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I. PHYSICAL CONCEPTS

1. Atomic Structure

Every atom has a nucleus which is composed of elementary particles, protons and neutrons. The protons possess a positive charge while neutrons have no electrical charge. Orbiting the nucleus are very small negatively charged particles called electrons. Neutral atoms have the same number of positively charged protons as negatively charged electrons. Atoms differ from each other in several ways. Elements are distinguished by the number of protons in the nucleus. Each element possesses physical and chemical properties which are unique to that element. Atoms of the same element may vary from each other by the number of neutrons in the nucleus (e.g. ^{12}C vs. ^{14}C). These elemental variations are called isotopes. They cannot be distinguished from other isotopes of the same element by chemical analysis since they react identically. Another possible difference between atoms is the number of electrons orbiting the nucleus. Since neutral atoms have the same number of electrons as protons, an atom which has a different number of protons and electrons is called an ion and may be either positively or negatively charged.

2. Ionizing Radiation

Radiation can either be particles or electromagnetic energy which is emitted or radiated in all directions from a localized source. Two primary types of radiation are ionizing and non-ionizing. Examples of non-ionizing radiation include microwaves, radio waves and visible light. Ionizing radiation is unique in that the emissions are energetic enough to cause ionization by the removal of orbital electrons. The three principal types of ionizing radiation are called alpha, beta and gamma. These three types of radiation are emitted from the nuclei of atoms which are unstable. The transformation to stability is achieved by adjusting the ratio of neutrons to protons within the nucleus of the atom by the emission of particulate radiation. The optimum ratio of neutrons to protons for stability is averaged to be 1.54 to 1.

3. Energy

The energy of ionizing radiation is measured in “electron volts”. One electron volt (eV) is the energy gained by an electron passing through a one volt potential. One eV is equivalent to 1.6×10^{-19} Joules. One electron volt is an extremely small amount of energy. The amount of energy associated with radioactivity is usually expressed in thousands of electron volts (keV) or millions of electron volts (MeV).

4. Radioactive Decay

Radioactive decay is the term used to describe the eventual transformation of radioactive atoms into stable, non-radioactive atoms. As charged particles are emitted, the number of protons and/or neutrons is changed. The resulting atom is called a “daughter product.” The daughter may also be radioactive with its own type and energy of emissions. Sometimes a series of decays must happen before a stable atom is produced. This is known as a decay chain. The formula for determining the amount of radioactivity at any time (t) is:

$A_t = A_0 e^{-\lambda t}$ Where λ = the decay constant for the particular radioisotope. This constant is also equal to $\ln 2/T_{1/2}$.

5. *Alpha Particles*

Alpha particles are positively charged helium nuclei (2 protons and 2 neutrons) which are ejected from heavy atoms having a low neutron to proton ratio. Alpha particles are monoenergetic, in that all alpha emissions from like atoms are ejected with the same kinetic energy. Due to the relatively large size and electrical charge, their range and penetrating ability is very small. Consequently, alpha particles do not pose a hazard outside the body. However, if alpha-emitting material is inhaled or ingested, the alpha particles can cause serious harm to live tissue where the material is deposited.

6. *Beta Particles*

Beta particles are energetic electrons emitted from the nuclei of atoms with high neutron to proton ratios. The transformation, which occurs in the nucleus, results in the conversion of a neutron into a proton and the ejection of a beta particle. The energy of the beta particle is not monoenergetic as it is for alphas. The beta particle has a range of possible energies from zero to a maximum possible energy which is unique to the radioisotope. Although beta particles are negatively charged, their very small size allows them to travel considerably farther in air than alphas. The ability of beta particles to penetrate solid materials is still very restricted. Only the most energetic beta particles may penetrate thin sheets of paper or plastic. Beta particles pose a significant internal hazard, and also may pose a small hazard to skin surfaces or to the lens of the eye, depending on their energy. A few radioactive isotopes are known as "pure beta" emitters. They are unique because there is no associated gamma ray directly following beta decay. Some examples of pure beta emitters are ^{3}H, ^{14}C, ^{35}S, ^{99}Tc and ^{32}P.

