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DEFINITIONS OF TERMS USED IN THIS MANUAL

**ALARA** - Acronym for "As Low As Reasonably Achievable", a basic concept of radiation protection that specifies that radioactive discharges to the environment and radiation exposure to personnel be kept as far below regulatory limits as feasible.

**Airborne radioactive material** - any radioactive material dispersed in the air in the form of dusts, fumes, mists, vapors or gases.

**Airborne radioactivity area** - (1) any room, enclosure, or operating area in which airborne radioactive material exists in concentrations in excess of the amounts specified in RHA 3.53, Appendix B, Table I, Column 3 of S.C. DHEC Radioactive Materials Regulation 61-63 title A; or (2) any room, enclosure, or operating area in which, averaged over the number of hours in any week during which individuals are in the area, exceed 25 percent of the amounts specified in RHA 3.53, Appendix B, Table I, Column 3 of Radioactive material Regulations 61-63 Title A.

**ALI (Annual Limit on Intake)** - The 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 smaller 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 Sv) or a committed dose equivalent of 50 rems (0.5 Sv) to any individual organ or tissue.

**BRH** - As used in this manual: South Carolina Department of Health and Environmental Control - Bureau of Radiological Health.

**Calendar quarter** - not less than 12 consecutive weeks nor more than 14 consecutive weeks. The first calendar quarter of each year shall begin in January; and subsequent calendar quarters shall be such that no day is included in more than one calendar quarter or omitted from inclusion within a calendar quarter. No licensee shall change the method observed by him of determining calendar quarters except at the beginning of a calendar year.

**Contamination** - The deposition of unwanted radioactive material on the surfaces of structures, areas, objects, or personnel.

**Contaminated area** - Any area where there exist loose surface (removable) contamination greater than or equal to:

1. 200 disintegrations per minute beta/gamma or
2. 20 disintegrations per minute alpha

**Controlled Area** - a defined area in which the occupational exposure of personnel to radiation or radioactive material is under the supervision of an individual in charge of radiation protection.

**Curie** - The basic unit used to describe the intensity of radioactivity in a sample of material. That amount of radioactivity that will disintegrate at the rate of 3.7 E 10 disintegrations per second or 2.22 E 12 disintegrations per minute (dpm). 684
Commonly used fractions of the curie:

1. Pico Curie - one trillionth part = 2.22 dpm
2. Nano Curie - one billionth part = 2.22 E 3 dpm
3. Micro Curie - one millionth part = 2.22 E 6 dpm
4. Milli Curie - one thousandth part = 2.22 E 9 dpm

DAC (Derived Air Concentration) - The concentration of a given radionuclide in air which, if breathed by the reference man for a working year of 2,000 hours under conditions of light work (inhalation rate 1.2 cubic meters of air per hour), results in an intake of one ALI.

Dpm - The number of radioactive disintegrations per minute, which is determined by:

\[
\text{DPM} = \frac{\text{observed cpm} - \text{background}}{\text{instrument efficiency}}
\]

Dose rate - The radiation dose delivered per unit of time. Measured, for example, in Rem per hour.

Exposure - The absorption of radiation or ingestion of a radionuclide. Acute exposure is generally accepted to be a large exposure received over a short period of time. Chronic exposure is exposure received during a lifetime.

"Bureau" or BRH - the South Carolina Department of Health and Environmental Control - Bureau of Radiological Health.

Gamma ray - High energy, short wavelength electromagnetic radiation emitted from the nucleus of an atom. Gamma radiation frequently accompanies alpha and beta emissions.

Half-life - The time in which half the atoms of a particular radioactive substance disintegrate to another nuclear form.

Half value thickness - The thickness of any given absorber that will reduce the intensity of a beam of radiation to one-half its initial value. Tenth value thickness - same as above but with reduction to one-tenth the original value.

High Radiation Area - means any area, accessible to individuals, in which there exists radiation at such levels that the whole body could receive in any one hour a dose in excess of 100 millirem.

Ionizing radiation - Any radiation capable of displacing electrons from atoms or molecules, thereby producing ions: alpha, beta, gamma, X-rays, and neutrons.

Isotope - One of two or more atoms with the same number of protons, but different numbers of neutrons in their nuclei. Carbon-12, carbon-13, and carbon-14 are isotopes of the element carbon, the numbers denoting the approximate atomic weights.
Isotopes have very nearly the same chemical properties, but different physical properties (for example carbon-12 and -13 are stable, carbon-14 is radioactive. For the purposes of this manual the word "isotope" means "radioactive or radio isotope".

License - except where otherwise specified, means either a general license or specific license issued pursuant to DHEC Radioactive material Regulations.

Natural radioactivity - radioactivity of naturally occurring nuclides.

Radionuclide - a radioisotope. For the purposes of this manual the word "nuclide" means radionuclide or radioisotope.

Occupational dose - exposure of an individual to radiation (i) in a restricted area; or (ii) in the course of employment in which the individual's duties involve exposure to radiation; provided, that occupational dose shall not be deemed to include any exposure of an individual to radiation for the purpose of medical diagnosis or medical therapy of such individual.

Primary use area - any area such as a table, bench top or portion of a bench top that is set aside for the staging and manipulation of potentially contaminated items or unsealed source material. These areas will be delineated by placing two inch wide yellow and magenta tape around the perimeter of the area and a readily visible sign bearing the radiation trifoil and the words "CAUTION CONTAMINATED AREA". Use of these areas will assist in segregation of contaminated and non-contaminated items and help to minimize materials stored in the fume hood.

Personnel monitoring equipment - devices designed to be carried or worn by an individual for the purpose of measuring the dose an individual receives (e.g. film badges, film rings, pocket chambers, pocket dosimeters, thermoluminescent dosimeters, etc.).

Radiation - gamma rays, Xrays, alpha and beta particles, highspeed electrons, neutrons, and other nuclear particles; but not sound or radio waves, or visible, infrared, or ultraviolet light.

Radiation Area - any area, accessible to individuals, in which there exists ionizing radiation at such levels exceeding those listed in Title A, RHA 1.2.24. Any area in which there exist ionizing radiation at such levels such that the whole body could receive in any one hour a dose in excess of 5 millirem, or in any 5 consecutive days a dose in excess of 100 millirem.

Radiation Safety Officer (RSO) - any person directly responsible for protection against radiation. At Clemson the RSO is J.L. Addis.

Radioactive material - any material, solid, liquid, or gas, which emits radiation spontaneously.

Restricted area - any area to which access is controlled by the licensee for purposes of protection of individuals from exposure to radiation and radioactive materials. "Restricted area" shall not include any areas used for residential quarters, although a separate room or rooms in a residential building may be set apart as a restricted area.
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.

Smear - A piece of filter paper or cloth disk which is wiped over a surface and analyzed to determine if the surface is contaminated with loose radioactive material (reported in units of dpm / 100 cm$^2$).

Source of radiation - any radioactive material, or any device or equipment capable of producing or emitting radiation.

Survey - an evaluation of the radiation hazards incident to the production, use, release, disposal, or presence of sources of radiation under a specific set of conditions. When appropriate, such evaluation includes a physical survey of the location of materials and/or equipment and measurements of levels of radiation or concentrations of radioactive material present.

Unrestricted area - any area access to which is not controlled by the licensee for purposes of protection of individuals from exposure to radiation and radioactive materials, and any area used for residential quarters.

Whole body - the entire body, or a major portion thereof, or the head and trunk, or the active blood forming organs, or the lens of the eyes or the gonads. Whole body does not refer to the skin of the whole body.

UNITS OF RADIATION DOSE.

Dose - the quantity of radiation absorbed, per unit of mass, by the body or by any portion of the body. When these regulations specify a dose during a period of time, the dose means the total quantity of radiation absorbed, per unit of mass, by the body or by any portion of the body during such period of time. Several different units of dose are in current use. Definitions of units as used in DHEC regulations are set forth in the following paragraphs of Title-A 1.3.2 and 1.3.3

Rad - Radiation Absorbed Dose: a measure of the dose of any radiation to body tissues in terms of the energy absorbed per unit mass of the tissue. One rad is the dose corresponding to the absorption of 100 ergs per gram of tissue. (One millirad [mrad] = 0.001 rad)

Rem - a measure of the dose of any radiation to body tissue in terms of its estimated biological effect relative to a dose of one roentgen (R) of X-rays. (One millirem [mrem] =0.0010 rem.) The relation of the rem to other dose units depends on the biological effect under consideration and upon the conditions of irradiation. For the purpose of these regulations, any of the following is considered to be equivalent to a dose of one rem:

A dose of 1 R due to X - or gamma radiation;
A dose of 1 rad due to x -, gamma, or beta radiation;
A dose of 0.1 rad due to neutrons or high-energy protons.
DEFINITIONS FOR RADIOACTIVE WASTE SECTION

RADIOACTIVE WASTE: Any waste material that contains:

1. Radioactively contaminated laboratory trash such as glassware, paper, lab clothing, gloves, culture dishes, syringes, etc.

2. Animal carcasses containing residual radioactive tracers.

3. Sealed radioactive sources used for instrument response checks or research. Notify the R.S.O. before disposing of any sealed sources. Do not dispose of sealed sources in the regular laboratory rad waste. There are special requirements for their disposal.

4. Aqueous or organic solutions containing radioactive contaminants.

LIQUID RADIOACTIVE WASTE - Waste containing radioactive materials in aqueous or organic solutions.

DRY ACTIVE WASTE - Dry laboratory trash to include: paper, gloves, glassware, utensils, etc.

LIQUID SCINTILLATION WASTE - Scintillation solvents, fluors and radioactive material and/or the containers that held them.

SHORT HALF-LIFE WASTE - Wastes containing radioactive materials with half-lives of 65 days or less.

LONG HALF-LIFE WASTE - Wastes containing radioactive materials with half-lives of greater than 65 days.

WASTE CLASSIFICATIONS - (from campus waste disposal form)

1. DAW - Dry active waste: glassware, plastic, paper etc. (no liquids).
2. BOL - Bulk organic liquids: liquid organic solvents (toluene, hexane, benzene, dioxane)
3. A/T-P/T - Animal tissue plant tissue
4. LSV - LSV liquid scint vials of glass or plastic that contain or have contained organic liquids.
II. INTRODUCTION

License to use Radioactive Material

The State of South Carolina is authorized by the U.S. Nuclear Regulatory Commission to regulate the use of Radioactive Materials within the state. Clemson University is licensed by the S.C. Department of Health and Environmental Control under Radioactive Materials Regulation 61-63 Title-A to possess and use radioactive materials. The main campus, Clemson Institute of Environmental Toxicology (C.I.E.T) and Environmental Engineering and Earth Science (EEES) and the Clemson University Biomedical Institute (operate under license #540 and the Clemson Environmental Engineering Laboratory operates under license #482. It is the responsibility of the Radiation Safety Committee (RSC), Radiation Safety Office, the Authorized Investigators, and the end users to ensure that these license conditions are met.

Radioactive materials are used at University facilities in support of a variety of biotechnical research and teaching activities. Radioactive materials and radiation producing equipment are important tools used in all of the scientific disciplines pursued at the University.

Both Federal and State governments regulate the possession and use of radioactive material and radiation sources. Radioactive source material is controlled in accordance with rules and regulations contained in the South Carolina Department of Health and Environmental Control (S.C. DHEC) Regulation 61-63 Radioactive Materials (Title A). The University is authorized to possess and use radioactive materials in accordance with the limitations and precautions specified in the University’s Broad Scope Radioactive Materials licenses (#540 and #482). In order to qualify for issuance of these licenses, the University has committed to certain license conditions in its application to possess and use radioactive materials. It is important to note that these practices and procedures, which are committed to in our license applications, became conditions of use upon the approval of the licenses, and carry the weight of law.

One of the special conditions of license approval is establishment and maintenance of a Radiation Safety Committee (RSC). The Code of Federal Regulations Title 33 and South Carolina Title-A regulations both require that a Radiation Safety Committee composed of such persons as a radiological safety officer and persons trained and experienced in the safe use of radioactive materials be formed as a prerequisite to issuance of a Type-A Radioactive Materials License of Broad Scope. License conditions specify that the RSC is the final authority in all matters pertaining to the possession and use of radioactive materials.

