 20 for alpha particles.

EXTERNAL AND INTERNAL RADIATION EXPOSURES

There are two potential primary exposure types connected with work involving radioisotopes: external and internal exposure to radiation. Each must be carefully evaluated prior to working with radioactive materials, and precautions must be taken to prevent these exposures.

External Radiation Exposure

External hazards arise when radiation from a source external to the body penetrates the body and causes a dose of ionizing radiation. These exposures can be from gamma or x-rays, neutrons, alpha particles or beta particles; they are dependent upon both the type and energy of the radiation.

Most beta particles do not normally penetrate beyond the skin, but when sufficiently intense, can cause skin and/or eye damage. Very energetic beta particles, such as those emitted by ^{32}P, can penetrate several millimeters into the skin. Shielding is needed in order to reduce the external radiation exposure. Typically, a ½ inch thick sheet of Plexiglas is an effective shield for most beta particles.

Alpha particles, because of higher mass, lower velocity, and greater electrical charge compared to beta particles, are capable of traveling a few inches in air and rarely penetrate the outer dead skin layer of the body. Therefore, alpha particles typically are not an external radiation hazard.

X and gamma rays, along with neutron radiation, are very penetrating, and are of primary importance when evaluating external radiation exposure and usually must be shielded. The onset of first observable effects of acute radiation exposure, diminished white blood cell count, may occur at a dose of approximately 100 rads of acute whole body radiation exposure. The LD_{50} for humans (dose where 50% of the exposed population may die from a one time exposure of the whole body) is about 500 rads, assuming no medical intervention.

Exposure to external radiation may be controlled by limiting the working time in the radiation field, working at a distance from the source of radiation, inserting shielding between the worker and the source, and by using no more radioactive material than necessary.

Internal Radiation Exposure

Radioactive material may be internally deposited in the body when an uptake occurs through one of the routes of entry: inhalation, ingestion and skin contact. These exposures can occur when radioactive material is airborne; is inhaled and absorbed by the lungs and deposited in the body; is present in contaminated food, drink or other consumable items and is ingested; or is spilled or aerosolized onto the skin and absorbed or enters through cuts or scratches. Internal deposition may also result from contaminated hands, with subsequent eating or rubbing of the eyes.

Internal exposure arises when radiation is emitted from radioactive material present within the body. Although external hazards are primary caused by x-rays, gamma rays, high energy betas and neutrons, all forms of radiation (including low energy betas, gammas and alphas) can cause internal radiation exposures. Alpha particles create a high concentration of ions along their path, and can cause severe cellular damage to internal organs and tissue when they are inhaled or ingested. Once these particles get into the body, damage can occur since there is no protective dead skin layer to shield the organs and tissues. Internal exposures are not limited to the intake of large amounts at one time (acute exposure). Chronic exposure may arise from an accumulation of small amounts of radioactive materials over a long period of time.

ALARA

ALARA is the acronym meaning **As Low As Reasonable Achievable**. It is a requirement in the regulations, meaning all facilities possessing radioactive materials licenses must have a formal ALARA program. It may be defined as a professional standard of excellence, and is practiced by keeping all doses, releases, contamination and other risks as low as reasonably achievable utilizing engineering and administrative controls.

Three primary means of eliminating or reducing radiation exposures are time, distance, and shielding.

Time:

Minimize the time that radioactive materials are handled. Since the amount of exposure occurs as a function of duration of exposure, less time means less exposure. This may be achieved by conducting “dry runs” (practicing the procedures to be performed, with all of the steps and manipulations performed without the hazardous materials). Conduct the work quickly and efficiently, but do not rush.

Distance:

Maximize the distance from the radioactive materials. Dose is inversely proportional to the distance; therefore, greater distance means less dose. Do not increase the distance to the point wherein dexterity or control of the materials is jeopardized. A way to calculate the proper distance is to use the inverse square law. The “inverse square law” states that radiation intensity from a point source varies inversely as the square of the distance from the source.

$$\frac{I_1}{I_2} = \frac{(R_2)^2}{(R_1)^2}$$

Where I_1 = radiation intensity at distance R_1 from the source
I_2 = radiation intensity at distance R_2 from the source

Shielding:

Use shielding wherever it is necessary to reduce or eliminate exposure. By placing an appropriate shield between the radioactive source and the worker, radiation is attenuated and the exposure may be completely eliminated or reduced to an acceptable level. The type and amount of shielding needed to achieve a safe working level varies with the type and quantity of radioactive material used.

RADIOACTIVE DECAY

Radioactive materials have an associated half-life, or decay time characteristic of that isotope. As radiation is emitted, the material becomes less radioactive over time, decaying exponentially. Since it is impossible or impractical to measure how long one atom takes to decay, the amount of time it takes for half of the total amount of radioactive material to decay is used to calculate half-life. Some radioisotopes have long half-lives; for example, C-14 takes 5,730 years for any given quantity to decay to half of the original amount of radioactivity. Other radioactive materials have short half-lives; P-32 has a 14.3 day half-life, and Tc-99m (used in human and animal nuclear medicine diagnostic procedures) has a half-life of 6 hours.

This is important for many reasons. When deposited in the human body, the half-life of the radioactive material present in the body affects the amount of the exposure. If the radioactive material contaminates a workbench or equipment, and is not removable, the amount of time before the contaminated items may be deemed to be clean is determined by the radioactive half-life.