Isotope	Max Beta Energy	Half-Life	Max Range in Air
H-3	18.6 keV	12.3 Years	0.152 Inches
C-14	155 keV	5,730 Years	10 Inches
S-35	167 keV	87.2 Days	11 Inches
Tc-99	290 keV	210,000 Years	24 Inches
P-32	1.71 MeV	14.3 Days	19.7 feet

7. *Gamma Rays*

Gamma rays are essentially light packages or "photons" which are emitted from some unstable atoms which have just undergone a transformation by emitting a charged particle. Depending on the radioisotope, there may be one or several gamma rays emitted with differing energies. In addition the probability or frequency of their emission can vary from 100% to well under 1% as each transformation or decay occurs. Since gamma rays have no mass or charge, their range and penetrating ability are significant. Gammas have no finite range in any medium, but are best attenuated or shielded by dense material. The thickness of shielding material is cited in half value layers. One half value layer is that thickness of material which reduces the amount of radiation by 50%. Gamma rays may be an external hazard as well as an internal hazard.

8. X-rays

X-rays are also photons which are capable of causing ionizations and are similar in every way to gamma rays except in their point of origin. Gamma rays are emitted from the nucleus of an atom and x-rays come from the electron orbitals. The most common source of x-rays is from radiation producing machines. Some of the more common x-ray or gamma ray producing radioisotopes are listed below.

Isotope	Photon Energy	Yield	Half-Life
Cs-137	*662 Kev	90%	30.17 Years
Co-60	1.33 & 1.17 Mev	100%	5.26 Years
I-125	27.5 Kev	73.20%	60 Days
I-131	364 Kev	81.20%	8.06 Days
Cr-51	320 Kev	9.80%	27.8 Days

**662 Kev Photon emitted from Daughter product, Ba-137m (2.5 Min half-life)*

Another source of x-rays comes from the abrupt change in velocity of beta particles. X rays generated by this process are referred to as ***"bremstrahlung"*** (braking radiation). The creation of these x rays is dependent on the atomic number of the absorbing material. The higher the atomic number the greater the likelihood that an x ray will be produced. The energy of the x ray is directly proportional to the atomic number of the absorber and the energy of the beta particle. Due to bremstrahlung, it is preferable to shield high energy beta particles with materials of low atomic number. Plastic or acrylic materials are generally used for beta shields. Although the production of x rays should be minimized, the resultant exposure rate from bremstrahlung is usually insignificant.

9. Half-Life

One half-life is the length of time required for the amount of radioactivity present to be reduced by 50%. At each subsequent time interval equaling one half-life, the previous amount of radioactivity is further reduced by half. The half-life can be viewed as the probability of decay. An individual radioactive atom may decay at any time, but for a given quantity of radioactivity, the number of particle emissions per unit time, also referred to as "disintegration rate," will be a constant.

10. Units

A ***"Curie"*** is a unit of measurement which quantifies the amount of radioactivity present as a disintegration rate. One Curie (Ci) is referenced as the amount of radioactivity present in 1 gram of radium and is equivalent to 3.7 x 10^{10} disintegrations per second (DPS).

Units	DPM	DPS
1 Ci.	2.22E+12	3.70E+10
1 mCi.	2.22E+09	3.70E+07
1 uCi.	2.22E+06	3.70E+04

A Bequerrel is an S.I. unit which describes how much radioactivity is present. One Bequerrel (Bq.) is a very small amount of radioactivity which is equivalent to 1 disintegration per second.

A ***"Roentgen"*** is a unit of measurement which quantifies radiation exposure in air from x-rays or gamma rays only. One Roentgen (R) of exposure provides 2.58 x 10^{4} coulombs of charge per kilogram of air.

A ***"Rad"*** is a unit of measurement which quantifies the dosage of energy deposited in any medium from any type of ionizing radiation. One rad is equivalent to 100 ergs of energy deposed per gram of absorbing material.

A ***"Gray"*** (Gy) is the S.I. unit for absorbed dose. One Gray is equivalent to 100 rads.

A ***"Rem"*** is a unit of measurement also known as "dose equivalent" which numerically describes the relative amount of biological damage which may occur from doses of ionizing radiation. The rem is derived by the product of the dose received in rads and a quality factor which is unique to each type of radiation. This equates the effectiveness of each type of radiation to cause biological damage. The rem is used to report doses to persons or organs.

A ***"Sievert"*** (Sv) is the S.I. unit for dose equivalent. One Sievert is equivalent to 100 rems.