The University’s Radiation Safety Officer (RSO) serves as an agent of the RSC and has developed a radiation safety program to assure compliance with the provisions the license. This program is designed to protect the health and safety of University employees, members of the general public, and the environment from the potentially harmful effects of ionizing radiation. It is University policy to maintain radiation exposure to personnel and the environment “as low as reasonably achievable” (ALARA).
This "Radiation Safety Manual" sets forth the rules and procedures of the Radiation Protection Program. Users should become familiar with the requirements and guidelines put forth in the manual. These requirements and guidelines are intended to assist the end user of radioactive materials and aid the University at large in meeting the regulatory compliance commitments relative to our authorization to possess and use radioactive materials and machine produced radiation.

The Radiation Safety Office performs periodic inspections of areas in which radioactive materials and/or radiation producing equipment is stored and/or used. Inspections are performed in order to ensure compliance with the conditions and limitations of the University’s Radioactive Materials Licenses, and with State regulations Title-A and Title-B, pertaining to radioactive materials and radiation producing equipment respectively. Violations of established rules, regulations and procedures may result in the loss of privilege to use radioactive materials or radiation producing equipment as well as cause undue hazards to both the user and personnel in surrounding work areas.

Radiation safety depends on each user following the guidelines and procedures described in the Radiation Safety Manual.

Please note that nothing in this manual or the radiation safety program proper relieves anyone from meeting the requirements and procedures of other programs of environmental health and safety to include chemical hygiene and hazardous waste management.

A. This manual has two objectives:

   1. To provide information to the authorized users, and the individuals who work under his/her direction, and to standardize the practices and procedures for the safe use of isotopes, and

   2. To provide explicit directions on how to properly handle the radioactive (rad) wastes which are generated as a result of the use of radioactive materials.

B. The manual is divided into sections that deal with each objective. Part one deals with the radiation safety program, protective measures, and provides information on radiation protection. Part two deals with radioactive waste minimization and management.

C. For more information, please call the University Radiation Safety Office at 656-7165, or 656-2583. The Radiation Safety Facility is located on Madren Center Rd. near the Waste Treatment Plant. The postal address is 208 N. Palmetto Blvd. and e-mail may be sent to ajess@clemson.edu.
1. Copies of the Radiation Safety Manual, the Radiation Study Guide, as well as other reference materials concerning the safe use of radioactive materials and radiation exposure may be obtained from the Radiation Safety Office. Consult the R.S.O. and refer to Title A: Radioactive Material Regulation 61-63 issued by the S.C. Bureau of Radiological Health for explanations concerning the regulations pertaining to the use of radioactive materials.
III. RADIATION SAFETY PROGRAM

Individuals involved in the radiation safety program at Clemson University include:
Members of the Radiation Safety Committee (R.S.C.), the Radiation Safety Officer
(R.S.O.) and staff, Authorized Investigators, Radiation Workers.

Prospective Authorized Investigators apply to the R.S.C. for authorization to use specific
radioactive isotopes and/or radiation producing machines. By applying for and
accepting authorization the Authorized Investigator accepts responsibility for how the
isotopes or radiation producing machines are used in the research laboratory or in other
authorized places of use under their supervision. The Authorized Investigator must
establish a sound and current radiation safety program for all users under his/her
direction. The R.S.C. requires that such a program be outlined in the application for
authorization to possess and use radioactive source material or radiation producing
machines. Once approved, the tenants of the application become local conditions of use.
The program should include certain elements that are described in the following sections.

A. Responsibilities of the Radiation Safety Committee (RSC)

The Committee has the authority to define the policies, procedures, and standards
governing the use of sources of radiation at all University facilities, to include
approval of all Authorized Investigators. The RSC is the final authority in all
matters relating to the safe possession and use of radioactive materials and
radiation producing equipment.

The RSC may terminate the authorization to possess and use radioactive materials
and/or other sources of radiation in a research study, and/or place restrictions on
the use of radiation by an Authorized Investigator.

B. Authorized Investigators Duties And Responsibilities

1. Who is an Authorized Investigator?

The Radiation Safety Committee (RSC) and the Radiation Safety Officer
(RSO) issue "authorizations" to qualified personnel permitting them to
possess and use sources of radiation in University facilities. These
personnel are called Authorized Investigators (AI). The AI, usually a
faculty member, shares the legal responsibility for the safe handling of
radioactive material or radiation producing devices under their
jurisdiction. All university personnel and students directly involved in the
use of sources of radiation conduct their operations under the supervision
of an AI.

2. Initial Authorization to use radioactive materials and radiation producing
devices
Initial approval is obtained by submitting an application for authorization to the Committee on forms available through the Radiation Safety Office. The application will describe such items as:

- the facility or areas where the radioisotopes/radiation will be used,
- the radioisotope(s) or other sources of radiation which will be used, and
- procedures and work practices which will be followed.

3. Condition of Authorizations to Use Radioactive Material

An authorization defines for the Investigator:

- radionuclides or radiation producing equipment that may be used;
- allowable possession limit of each radionuclide;
- how the radionuclides may be used;
- which laboratories or areas that are authorized for used;
- the survey schedule of each lab;
- the required record keeping in the lab;
- any special conditions of authorization;
- which lab personnel, called "radiation workers," may use radionuclides or operate radiation producing equipment.

4. Responsibility of Authorized Investigator (AI)

The Authorized Investigator shares the legal responsibility for the safe use of radioactive materials and/or radiation producing devices. The Authorized Investigator:

- Administers and enforces safety rules and regulations established by the RSC and stated in the University’s Radiation Protection and Waste Management Manual which are necessary to the radiation safety program in the areas within the scope of their authority.

- Ensures that personnel under their supervision are familiar with standard operating procedures specific to the authorized use area and for the radioisotopes in use and provide supervision adequate to ensure that these procedures are followed.

- Performs or cause to be performed radiation / contamination surveys sufficient to demonstrate control of radioactive materials or radiation producing devices possessed and used under their authorization.

- Ensures that all employees working with, or in the vicinity of radioisotopes or radiation producing devices are properly trained, informed, and monitored.
• Informs the Radiation Safety Office of additions or deletions of personnel working with radioisotopes or radiation producing devices.

• Reports promptly to the RSO any condition that may lead to or cause a violation of radiation safety regulations, which could cause unnecessary personnel exposure to radiation and/or could cause the unplanned release of radioactive materials into the environment.

• Maintains an inventory of all radioisotopes in the AI’s possession.

• Properly label and secure all radioactive materials or radiation producing devices from unauthorized access or removal.

• Provides a survey meter and/or other detection equipment suitable for detection of the radiation emitted from the isotopes or equipment being used and which is calibrated at least annually.

• Assures designation of a responsible individual to oversee radioisotope work during short absences, and a “stand-in” AI during periods of extended absences (greater than 60 days).

5. How to Amend an Authorization

The AI may request amendments to an authorization such as increasing activity or isotopes possessed or adding additional laboratory space. Contact Radiation Safety Office at 656-7165

e-mail: Rad Safety Officer: Ajess@clemson.edu,
Asst. Rad Safety Officer: Price3@clemson.edu

C. Radiation Worker Duties and Responsibilities

All University personnel who handle radioactive material or who are occupationally exposed to radiation during their employment or study are “Radiation Workers”. Radiation workers may be Authorized Investigators, graduate students, undergraduate students, technicians, post-doctorates, visitors, or any other individual who handles radioactive material or is exposed to radiation.

Individuals who use radioactive materials must assume that certain responsibilities are inherent in their work. The individual worker is the "first line of defense" in protection of people and the environment from the possible harmful effects of exposure to radiation. Since the workers, themselves, are the direct handlers of the radioactive material, the final responsibility lies with them for safety and compliance with applicable laws and regulations. For this reason, it is critical that they be aware of the risks, safe practices and requirements for use of radioactive materials.
1. **Responsibilities of Radiation Workers**

The following practices and procedures are to be followed by all radiation workers:

- Each worker must meet the radiation safety training requirements. Workers are prohibited from handling radioactive materials without line of sight supervision until this requirement has been met.

- Radiation workers are responsible for following the rules, regulations, and Radioactive materials license conditions outlined in this manual.

- Radiation workers must wear their assigned radiation monitoring equipment during the use of radioactive materials or radiation producing equipment.

- Radiation workers must keep their radiation exposure ALARA (As Low As Reasonably Achievable).

- The user must monitor radiation work areas after each use of unsealed radioactive material – at least daily after use. It is the responsibility of the worker to clean any spills or contamination that is found in their work area.

- No changes in experimental standard operating procedures are to occur without the approval of the Authorized Investigator.

- Any abnormal occurrence must be reported immediately to the authorized investigator, such as spills, significant contamination, theft or loss of radioactive material, suspected internal uptakes, equipment failure, loss of personnel dosimeter, or unplanned release of radioactive materials. If the AI cannot be reached, contact the Radiation Safety Office.

- Radiation workers are responsible for returning their personnel dosimeter on time and reporting any loss or contamination of the dosimeter to the Radiation Safety Office.

- Each new radiation worker is responsible for informing the RSO of any occupational exposures to ionizing radiation that have occurred as a result of previous employment.

- He/she is responsible for checking hands, feet, body and clothing for radioactive contamination after each use of unsealed source material, or upon exit from areas with concentrations of loose surface contamination greater than or equal to 200 dpm/100 cm$^2$ \(\beta/\gamma\) or greater than or equal to 20 dpm/100 cm$^2$ \(\alpha\).
• Ensuring that items are checked for contamination before removal from an approved radioactive materials use area.

2. Classifications of Radiation Workers under the supervision of the AI

a. Senior Radiation Worker

A Senior Radiation Worker is a radiation worker who by virtue of training and significant experience in the use of radioactive material and radiation protection practices is permitted to supervise the work of others.

A Senior Radiation Worker may undertake to train previously inexperienced individuals in the use of radioisotopes.

A Senior Radiation Worker assists in the day-to-day management of the work that is conducted under an authorization and may be formally designated by the AI as an alternate or area supervisor.

b. Radiation Worker

Radiation Workers have received radiation safety training and have sufficient on the job experience to work under indirect supervision of the AI or Senior Radiation Worker. The radiation worker may work more or less independently in that the AI or Senior Rad Worker does not have to be physically present, but must be accessible within an acceptably short period of time for instance by telephone.

c. Radiation Worker Trainees

A trainee is any individual that works under the direct supervision of the AI or Senior Rad Worker. Trainees are not considered to have sufficient training and experience to work independently of line of sight supervision.

3. How to Add a New Radiation Worker

Notify the RSO of the addition of a new radiation worker by submitting a “Rad Worker Registration/Dosimetry Request Form” to the Radiation Safety Office via fax or mail, or e-mail the required information to ajess@clemson.edu

4. Training of Radiation Workers

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One of the most important conditions of the University's radioactive license is that all radiation workers at University facilities must have radiation safety training. If an individual does not comply with this requirement, the Authorized Investigator is asked to restrict that person to line of sight supervision until training is satisfied.

a. **Bypass Exam**

Individuals who have sufficient previous experience will be offered a more abbreviated form of training. This training will consist of a lecture on radiation protection emphasizing procedures specific to Clemson University and will include a written exam. A minimum acceptable exam score of 75% is required to demonstrate minimum competence.

b. **Classroom training**

Classroom training will normally be scheduled at the beginning of the fall, spring, and summer semesters. Additional classroom sessions may be added if there are personnel who need training between regularly scheduled classes.

c. **Alternate training**

Alternate training methods are available to accommodate personnel who require training when no classroom is scheduled, such as between semesters.

D. **Responsibilities of the Radiation Safety Officer**

1. Administration of the day-to-day activities of the Radiation Safety Office.

2. Serving as a permanent member of the RSC, reviewing for approval / disapproval all applications for the use of radioactive materials and / or equipment capable of producing ionizing or non-ionizing radiation.

3. Development and maintenance of the University’s Radiation Safety Program, and ensuring that the program meets all applicable regulatory and license commitments.

4. Provision of liaison with appropriate University administrative offices, project investigators, other institutional committees or boards, and various regulatory and funding agencies.
5. Supervision of all aspects of the radiation detection and measurement and protective activities and related record-keeping activities to include: personnel monitoring, lab audits, radiation / contamination surveys, radiological waste disposal, and instrument calibration.

6. Supervision of acquisition and inventory control of all radioactive materials and / or machines capable of producing radiation.

7. Training and consultation with users or potential users of radioactive materials and/or radiation producing machines concerning proper practices and procedures to insure safe use.

