HOWARD UNIVERSITY

Radiation Safety Office

RADIATION SAFETY MANUAL

Tenth Edition

Adopted July 2015

FOREWORD

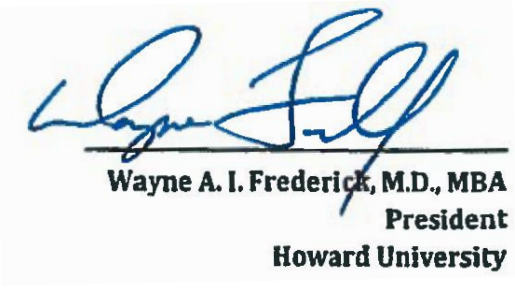
This manual presents Howard University and Howard University Hospital with guidelines with regards to necessary precautions and regulations in the safe handling of radioactive material and radiation producing machines in clinical services, research and training activities. Thus, the scope of the manual is broad yet focused on radiation safety. The regulatory bodies establish guidelines to ensure worker safety, therefore, it is the responsibility of each individual to follow all established guidelines to ensure their and others' safety in the workplace.

The manual contains significant information for all personnel, whether their contact with radiation is only a casual one or actually involves direct use of ionizing radiation sources. In addition, faculty members, researchers, technicians, students, administrators, and housekeeping personnel, should be particularly aware of the pertinent information which relates to their own responsibilities for maintaining radiation safety.

Under the provisions of a broad license and a human use license issued by the U.S. Nuclear Regulatory Commission, Howard University and Howard University Hospital are authorized to procure radioactive materials for non-human and human uses. These licenses are contingent upon the existence of the Howard University Radiation Safety Committee and a radiation safety program.

To ensure that all requirements of the broad and human use licenses are being followed, the University and Hospital are subject to periodic inspection by the Nuclear Materials Safety Branch, Region I of the U.S. Nuclear Regulatory Commission. The inspections are thorough and include checks on monitoring of laboratory areas, procurement, use and disposal records, personnel monitoring procedures, experiment techniques, storage, therapeutic and diagnostic uses. Violation of these and other requirements can result in the termination of these licenses. Thus, it is imperative that all persons comply with the contents of this guide, the conditions imposed by the Howard University Radiation Safety Committee, and the regulations of the U.S. Nuclear Regulatory Commission as well as those of the District of Columbia Department of Health.

All persons, working with sources of ionizing radiation at Howard University and Howard University Hospital should be familiar with the contents of this manual and shall abide by the policies herein established.



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PREFACE

In every facility where radioactive materials or radiation producing machines are utilized, it is necessary to develop, document and maintain policies which establish specific methods and procedures to uphold safety and compliance. Safety is the practice of a set of rules, guidelines and procedures which protects workers, facilities, the general public and the environment. Compliance is the maintenance of procedures, practices, documents and records which demonstrates that federal and District of Columbia laws and regulations are not compromised. It is a necessary challenge for all administrators, safety committee members, faculty, staff, students and workers to maintain safety and compliance. In laboratory and research facilities, the challenge is accentuated with the myriad of procedures and materials utilized, and the continuous change and evolution of these conditions.

This document will serve as a guide to meeting this challenge by defining the structure, policy, procedures, responsibilities and regulatory stance set forth by the U.S. Nuclear Regulatory Commission (NRC), the District of Columbia Health (DC Health), the HU/HUH NRC Licenses, the Radiation Safety Committee (RSC), and the Radiation Safety Office. However, it is important that all principal investigators and workers remember that the burden of daily compliance and safe practices is their own, and that they are the most critical link in the maintenance of these goals.

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RADIATION SAFETY PROGRAM

1.1 INTRODUCTION

Under the provisions of human use and broad scope licenses issued by the U.S. Nuclear Regulatory Commission, Howard University and Howard University Hospital are authorized to procure radioactive material for human use (clinical applications) and non-human (conducting research, respectively. These licenses are contingent upon the existence of the Howard University Radiation Safety Program and Radiation Safety Committee (RSC). Howard University and Howard University Hospital has two licenses:

- **Human Use License # 08-03075-07 (Limited)**
- **Non-human Use (Research & Development) License # 08-00386-19 (Broad Scope License)**

The goal of the Radiation Safety Program at Howard University is to facilitate safe conditions for the proper use of radiation, maintain radiation exposures As Low as Reasonably Achievable (ALARA) and to ensure that operations are in compliance with the applicable State and federal regulations.