II. REGULATORY ISSUES AND RISK

1. *Dose Limits*

Occupational dose limits are set by the federal government and are cited in Title 10 of the Code of Federal Regulations. The following is a list of the limits for external occupational dose to adult workers.

Deep Dose Equivalent (DDE)	5 rems per calendar year
Lens Dose Equivalent (LDE)	15 rems per calendar year
Shallow Dose Equivalent (SDE)	50 rems per calendar year
Shallow Dose Equivalent Maximum Extremity (SDE_{ME})	50 rems per calendar year

Occupational dose limits for minors are limited to 10% of the limits for adult workers.

Dose limits to an embryo or fetus from occupational exposure shall be restricted to 0.5 rems DDE over the term of pregnancy. Fetal or embryonic cells are rapidly dividing and are therefore more radiosensitive and warrant a lower dose limit.

Note: It is strongly recommended that pregnant radiation workers advise the Radiation Safety Officer of their condition when they become aware of it. A workplace evaluation and possible changes in personnel monitoring may be warranted. (See Radiation Safety Manual Chapter IV, Section F.)

Facilities or institutions in which it is likely that persons would receive 10% of the prescribed limits shall provide individual monitoring devices for those persons. (See “Dosimetry” in Section III of this document.)

Dose limits are determined partially by the varying radiosensitivity of particular organs or tissues. Tissues which are less differentiated or cells which are rapidly dividing are the most radiosensitive. Other parts of the body which are less radiosensitive, such as the skin or extremities do not warrant as much dose restriction as shown in the limits for shallow dose equivalent.

Radioactive material taken up by the body contributes to the dose received and is directly proportional to the amount of uptake. The amount of radioactive material taken up which results in 5 rems committed effective dose equivalent (CEDE)* or 50 rems to an organ is called the annual limit on intake (ALI). Due to the differences in the emissions and affinity for particular organs, the ALI is varies widely for different radioactive elements. For most radioactive materials used at SDSU the internal hazard far outweighs the hazard outside the body. Therefore, it is very important to avoid practices which may result in an ingestion, inhalation or dermal absorption of radioactive materials.

* Committed Effective Dose Equivalent is that dose to organs or tissues resulting from a single intake for 50 years following the intake multiplied times a weighting factor which proportionalizes the stochastic risk to the total risk of stochastic effects if the whole body were irradiated uniformly. (See the definition of stochastic effects in the following section on risks.)

2. *Risks*

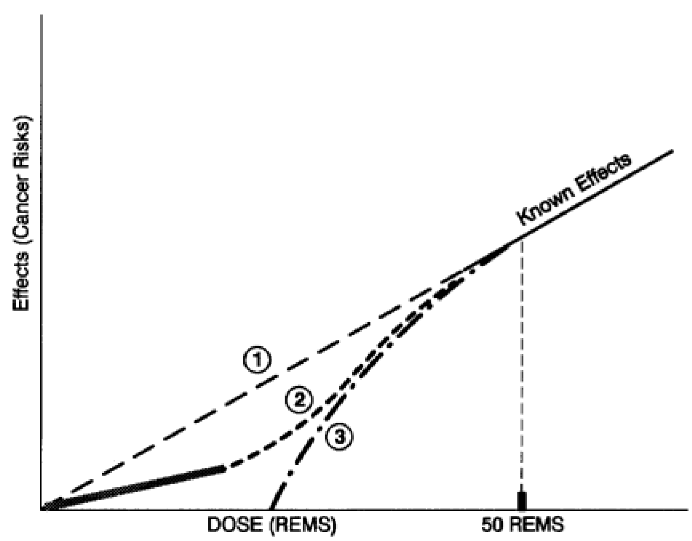
Most of the data used to evaluate risks from exposure to ionizing radiation comes from bomb survivors in Japan and radiation therapy patients.

The following are committees or other organizations involved in the study of biological effects and risks associated with exposure to ionizing radiation. Based on risk estimates, recommendations are made regarding dose limits to members of the general public and those occupationally exposed.

a) United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR)
b) The Committee on the Biological Effects of Ionizing Radiation (BEIR)
c) National Council on Radiation Protection and Measurements (NCRP)
d) International Commission on Radiological Protection (ICRP)

The Law of Bergonie and Tribideau states that cells which are less differentiated or are rapidly dividing are the most radiosensitive.