IV. GENERAL SAFETY RULES FOR USE OF RADIOACTIVE MATERIALS

All personnel who work with radioactive materials are responsible for protecting themselves and others from any radiation hazards arising from their work. Good housekeeping and careful laboratory techniques are the primary means of preventing the spread of contamination and preventing the internal uptake of radioactive materials into the body. The following rules must be observed.

A. General Radiological Safety Rules and Procedures

1. Knowledge of Proper Procedures

All persons who work with radioactive materials shall be fully aware of the procedures specified in this manual, and be instructed in matters of radiological safety. Copies of this manual and other technical data pertaining to radiation safety are available through the Radiation Safety Office. It is the responsibility of the AI to ensure that all personnel working under his/her supervision have read and understand the contents of this manual.

2. Eating and Drinking

Eating, drinking, smoking, the application of cosmetics, and other similar activities that could lead to the internal uptake of radioactive contamination, are prohibited in areas where unsealed radioactive materials are used or stored. One's hands should always be washed after handling radioactive materials, especially before eating.

3. Housekeeping

High standards of cleanliness and good housekeeping must be maintained in all laboratories where radioactive material is present.

4. Janitorial Staff
Janitorial personnel shall not empty any containers or otherwise remove any material marked as "Radioactive Material". Janitorial staff will perform their duties such as mopping in “clean” areas (meeting unrestricted release limits for removable contamination) only. The AI or designated radiation worker shall be responsible for all housekeeping otherwise.

5. **Glassware and other Utensils**

Contaminated glassware and other utensils shall be segregated from other laboratory glassware or utensils and will be labeled with tape or tags bearing the radiation trifoil and the words "CAUTION RADIOACTIVE MATERIAL".

a. **Contaminated area for staging Areas**

Staging areas should be used to segregate clean from contaminated material. This "staging area" may be a table, an entire bench top or a portion of a bench top, and should be delineated by placing yellow and magenta tape or rope around the perimeter of the area, and a sign bearing the radiation caution symbol and the words "CONTAMINATED AREA".

b. Although the entire laboratory is a "RADIOACTIVE MATERIALS AREA" and any item within the lab has a potential for becoming contaminated, items within this area will be considered to be contaminated and should be surveyed before being removed to clean areas of the lab or before being removed from the lab proper.

6. **Containers**

Radioactive materials will not be left in uncovered containers. Glass containers should be placed inside larger break-resistant secondary containers (or inside fume hoods). Any container of licensed material shall bear a durable, clearly visible label identifying the radioactive contents so that individuals handling or using the containers or working in the vicinity may take precautions to avoid or minimize exposures.

a. At a minimum, the label will bear the radiation caution symbol and the words "CAUTION-RADIOACTIVE MATERIAL".
7. **Work Surfaces**

Disposable absorbent pads or lipped trays will be used to protect work surfaces and to confine spills. Work with radioactive materials shall be performed in ventilated fume hoods if the manipulation of such materials involves any possibility of airborne contamination.

a. Whenever possible, chemical procedures are to be carried out with all of the equipment in a tray containing absorbent paper, which has a volume large enough to accommodate twice the experimental volume in the event of an accident.

b. Heating and boiling of radioactive solutions, mechanical mixing and/or grinding, and work with radioactive iodine will take place in a fume hood with an average capture velocity of at least 100 linear ft/sec at an opening of not less than 18”.

8. **Trail Runs**

Before a new nuclide or procedure is introduced, it is accepted practice to rehearse the operations without the radionuclide present. This will help to increase efficiency, identify problem areas, and may reduce the time needed to complete the task.

9. **Protective Clothing**

At a minimum, a lab coat and gloves shall be worn whenever the possibility of contamination exists i.e., any time unsealed source material is handled. Potentially contaminated lab coats will not be worn outside of the lab.

a. Eye protection is required for all lab occupants under the University’s Chemical Hygiene Plan, and is additionally important as protection to the lens of the eye from high-energy betas emitted from P-32.

10. **Pipetting**

Pipetting or similar operations of radioactive solutions by mouth are strictly prohibited.

11. "**ALARA**" Concept
All exposure to radiation will be kept ALARA (As Low As Reasonably Achievable). Radioisotopes shall be used in such a manner that radiation exposure to personnel and to the environment shall be kept as low as possible. The use of appropriately designed shields and proper work practices will help to minimize exposure. Engineering controls such as fume hoods and glove boxes will help to prevent internal exposure.

12. Remote Handling / Shielding

Whenever possible, remote handling devices such as tongs or forceps should be used when working with significant activities of gamma emitters or high-energy beta emitters. This will increase the distance from the source and thereby reduce the rate of exposure.

a. Do not work over open containers of beta emitters. Lead and/or Plexiglas shields should be used for sources having high radiation intensity. Do not use thin sheet, high-density materials (Pb sheeting) for the shielding of high energy (approaching > 1 meV.) beta radiation.

13. Personnel Monitoring

Personnel monitoring devices such as film badges or Thermoluminescent Dosimeters (TLDs) will be utilized based on the type and amount of radioisotopes being used. Film badges or pocket ion chambers cannot detect low energy beta radiation from H-3 and C-14, but will be required for work with higher energy radiations such as P-32 and gamma emitters, which are capable of producing whole body exposure rates > 0.5 mrem/hr.

All personnel who have been designated to wear monitoring equipment by the Radiation Safety Officer shall wear these devices when they work with or near radioactive materials.

14. Monitoring

While working with radioactive materials periodically monitor hands, feet, clothing, and the immediate work area to check for radioactive contamination. Personnel shall monitor themselves and their work surfaces for contamination after each use of unsealed radioactive materials.
15. **Removal of Equipment**

All equipment that is suspected to have come in contact with unsealed radioactive source material or which has been inside radioactive materials work areas shall be considered potentially contaminated. The equipment must be monitored for contamination by an Senior Rad Worker before being removed from the laboratory.

16. **Maintenance or Renovation**

Whenever maintenance or renovation of potentially contaminated facilities or equipment (sinks, hoods, pumps, lab benches, etc.) is required, a survey of the area will be performed. Radiation Safety Office will perform the survey if other qualified personal are not available.

17. **Waste**

Radioactive wastes will be placed in specially marked receptacles. Radioactive liquids, other than reinstate from the washing of contaminated glassware, may not be disposed of via the sanitary sewer. See “Part Two - Radioactive Waste Disposal” for specific waste handling procedures.

18. **Animals**

The Animal Research Committee and the Radiation Safety Committee must approve isotopic work with animals. See section F. Part Two of the Radiation Safety and Waste Management manual for animal/biological waste handling procedures.

a. Animals which have been injected with or that have ingested radionuclides will be handled with the following precautions:

   (1) All excreta and animal bedding will be double bagged and treated as radioactive biological waste.
   (2) Cages will be monitored for radioactivity and decontaminated as necessary.
   (3) Appropriate warning signs shall be posted on the cages.
   (4) Adequate ventilation must be provided when animals are injected with radionuclides, which may be expired and dispersed into a room.

a. Researchers are encouraged to consult the R.S.O. prior to applying for approval to conduct animal research involving the use of radionuclides.
19. **Personnel Injuries**

All injuries to personnel involving radioactive material, no matter how slight, shall be monitored to determine if the wound is contaminated. Special protection is required to prevent the entry of radioactive materials into the body through wounds. Consult the R.S.O. before handling unsealed source material with an open wound.

**NOTE:** THE SAFETY OF AN INJURED INDIVIDUAL ALWAYS TAKES PRECEDENCE OVER CONTAMINATION CONTROL. Decontamination efforts are secondary to the provision of first aid and medical attention for the injured individual.

20. **Moving Authorized Places of Use**

Contact the RSO for approval prior to moving or modifying laboratory or other areas which are authorized for the use or storage of radioactive materials or radiation producing equipment. Notification should be given 30 days in advance to allow time for approval and for performance of termination surveys.

V. **INSTRUMENTATION**

Radiation detection in radioactive materials areas will usually be accomplished by using some type of gas filled detector, such as a Geiger-Muller (G.M.) detectors or an ion chamber.

A. **Types of Radiation Detection Instruments**

1. **G.M. Detectors**

These instruments may be calibrated in mR/hour or in cpm. An end window or pancake probe with a thin detector window will be used (window density thickness of 1.0 to 2 mg/cm²). These instruments are approved for the detection of low energy betas (>150 keV.) and most gamma radiations.

2. **Ion Chambers**

An air filled ion chamber will be the preferred instrument to set personnel dose rates and are required for use in high radiation areas.
3. **Scintillation Detectors**

   Hand held scintillation detectors will be used for the detection of low energy gamma emitters such as I-125. This type detector will normally use a thin NaI(Tl) crystal (approximately 1 mm thick). Typical energies detectable are 10 to 60 keV.

4. **Liquid Scintillation Detectors**

   Liquid scintillation counters will be used for analyzing air samples, smear samples, liquid samples, and samples supporting specific research projects for the presence of low energy $\beta\gamma$ radiations which cannot be detected with hand held detectors.

B. **Instrument Calibration**

   Portable radiation detection instruments will be calibrated by the Radiation Safety Office, returned to the manufacturer, or sent to a certified vendor for calibration.

   Instrumentation calibrated by the Radiation Safety Office will be calibrated in accordance with procedures approved by the S.C. Bureau of Radiological Health.

   1. **Calibration Frequency**

      Calibration Frequency shall not exceed 12 months. Instruments which do not display a current calibration sticker (within the last 12 months) are not approved for use.

C. **Instrument Use – preoperational checks**

   Before using any portable detection instrument the following pre-operational instrument checks will be made:

   1. Inspect the instrument for signs of physical damage.
   2. Verify that the instrument calibration is current, within the last year. Do not use an instrument that is out of calibration.
   3. Turn the instrument control knob to the battery check position or depress the battery check button. If batteries are bad or weak, replace them.
   4. If the instrument has a "zero" position on the control knob, move the knob to the zero position and adjust so that the instrument needle reads zero.
   5. Response check the instrument by exposing the detector to a known source of ionizing radiation to insure functionality before use.
   6. Most hand held instruments have several scales (X 0.1, X1, X10, X100). Set the instrument to the highest scale and begin the survey. If no indication is seen, set the instrument to successively lower scales until activity is detected.
VI. RADIATION AND CONTAMINATION SURVEYS

Each user of radioisotopes is responsible for performing surveys of the use area to assure that radioactive sources are adequately shielded and to check for control of radioactive contamination. Survey data will be recorded on a blank "radiation / contamination survey data sheet" (attachment) and / or in a radiation safety logbook kept by the users at the authorized place of use.

A. Survey Frequency

1. Each individual user is personally responsible for checking themselves for contamination before leaving radioactive materials areas where unsealed source material has been handled or when leaving areas contaminated above clean area limits.

2. A contamination survey of the immediate work area should be conducted on any day that unsealed source materials are used. This “use survey” ensures that licensed materials have been properly controlled.

3. A formal survey of the entire work area (laboratory) should be conducted weekly in any use area where unsealed source material has been used in that week. No survey is required in a week if no radioactive materials work is conducted.
   a. A plan view map of the lab space showing areas of primary use and locations of sample points should be included to document the weekly survey. Contamination surveys will be reported in units of dpm/100 cm².
   b. During a periods of non-use of radioactive materials there may be times that no routine contamination surveys are performed. On the first contamination survey subsequent to a period of non-use, please make a note documenting “no use of radioactive materials since previous survey” or works to this affect. This will help to identify periods where survey data and/or use records should not be available for review or audit.

B. Radiation Surveys

Radiation surveys to verify exposure rates may be required in certain situations. These surveys are preformed in order to determine the radiation levels in the vicinity of storage areas, work areas, waste containers, and in adjacent unrestricted areas.

1. Survey requirements
a. These Radiation surveys will be made on a periodic basis in areas where gamma emitting or high-energy beta (>1.0 MeV.) emitting isotopes are used or stored in sufficient quantities to produce whole body exposure rates of ≥ 2 mrem/hour.

b. Radiation surveys will be conducted with a hand held survey meter that is calibrated in units of mR/hr or mrem/hr.

c. Exposure rates will be documented on the weekly survey form.

2. Exposure rate action levels.

   a. General area dose rates unrestricted areas will not exceed .05 mR/hr. General area dose rates shall be measured with the detector held at waist level and at a distance of no more than 3 feet from the source.

   b. Dose rates in a Radioactive Materials Area will not exceed 2 mR/hr when measured at a distance of no more than 12 inches from the source of exposure or at the posted boundary to a Radiation Area.