The equation, which is used to calculate radioactive decay, is shown below.

$$\mathbf{A=A_O e^{-kt}}$$

Where
A=Current amount of radioactivity
A_0=Original amount of radioactivity
e= base natural log (approximately 2.718)
k= the decay constant = $0.693/t_{1/2}$ (where $t_{1/2}$=half-life)
t= the amount of time elapsed from A_o to A

Example:

Let's say that on September 1, 1980 the original amount of Cs-137 was 2.0 µCi and you want to known how much activity that you will have on September 1, 2004.

$$A=A_o e^{-kt}$$

$A = ?$
$A_o = 2.0\ \mu Ci$
$t_{1/2} = 30.17$ years (the half-life for Cs-137)
$t = 24$ years

$$A = 2.0\ e^{-(.693/30.17)\ 24}$$
$$A = 2.0 * 0.576$$
$A = 1.15\ \mu Ci$ which is how much activity that you have on September 1, 2004.

It is important to be careful of the units for time. Days, hours, and years must not be mixed in the calculation.

ROUTES OF EXPOSURE TO RADIATION

Minimizing the amount of radioactive materials handled in all cases will reduce exposure potential, since exposure is directly related to the amount used and how it is handled.

The three routes of entry into the body for radioactive materials are **inhalation, ingestion,** and **skin contact (absorption/injection)**. Precautions should be taken to avoid each of these means of internal exposure to radiation.

External radiation exposure is possible with certain kinds of radiation. Methods of minimizing this potential are **time, distance, shielding and minimizing the amount used.**

CLEAN LABORATORY CONDITIONS & CONTAINMENT

Good housekeeping is an important component of laboratory safety. Sloppy work habits, incorrect procedures or shortcuts, lack of containment, crowded or cluttered work areas and similar situations may cause or contribute to accidents or contamination. The following practices will assist in maintaining effective safety.

1. Maintain neat and clean work areas. Clutter, debris and crowded conditions interfere with the careful handling required in hazardous materials use.
2. Follow experimental procedures carefully. Radioisotope approvals are contingent upon following the procedures, statements and representations made in the principal investigator's approval. Departures from the procedures may place the approval in jeopardy.
3. Use absorbent poly-backed laboratory paper with the plastic side down, to protect surfaces from inadvertent spills or splashes. Laboratory benches, fume hoods, trays containing samples, waste areas and floors in the radioactive work areas are some of the locations where absorbent paper is useful.
4. Use secondary containment for all radioactive solutions, samples, liquid waste or any other hazardous materials, which may be spilled. Use trays, boxes, bus trays and other types of secondary containment to catch spills, splashes and possible container ruptures.

5. When transporting radioactive materials use a cart; this will prevent accidentally dropping or tipping the container.
6. Clean up the work areas and survey for contamination after the work is finished. If contamination is present, decontaminate or dispose of the contaminated materials in the radiation waste.
7. Use tightly sealed or capped containers when moving, heating, centrifuging or vortexing. Spills, evaporation, gases, container breakage or splashes may occur in any procedure where energy is put into the system.

FOOD AND DRINK POLICY

There shall be no **food, drink, or applying cosmetics** in the laboratories, which have licensable radioactive materials. There shall be no storage, use or disposal of any "consumable" items in laboratories (including refrigerators within laboratories). Rooms which are adjacent, but are separated by floor to ceiling walls, and do not have any radioactive materials present, may be used for food consumption or preparation at the discretion of the principal investigator who is responsible for these areas.

It is important to be aware that even the presence of empty food and drink containers in the normal trash may cause a violation, since it is construed as "evidence of consumption" by regulators and the burden of proof to the contrary then lies with the licensee. Please also note that smoking as well as gum and tobacco chewing are prohibited in laboratories.

Floor to ceiling enclosures must separate food areas from hazardous materials areas, due to the potential for releases of hazardous materials into the air, then into the food areas when only partial barriers are present.

If empty food or drink containers are used for storage or disposal of laboratory waste, reagents or other materials must be clearly labeled. If used for disposal of items contaminated with radioactive materials, the containers must be clearly labeled with the radioactive materials warning symbol, and the nuclide, quantity of activity and date, and whether it is water soluble or not.

SECURITY AND STORAGE OF RADIOISOTOPES

Security

It is required by 25 TAC §TAC289.202(y) that the security of licensable radioactive materials must be in place at all times. Violations of this regulation are frequently cited at institutions utilizing radioactive materials, and place the license to use such materials in jeopardy. The regulations for Unrestricted Areas read as follows:

- The licensee shall secure radioactive material from unauthorized removal or access.

- The licensee shall maintain constant surveillance, using devices and/or administrative procedures to prevent unauthorized use of radioactive material that is in an unrestricted area and that is not in storage.

This means that all locations where radioactive materials are present must be under constant attendance by the radiation worker, or otherwise locked or secured to prevent unauthorized removal or tampering. **Any loss of radioactive materials must be reported to the Radiation Safety Office immediately (512) 471-3511.**

Storage

Storage of radioactive materials shall be in secured or locked cabinets, refrigerators, freezers, or waste areas, unless attended by the licensee. Radioactive materials shall be stored in sealed containers in such a way as to prevent accidental spillage or breakage, and to prevent release into the air. If the nuclide requires shielding, it shall be stored in shielded containers in order to prevent doses to personnel accessing the storage areas.

If the radioactive material has been stored in a freezer or ultra freezer, it is imperative that the material be thawed and then opened and handled in a certified fume hood or biological safety cabinet. Aerosols from stored radioactive materials may cause contamination of adjacent areas and unnecessarily expose personnel if not handled in the proper way after storage.

All radioactive materials, whether in storage, waste or use, must be labeled with the radioactive warning symbol and the words “Caution Radioactive Materials”.