Although it is not known precisely what effects there are to biological organisms at low chronic doses of radiation, a conservative perspective should be maintained in an attempt to keep doses as low as reasonably achievable (ALARA… *refer to page 10*). Until the effects from low doses of radiation are more defined, the current viewpoint is that there is no threshold dose under which the incidence of cancer cannot be attributable. This perspective is also known as the linear-no-threshold dose model (curve 1). Some scientists believe that the risk drops off to zero at some low dose (curve 3) the threshold effect. The ICRP and NCRP endorse the linear quadratic model as a conservative means of assuring safety (curve 2).



A common sense approach should be to reduce the potential for exposure whenever practical. At higher doses of radiation (25-50 rems), detrimental effects are known to occur. There is a linear dose response at high doses of radiation indicating increases in the occurrence or the severity of induced effects as the dose increases.

There are two types of effects which could result from exposure to ionizing radiation: *stochastic* and *non-stochastic*. Stochastic effects are those which are not categorized by their severity but by their incidence. Based on the probability of occurrence, an example of a stochastic effect would be cancer. Non-stochastic effects (also referred to as deterministic) are those effects for which their severity is based on increasing exposure rather than the occurrence. For deterministic effects, a minimum threshold dose must be received before the effect will occur. An example of a non-stochastic effect would be erythema or skin reddening. There is a threshold amount of exposure before non-stochastic effects would occur. For stochastic effects, the conservative perspective assumes no threshold and that any amount of exposure may cause the effect. The goal in radiation safety is to eliminate non-stochastic effects and reduce the incidence of stochastic effects.

a) ***Somatic effects*** are those which are observable in the exposed individual. An example of a somatic effect would be the formation of cataracts in the lens of the eye or blood pH changes.

b) ***Teratogenic effects*** are those which occur to the developing fetus during gestation. Since the fetus is rapidly developing, its radiosensitivity is high.

c) ***Mutagenic effects*** are those which involve the disruption of the base pair sequence in DNA molecules which may result in a genetic defect or mutation. Although the current regulatory position is based on the conservative viewpoint that there is no threshold dose required for such biological aberrations, experimental evidence suggests a repair mechanism corrects what could be point mutations. At very high doses of radiation the repair mechanism becomes inadequate to prevent mutations.

d) ***Genetic effects*** are similar to mutagenic effects but the genetic aberration occurs in one or both of the sex cells which may effect the progeny.

It is implied that by becoming a radiation worker, an acknowledgment exists of the presence of risk. A balance exists between the risks to be accepted versus the benefit of the work. Although limits are in place which should never be exceeded, no individual can determine the acceptability of risk for another. In the evaluation of risk, you should compare the relative risks which are incurred in everyday life to your anticipated use of radioactivity. If you understand what is known about radiation and are willing to use common sense and good judgment, you are likely to conclude your risk from occupational exposure at SDSU to be one of the smallest factors to consider.

A number of studies have been performed in an attempt to quantify the risk of cancer to exposed populations. Numerical estimations of the risk are dependent on differences within the exposed population such as age and sex. Differences in the relative risk are also dependent on the type of radiation, the manner in which it was received and the probability of the particular induced effect (e.g. leukemia vs. tumor formation etc.). Reasonable estimates of mortality due to cancer from exposure to ionizing radiation range from 3.5 to 8.0 E-4/rem.

III. ADMINISTRATIVE ISSUES

1. Regulatory Authority

The State of California Department of Health Services is granted regulatory authority by the Nuclear Regulatory Commission to oversee the acquisition and use of radioactive materials and radiation producing machines within the state. The Dept. of Health Services considers for approval applications for radioactive materials licenses, performs inspections of licensee facilities, and issues citations for points of non-conformance.

2. Radioactive Materials License

SDSU has been granted a Broad Scope Type A Radioactive Materials License which offers the highest degree of latitude in the administration of the radiation safety program. The Broad Scope Type A License allows the licensee to propose their own methods to manage radiation related issues as determined by a Radiation Safety Committee (RSC).

3. Radiation Safety Committee

The SDSU Radiation Safety Committee creates policy and regulates the acquisition and use of radioactive materials and radiation producing machines within the terms of the license.