C. Contamination Surveys

Contamination surveys by direct survey (frisk) will be conducted with hand held radiation detection instruments calibrated in units of counts per minute (cpm) or mR/hr.

1. Direct Survey (frisk)

   Direct monitoring for beta/gamma surface contamination will be by G.M. survey meter equipped with a thin window probe. The area will be surveyed by slowly moving the instrument probe over the surface in question at a distance of no more than ½ inch and at a rate of no more that 2 inches of travel per second.

   a. The instrument should be set on the slow response setting and in the audible mode if the instrument is equipped with a speaker.

   b. A direct reading of 100 cpm or >.05 mR/hr above background (bkg) indicates a contaminated area or item. If contamination is indicated by direct survey, a smear survey will be conducted to determine if the contamination is removable.

   c. Survey by direct frisk is not permitted to certify an item or area as "clean" for release to unrestricted areas if the background radiation level is >300 cpm on the meter being used.

2. Smear Surveys
Smear surveys are conducted by thoroughly wiping a surface with a commercially available cloth, or paper disk, or a "Q-tip", and analyzing the sample with an appropriate detection instrument.

a. Surface contamination is reported in units of dpm / 100 cm.² (4" X 4"). If the surface is large, 100 cm² may be approximated by placing the fingertips of the index and middle finger over the disk and, with moderate pressure, drawing an 18" S pattern on the surface. A "q-tip" may be used for objects smaller than 100 cm² and the entire surface should be wiped.

b. A field evaluation of a smear sample may be obtained using a hand held G.M. instrument with a pancake or end window probe. Assuming 10% efficiency, a sample with a direct reading of 100 cpm above background has an activity of approximately 1000 dpm.

c. Hand held detection equipment is not sensitive enough to accurately detect smear sample activities below the 200dpm/100cm² Unrestricted area limit. A laboratory counters, such as a liquid scintillation counter is required for accurately analyzing smear samples to the 200 dpm/100cm² removable contamination limit.

d. If H-3 is the radioactive nuclide of interest, the smear sample must be analyzed in a liquid scintillation counter.

D. Source Inventory and Leak Check Surveys

1. **Inventory**

Each AI shall conduct a physical inventory at intervals not to exceed six (6) months to account for all radioactive material received and possessed under that particular R.S.C. approval. Records of source inventory and leak checks will be maintained for inspection by the BRH. These records shall include:

a. The quantities and kinds of radioactive material
b. Location of all radioactive material
c. Date the inventory was conducted, and
d. Name of the individual conducting the inventory.

2. **Leak Check Criteria**

a. Any beta and/or gamma emitting sealed source with an activity ≥ 10 mCi of radioactive material, other than H-3, with a half-life greater than thirty days and in any form other than gas shall be tested for leakage at intervals not to exceed six months.
b. Alpha or neutron emitting sealed sources with an activity of $\geq 10$ mCi will be leak checked at intervals not to exceed six months.

c. All newly obtained sealed sources will be tested for leakage prior to being put into service. If a source has not been removed from the storage location or container since the last leak check, only a physical inventory will be performed. No leak check will be required until the next time the source is removed from its storage container or location.

3. **Leak Test Procedure**

   a. Source leak test will be conducted in accordance with Radiation Protection “Leak Check Procedure" #007. Survey data will be recorded on "source leak check survey data form" (see attachments).

   b. If the test reveals the presence of 0.005 microcuries or more of removable contamination, the source will immediately be withdrawn from use and shall be decontaminated, repaired, or disposed of in accordance with BRH regulations.

   c. Note: Sealed sources will not be included for disposal in normal D.A.W. waste. Special approval must be obtained from the disposal site and the BRH for disposal of sealed sources.

VII. **TRANSFER OF RADIOACTIVE SOURCE MATERIAL**

   A. **Title - A regulations** require that an official record be maintained for each transfer of radioactive source material between licensees.

      1. As the original holder of the source material to be transferred, the University will verify that the prospective recipient of the transfer is licensed by an “agreement state” or by the U.S. Nuclear Regulatory Commission to possess the specific nuclide and in the quantity and physical form in question.

   B. **Sharing of Source Materials**

   University policy requires that Authorized Investigators maintain a record for each transfer of source material between users. The transfer will be documented on the “radioactive material transfer form” (see attachments). Several investigators may wish to share quantities of source material as a matter of convenience or as a cost cutting measure.

   The steps below will be followed in order to meet the regulatory requirement for recording a transfer of radioactive material from one Authorized Investigator to another.
1. The AI who takes receipt of the original shipment of radioactive material will log into his source "use / inventory record" (see attachments) the following:
   a. The serialized shipment number of the original shipment (from the R.S.O. shipment receipt log)
   b. Nuclide and total activity
   c. Date of receipt or transfer

2. A "Rad Material Transfer Form" (see attachments) will be completed for each aliquot of source material being transferred. The signed original of the form will be retained and a copy provided to each AI who receives the transferred source material.

3. The transfer form will list the following:
   a. Original shipment number
   b. The total activity of the nuclide transferred
   c. Name and / or authorization number of the other party to the transfer in the "comments" column of the "Use / Inventory Form"
   d. The date the transfer took place

VIII. CONTAMINATION LIMITS AND CONTROL

A. A Restricted area is any area to which access is controlled for the purposes of protection of individuals from exposure to radiation and radioactive materials. Before removing any piece of equipment from a restricted area where unsealed source material is used, a contamination survey will be performed on the equipment. Unrestricted area limits will be met for unconditional release of items or equipment from a Restricted Area, such as, a laboratory which is designated as a Radioactive Materials Area.

1. Unrestricted Area Limits

<table>
<thead>
<tr>
<th>Type contamination</th>
<th>Beta/Gamma</th>
<th>Alpha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Removable</td>
<td>&lt;200 dpm/100 cm²</td>
<td>&lt;20 dpm/100 cm²</td>
</tr>
<tr>
<td>Non-removable</td>
<td>&lt;100 cpm above bkg.</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>or</td>
<td>or</td>
</tr>
<tr>
<td></td>
<td>&lt;.05 mR/hr</td>
<td></td>
</tr>
</tbody>
</table>
2. This is a direct reading that should be taken with a G.M. instrument calibrated in cpm or in mR/hr equipped with a thin window, pancake or end window probe. Direct readings of >100 cpm above bkg. or >.05 mR/hr above area background when measured at near contact with the source (a distance of no more than 1/2") indicate a contaminated article or area.

3. Background in the area where the measurement is made will be no more than 300 cpm. Some instruments acceptable for this purpose are: Ludlum model #3, Eberline E-120/E-530, RM-14, 16,19.

IX. SPILLS OF RADIOACTIVE MATERIALS

All spills of radioactive material require immediate response. In the event of a spill, initial response rest with the individuals working in the area, involved with, and/or responsible for the spill.

UNDER NO CIRCUMSTANCES SHALL AN UNTRAINED PERSON BE ALLOWED TO EXAMINE OR CLEAN UP A SPILL OF RADIOACTIVE MATERIAL. If assistance is needed, contact the R.S.O.

A. Laboratory Contamination

1. Minor spills of radioactive materials over relatively small surface areas may be decontaminated by laboratory personnel.

2. If laboratory contamination is widespread (on workbench, chairs, floor, etc.) or involves multi uCi to mCi levels of activity, the Radiation Safety Officer or his designee will supervise the decontamination activity.

B. Response to Spills

The following general guidelines should be followed when responding to a spill.

1. Inform other laboratory personnel of the spill. Have them leave the area, but remain in one place in order to minimize the possible spread of contamination.

2. Stop and/or confine the spill and restrict access to the contaminated area. If the material is a liquid, place an absorbent material such as paper towels, tissues, cloth, etc. over the spill to prevent its spread. If the material is a powered solid, attempt to contain its spread by gently covering the area with a similar protective barrier preferably wet cloth or wet absorbent paper. Secure any local ventilation equipment that may aid in the transport of the material or cause airborne contamination. Post or cordon off the area and restrict access to those individuals directly involved with the cleanup.
3. Monitor any personnel that were in the area at the time of the spill. Begin with the head giving special attention to the nose and mouth to assess the possibility that internal uptake may have occurred. Any facial contamination will be immediately reported to the R.S.O. Remove any contaminated clothing and decontaminate as necessary.

4. Decontaminate the area. If the activity of the material is not known prior to the spill, obtain a sample from the spill in order to evaluate the proper decontamination technique to be used. Perform a survey after each decontamination order to assess the effectiveness of the effort.

5. Begin wiping or mopping at the periphery of the spill and work toward the center of the contamination. Any personnel involved in the decontamination effort will wear at a minimum: a lab coat, double vinyl or rubber gloves, and plastic shoe covers. If these items are not available in the lab they may be obtained from the R.S.O.

6. Place all contaminated items in proper waste containers. Contamination not readily removable after three attempts should be reported to the R.S.O.

X. TRANSPORTING AND STORAGE

A. Transporting

Radioactive materials should be "doubly-contained" when in transit in order to help prevent and contain any leakage. Radioactive material will not be left unattended during transport. Notify the R.S.O. any time rad material with a dose rate of 50 mR/hr at 1" from the object is to be moved outside the controlled area.

B. Storage

Radioactive materials will not be left unattended in places where unauthorized persons may handle or remove them. Food and beverages shall not be stored in the same place as radioactive material (e.g., the same refrigerator). Use a plastic box or other secondary container for items in storage.

1. All radioactive material will be stored in such a manner that the dose rates at the posted boundary of the area or 12" from the surface of any container is <2 mR/hr.

NOTE: Loss or theft of radioactive material must be reported immediately to the Radiation Safety Officer.
XI. PROCUREMENT OF RADIOACTIVE MATERIALS

Radioactive materials may be ordered only by an authorized investigator and only after receiving prior approval from the Radiation Safety Office. Approval may be obtained by submitting a completed “Application for Radioisotope Procurement Form” (appendix #13). Fax the request to 656-7630 or ajess@clemson.edu

Packages containing radioactive materials will be delivered to the following address:

Radiation Safety Office Radiation Safety Facility
Moorman House Madren Center/Dike Rd.
208 N. Palmetto Blvd. Clemson, S.C. 29631
Clemson, SC 20631 Attn: Jess Addis
Attn: Jess Addis

XII. RECEIPT OF PACKAGES OF RADIOACTIVE MATERIALS

Receipt and surveys of packages containing radioactive materials will be conducted in accordance with Radiation Safety Procedure #006-09. All packages of radioactive material will be delivered to the Radiation Safety Office. Packages will be received between the hours of 08:00 and 4:30 Mon-Fri unless prearranged with the shipper.

A. Package Receipt and Survey

1. At a minimum, gloves will be worn when opening packages containing radioactive materials.

2. Visually inspect the package for any signs of physical damage. Substantial damage to the exterior of a package may indicate loss of integrity of the inner container and should be placed inside a fume hood for opening.

3. Remove and review the packing slip to identify the nuclide and total activity contained in the package.

4. If the nuclide is in a gaseous or volatile form, such as I-125 or I-131, open the package inside a fume hood. Tongs or forceps should be used when handling vials containing concentrated radionuclides such as gamma or high-energy beta emitters (I-125 & P-32).

5. Perform a radiation survey of the package. If radiation levels are > 2 mR/hr at 12” the package should be placed in a posted radiation area.

6. If the surface dose rate exceeds 200 mrem/hr or if the dose rate at three ft. exceeds 10 mrem/hr, the R.S.O. will immediately notify S.C. BRH.

7. Perform a contamination survey on the exterior of the package.
8. If the removable contamination level on the exterior of the package exceeds 200 dpm/100 cm², the package will be bagged or placed in a posted contaminated area.

9. If removable contamination levels are found on the package surface in excess of 22,000 dpm/100 cm², the campus R.S.O. will immediately notify the final delivery carrier and the S.C. BRH.

10. Check the integrity of the final source container (usually a lead or plastic container) and perform a contamination survey of its surface. Look for broken seals or vials, loss of liquid, condensation, or discoloration of the packing material that could indicate leakage.

11. Perform a contamination survey of the stock vial and analyze it with a liquid scintillation counter or other currently calibrated radiation detection device with a minimum detectable activity of less than 200 dpm for the nuclide in question.

12. If the contamination levels exceed 200 dpm / 100 cm² decontaminate the vial or place it in a plastic bag marked as "contaminated".

13. If the removable contamination level on the stock vial exceeds 50,000 dpm / 100 cm², the manufacturer will be contacted to report loss of the material.