RADIATION SAFETY FOR X-RAY

The Texas Department of Health (TDH), Bureau of Radiation Control, regulates all radiation producing equipment such as diffractometers, x-ray spectrometers, electron accelerators, diagnostic and therapeutic x-ray machines, and electron microscopes. Equipment of this type must be registered with Bureau of Radiation Control through the Radiation Safety Office.

Personnel who use radiation generating equipment may be required to use whole body and extremity dosimeters. Signs warning of radiation must be posted near radiation producing equipment. Examples of the signs are as follows **CAUTION RADIATION— THIS EQUIMENT PRODUCES RADIATION WHEN ENERGIZED** or **CAUTION X-RAY EQUIPMENT.**

Safety devices such as collimators, interlocks, shielded rooms, warning lights and other safety equipment deemed necessary by Radiation Safety Office shall be used on all radiation producing machines on campus.

TRANSFER OF RADIOACTIVE MATERIALS

Transfer of radioactive material between authorized users of different projects must be reported prior to the transfer to the Radiation Safety Office. These transfers must be between authorized users, and within the limits of the approved quantities. The transfer should not take place until the authorization to do so has been given by the Radiation Safety Office.

It is required that we document any transfer of radioactive materials by reassigning the shipment receipt in our inventory database. To transfer a shipment, contact the Radiation Safety Office and supply the information to the Radiation Safety staff, which will confirm approval to transfer the material and document the change in the inventory database.

Radioactive materials shall never be transferred to individuals who are not approved. Individuals who receive the radioactive materials must be radiation workers.

DISPOSAL OF RADIOACTIVE WASTE

Federal and state statutes and regulations strictly govern the disposal of radioactive waste. To comply with these statutes and regulations, we must follow the requirements and procedures developed by the University.

Radioactive waste may be disposed of by three methods. Each method must meet the requirements of the **25 TAC §289.202(ff)**. These methods are as follows:

1. Sanitary sewer
2. Solid waste
3. Liquid waste

SANITARY SEWER

Radioactive materials may be discharged into the University's sanitary sewer system provided:

1. The material is readily soluble, or is a readily dispersible biological material, in water,
2. The quantity of licensed radioactive material that the University releases into the sewer in 1 month divided by the average monthly volume of water released into the sewer by the licensee does not exceed the concentration listed in Table III of 25 TAC §25TAC289.202(ggg) (2), and
3. The total quantity of licensed radioactive material that the University releases into the sanitary sewerage in a year does not exceed 1 Ci (37GBq) of all radioactive materials combined.

If your liquid waste is not water soluble, place this waste in a plastic container and label the content and the activity. The plastic containers can be obtained from the Radiation Safety Office.

DAILY DISCHARGE LIMITS OF RADIOACTIVE MATERIALS INTO THE SANITARY SEWER SYSTEM WITHOUT CONTACTING RADIATION SAFETY

ISOTOPE	LIMIT (µCi)
H-3	1000
C-14	100
Na-22	1.0
Na-24	10
P-32	10
P-33	0.1
S-35	100
Ca-45	10
Fe-55	100
Fe-59	10
I-125	1.0

SOLID WASTE

Solid radioactive waste is typically collected the last Tuesday of the each month. The Radiation Safety Office sends each authorized user a notification prior to the pick-up date. A completed waste pick up form must be returned to our office before the pick up date or your waste will not be picked up. The waste must be prepared for pick-up by:

1. Separating the waste by half-life - short from long.
2. Separating the liquid scintillation vials and sharps from the solid waste.

All radioactive waste shall be separated from non-radioactive waste. **Under no circumstances is it permissible to dispose of any radioactive material into the non-radioactive trash.** For more information see the UT Radiation Safety web site at http://www.utexas.edu/safety/ehs/radiation.html.

LIQUID WASTE

Liquid radioactive waste is typically collected at the same time as solid radioactive waste. Liquid radioactive wastes typically picked up are not water soluble (toluene, xylene, etc.) or are harmful to fish, shellfish or the ecological system.

FACILITY DECONTAMINATION

It shall be the responsibility of the authorized user to decontaminate any laboratory or facility, which becomes contaminated. Also, upon vacating all premises where radioactive materials have been used, the authorized user shall ensure that all residual radioactive materials are properly removed and disposed. The Radiation Safety Office must be notified before vacating areas where radioactive materials have been used.

OCCUPATIONAL DOSE LIMITS

The annual dose limit for a radiation worker is 5 rem (0.05 Sv) or 5000 mrem per year. The annual dose limit to the general public is 0.1 rem (1mSv) or 100 mrem per year.

PREGNANT RADIATION WORKER

A special situation arises when a radiation worker may become pregnant. Under these conditions, radiation exposure could also involve exposure to the embryo or fetus. The embryo or fetus is more radiosensitive than an adult, particularly during the first four months of pregnancy. This can be a problem since many workers are unaware of their pregnancy during the first month or two of gestation.

The maximum permissible exposure for the fetus of a declared pregnant worker during the gestation period is 500 mrem. There are relatively few research laboratories where radiation levels are high enough that a fetus would receive this dose before birth. If a radiation worker is pregnant, she may notify the Radiation Safety Officer, and then declare the pregnancy in writing in order for the prenatal exposure limits to take effect. The pregnant radiation worker will then meet with the Radiation Safety Officer and a complete assessment of her radiation exposure potential will be made.

If notification is not made in writing, the radiation exposure limits remain at the occupation level, that is, 5000 mrem per year. An individual may "un-declare" her pregnancy at any time, but this also should be documented.

Declared pregnant workers (DPW) may be assigned two badges, one for the whole body, normally worn on the torso and one for the fetus, normally worn on the abdomen.

PERSONNEL MONITORING

The purpose of personnel monitoring is to provide early notice if your exposure is not below the limits and **ALARA**. The monitoring program also provides a permanent record of your occupational exposure.