4. Radiation Use Authorization

Persons petitioning to use ionizing radiation at SDSU must submit an application for a Radiation Use Authorization (RUA). The application describes to the Radiation Safety Committee the isotopes and quantity of radioactive materials required for a specific project. If approved, the RUA limits users to the type and quantity of radioactive material requested and where the material may be used. The Principal Investigator (PI) is required to respond to periodic written correspondence from the Radiation Safety Officer in order to keep the RUA active. The RUA also directs the PI to adhere to specific responsibilities as required by the committee. In the event the PI terminates their service to the university or the RUA is to be terminated for any reason, the RSO is to receive advance notification in order to perform a decommissioning survey.

5. Radiation Safety Officer

The Radiation Safety Officer (RSO) is responsible to ensure safe working conditions regarding the use of ionizing radiation. The RSO is also required to make sure all license conditions are followed and to enforce policy in accordance with directives from the RSC. The ultimate goal is to protect radiation related research by maintaining the integrity of the license and addressing radiation related safety issues. The RSO is empowered to immediately revoke any Radiation Use Authorization and confiscate all radioactive materials if there is evidence of gross negligence by laboratory personnel.

6. Principal Investigator

The Principal Investigators (PI) are ultimately responsible for all safety issues within the laboratory. They are responsible for performing corrective action to resolve problems noted by the Radiation Safety Officer or the Radiation Safety Committee. By signing the Radiation Use Authorization, the PI agrees to comply with the radiation safety manual and any special provision noted on the RUA. The PI is required to respond to periodic written correspondence from the Radiation Safety Officer in order to keep the RUA active and to notify the RSO in advance if the RUA is to be terminated. In the event the PI is away for an extended absence such as a sabbatical they must designate an interim PI with the authority to make decisions for them in their absence.

7. Radiation Workers

Approval to become a radiation worker results from the recommendation of the PI and completion of training in basic radiation safety administered by the RSO at SDSU. Radiation workers are expected to conduct themselves in a professional manner and to keep their exposure to radiation as low as reasonably achievable (ALARA). They are obligated to report radiation safety concerns to their direct supervisor or the RSO. While using radioactive materials, radiation workers are required to follow the directives in the Radiation Use Authorization and the Radiation Safety Manual.

8. Security

All radioactive materials obtained under a Radiation Use Authorization or under authority of the Radioactive Materials License must be locked or secured from unauthorized removal at all times. The laboratory environment where radioactive materials are stored or permitted for use is called the “controlled area.” Usually the presence of a radiation worker in the controlled area who can prevent the unauthorized removal of radioactive material is sufficient security.

9. *Dosimetry*

a) *External*

Monitoring devices for assessing a person’s external occupational dose from ionizing radiation are called dosimeters. They are provided at the discretion of the RSO or if the likelihood exists that a radiation worker could receive 10% of the prescribed occupational limits. They are issued only for projects approved by the SDSU Radiation Safety Committee. Dosimetry records are permanent legal records, therefore it is advisable to wear the dosimetry continuously while in the working environment, not only during radioactive procedures. Under no circumstances should you wear another persons dosimeter. If a dosimeter is lost or damaged, advise the Radiation Safety Officer so a replacement dosimeter can be provided before work resumes. When not in use, please keep your dosimetry in a central location to expedite quarterly replacements. Personnel may receive a copy of their dosimetry records upon written request. Currently SDSU uses thermoluminescent dosimeters (TLDs) to assess external dose. For persons who have been issued extremity dosimeters (finger rings), it is important to remember to wear the ring inside the disposable gloves.

b) *Internal Dose*

To evaluate dose resulting from an intake of radioactive material, the amount of material and the approximate time of the intake must be considered. A bioassay must be done to measure the quantity of radioactive material taken up by the body. Depending on the radioisotope and mode of intake (e.g. inhalation vs. ingestion), the amount of activity determined from bioassay data is directly proportional to the dose received by particular organs or to the entire body. Types of bioassays which may be performed are whole body counting, thyroid counting or urine bioassays.

10. *Pregnancy*

Female radiation workers who are pregnant have the option to inform the RSO of their pregnancy. If a worker declares her pregnancy in writing, the RSO is required to evaluate work practices and make reasonable recommendations in accordance with ALARA (see Radiation Safety Manual). In some instances a fetal dosimeter is issued and replaced on a monthly basis. The dose limit for the fetus from occupational sources is 500 mrem (one tenth of the permissible dose to the mother) over the 9 months gestation period. The declaration of pregnancy is confidential.