14. Carefully monitor the empty package and packing materials before discarding into clean waste. The empty package and packing material must meet the limits for an unrestricted area before being released into clean waste. All labeling or marking denoting radioactive materials must be removed and/or defaced beyond recognition prior to disposal in clean waste.

15. Record all survey data in the "package receipt and survey log", assigning the next serialized shipping number to the package.

16. The nuclide will be placed in a secondary transport container and delivered to the principle investigator.

17. All packages of radioactive materials will be surveyed within three hours of receipt if received during normal working hours or within three hours after the beginning of the next shift if the receipt was made after normal working hours.

18. Packages containing radioactive materials will not be accepted for delivery after normal working hours unless prearranged by the shipper.
XIII. LABELING AND POSTING REQUIREMENTS

A. All areas, items, or containers within Restricted Areas will be posted with appropriate warning signs or labels as defined by S.C. DHEC Title-A Radioactive Materials Regulation 61-63.

1. Restricted Area

Any area to which access is controlled by the licensee for purposes of protection of individuals from exposure to radiation and rad materials.

2. Radioactive Materials Area

At a minimum, the entrance doors to rooms and laboratories in which radioactive materials are stored or used will be posted with a yellow and magenta sign bearing the radiation trifoil and the words "CAUTION-RADIOACTIVE MATERIALS".

3. Radiation Area

A radiation area is any area where there exist dose rates such that a major portion of the body could receive a dose of 2 millirem in any one hour. Dose rates of > 2 mR/hr but <100 mR/hr require posting as a RADIATION AREA. The dose rate at the boundary of a radiation area may not exceed 2 mR/hr. The posting of equipment as a radiation area will be based on a dose rate of 2 mR/hr measured at a distance of 12" from the source.

4. High Radiation Area

Any area where there exist dose rates such that a major portion of the body could receive a dose of 100 millirem in any one hour will constitute a HIGH RADIATION AREA. Dose rates of ≥ 100 mR/hr require posting as a HIGH RADIATION AREA. The dose rate at the boundary of a high radiation area shall not exceed 100 mR/hr. The posting of equipment as a high radiation area may be based on a reading of 100 mR/hr when measured at a distance of no more than 12".

5. Airborne Radioactivity Area

Any room, enclosure or operating area where airborne radioactivity is in excess of 20% of the amounts specified in S.C. DHEC Title A RHA 3.53 Appendix B, Table I Column 3.

6. Contaminated Area-
Any area with removable surface contamination $\geq 200 \text{ dpm/100 cm}^2 \text{ beta / gamma or 20 dpm / 100 cm}^2 \text{ alpha}$

7. **Additional Postings**

DHEC Form RHA-20, Notice to Employees and the DHEC "Emergency Radiological Assistance" Form will be posted in a highly visible location within the lab or use area.

XIV. **BASIC PROTECTION MEASURES**

Earlier in this manual the "ALARA Concept" was mentioned. This idea that radiation exposure should be kept as low as reasonably achievable is based on a linear extrapolation model. This concept holds that any exposure no matter how small has some negative effect. When attempting to limit personnel exposure to ionizing radiation, controlling the variables of Time, Distance, and Shielding will have the greatest effect.

A. **Time**

For a source of given strength, the absorbed dose is proportional to the duration of the exposure. Experiments should be carefully planned to minimize exposure time. This is one reason it is a good practice to use trial runs without the radionuclide present to increase your efficiency, identify problem areas, and possibly reduce the time needed to complete a task.

B. **Distance**

The exposure rate from a point source of radiation is inversely proportional to the square of the distance. In other words, increasing the distance by a factor of 2 will decrease the exposure rate by a factor of 4.

C. **Shielding**

Shielding is any material that is used to absorb or attenuate radiation before it reaches a point of interest.

1. High energy beta Particles such as those from the decay of P-32 (E Max. 1.73 MeV), will be shielded using low density material such as lexan sheeting to avoid x-ray production from Bremstrahlung radiation.

2. Gamma or X-ray shields will be composed of high atomic number materials such as lead, concrete, or water. When more that one thickness of shielding is used, the joints of the shielding should be overlapped.

3. Neutron shields should be constructed of hydrogenous materials such as water, paraffin, or plastic.
4. **Half value / Tenth Value Layer** shielding (gamma):

The thickness of shielding material required to reduce the exposure rate to one half or one tenth of its original value respectively. A table of some measured HVL and TVL values for various shield materials is shown below.

<table>
<thead>
<tr>
<th>Radiation</th>
<th>Half value layer</th>
<th>Tenth value layer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lead</td>
<td>Concrete</td>
</tr>
<tr>
<td>125 kVp X-ray</td>
<td>0.28 mm</td>
<td>2.0 cm</td>
</tr>
<tr>
<td>Cs-137</td>
<td>6.5 mm</td>
<td>4.8 cm</td>
</tr>
<tr>
<td>Co-60</td>
<td>12 mm</td>
<td>6.2 cm</td>
</tr>
</tbody>
</table>

XV. **EXPOSURE LIMITS**

A. **External Radiation Exposure Limits**

Federal / State Limits - Maximum Permissible Occupational Exposure in a Restricted Area:

<table>
<thead>
<tr>
<th>Applicable area of body</th>
<th>Rem Per Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole body; head and trunk, active blood forming organs, gonads</td>
<td>5 rem (0.05 Sv)</td>
</tr>
<tr>
<td>Hands and forearms; feet and ankles (Up to the elbow and/or knee)</td>
<td>50 rem (0.5 Sv)</td>
</tr>
<tr>
<td>Skin of whole body</td>
<td>50 rem (0.5 Sv)</td>
</tr>
<tr>
<td>Eye dose equivalent</td>
<td>15 rem (0.15 Sv)</td>
</tr>
</tbody>
</table>

B. **Exposure of Minors**

Occupational exposure to any individual who is under the age of 18 is permitted only if their exposure is limited to less than 10% of the limits specified above. For this reason, minors will not be employed as full-time radiation workers.

C. **Pregnant Worker Exposure Limits**

The Nuclear Regulatory Commission (NRC) and the State of S.C. require instruction of women radiation workers in the hazards associated with radioactive materials and radiation; and, in the precautions and safety measures to be followed to minimize radiation exposure. The limit for external radiation exposure to pregnant workers is: **500 millirem for the entire gestation period**

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It is the responsibility of each women working with radioactive materials or with radiation producing equipment to notify in writing both her immediate supervisor and the Radiation Safety Officer as soon as she is aware of her pregnancy.

NOTE: For further information on radiation exposure during pregnancy see the guide at the end of part one of this manual and contact the Radiation Safety Officer.

XVI. PERSONNEL RADIATION MONITORING

Any individual who enters a Restricted Area under such circumstances that he receives, or is likely to receive a dose in any calendar year in excess of 10% of the applicable values specified in Title-A Radioactive Materials Regulation 61-63, RHA 3.17 and listed below will be monitored for occupational external radiation exposure. Personnel monitoring will be by TLD (thermoluminescent dosimeter) provided by a NAVLAP certified vendor.

A. Personnel TLDs

All personnel TLDs will be changed quarterly.

The following practices will be observed when wearing a personnel monitoring device:

1. If an individual has been issued a TLD, it will always be worn any time the individual enters a restricted area.
2. Whole TLDs should normally be worn on the trunk of the body between the waist and neck preferably in the vicinity of the collar and breast pocket.
3. Extremity monitoring may be required when handling high-energy beta emitters or high dose rates of gamma emitters. A ring badge/TLD should be worn on a finger of the hand used to hold the source. Rubber gloves will be worn over the badge. A ring badge will be worn so that the active area of the badge faces the source.
4. Personnel monitoring devices will not be taken home. TLDs will be left in a secure area away from the radiation source.
5. Personnel dosimetry will only be worn by the individuals to whom they are officially issued. No personnel monitoring device will be intentionally exposed to ionizing radiation unless it is being worn by the person to whom it was issued for the purpose documenting occupational exposure to radiation.
6. Personnel monitoring devices will not be worn while undergoing medical procedures. The TLD badge is for monitoring your occupational exposure - not medical exposure.

B. Self Reading Dosimeters
Self-reading dosimeters are fountain pen sized devices that directly measure exposure to X or gamma radiation. A separate charging device is used to set the device to the zero position. Like charges are placed on a center electrode and a movable quartz fiber. As radiation is incident on the sensitive volume of the dosimeter the charge between the fixed and movable electrode is lost and the movable quartz fiber moves closer to the fixed electrode. This movement may be viewed against an internal scale through a built in compound microscope. Self-reading dosimeters are available in various scales, the most prevalent being 0 - 200 millirem.

1. Self-reading dosimeters will detect only X and gamma radiation.

2. Self-reading dosimetry will be worn by personnel when entering any area posted as a High Radiation Area.

3. Self-reading dosimeters will be calibrated at least annually according to Radiation Protection Procedure #001-10 "Calibration Standards and Frequencies".

C. Internal Monitoring - Bioassays

Persons who may be exposed to radioactive materials in such a manner that an internal uptake approaching 0.1 ALI is possible shall submit urine samples for analysis.

1. Routine Measurements
   a. Baseline measurements, An individual's baseline measurement of radioactive material within the body will be conducted prior to initial work activities that involve exposure to radiation or radioactive materials, for which monitoring is required

   b. Periodic measurements. - The frequency of periodic measurements shall be based on the worker's access, work practices, measured levels of airborne radioactive material, and exposure time. Periodic measurements will be made when the cumulative exposure to airborne radioactivity, since the most recent bioassay measurement, is > 0.02 ALI (40 DAC hours).

   c. Termination measurements. When an individual is no longer subject to the bioassay program, because of termination of employment or change in employment status.

2. Internal Uptake
A bioassay will also be initiated anytime an internal uptake of radioactive material is suspected to have occurred, for instance, when facial and/or nasal contamination is found.

3. **Radiation Protection Personnel**

A bioassay will be conducted at least monthly for personnel who have collected or processed rad waste at any time during the previous four week period.

4. **Special Monitoring**

Situations such as a failed respiratory protective device, inadequate engineering controls, inadvertent ingestion, contamination of a wound, or skin absorption shall be evaluated on a case-by-case basis. Circumstances that should be considered when determining whether potential uptakes should be evaluated include:

a. The presence of unusually high levels of facial and/or nasal contamination,

b. Entry into airborne radioactivity areas without appropriate exposure controls,

c. Operational events with a reasonable likelihood that a worker was exposed to unknown quantities of airborne radioactive material (e.g., loss of system or container integrity),

d. Known or suspected incidents of a worker ingesting radioactive material,

e. Incidents that result in contamination of wounds or other skin absorptions,

f. Evidence of damage to or failure of a respiratory protective device.

5. **Evaluation Level**

If initial bioassay measurements indicate that an intake is greater than an evaluation level of 0.02 ALI, additional available data, such as airborne measurements or additional bioassay measurements, will be used to obtain the best estimate of actual intake.
6. **Investigation Level**

For single intakes that are greater than 10% of the ALI, a thorough investigation of the exposure shall be made. If an internal uptake exceeds an investigation level of 0.1 ALI, multiple bioassay measurements and an evaluation of available workplace monitoring data will be conducted. In this case, daily measurements will be made until a pattern of bodily retention and excretion can be established.

a. For uptakes exceeding the ALI’s, the bioassay data evaluations shall consider additional data on the physical and chemical characteristics and the exposed individual’s physical and biokinetic processes.

7. **Sampling**

Bioassays will be performed by obtaining a urine sample from the exposed individual, mixing one ml. of the sample urine with 10 ml. of a commercially available scintillation cocktail, and analyzing the sample with a liquid scintillation counter.

8. **Thyroid Scan**

Bioassay for I-125 may also be conducted by performing a thyroid count. This analysis will be performed utilizing a NaI(TL) crystal detector, designed for the detection of low energy (10-60 keV) gamma photons. The detector will be placed in contact with the neck, over the thyroid of the individual under consideration, and conducting a 10 minute count.

a. The instrument used to conduct the thyroid count will have the efficiency set utilizing an I-129 NIST traceable source placed within a plastic neck phantom which approximates the physical characteristics and geometry of the thyroid of reference man.