Most projects monitor whole body dose with a dosimeter (film badge, TLD, etc.). Extremity doses are typically monitored with a ring dosimeter.

The regulations require monitoring for any worker who might exceed 10 percent of the applicable limit, and any worker in a high or very high radiation work area. The University requirements for dosimeters are as follows:

1. Any person likely to receive 10% of the allowable limit.
2. Any person working with millicurie quantities of a beta emitter with energies greater than 0.5 MeV.
3. Any person working with greater than 5.0 millicuries of a gamma emitter with energies less than 0.1 MeV.

4. Any person working with millicurie quantities of gamma emitter with energies greater than 0.1 MeV.

Whole body dosimeters and extremity dosimeters are worn where the highest exposure is expected. Ring dosimeters are worn underneath gloves to avoid contamination. If you are supplied both types, wear both whenever you are working with radiation.

Several things can invalidate a dosimeter reading:
Loss: A lost dosimeter cannot be processed
Sharing: If two people use a dosimeter, it is not clear which one received the exposure
Improper Storage: A dosimeter stored in a radiation area will accumulate radiation dose even though it is not in use. Some dosimeters will give a false reading if stored in high temperature areas. Store dosimeters in your work area, but away from radiation. Do not store them on the self over the work area.
Misuse: Do not use a personnel dosimeter to measure area exposure or leakage radiation from a device, or your personal medical exposure.

A missing or invalid dosimeter reading creates a gap in your radiation dose record and gives the impression of a lackadaisical monitoring program.

BIOASSAYS

Individuals who handle large amounts of easily ingested radionuclides may be required to participate in a bioassay monitoring program. The bioassay requirement for each project is described in the Radiation Safety Manual located in each lab.

If you routinely handle or observe iodinations where one millicurie or more of radioactive iodine is used, your thyroid must be monitored for uptake.

If you handle more than 40 mCi of tritium (H-3), you bioassay will be required to participate in a bioassay program.

If there appears to be a likelihood that a significant internal exposure has occurred, the Radiation Safety Officer may require further bioassays as deemed necessary.

APPENDIX

The most current versions of the following documents are available at the UT Radiation Safety Web Site: http://www.utexas.edu/safety/ehs/radiation.html

HYDROGEN-3
[^{3}H]

PHYSICAL DATA

Beta Energy:	18.6 keV (maximum)
	5.7 keV (average) (100% abundance)
Physical Half-Life:	12.3 years
Biological Half-Life:	10-12 days
Effective Half-Life:	10-12 days *

*Forcing liquids to tolerance (3-4 liters/day) will reduce the effective half-life of ^{3}H by a factor of 2 or 3. (Relatively easy to flush out of system with fluids.)

Specific Activity:	9,640 Ci/gram
Maximum Beta Range in Air:	6 mm = 0.6 cm= ¼”
Maximum Beta Range in Water:	0.006 mm = 0.0006 cm = 3/10,000”
Penetrability in Matter or Tissue:	Insignificant*

*[0% of beta particle energy transmitted through dead layer of skin]

RADIOLOGICAL DATA

Least radiotoxic of all radionuclides
Critical Organ: Body Water or Tissue
Routes of Intake: Ingestion, Inhalation, Puncture, Wound, Skin Contamination (absorption)
External exposure from weak ^{3}H beta energy – not a radiological concern
Internal exposure & contamination are primary radiological concerns

Committed Dose Equivalent (CDE):	64 mrem/mCi (ingested)
	64 mrem/mCi (inhaled)
	64 mrem/mCi (puncture)
Committed Effective Dose Equivalent (CEDE):	90 mrem/mCi (ingested)
	63 mrem/mCi (inhaled)
Annual Limit on Intake (ALI)*:	80 mCi (ingestion or inhalation) [^3H_2O]]

*[1.0 ALI = 80 mCi (^{3}H) = 5,000 mrem CEDE]

Skin Contamination Exposure Rate: 57,900 mrad/hr/mCi (contact)*

* Exposure rate to dead layer of skin only.
* Skin contamination of 1.0 uCi/cm^2 = 0 mrad/hr dose rate to basal cells

Rule of Thumb: 0.001 uCi/ml of ^{3}H in urine sample is indicative of a total integrated whole body of approximately 10 mrem (average person) if no treatment is instituted (i.e., flush with fluids); [NCRP-65, 1980]

SHIELDING

None required

SURVEY INSTRUMENTATION

CANNOT detect ^{3}H using a G-M or NaI survey meter
Liquid scintillation counter (indirect) is the only monitoring method

CARBON-14
[^{14}C]

PHYSICAL DATA

Beta Energy:	156 keV (maximum) 49 keV (average) (100% abundance)
Physical Half-Life:	5,730 years
Biological Half-Life:	12 days
Effective Half-Life:	12 days (Bound)
Effective Half-Life:	40 days (Unbound)
Specific Activity:	4,460 mCi/gram
Maximum Beta Range in Air:	24.00 cm = 10 inches
Maximum Beta Range in Water/Tissue:	*0.28 mm = 0.012 inches
Maximum Range in Plexiglas/Lucite/Plastic:	0.25 mm = 0.010 inches

*Fraction of ^{14}C beta particle transmitted through dead layer of skin: At 0.007 cm depth = 1%

RADIOLOGICAL DATA

Critical Organ:	Fat Tissue
Route of Intake:	Ingestion, Inhalation, Skin Contact
External exposure:	Deep dose from weak ^{14}C beta particles is not a radiological concern
Internal exposure & contamination:	primary radiological concerns
Committed Dose Equivalent (CDE): (Fat Tissue)	2.08 mrem/uCi (ingested) 2.07 mrem/uCi (puncture) 2.09 mrem/uCi (inhalation)
Committed Effective Dose Equivalent (CEDE):	1.54 mrem/uCi (ingested)
Annual Limit on Intake (ALI)*:	2 mCi (ingestion of labeled organic compound) 2,000 mCi (inhalation of carbon monoxide) 200 mCi (inhalation of carbon dioxide)

*[1.0 ALI = 2 mCi (ingested C-14 organic compound) = 5,000 mrem CEDE]

Skin Contamination Dose Rate: 1,090-1,180 mrem per 1.0 uCi/cm^2 (7 mg/cm^2 depth)
Dose Rate to Basal Cells from Skin Contamination 1.0 uCi/cm^2 = 1400 mrad/hour.