11. *Shipping and Receiving*

All radioactive materials, with the exception of smoke detectors and self luminous signs shall be received through the Department of Environmental Health and Safety. EH&S is required to inspect all radioactive material shipped to university property as specified in SDSU’s radioactive materials license. The packages are checked for physical integrity, emergent exposure rate, surface contamination and compliance with shipping regulations and intended use. A record of the receipt will be made and the package will be distributed to the authorized user. In the event a package containing radioactive material is distributed directly to the lab from a courier, please notify EH&S promptly in order to comply with the required inspection.

The regulations for shipping radioactive material are, at best, confusing. Please notify EH&S in the event you intend to ship radioactive material. Proper documentation, labeling, and packaging is important to avoid regulatory problems. Prior to shipping, a copy of the recipient's radioactive materials license must be obtained. Advance notice should be considered when intending to ship radioactive material. The term radioactive material applies not only to radioactive solutions or samples but also to items which may be inadvertently contaminated such as refrigerators or centrifuges. Any item which leaves the campus property is considered shipping.

IV. WORK PRACTICES

1. ALARA

It is the responsibility of every radiation worker to keep their exposure to radiation as low as reasonably achievable or ALARA. Three ways to reduce your exposure are time, distance and shielding. Minimize your time in areas where exposure levels are likely to exceed background. Maximize your distance from sources of radiation. Exposure levels from x or gamma ray sources are reduced inversely, proportional with the square of the distance. Doubling your distance will reduce the exposure rate to 1 fourth ($X \approx 1/D^2$). Remember to use shielding which is appropriate for the type of radiation.

Note: It is important to keep in mind that time, distance and shielding all work together to reduce your exposure, but depending on the situation, one method may be more practical and effective than another.

2. Signs and Labels

All entries to laboratories where radioactive materials are approved to be used or stored are posted by EH&S with a sign stating “Caution Radioactive Materials” and displaying the radiation emblem. The purpose of the signs is to alert persons to the possible presence of radioactive materials. Persons entering these areas should not touch objects unless they know them to be free from contamination. These areas do not pose a radiation hazard to individuals by their presence in the area.

When radioactive material is removed from the stock container, an obvious indication must be made to alert other persons that radioactivity is present. Typically, adhesive tape which is imprinted with the words “radioactive material” is used to denote work spaces or items which contain radioactivity.

Areas which have levels of radiation warranting restricted access are labeled as "Radiation Areas." Access to radiation areas is limited to authorized persons who have been issued dosimetry.

3. Protective Apparel

Whenever working with loose radioactive material, you are required to wear disposable gloves and a lab coat. The benefit of gloves as contamination control apparel is defeated as soon as you handle any clean item with contaminated gloves. Gloves should never be worn while handling items expected to be clean. Wearing sandals or open toed shoes is always discouraged. Your feet should be covered to prevent skin contamination from spills or splashes.

If you discover that your lab coat is contaminated, it should either be disposed as solid radioactive waste or placed in a bag for decay. Advise the RSO if your lab coat is contaminated to determine if decay is appropriate and to verify that your skin has not been contaminated.

4. Process Area

It is prudent practice to restrict the dispensation and manipulation of loose radioactive materials to as few locations within the lab as possible. The process areas should have laminated absorbent paper on the lab bench to insulate the surface from contamination and limit the spread of spills. The area should be identified as a process area by defining the perimeter with caution tape or other obvious indication. Clear definition of the process area is useful in determining where clean items such as notebooks and calculators may be kept. Items which are expected to be clean should never be within the process area. Shielding material which is appropriate to the type of radiation is to be present in the process area. Although the process area is where you would expect to find radioactivity, perpetual contamination should not be allowed.

5. Monitoring

Post procedure monitoring is required of radiation workers following the completion of a procedure with loose radioactive materials. With the exception of tritium, the laboratory should have a portable instrument to check for contamination. The purpose of post procedure monitoring is to identify and remove contamination. It is the responsibility of each radiation worker to perform decontamination when contamination is found. After cleaning the area, some residual contamination may still be present. Wipes of the surface may need to be taken to determine if the contamination is "fixed" (not removable). If fixed contamination is present, the area should be labeled as radioactive with the count rate or activity, the date and isotope, if known.