XVII. **FACILITIES**

A. **Work Areas**

Portions of the laboratory should be designated as radioactive material work areas. Keep these areas isolated from other non-radioactive areas in order to reduce the likelihood of the spread of contamination. The radioactive material work areas should be clearly labeled and laboratory personnel not working with radionuclides should be restricted from these areas. Yellow and magenta rope, ribbon or tape and appropriate warning signs may be used for this purpose. These may be obtained from the R.S.O.
B. Storage

All radioactive material under the control of an AI shall be stored in a secure, lockable storage area. If more than one user shares a common facility, all radioactive material belonging to each AI shall be segregated in such a way that accidental transfer of material is unlikely.

C. Fume Hoods

A fume hood is necessary when working with volatile radionuclides (iodine) or when heating or stirring solutions containing radioactive materials. All work should be performed in a hood that has a capture velocity of 100 linear ft. / min. measured at a sash height of 18" and at least 60 linear ft./min. fully open. Desirable characteristic of rad material fume hoods:

1. The hoods should be designated as a Radioisotope Fume Hood by the vendor.
2. The interior should be one-piece, seamless material, with covered corners free of joints, cracks or gaskets. The preferred material is stainless steel.
3. Ducts should be of stainless steel. Each hood should be ducted independently directly to the roof.
4. Blowers should be roof-mounted, spark-proof, explosion-proof units.
5. A HEPA filter should be used in the exhaust duct if the unit is to be heavily used for radioisotope work.
6. New units should have an air motion sensor and alarm to ensure proper air velocity and direction. Older units should have, at a minimum, a signal light to show that the motor is receiving power.
7. When possible locate hoods in areas that would not have to be passed in order to exit in case of an emergency. As much as possible, locate hoods in a draft-free, low-traffic area. If ceiling mounted vent ducts terminate directly over a fume hood, provisions should be made to deflect the incoming air away from the fume hood opening.

XVIII. DECONTAMINATION

A. Area Decontamination Action Levels

1. If laboratory contamination is localized (e.g. small portion of a workbench or floor) and is found to be 200 dpm/100 cm² or more (as determined by wipe tests), then the area will be posted as contaminated and/or decontaminated.
2. If laboratory contamination is widespread, (e.g. on workbench, chairs, floor, refrigerator etc.) or if removable contamination in any area exceeds 1,000 dpm/100 cm² alpha or 50,000 dpm/100 cm² beta/gamma, it should be reported to the R.S.O.

B. Personnel Decontamination

1. **Skin Contamination**, even in small amounts, should be treated seriously. External contamination results in local skin exposure. Radionuclides may penetrate intact skin, especially when organic solvents are present. Contamination may be ingested or inhaled and may be spread to other areas or personnel. Therefore, it is most critical to remove loose contamination as quickly and safely as possible. In general, except for decontamination of hands, all procedures should be supervised by the R.S.O. or his designee.

   a. The following procedures should be used to decontaminate the skin:

      (1) Prior to commencing personnel decontamination carefully monitor the contaminated area to establish the level of contamination. This is important so that dose to the contaminated area can be calculated.
      (2) Wet contaminated area and apply mild soap; use warm -- not hot water.
      (3) Work up a good lather and use a soft bristled brush, if necessary. Clean the area as you would normally.
      (4) Dry and monitor between washes.
      (5) If contamination levels are still detectable after three washings, notify radiation safety personnel.

   b. **Hair decontamination**:

      (1) Shampoo hair in the normal manner with the head deflected to the side or backwards
      (2) Rinse well with warm water, towel dry and monitor for contamination. If no activity is detectable, allow the hair to completely dry and resurvey by direct frisk.
      (3) Even small amounts of water can mask detection of beta contamination.

   c. If **eyes** are contaminated:

      (1) Contact the R.S.O.
      (2) Spread eyelids and rinse gently with water in a direction from the nose to edge of the face.
d. If whole body contamination exists notify the R.S.O.

Personnel with whole body contamination will be dressed in full body disposal coveralls and transported to the Radiation Safety Facility for decontamination in a personnel decontamination shower.

(1) Remove all clothing and bag.
(2) Shower immediately with water; brush with mild soap.
(3) Repeat at least twice.
(4) Towel dry and perform a whole body frisk.

e. Contaminated wounds

Any wound acquired in the presence of loose surface contamination or while working with unsealed radionuclides should be considered contaminated until proven otherwise. The following procedures should be instituted.

(1) Notify the campus R.S.O. immediately.
(2) Rinse the wound under running water.
(3) Delimit contaminated area with waterproof material.
(4) Decontaminate the skin around wound.
(5) Remove wound cover and apply sterile dressing
(6) If highly radiotoxic substances are involved, a venous tourniquet may be applied close to the wound.

2. If facial contamination occurs or if internal contamination is suspected, the following action should be taken.

a. Notify the R.S.O.

c. Determine the time of accident, the type of uptake (ingestion, inhalation, absorption), the radionuclide involved, and the chemical nature and level of activity of the contaminant if possible
XIX. INSTRUCTION CONCERNING PRENATAL RADIATION EXPOSURE

This material is taken directly from the US Nuclear Regulatory Guide 8.13 "Instruction Concerning Prenatal Radiation Exposure". It provides instructions about the health protection problems associated with prenatal radiation exposure. It is intended for female employees working in or frequenting any area where radioactive material or radiation producing equipment is used. Anyone who supervises employees who work with radioactive materials or radiation producing equipment will likewise be familiar with this guideline.

After reading the information below, please complete and return the attached certification to:

J.L. Addis  
Environmental Health & Safety  
208 N. Palmetto Blvd. Moorman House

Contact the RSO for questions concerning this material.

A. Possible Health Risks To Children Of Women Who Are Exposed To Radiation During Pregnancy

During pregnancy, you should be aware of things in your surroundings or in your style of life that could affect your unborn child. For those of you who work in or visit areas designated as Restricted Areas (where access is controlled to protect individuals from being exposed to radiation and radioactive materials), it is desirable that you understand the biological risks of radiation to your unborn child.

1. Background Radiation

Everyone is exposed daily to various kinds of radiation: heat, light, ultraviolet, microwave, ionizing, and so on. For the purposes of this guide, only ionizing radiation (such as x-rays, gamma rays, neutrons, and other high-speed atomic particles) is considered. Actually, everything is radioactive and all human activities involve exposure to radiation. People are exposed to different amounts of natural "background" ionizing radiation depending on where they live. Radon gas in homes is a problem of growing concern. Background radiation comes from three sources:
Background Radiation | Annual Dose  
---|---  
Terrestrial radiation from soil and rocks | 50 millirem  
Cosmic radiation from outer space | 50 millirem  
Radioactivity normally found within the human body | 25 millirem

a. The first two of these sources expose the body from the outside, and the last one exposes it from the inside. The average person is thus exposed to a total dose of about 125 millirem per year from natural background radiation.

2. Medical Procedures

In addition to exposure from normal background radiation, medical procedures may contribute to the dose people receive. The following table lists the average doses received by the bone marrow (the bloodforming cells) from different medical applications.

<table>
<thead>
<tr>
<th>XRay Procedure</th>
<th>Average Dose **</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal chest examination</td>
<td>10 millirem</td>
</tr>
<tr>
<td>Normal dental examination</td>
<td>10 millirem</td>
</tr>
<tr>
<td>Rib cage examination</td>
<td>140 millirem</td>
</tr>
<tr>
<td>Gall bladder examination</td>
<td>170 millirem</td>
</tr>
<tr>
<td>Barium enema examination</td>
<td>500 millirem</td>
</tr>
<tr>
<td>Pelvic examination</td>
<td>600 millirem</td>
</tr>
</tbody>
</table>

**Variations by a factor of 2 (above and below) are not unusual.
3. **NRC Position**

NRC regulations and guidance are based on the conservative assumption that any amount of radiation, no matter how small, can have a harmful effect on an adult, child, or unborn child. This assumption is said to be conservative because there are no data showing ill effects from small doses; the National Academy of Sciences recently expressed "uncertainty as to whether a dose of, say, 1 rad would have any effect at all." Although it is known that the unborn child is more sensitive to radiation than adults, particularly during certain stages of development, the NRC has not established a special dose limit for protection of the unborn child. Such a limit could result in job discrimination for women of childbearing age and perhaps in the invasion of privacy (if pregnancy tests were required) if a separate regulatory dose limit were specified for the unborn child. Therefore, the NRC has taken the position that special protection of the unborn child should be voluntary and should be based on decisions made by workers and employers who are well informed about the risks involved.

a. For the NRC position to be effective, it is important that both the employee and the employer understand the risk to the unborn child from radiation received as a result of the occupational exposure of the mother. This document tries to explain the risk as clearly as possible and to compare it with other risks to the unborn child during pregnancy. It is hoped this will help pregnant employees balance the risk to the unborn child against the benefits of employment to decide if the risk is worth taking. This document also discusses methods of keeping the dose, and therefore the risk, to the unborn child as low as is reasonable achievable.
4. **Radiation Dose Limits**

The NRC’s present limit on the radiation dose that can be received on the job is 1,250 millirems per quarter (3 months). Working minors (those under 18) are limited to a dose equal to onetenth that of adults, 125 millirems per quarter. (See § 20.101 of 10 CFR Part 20.)

a. Because of the sensitivity of the unborn child, the National Council on Radiation Protection and Measurements (NCRP) has recommended that the dose equivalent to the unborn child from occupational exposure of the expectant mother be limited to 500 millirems for the entire pregnancy (Ref.2). The 1987 Presidential guidance (Ref. 1) specifies an effective dose equivalent limit of 500 millirems to the unborn child if the pregnancy has been declared by the mother; the guidance also recommends that substantial variations in the rate of exposure be avoided. The NRC (in § 20.208 of its proposed revision to Part 20) has proposed adoption of the above limits on dose and rate of exposure.

5. **Advice for Employee and Employer**

Although the risks to the unborn child are small under normal working conditions, it is still advisable to limit the radiation dose from occupational exposure to no more than 500 millirems for the total pregnancy. Employee and employer should work together to decide the best method for accomplishing this goal. Some methods that might be used include reducing the time spent in radiation areas, wearing some shielding over the abdominal area, and keeping extra distance from radiation sources when possible. The employer or health physicist will be able to estimate the probable dose to the unborn child during the normal ninemonth pregnancy period and to inform the employee of the amount. If the predicted dose exceeds 500 millirems, the employee and employer should work out schedules or procedures to limit the dose to the 500 millirem recommended limit.

a. It is important that the employee inform the employer of her condition as soon as she realizes she is pregnant if the dose to the unborn child is to be minimized.
6. **Internal Hazards**

This document has been directed primarily toward a discussion of radiation doses received from sources outside the body. Workers should also be aware that there is a risk of radioactive material entering the body in workplaces where unsealed radioactive material is used. Nuclear medicine clinics, laboratories, and certain manufacturers use radioactive material in bulk form, often as a liquid or a gas. A list of the commonly used materials and safety precautions for each is beyond the scope of this document, but certain general precautions might include the following:

a. Do not smoke, eat, drink, or apply cosmetics around radioactive material.

b. Do not pipette solutions by mouth.

c. Use disposable gloves while handling radioactive material when feasible.

d. Wash hands after working around radioactive material.

e. Wear lab coats or other protective clothing whenever there is a possibility of spills.

Remember that the employer is required to have demonstrated that it will have safe procedures and practices before the NRC issues it a license to use radioactive material. Workers are urged to follow established procedures and consult the employer’s radiation safety officer or health physicist whenever problems or questions arise.

B. **Effect On The Embryo / Fetus of Exposure To Radiation and Other Environmental Hazards**

In order to decide whether to continue working while exposed to ionizing radiation during her pregnancy, a women should understand the potential effects on an embryo/fetus, including those that may be produced by various environmental risks such as smoking and drinking. This will allow her to compare these risks with those produced by exposure to ionizing radiation.