SHIELDING

None required

SURVEY INSTRUMENTAION

Can detect ^{14}C using a thin window G-M survey meter probe must be at close range (1 cm.)

G-M survey meters have very low counting efficiency for ^{14}C (5%)

Liquid scintillation counter (indirect counting) may be used to detect removable ^{14}C on wipes

PHOSPHORUS-32
[^{32}P]

PHYSICAL DATA

Beta energy:	1.709 MeV (maximum) 0.690 MeV (average, 100% abundance)
Physical half-life:	14.3 days
Biological half-life:	1,155 days
Effective half-life:	14.1 days (bone)/13.5 days (whole body)
Specific activity:	285,000 Ci/gram
Maximum range in air:	610 cm = 240 inches = 20 feet
Maximum range in water/tissue:	0.72 cm = 1/3 inches
Maximum range in Plexiglas:	0.61 cm = 3/8 inches

RADIOLOGICAL DATA

Critical organ (biological destination) (soluble forms): Bone
Critical organs (insoluble forms or non-transportable ^{32}P compounds): Lungs (inhalation) and G.I. tract/lower large intestine (ingestion)

Routes of intake: Ingestion, inhalation, puncture, wound, skin contamination (absorption)

External and internal exposure from ^{32}P

Committed Dose Equivalent (CDE):	32 mrem/mCi (ingestion) 37 mrem/mCi (puncture) 96 mrem/mCi (inhaled/Class W/lungs) 22 mrem/mCi (inhaled/Class D/bone marrow)
Committed Effective Dose Equivalent: (CEDE)	7.50 mrem/Ci (ingested/WB) 5.55 mrem/Ci (inhaled/Class D) 13.22 mrem/Ci (inhaled/Class W)
Skin contamination dose rate:	8,700-9,170 mrem/mCi/cm^2 (7 mg/cm^2 or 0.007 cm depth in tissue)

Dose rate to basal cells from skin contamination of 9,200 mrad/hr: 1.0mCi/cm^2 (localized dose)

Bone receives approximately 20% of the dose ingested or inhaled for soluble ^{32}P compounds.

Tissue with rapid cellular turnover rates shows higher retention due to concentration of phosphorous in the nucleoproteins.

^{32}P is eliminated from the body primarily via urine.

SHIELDING

¼ thick Plexiglas/acrylic/Lucite/plastic/wood
Do not use lead foil or sheets! Penetrating Bremsstrahlung x-rays will be produced!

Use lead sheets or foil to shield Bremsstrahlung x-rays only after low density Plexiglas/acrylic/Lucite/wood shielding.

SURVEY INSTRUMENTATION

GM survey meter and end window or pancake probe.

Low energy NaI probe is used only to detect Bremsstrahlung x-rays.

Liquid scintillation counter (indirect counting) may be used to detect removable surface contamination of ^{32}P on smears or wipes.

PHOSPHORUS-33
[^{33}P]

PHYSICAL DATA

Beta energy:	0.249 MeV (maximum, 100% abundance)
	0.085 MeV (average)
Physical half-life:	25.3 days
Biological half-life:	19 days (40% of intake; 30% rapidly eliminated from body, remaining 30% decays)
Effective half-life:	24.9 days
Specific Activity:	1,000 – 3,000 Ci/millimole
Maximum beta range in air:	89 cm = 35 inches = 3 feet
Maximum range in water/tissue:	0.11 cm = 0.04 inches
Maximum range in Plexiglas:	0.089 cm = 0.035 inches

RADIOLOGICAL DATA

Critical organ (biological destination) (soluble forms): Bone marrow

Critical organs (insoluble forms or non-transportable ^{33}P compounds): Lungs (inhalation) and G.I. tract/lower large intestine (ingestion)

Routes of intake: Ingestion, inhalation, puncture, wound, skin contamination (absorption)
Internal exposure and contamination are the primary radiological concerns

Committed Dose Equivalent (CDE): 0.5 mrem/mCi (inhalation)

Skin contamination dose rate: 2,910 mrem/hr/uCi/cm^2 (7mg/cm^2 or 0.007 cm depth in tissue)

Fraction of ^{33}P beta particles transmitted through the dead skin layer is about 14%.

Tissue with rapid cellular turnover rates shows higher retention due to concentration of phosphorus in the nucleoproteins.

^{33}P is eliminated from the body primarily via urine.

Phosphorus metabolism : 30% is rapidly eliminated from the body
40% has a 19-day biological half-life
60% of ^{33}P (ingested) is excreted from the body in first 24 hrs

SHIELDING

Not required; however low density material is recommended, e.g., 3/8 inch thick Plexiglas, acrylic, Lucite, plastic or plywood

SURVEY INSTRUMENTATION

GM survey meter with a pancake probe
Liquid scintillation counting of wipes may be used to detect removable surface contamination.