6. Detectors

When using a Geiger counter or other count rate instruments, it is important to remember it should not be used to quantify the amount of radioactive material, but simply to establish the presence of it. Its function is to count ionization events and it is calibrated for count rate measurements. The count rate observed, usually expressed in counts per minute (CPM), will always be less than the actual emission or disintegration rate of the material. The ratio of count rate observed to disintegration rate of the material is the efficiency of the instrument for that isotope. The efficiency of the instrument to detect the presence of radiation varies with the type of radiation and its energy. The efficiency of a portable count rate instrument will never approach 100%. The table below lists commonly used radioisotopes at SDSU and their approximate detection efficiencies.

Detector Efficiency = CPM/DPM x 100 (Expressed as a percentage)

Isotope	Geiger Counter Efficiency
H-3	N/A
C-14	5%
S-35	5%
P-32	30%
I-125	0.10%

Conventional portable instruments are incapable of detecting the presence of tritium. If a procedure involves the use of tritium, wipes will have to be taken of the area to determine the presence of loose contamination. The wipes must be evaluated using a liquid scintillation counter (LSC).

Before using a contamination monitor, make sure that there is a current calibration sticker and that the batteries are good. Take note of the background count rate before proceeding. When scanning surfaces, the instrument should be set to the lowest counting scale possible. Typically, for Geiger counters, the background rate varies between 20 and 80 counts per minute. The probe should be held close to the surface being checked but not in contact with it. Move the probe slowly to check other areas of interest, no faster than 2 inches per second. Areas which have a count rate twice the background rate should be considered contaminated and cleaned. When contamination is discovered it should be cleaned up immediately and rechecked.

If a laboratory has an exemption to permit food and beverages in an isolated section of the lab, further contamination checks are required. Consult the RSO for details regarding the clean area policy.

Radiation Safety Staff performs periodic monitoring of laboratories to supplement the efforts of laboratory personnel. Monitoring frequency is determined by the radiological safety index listed on the RUA and laboratory history.

7. *Inventory of Radioactive Material*

An inventory log must be maintained by authorized users of all radioactive material received under the Radiation Use Authorization. The receipt date, isotope, activity and chemical form must be stated on the inventory. The log entry should be done promptly upon receipt of the material. In addition, each removal of radioactive material from the stock container must be indicated by noting the date of removal, the activity removed and the initials of the person removing the material. If volumetric units are used to track usage, the concentration (activity per unit volume) must be indicated. The records must be legible and clearly comprehended by persons not affiliated with the lab. Records must be maintained by the laboratory for at least a year.

At the beginning of each calendar quarter the Radiation Safety Office distributes an inventory log of all radioactive materials received by each PI. Using the inventory record maintained by the lab, the inventory routed to the PI must be amended to reflect usage of radioactive material.

V. WASTE MANAGEMENT

1. *General*

All containers for radioactive waste will be provided by Radiation Safety Staff. All waste should be doubly contained by using two plastic liners for solid waste and a secondary container for liquid waste.

The laboratory must segregate radioactive waste by half-life, chemical and physical form. Short-lived isotopes (e.g. ^{32}P, ^{35}S, and ^{125}I) each require their own waste container. Longer-lived materials such as ^{3}H and ^{14}C may be combined in the same container as long as their activities are listed separately.

The radioisotopes in each container must be specified on either the affixed tag or label before depositing waste. A reasonable estimation of the activity must be made for each radioisotope prior to pickup by EH&S. You should not attempt to estimate the activity of any waste using a Geiger counter. You must either make a reasonable estimate from the use log maintained in the lab or, in the case of liquid waste, sample the waste and count on a liquid scintillation counter. This data can be used to calculate activity for the entire jug. In addition, the name of the PI and the date the activity was estimated must also be indicated on the tag.

Waste should never be intentionally stored in the lab for decay.

Call EH&S at 4-6778 or 4-6879 to arrange waste pickups. Usually we can pick up the waste and provide replacement containers in the same day. Because occasionally we are unable to pick up the waste in the same day, plan ahead to ensure adequate container space is available before starting a procedure.