1. **Radiation Risk**

Table 1 provides information on the potential effects resulting from exposure of an embryo/fetus to radiation and non-radiation risks. The second column gives the rate at which the effect is produced by natural causes in terms of the number per thousand cases. The fourth column gives the number of additional effects per thousand cases believed to be produced by exposure to the specified amount of the risk factor.
The following section discusses the studies from which the information in Table 1 was derived. The results of exposure of the embryo/fetus to the risk factors and the dependence on the amount of exposure are explained.

a. **Childhood Cancer**

Numerous studies of radiation-induced childhood cancer have been performed, but a number of them are controversial. The National Academy of Science (NAS) BEIR report reevaluated the data from these studies and even reanalyzed the results. Some of the strongest support for a causal relationship is provided by twin data from the Oxford survey (Ref. 4). For maternal radiation doses of 1,000 millirems, the excess number of deaths (above those occurring from natural causes) was found to be 0.6 deaths per thousand children (Ref. 4).

b. **Mental Retardation and Abnormal Smallness of the Head (Microcephaly)**

Studies of Japanese children who were exposed while in the womb to the atomic bomb radiation at Hiroshima and Nagasaki have shown evidence of both small head size and mental retardation. Most of the children were exposed to radiation doses in the range of 1 to 50 rads. The importance of the most recent study lies in the fact that investigators were able to show that the gestational age (age of the embryo/fetus after conception) at the time the children were exposed was a critical factor (Ref. 7). The approximate risk of small head size as a function of gestational age is shown in Table 1. For a radiation dose of 1,000 millirems at 4 to 7 weeks after conception, the excess cases of small head size was 5 per thousand; and 8 to 11 weeks, it was 9 per thousand (Ref. 7).

(1) In another study, the highest risk of mental retardation occurred during the 8 to 15 week period after conception (Ref. 8). A recent EPA study (Ref. 16) has calculated that excess cases of mental retardation per live birth lie between 0.5 and 4 per thousand per rad.
c. **Genetic Effects**

Radiation-induced genetic effects have not been observed to date in humans. The largest source of material for genetic studies involves the survivors of Hiroshima and Nagasaki, but the 77,000 births that occurred among the survivors showed no evidence of genetic effects. For doses received by the pregnant worker in the course of employment considered in this guide, the dose received by the embryo/fetus apparently would have negligible effect on descendants (Refs. 17 and 18).

2. **Non-radiation Risks**

a. **Occupation**

A recent study (Ref. 9) involving the birth records of 130,000 children in the State of Washington indicates that the risk of death to the unborn child is related to the occupation of the mother. Workers in the metal industry, the chemical industry, medical technology, the wood industry, the textile industry, and farms exhibited stillbirths or spontaneous abortions at a rate of 90 per thousand above that of workers in the control group, which consisted of workers in several other industries.

b. **Alcohol**

It has been recognized since ancient times that alcohol consumption had an effect on the unborn child. Carthaginian law forbade the consumption of wine on the wedding night so that a defective child might not be conceived. Recent studies have indicated that small amounts of alcohol consumption have only the minor effect of reducing the birth weight slightly, but when consumption increases to 2 to 4 drinks per day, a pattern of abnormalities called the fetal alcohol syndrome (FAS) begins to appear (Ref. 11). This syndrome consists of reduced growth in the unborn child, faulty brain function, and abnormal facial features. There is a syndrome that has the same symptoms as fullblown FAS that occurs in children born to mothers who have not consumed alcohol. This naturally occurring syndrome occurs in about 1 to 2 cases per thousand (Ref. 10).
(1) For mothers who consume 2 to 4 drinks per day, the excess occurrences number about 100 per thousand; and for those who consume more than 4 drinks per day, excess occurrences number 200 per thousand. The most sensitive period for this effect of alcohol appears to be the first few weeks after conception, before the mother-to-be realizes she is pregnant (Refs. 10 and 11). Also, 17% or 170 per thousand of the embryo/fetuses of chronic alcoholics develop FAS and die before birth (Ref. 15). FAS was first identified in 1973 in the United States where less than fullblown effects of the syndrome are now referred to as fetal alcohol effects (FAE) (Ref. 12).

c. **Smoking**

Smoking during pregnancy causes reduced birth weights in babies amounting to 5 to 9 ounces on the average. In addition, there is an increased risk of 5 infant deaths per thousand for mothers who smoke less than one pack per day and 10 infant deaths per thousand for mothers who smoke one or more packs per day (Ref. 13).

d. **Miscellaneous**

Numerous other risks affect the embryo/fetus, only a few of which are touched upon here. Most people are familiar with the drug thalidomide (a sedative given to some pregnant women), which causes children to be born with missing limbs, and the more recent use of the drug diethylstilbestrol (DES), a synthetic estrogen given to some women to treat menstrual disorders, which produced vaginal cancers in the daughters born to women who took the drug. Living at high altitudes also gives rise to an increase in the number of lowbirthweight children born, while an increase in Down's Syndrome (mongolism) occurs in children born to mothers who are over 35 years of age. The rapid growth in the use of ultrasound in recent years has sparked an ongoing investigation into the risks of using ultrasound for diagnostic procedures (Ref. 19).
PREGNATAL RADIATION EXPOSURE

TRAINING CERTIFICATION

I hereby certify that I have received a copy of "Possible Health Risks to children of Women Who are Exposed to Radiation During Pregnancy" and have been given an opportunity to ask questions concerning the health protection problems associated with prenatal radiation exposure.

Printed name:__________________________________________________________

Signature:______________________________________________Date:________

Licensee's
signature:______________________________________________Date:________

Please return to the R.S.O. at:

J.L. Addis  
Environmental Health and Safety  
208 N. Palmetto Blvd.  Moorman House.  
Clemson, SC  29631
I. POLICY AND PURPOSE

This policy is designed to ensure that all radioactive wastes generated under the university’s radioactive materials license(s) are properly accounted for and safely handled. Implementation of these practices and procedures will promote the University's compliance with applicable state and federal regulations governing the processing, packaging, storage and disposal of radioactive waste.

II. GENERAL RULES AND POLICIES

A. Responsibilities

The Authorized Investigator will assure that each individual user under his/her supervision is informed in the proper practices and procedures for the handling and packaging of radioactive waste. The use of radioactive materials, the handling, packaging, storage and the ultimate disposal of radioactive wastes is strictly regulated by S.C. DHEC and the U.S. NRC.

1. It is necessary for laboratory personnel to segregate radioactive waste into appropriate categories, and additionally it is important that some types of waste not be inter-mixed. Failure to properly package the waste could lead to spills, unnecessary exposure, fines for regulatory infractions, and in a worst case, to an embargo of waste shipments from Clemson University.

B. Waste minimization

The disposal of radioactive waste at a commercial burial facility is very expensive. Work involving radioactive materials should be pre-planned and practiced in order to minimize the volume of waste generated. Care must be exercised to separate radioactive waste from non-radioactive waste as it is generated.

III. WASTE CATEGORIES

The following categories of radioactive wastes are generated as a byproduct of research conducted at the University.

A. Primary Categories

1. Short Half-Life Waste - containing isotopes with a radiological half-life of less than 65 days.

2. Long Half-Life Waste - containing isotopes with a radiological half-life of greater than 65 days.
B. Waste Classification

Radioactive waste is further divided into classifications dependent on its physical/chemical properties.

1. **DAW (Dry Active Waste)** - Radioactively contaminated lab trash such as glassware, paper, lab clothing, gloves, culture dishes, syringes, etc. (no free standing liquids).

2. **Liquid Waste** - Aqueous or organic waste solutions containing radioactive materials or plant tissue to include: carcasses, excreta, organs, blood, or tissue samples.

3. **Mixed Waste** - Radioactive waste, which also contains hazardous materials/chemicals.

4. **Sealed Sources** - Encapsulated radioactive sources used for instrument response checks or research.

C. Radioactive Waste Containers

1. Containers for all types of radioactive waste may be obtained from the Radiation Safety Office.

2. Each container of waste shall bear a "Rad Tag" or sign with the radiation symbol and the words "Caution - Radioactive Material" or "Radioactive Waste".

3. Separate waste containers will be used for short half-life and long half-life wastes. This will help to reduce the University's waste disposal costs, since the short half-life wastes will be decayed to background and disposed of as "clean", non-radioactive waste.

4. Radioactive wastes may be stored only in restricted areas where it can be secured against unauthorized removal. Storage areas must be listed as an authorized place of use on the individual Authorized Investigators Radioactive Materials approval and must be posted in accordance with University posting procedures. Radioactive waste containers may not be left unattended in a corridor.

5. Radioactive waste containers should be removed from the lab as soon as they are 3/4 full. Waste container and area dose rates should be checked periodically. Position waste containers in an area such that exposure to personnel is minimized.
a. If the dose rate from a waste container is greater than 2 mR/hr at 12 inches or causes the general area (measured at 3 feet) dose rate to exceed 0.5 mR/hr call the R.S.O. for a waste pickup. If the container dose rate exceeds 2 mR/hr at 12 inches it must be located in a posted Radiation Area.

6. Liquid waste containers are subject to breakage or leakage and should be stored so that if accidental breakage or leakage should occur, the contents will be contained in a small area, e.g., by setting it in a large pan. Liquid containers shall have positive-fitting caps, and must be kept closed.

IV. SPECIFIC DISPOSAL PROCEDURES

Radiation Safety personnel will remove radioactive waste from the laboratories. The transfer of the waste from the authorized user to the Radiation Safety Office will be documented on a "radioactive waste disposal form" (see attachments). For waste pickup call 656-7165, or fax a request to 656-1804.

A. Dry Active Waste (DAW)

1. This waste classification is made up of normal laboratory waste, such as, paper, plastic, absorbent coverings, towels, empty test tubes and syringes, culture dishes and other glassware. DAW may contain no freestanding liquids.

2. Items Prohibited in DAW

   a. Liquid in vials, syringes, etc.

   b. Hazardous/infectious/reactive materials

   c. Biological tissues or products in quantities sufficient to produce an odor problem

   d. Sealed/encapsulated radioactive sources
3. **Packaging**

   a. Dry radioactive wastes will be placed in standardized radioactive labeled waste cans that are lined with thick poly bags. Waste cans, bags, and labels are obtained from the Radiation Safety Office. The use of office-style waste cans is specifically prohibited.

   b. Syringes, needles, and pipettes should be placed in separate puncture proof containers before being placed in the waste can. This will prevent puncture of the plastic bag and minimize the possibility of injury to personnel handling the waste.

   (1) Broken glassware should be wrapped in heavy paper or cardboard and taped before being discharged into waste cans.

   c. Do not over-fill the bag. Leave sufficient room so that the bag top can be twisted and sealed with duct tape. Double bagging when the waste is picked up may be necessary to insure package integrity.

B. **Liquid Scintillation Waste** (Organic)

Waste liquids may be organic or aqueous based and further may be regulated or deregulated. The classification deregulated or regulated applies only to Radiation Safety Personnel and to the final disposal of the waste.

In all respects the generator of the waste shall handle all waste liquids containing any radioactive isotope(s) in any concentrations as fully regulated in the sense that all waste liquids shall be stored and labeled as radioactive material or waste.

All liquid radioactive waste that is organic based will be collected and transported to the Radiation Safety Facility and processed for off site disposal.

1. There are two classes of waste scintillation fluid whether in vials or packaged as bulk liquid.

   a. **De-regulated Scintillation Fluid/Vials**

   Only liquid scintillation fluid and/or vials that have contained scintillation fluid with a activity of $< 0.05 \mu \text{Ci} / \text{ml}$ of C-14 and/or H-3 are considered **deregulated**. This classification is a deminimus level and applies only to the isotopes C-14 and/or H-3.
b. **Regulated Liquid Scintillation Fluid / Vials**

Waste fluids containing isotopes containing concentrations of H-3 and/or C-14 $> 0.05 \mu$Ci/ml or waste fluids containing isotopes other than C-14 or H-3 in any concentration are considered regulated.

1. Regulated organic based waste scintillation fluids will be handled and disposed of as "mixed waste" (waste that is considered both hazardous and radioactive). Please contact the R.S.O. prior to initiating work that may produce waste in this category.
   
a. **Keep regulated and deregulated classes of liquid scintillation waste separated.** If you have any questions concerning the disposal of scintillation fluid or mixed waste, please call the Radiation Safety Officer before initiating the use of these compounds.

2. **Packaging**

Waste liquid scintillation fluid may be packaged in individual counting vials or in bulk containers.

a. **Scintillation Vials**

Leave the waste scintillation fluid in their vials, tightly capped, and place them in a separate, standardized, labeled waste can. The can will be lined with a thick poly bags. Do not place absorbent material inside the bag containing the waste vials. If leakage of the fluid from the inner bag is a problem, the can will be double lined and absorbent material placed inside the first bag.

(1) Vials will also be accepted upright in their original shipping trays.

(2) Do not put other types of waste in the liquid scintillation waste can. Items such as rubber gloves, vials containing high-activity stock solutions, and vials with volumes greater than 50 ml are prohibited.
(3) The re-use of scintillation vials is discouraged due to the possibility of contamination of the user. If done, however, the contents may be emptied into a carboy and treated as bulk liquid.