SULFUR-35
[^{35}S]

PHYSICAL DATA

Beta energy:	167 keV (maximum) 53 keV (average) (100% abundance)
Physical half-life:	87.2 days
Biological half-life:	623 days (unbound ^{35}S)
Effective half-life:	44-77 days (unbound ^{35}S)
Specific activity:	42,400 Ci/gram
Maximum beta range in air:	26.00 cm = 10.2 inches
Maximum beta range in water or tissue:	0.32 mm = 0.015 inches
Maximum beta range in Plexiglas:	0.25 mm = 0.01 inches

Fraction of ^{35}S betas transmitted through the dead layer of skin = 12%

RADIOLOGICAL DATA

Critical organ: Testis
Routes of intake: Ingestion, inhalation, puncture, wound, skin contamination (absorption)
External exposure (deep dose) from weak ^{35}S beta particles is not a radiological concern.
Internal exposure and contamination are the primary radiological concerns.

Committed dose equivalent (CDE):	10.00 mrem/uCi (ingested) 0.352 mrem/uCi (puncture)
Committed effective dose equivalent: (CEDE)	2.6 mrem l/uCi (ingested)* *(Assumes a 90 day biological half-life)
Annual limit of intake (ALI):	10 mCi (ingestion of inorganic compounds) 6 mCi (ingestion of elemental ^{35}S) 8 mCi (ingestion of sulfides or sulfates/LLI) 10 mCi (inhalation of ^{35}S vapors) 20 mCi (inhalation of sulfides or sulfates) 2 mCi (inhalation of elemental ^{35}S)

1.0 ALI = 10 mCi (inhalation ^{35}S vapors) = 5,000 mrem CEDE
1.0 ALI = 8 mCi (ingestion sulfides/sulfates LLI) = 50,000 mrem CDE

Skin contamination dose rate: 1,170 – 1,260 mrem/1.0 uCi/cm^2 (7.0 mg/cm^2 depth)

Beta dose rate for ^{35}S: 14.94 rad/h (contact) in air per 1.0 mCi
0.20 rad/h (6 inches) in air per 1.0 mCi

SHIELDING

None required (¾ mm Plexiglas shielding optional)

SURVEY INSTRUMENTATION

Can detect using a thin window GM survey meter (pancake), however, probe must be close range, recommend 1 cm distance.

GM survey meter has low efficiency, usually 4 – 6%.

Liquid scintillation counter (wipes, smears) may be used for secondary, **but will not detect non removable contamination!**

IODINE-125
[^{125}I]

PHYSICAL DATA

Gamma Energies:	35.5 keV (7% abundance/93% internally converted gamma)
(No betas emitted)	27.0 keV (113%, x-ray)
	27-32 keV (14%, x-ray)
	31.0 keV (26%, x-ray)

Specific Gamma Ray Constant: 0.27 to 0.70 mR/hr per mCi at 1 meter
(Current literature indicates 0.27 mR/hr per mCi at 1 meter)

Physical Half-Life:	60.1 days
Biological Half-Life:	120-138 days (unbound iodine)-thyroid elimination
Effective Half-Life:	42 days (unbound iodine)-thyroid gland

Specific Activity:	17,400 Ci/gm (theoretical/carrier free)
Intrinsic Specific Activity:	22.0 Ci/millimole

RADIOLOGICAL DATA

Critical Organ (Biological Destination): Thyroid
Routes of Intake: Ingestion, inhalation (most probable), puncture, wound, skin contamination (absorption)

External and internal exposure and contamination concerns exits in use of ^{125}I

Committed Dose Equivalent (CDE):	814 mrem/mCi (thyroid/inhalation/class “D”)
	1,185 mrem/mCi (thyroid/ingestion/NaI form)
	910 mrem/mCi (thyroid/inhalation)
	1,258 mrem/mCi (any organ/puncture/adult)

Committed Effective Dose Equivalent (CEDE): 24 mrem/mCi (whole body/inhalation)

SHIELDING

Lead foil or sheets (1/32 to 1/16 inch thick): 0.152 mm lead foil

SURVEY INSTRUMENTATION

Survey meter equipped with a low energy NaI scintillation probe is necessary.
Survey meter equipped with GM pancakes or end window GM probes are inefficient. These probes are not useful for contamination monitoring; they are only about 0.1% efficient.

IODINE-131
[^{131}I]

PHYSICAL DATA

Gamma Energies:	364 keV (81% abundance)
	637 keV (7% abundance)
	284 keV (6% abundance)
Beta Energies:	606 keV (89% abundance)
	334 keV (7% abundance)
	248 keV (2% abundance)

Specific Gamma Ray Constant: 0.28 mR/hr per mCi at 1 meter

Physical Half-Life:	8.04 days
Biological Half-Life:	120-138 days (unbound iodine)-thyroid elimination
Effective Half-Life:	7.6 days (unbound iodine)-thyroid gland
Specific Activity:	124,000 Ci/g

RADIOLOGICAL DATA

Critical Organ (Biological Destination): Thyroid
Routes of Intake: Ingestion, inhalation (most probable), puncture, wound, skin contamination (absorption)

External and internal exposure and contamination concerns exits in use of ^{131}I

Committed Dose Equivalent (CDE):	1.08 rem/μCi (thyroid/inhalation)
	1.76 rem/μCi (thyroid/ingestion)

SHIELDING

Lead: Half Value Layer = 3 mm Tenth Value Layer = 11 mm

SURVEY INSTRUMENTATION

Survey meter equipped with GM pancakes or end window GM probes.
Liquid Scintillation Counter or Gamma Counter for wipe tests.