With any radioactive material, appropriate consideration should always be given regarding potential exposure. This is particularly important when working with gamma emitting or high energy beta emitting isotopes. An effort should always be made to keep radiation exposures as low as reasonably achievable or ALARA.

2. Solid Radioactive Waste

The container for solid radioactive waste will usually come unassembled with two plastic liners. Laboratory personnel will have to assemble the box and place both of the liners in the box (one inside the other).

No pourable liquids are allowed. All liquid must be decanted into a container provided by EH&S. Gels may be placed in the solid waste box.

Do not place contaminated lead, animal tissue, biohazardous or infectious materials in the solid waste. Any radioactive biohazards or infectious radioactive waste must be sterilized prior to inclusion in the waste box. All biohazard insignias must be defaced before placing in the waste box.

All liquid scintillation vials must be reasonably emptied and segregated as dry waste. Vials previously containing ^{14}C or ^{3}H solutions must be segregated from all other solid waste and placed into another waste container provided by EH&S.

All radioactive sharps (e.g. needles, blades, or Pasteur pipettes) need to be segregated in some type of rigid container prior to their inclusion in the solid waste box.

The laboratory is responsible for taping the bags closed and sealing the box prior to pickup by EH&S. Regular masking tape is acceptable.

3. Liquid Radioactive Waste

Segregation by isotope should be done in the same manner as solid waste. Under NO circumstances may radioactive liquids be disposed in a sink.

Containers for liquid waste must be kept sealed using the cap provided when not in use.

Radioactive solutions which are organic (e.g. ether, xylene, toluene, hexane, alcohol etc.) need to be segregated in a separate jug whenever possible. The chemical constituents and their relative percentages by volume must be identified on the waste tag.

Rinses of gels or other items resulting in the generation of liquids which are radioactive must be considered radioactive waste and disposed appropriately. Contact the Radiation Safety Officer with any questions regarding potentially radioactive rinses.

Do not overfill the container. There is usually a fill line which should not be exceeded. Generally, do not fill beyond 3/4 full. Call Radiation Safety for waste pickup when approaching this capacity.

VI. INCIDENT RESPONSE

1. *Spills*

In the event radioactive liquid is spilled, the following steps should be taken in the following order:

a) Isolate the spill if possible. If an absorbent media (paper towels, etc.) is available, use it to limit the spread of the spill.

b) Announce to any other personnel in the area that a spill has occurred and to avoid the area. Do not leave the lab unless absolutely necessary. The types and quantities of radioactive material used at SDSU do not warrant an immediate evacuation due to a spill. It is important to ensure that personnel and their shoes are free of contamination prior to leaving the lab.

c) Call The Radiation Safety Officer at 4-6098 or the EH&S office at 4-6778. There is never any punitive action for reporting spills. It is important that safety personnel are notified in order to assess the extent of the spill or to assist in the cleanup. If the spill occurs in the evening or on a weekend, contact campus Public Safety at 4-1991. In addition, there are emergency phone numbers posted on the outside of the doors leading into all radioisotope laboratories.

d) If advised by safety personnel to clean the spill, start from the perimeter of the spill area and work toward the center to limit the spread of the spill. Remember to wear your lab coat, disposable gloves and dosimetry, if applicable. It may be necessary to enlist the help of a coworker to obtain supplies located outside the spill area to keep personnel involved in decontamination to a minimum.

Sometimes a severe contamination event can occur without having a spill. The presence of undiluted stock radioactive material on surfaces which foster migration, such as a floor, could be at least as serious from a contamination perspective as if a large volume of liquid were spilled. Whenever you find contamination in an area where you don't expect it or if contamination is pervasive, contact Radiation Safety.

2. *Personnel Contamination*

If your skin becomes contaminated wash the affected area immediately. Conventional soap and water is preferable for skin decontamination. The water temperature should be tepid to prevent the pores of your skin from either opening or closing, impeding decontamination efforts.

If your lab coat or clothing becomes contaminated, remove it immediately and place the item in a bag for disposal or decay as determined by Radiation Safety. The bag should be labeled with the date, the count rate if known, and the isotope. Whenever your lab coat or other clothing becomes contaminated, you should contact Radiation Safety for an assessment whether skin contamination has occurred and to determine the disposition of the contaminated garment. Under no circumstances should you take contaminated apparel off campus for laundering.