(4) Liquid scintillation vials containing organic solvents may not be emptied into the sewer.

C. Aqueous Waste

The University is authorized by S.C. DHEC to dispose of a limited quantity of radioactive material in aqueous solution by discharge into the University's sanitary sewer system. Only aqueous based solutions, such as biodegradable scintillation fluids, may be discharged into the sanitary sewer system. All waste disposed of by release into the sewer system will be readily soluble in water and meet all of the requirements of S.C. DHEC Title A Regulation 61-63 RHA 3.29.

If the Authorized Investigator has not requested and been issued a “dump quota” for authorization they may not dispose of radioactive waste be release into the sanitary sewer system. Other than washing of glassware, waste liquids will be presented to radiation safety personnel for disposal.

a. Sewer Disposal of Aqueous Waste

A sink in each licensee's laboratory will be designated as a "Radioactive Waste Sink". Do not use a sink for disposal of radioactive waste or for decontamination of laboratory apparatus unless it is so designated.

b. Liquid waste may be discharged into the sanitary sewer if the material is readily soluble (or is readily dispersible biological material) if it is aqueous based and contains no hazardous chemical waste constituents. Disposal should be accompanied by ample flushing with tap water.

c. The sewage system should not be used as a primary disposal route. Amounts and concentrations disposed of should be "as low as practicable".

d. Records of sewer disposal must be maintained on the Monthly and Yearly Aqueous Dump Record (see attachments). A copy of the yearly dump record must be sent to the Radiation Safety Office at the end of each calendar year.
2. If for any reason aqueous waste cannot be dumped into a designated drain at the authorized place of use, the waste will be transported to the Radiation Safety Facility and will be dumped into the facility’s sump. This designated sump drains to the sewage treatment’s 161,000-gallon main receiver tank, where raw sewage is first introduced into the treatment process. Daily dilution flow is approximately 850,000 gal / day.

a. Disposal of liquid waste occurring at the Radioactive Waste Facility will be documented on the "monthly and yearly dump record" against the quota assigned to the Authorized Investigator who generated the waste.

   (1) If aqueous waste is transferred to the Radioactive Waste Facility, the liquid waste will be tracked and documented on the Radioactive Waste Disposal Form as bulk aqueous waste.

D. Bulk Liquids

Small containers with more than 50 ml of liquid and uncapped or loosely capped containers (e.g., test tubes with parafilm covers or corks) must be decanted into a bulk liquid container.

1. Bulk Packaging

   a. Nalgene carboys are provided by the Radiation Safety Office for collection of waste bulk liquids. These containers are compatible with most organic solvents.

   b. The container must be sealed tightly with a cap designed for the container (Parafilm may not be used for this purpose).

E. Other Liquids

1. Stock solutions / high activity liquids:

   a. High activity waste solutions (activities > 0.05 μCi/ml) must be presented for disposal separately.

F. Biological Waste

This includes carcasses, excreta, organs, blood and bloody rags, and tissue samples in amounts sufficient to produce an odor problem.
1. **Packaging**

Radioactive waste containing infectious agents shall not be released from the laboratory unless the waste has been autoclaved or otherwise deactivated. Please do not initiate the production of biological waste until you have discussed your procedure with the R.S.O.

a. Radioactive biological waste will be placed in a heavy yellow radioactive waste bags making sure that the bag is not punctured. Liquid must not be able to leak out. The waste will be double bagged and absorbent will be used as necessary.

b. Blood should be packaged in a strong plastic container. Thin plastic containers such as empty milk jugs are not adequate for this purpose.

c. Animal carcasses containing long-lived nuclides and/or concentrations of H-3 or C-14 greater than 0.05 µCi/ml will be packaged in double walled metal drums. The inner drum will be double lined with thick poly bags. The animal will be packaged with a combination of lime and absorbent.

d. Animal carcasses with concentrations of < 0.05 µCi / gram of H-3 and/or C-14 may be disposed of without regard to radioactivity. The activity of the waste and its final disposition will be coordinated and documented by the Radiation Safety Office.

2. **Decay of animal carcasses contaminated with short-lived isotopes**

   (< 65 days).

a. Animal carcasses contaminated with short-lived isotopes may be held for decay by the Radiation Safety Office. The contaminated carcasses will be stored in a freezer dedicated for the purpose and posted as a Radioactive Materials Storage area.

b. Contaminated carcasses will be held for ten half-lives and surveyed to ensure that there is no activity detectable above background prior to final disposal.

c. If the radioactive biohazardous waste meets release criteria, it will be disposed of as biological waste by a licensed biohazard waste disposal contractor.
G. **Mixed Waste**

A mixed waste is a waste that is radioactive and also contains hazardous material. Mixed waste presents special problems in handling, storing, and final disposition. It is important that University personnel contact the R.S.O. prior to initiating work that will produce mixed waste.

1. A material is considered **Hazardous** if it meets any of the following criteria:
   
   
   b. If the waste substance is listed in E.P.A. Code of Federal Regulations Title 40, Resource Conservation and Recovery Act (RCRA).
   
   c. Assigned a threshold limit value (TLV) by the American Conference of governmental Industrial Hygienists, ACGIH).
   
   d. Is determined to be cancer causing, an irritant, a sensitizer, or has damaging effects on specific body organs.
   
   e. If the substance has any of the following characteristics:
      
      (1) Ignitability
      (2) Corrosivity (pH <2 or >12)
      (3) Reactivity
      (4) Toxicity

2. Disposal procedures employed in the Rad Waste Processing Facility involve crushing, compacting, and consolidation of liquids. These procedures may not be compatible with the presents of some hazardous substances.

   a. Mixed wastes are not acceptable for disposal at permanent radioactive waste repositories.

3. Please consult the R.S.O. before initiating research that is likely to produce mixed waste. It is more expensive to dispose of mixed waste and some types of mixed waste are not currently accepted for disposal at all.

H. **Improperly Packaged Waste**

Radiation safety personnel may refuse to accept any waste that is improperly packaged. It will be the licensee's responsibility to re-package the waste.
I. Short Lived Waste (< 65 day half-life)

1. Short-lived wastes are segregated and stored according to isotope for a period of not less than 10 half-lives.

2. After the waste has decayed for 10 half-lives, it is surveyed to confirm that it meets unrestricted area release limits. If the wastes meet clean release limits it is shredded to reduce waste volume and to destroy all radioactive material labeling.

3. After shredding, the waste is bagged and disposed at the regional class-D landfill as normal solid waste.

J. Waste Disposal Records

Disposal of all waste will be accounted for on the “Radioactive Waste Disposal Form” which is signed by the Authorized Investigator or his/her qualified designee. This is a legal requirement of our radioactive materials license. The completed form should agree with your isotope inventory.

1. Records documenting the transfer, processing, storage, and final disposal of radioactive wastes will be retained for a period of no less than five years from the disposal date or until authorized by the BRH.

   a. Each container of waste will be given a serialized number by the Radiation Safety Office and tracked according the Approved User who generated the waste, by isotope, activity, date of collection, and storage location.

   b. Each container of waste will bear the following information:

      (1) Rad waste accountability number
      (2) Description of the material (waste classification)
      (3) Surface contamination level of primary container
      (4) Surface dose rate
      (5) Nuclide and curie content
      (6) Approved users name and/or number
      (7) Signature and date
PRENATAL RADIATION EXPOSURE

TRAINING CERTIFICATION

I hereby certify that I have received a copy of "Possible Health Risks to children of Women Who are Exposed to Radiation During Pregnancy" and have been given an opportunity to ask questions concerning the health protection problems associated with prenatal radiation exposure.

Printed name:__________________________________________________________

Signature:____________________________________________________________Date:____________________

Licensee's signature:________________________________________Date:____________________

Please return to the R.S.O. at:

J.L. Addis
Environmental Health and Safety
208 N. Palmetto Blvd. Moorman House.
Clemson, SC 29631
CAUTION

RADIOACTIVE MATERIALS AREA
CAUTION

RADIATION AREA
CAUTION
HIGH RADIATION AREA
CAUTION

CONTAMINATED AREA
Attachment

CAUTION

AIRBORNE RADIOACTIVITY AREA
NAME OF AUTHORIZED INVESTIGATOR: ________________________________

RAD MATERIAL AUTHORIZATION #: ________________________________

Package and label the waste according to the following:

1. Tag each bag/container with a yellow rad material tag.
2. On tag place:
   (a) serialized rad waste accountability # (provided by Rad Safety Office)
   (b) the isotope(s)
   (c) waste form * (see notes below)
   (d) activity in millicuries for each isotope
3. Package all dry waste in heavy yellow bags provided by rad safety.
   Dry waste containing tritium (H-3) and Carbon-14 (C-14) may be mixed.
   Place all bulk liquid waste in jerricans provided by Rad Safety Office. keep organic and aqueous liquids separately.

<table>
<thead>
<tr>
<th>BAG #</th>
<th>ISOTOPE</th>
<th>WASTE FORM</th>
<th>ACTIVITY IN JERICAN #</th>
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MILLICURIES/BAG

Please check one of the following Hazardous waste statements:
This waste contains:  □ No RCRA/Hazardous waste:  □ The following RCRA/Hazardous waste (percent by volume): ________________________________

SIGNATURE OF AUTHORIZED INVESTIGATOR: ________________________________ DATE: ________________________________

* NOTES: Use the following categories for waste form designation:

- Dry active waste  DAW = glassware, plastic, paper etc. (no liquids).
- Bulk organic liquid  BOL = waste liquid which contains organic solvents (toluene, hexane, dioxan benzene, etc.)
- Bulk aqueous liquid  BAL = aqueous based waste liquids in containers with volumes ≥ 50 ml.
- Liquid scint. vials  LSV = waste liquid scintillation fluid in vials - glass and/or plastic. Do not place absorbent such as vermiculite inside bag with vials.
Rad Tech Notes:
1. Date of acceptance of waste: ________________________________

2. Dose rate @ contact with bag____ mR/hr Dose rate @ 12" ______________ mR/hr.

3. Temporary/final disposition of waste: bin/barrel # ____________________________

4. SIGNATURE
   ________________________________
   R.S.O./
   designee: ________________________________
## RADIATION SAFETY SOURCE LEAK CHECK

### SURVEY DATA

<table>
<thead>
<tr>
<th>Source No.</th>
<th>Nuclide</th>
<th>Sample cpm</th>
<th>Corrected cpm</th>
<th>Sample dpm</th>
<th>Sample uCi</th>
<th>Source Location</th>
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<th>Inst. used</th>
<th>Serial No.</th>
<th>Bkg. cpm</th>
<th>Efficiency</th>
<th>Cal due date</th>
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**Technician/R.S.O.**

(signature): ___________________________ Date: __________

Comments: 

____________________________________________________________________________

____________________________________________________________________________

756
### RADIOACTIVE MATERIALS USE / INVENTORY RECORD

**P.I./User:**

**Department:**

**Location:**

<table>
<thead>
<tr>
<th>Use of Material</th>
<th>Radioactive Waste</th>
<th>Source Inventory</th>
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<td><strong>Use of Material</strong></td>
<td><strong>Radioactive Waste</strong></td>
<td><strong>Source Inventory</strong></td>
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TO: Radiation Safety Office
208 N. Palmetto Blvd.

1. MATERIAL
REQUESTED:

Isotope Activity (expressed in mCi) Date Needed By

2. MANUFACTURER/SUPPLIER:
PURCHASE ORDER No:

3. CATALOG No.

4. RADIOACTIVE MATERIAL TO BE USED BY:

Dept. Ext.

(Authorized Investigator)

5. PLACE OF INTENDED USE: Building Rooms(s)

6. BRIEF DESCRIPTION OF USE:

(Attach form to Proposal for ALL NEW Studies)

7. AUTHORIZED INVESTIGATOR:

DATE: (Signature)

Amount of Isotope currently in my possession:
(Expressed in mCi)

COMMENTS: (Special instructions and/or precautions)

REMAINDER OF FORM TO BE COMPLETED BY RADIATION SAFETY OFFICE
8. Approved By: __________________________ DATE: ____________________

9. DATE MATERIAL RECEIVED BY RSO: _______________ RELEASED BY: ______

10. DATE ISSUED TO DEPARTMENT: __________________________ REC'D BY: _______

11. PURCHASE ORDER #: __________________________ RECEIPT LOG #: _____________