DEFINITIONS

ABSORPTION	The process by which the number of particles or photons entering a body of matter is attenuated by the interaction with the matter.
ACTIVATION	The process of making a material radioactive by the bombardment of neutrons, photons, or other nuclear radiation.
ALPHA	A positively charged particle ejected spontaneously from the nuclei of some radioactive elements. It is identical to a helium nucleus that has a mass number of 4 and an electrostatic charge of + 2.
ALI	(ANNUAL LIMIT ON INTAKE) Derived limit for the amount of radioactive material taken into the body of an adult worker by inhalation or ingestion in a year. ALI is the smallest value of intake of a given radionuclide in a year by the Reference Man that would result in a committed effective dose equivalent of 5 rem (0.05 Sievert (Sv)) or a committed dose equivalent of 50 rem (0.5 Sv) to any individual organ or tissue.
ATOM	The smallest particle of an element that retains the properties of that element.
ATTENUATION	The process by which a beam of radiation is reduced in intensity when passing through some material.
BACKGROUND RADIATION	Radiation from cosmic sources; naturally occurring radioactive materials, including radon and global fallout as it exists in the environment from the testing of nuclear explosive devices.
BECQUEREL	A unit, in the International System of Unit (SI), of measurement of radioactivity equal to one disintegration per second.
BETA	A charged particle emitted from a nucleus during radioactive decay, with a mass equal to 1/1837 that of a proton. A negatively charged beta particle is identical to an electron.
BREMSSTRAHLUNG	Secondary photon radiation produced by deceleration of charged particles passing through matter.
CALIBRATION	The check or correction of the accuracy of a measuring instrument to assure proper operational characteristics.
COLLECTIVE DOSE	Sum of the individual doses received in a given period of time by a specified population from exposure to a specified source of radiation.

CONTAMINATION	The deposition of unwanted radioactive material on the surface of structures, area, objects, or personnel.
CONTROL AREA	An area outside of a restricted area but inside the site boundary, access to which can be limited by the licensee or Radiation Safety Officer for any reason.
COUNTER	A general designation applied to radiation detection instruments or survey meters that detect and measure radiation.
COUNTER, (G-M)	Geiger-Miller counter is a radiation detection and measuring instrument. It consists of a gas-filled tube containing electrodes, between which is there is an electrical voltage but no current flowing. When ionizing radiation passes through the tube, a short, intense pulse of current passes from the negative electrode to the positive electrode and is measured or counted. The number of pulses per second measures the intensity of radiation.
COUNTER (SCINTILLATION)	The combination of phosphor, photomultiplier tube, and associated electronic circuits for counting light emissions produced in the phosphor by ionizing radiation.
CURIE	The basic unit used to describe the intensity of radioactivity in a sample of material. The curie is equal to 37 billion disintegrations per second, which is approximately the rate of decay of 1 gram of radium.
MICROCURIE	One millionth of a curie (µCi) is equal to $3.7X10^4$ disintegrations per second.
MILLICURIE	One thousandth of a curie (mCi) is equal to $3.7X10^7$ disintegrations per second.
PICOCURIE	One millionth of a microcurie (pCi) is equal to $3.7X10^{-2}$ disintegrations per second.
DAUGHTER – PRODUCTS	Isotopes that are formed by the radioactive decay of some isotopes. In the case of radium-226, for example, there are 10 successive daughter products, ending in the stable isotope lead-206.
DECAY (Radioactive)	The decrease in the amount of any radioactive material with the passage of time, due to the spontaneous emission from the nuclei of either alpha or beta particles, often accompanied by gamma radiation.

DECLARED (Pregnant Woman)	A woman who has voluntarily informed her employer, in writing, of her pregnancy and the estimated date of conception.
DAC	(Derived Air Concentration) The concentration of a given radionuclide in air that, if breathed by Reference Man for a working year of 2,000 hours under conditions of light work, results in an intake of 1 ALI.
DOSE	A generic term that means absorbed dose, dose equivalent, effective dose equivalent, committed dose equivalent, committed effective dose equivalent, total organ dose equivalent, or total effective dose equivalent. For the purpose of this training manual, "radiation dose" is an equivalent term.
DOSE RATE	The radiation dose delivered per unit of time. Measured, for example, in rem per hour.
DOSIMETER	A portable instrument for measuring and registering the total accumulated exposure to ionizing radiation.
DOSIMETRY	The theory and application of the principles and techniques involved in the measurement and recording of radiation doses.
EFFICIENCY	The net cpm (counts per minute) of a calibration standard source divided by dpm (disintegration per minute) of the source. It may or may not be multiplied by 100 to change the decimal value for the efficiency to percent.
GAMMA RAY	High-energy, short wavelength electromagnetic radiation (a packet of energy) emitted from the nucleus. Gamma radiation frequently accompanies alpha and beta emissions and always accompanies fission. Gamma rays are very penetrating and are best stopped or shielded against by dense materials, such as lead or uranium.
GRAY	The SI unit of absorbed dose. One gray is equal to an absorbed dose of 1 J kg^{-1} (100 rad).
HALF-LIFE (Physical)	The time taken for the activity of a radionuclide to lose half its value by radioactive decay.
HALF-LIFE (Biological)	The time required for the body to eliminate half of the material by natural biological means.
HALF-LIFE (Effective)	The time required for a radionuclide contained in a biological system, such as a human or animal, to reduce its activity by half as a combined result of radioactive decay and biological elimination.

ION	An atom that has too many or too few electrons, causing it to be chemically active; an electron that is not associated (in orbit) with a nucleus.
IONIZATION	The process of adding one or more electrons to, or removing one or more electrons from, atoms or molecules, thereby creating ions. High temperatures, electrical discharges, or nuclear radiation can cause ionization.
IRRADIATION	Exposure to radiation.
MASS NUMBER	The number of nucleons (neutrons and protons) in the nucleus of an atom. Also known as the atomic weight of an atom.
MILLIROENTGEN	A one-thousand part of a roentgen. (mR)
MONITORING	(radiation monitoring, radiation protection monitoring) The measurement of radiation levels, concentrations, surface area concentrations or quantities of radioactive material and the use of the results of these measurements to evaluate potential exposures and doses.
NEUTRON	An uncharged elementary particle with a mass slightly greater than that of a proton, and is found in the nucleus of every atom heavier than hydrogen.
Rad	(Radiation absorbed dose) The special unit for absorbed dose. 100 rad is equal to 1Gy (gray).
RADIATION	Alpha particles, beta particles, gamma rays, x-rays, neutrons, high-speed electrons, high-speed protons and other particles capable of producing ions.
RADIOACTIVITY	The spontaneous emission of radiation, generally alpha or beta particles, often accompanied by gamma rays, from the nucleus of an unstable isotope.
REACTOR (NUCLEAR)	A device in which nuclear fission may be sustained and controlled in a self-supporting nuclear reaction. The varieties are many, but all incorporate certain features, including fissionable material or fuel, a moderating material (unless the reactor is operated on fast neutrons), a reflector to conserve escaping neutrons, provisions for removal of heat, measuring and controlling instruments, and protective devices.

Rem	The special unit of any of the quantities expressed as dose equivalent. The dose equivalent in rem is equal to the absorbed dose in rad multiplied by the quality factor (1rem = 0.01Sievert).
ROENTGEN (R)	A unit of exposure to ionizing radiation. It is the amount of gamma or x-rays required to produce ions carrying 1 electrostatic unit of electrical charge in 1 cubic centimeter of dry air under standard conditions.
SEALED SOURCE	Radioactive material that is permanently bonded or fixed in a capsule or matrix designed to prevent release and dispersal of the radioactive material under the most severe conditions which are likely to be encountered in normal use and handling.
SHIELDING	Any material or obstruction that absorbs radiation and thus tends to protect personnel or materials from the effects of ionizing radiation.
SIEVERT	The SI unit of any of the quantities expressed as dose equivalent. The dose equivalent in sievert is equal to the absorbed dose in gray multiplied by the quality factor (1 Sv = 100 rem).
SURVEY	An evaluation of the radiological conditions and potential hazards incident to the production, use, transfer, release, disposal, or presence of radioactive material or other source of radiation. When appropriate, such an evaluation includes a physical survey of the location of radioactive material and measurement or calculations of levels of radiation, or concentrations or quantities of radioactive material present.
TLD	Thermoluminescent Dosimeter, crystalline material (for example CaF_2 with Mn impurity or LF) that emit light if they are heated after having been exposed to radiation.
ULTRAVIOLET	Electromagnetic radiation of a wavelength between the shortest visible and low-energy x-rays.
WIPE SAMPLE	A sample made for the purpose of determining the presence of removable radioactive contamination on a surface.
X-RAY	Penetrating electromagnetic radiation (photon) having a wavelength that is much shorter than that of visible light. They are produced by excitation of the electron field of an atom. In nuclear reactions, it is customary to refer to photons originating in the nucleus as gamma rays, and to those originating in the electron fields of the atom as X-rays.

ACUTE EXPOSURE – NORMALLY CONSIDERED 24 HOURS OR LESS

DOSE (REM)	PROBABLE EFFECT
0 – 25	No detectable clinical effects. Later effects highly improbable.
25 – 100	Possible slight transient blood change. Serious delayed effects improbable.
100 – 200	Nausea, fatigue, possible vomiting. Transient blood check master copy.
200 – 300	Nausea, vomiting, and diarrhea, following with latent period of up to one week with no ill effect. Then epilation, loss of appetite, fever, general malaise, followed by hemorrhage, inflammation of the mouth and throat, diarrhea, and emaciation in third week. Some deaths. A dose of 450 rems is considered to be a lethal dose to 50% of exposed individuals.
600 – more	Considered to be lethal, death as early as two weeks. However, with modern medical techniques individuals have survived exposure considerably greater than 600 rems.

Directions for Conducting a Radiation Safety Survey

Radiation safety surveys must be conducted on a weekly to monthly basis in each laboratory where radioactive materials are used. Appropriate detection equipment must be used for each nuclide monitored. Examples are as follows:

^{3}H	Beta	Liquid Scintillation Counter (Wipe Sample)
^{14}C	Beta	Liquid Scintillation Counter (preferred) or end window or pancake probe survey meter
^{32}P	Beta	End window or pancake probe survey meter
^{33}P	Beta	End window or pancake probe survey meter
^{35}S	Beta	End window or pancake probe survey meter
^{36}Cl	Beta	End window or pancake probe survey meter
^{125}I	Gamma	Low Energy Gamma (LEG) scintillation probe survey meter

1. Use a survey meter rather than liquid scintillation counter for monitoring all nuclides except ^{14}C and ^{3}H. Survey meters detect both removable and non-removable contamination, whereas wipes counted on a liquid scintillation counter detect only removable contamination. ^{3}H cannot be detected by any survey meter, so liquid scintillation counting is the only method to conduct a survey for ^{3}H.
2. You must survey in all areas and equipment where radioisotopes are used, stored or disposed, and the floors adjacent to those areas. This includes centrifuges, incubators, cold rooms, sealing equipment, pipettes and any other equipment, which has been used for radioisotope work.
3. Make a record of all laboratory surveys. The record should include who surveyed, where you surveyed, nuclides surveyed for, equipment identification, background readings, and results of the survey. Results include areas of contamination, nuclides and the reading from the instrument used.