1.2 HOWARD UNIVERSITY RADIATION SAFETY COMMITTEE

The Radiation Safety Committee was appointed by Dr. James Cheek, President of Howard University on March 23, 1970 to perform duties designed to maintain a coordinated approach to radiation protection throughout the University. Among such duties is the review and recommendation for approval or disapproval of all applications for the use of radiation sources within the University. Acting under this directive, the Committee has established procedures to provide guidance to all persons at Howard University who procure, receive or use sources of ionizing radiation.

The Howard University Radiation Safety Committee (RSC) was established to ensure that all sources of ionizing radiation at Howard University and Howard University Hospital are used safely, and, in a manner, which complies with applicable Federal and District of Columbia Health Regulations. The Committee governs the operation of the Howard University Radiation Safety Office, and currently has a total of 13 members.

1.2.1 Charge

The Committee shall:

- Ensure that licensed material will be used safely. This includes review as necessary of training programs, equipment, facilities, supplies and procedures;
- Ensure that licensed material is used in compliance with U.S. Nuclear Regulatory Commission (NRC) regulations and the institutional license;
- Ensure that the use of licensed material is consistent with the ALARA philosophy and program;
- Establish a table of investigational levels for occupational radiation exposures; and
- Identify program problems and solutions.

1.2.2 Responsibilities

To oversee the use of licensed material, the Committee shall:

- Be familiar with all pertinent NRC regulations, the license application, the licenses and amendments;
- Review on the basis of safety and approve or deny, consistent with the limitations of the regulations, the license and the ALARA philosophy, all requests for authorization to use radioactive material at Howard University and Howard University Hospital;
- Establish policy regarding the safe use of radioisotopes;
- Review the training and experience of the proposed authorized users, the Radiation Safety Officer (RSO) and the teletherapy physicist to determine that their qualifications are sufficient to enable the individuals to perform their duties safely and are in accordance with the regulations and the license;
- Prescribe special conditions that will be required during the proposed method of use of radioactive materials, such as requirements for bioassays, physical examination of users and special monitoring procedures;
- Provide technical advice to radioisotope users and to the Radiation Safety Officer;
- Review all instances of alleged infractions of use and safety policies and recommending appropriate remedial actions;
- Review quarterly the Radiation Safety Officer's summary report of occupational radiation exposure records of all personnel, giving attention to individuals or groups of workers whose occupational exposure appears excessive;
- Review quarterly, with the assistance of the Radiation Safety officer, all incidents involving byproduct material with respect to cause and subsequent actions taken;
- Review at least annually the Radiation Safety Officer's summary report of the entire radiation safety program to determine that all activities are being conducted safely, in accordance with NRC regulations and the conditions of the license and consistent with the ALARA program and philosophy. The review must include an examination of records, reports from the Radiation Safety Officer, results of the NRC inspections, written safety procedures and the adequacy of the management control system;
- Review recommendations on ways to maintain individual and collective doses ALARA;
- Review, on the basis of safety and with regard to the training and experience standards of the U.S. Nuclear Regulatory Commission, and approve or disapprove any individual who is to be listed as an authorized user, Radiation Safety Officer, or a Medical Physicist before submitting a license application or request for amendment or renewal;
- Review, on the basis of safety and approve with the advice and consent of the Radiation Safety Officer and the management representative or disapprove minor changes in radiation safety procedures that are not potentially important to safety and are permitted under the U.S. Nuclear Regulatory Commission regulations;

- Suspend or terminate any project or procedures found to be a threat to health and/or property;
- Establish a program to ensure that all persons whose duties may require them to work in or frequent areas where radioactive materials are used (e.g., nursing, security, housekeeping, physical facilities) are appropriately trained as required in 10CFR Sec. 19.2;
- Recommend remedial action to correct any deficiencies identified in the radiation safety program;
- Maintain written minutes of all Committee meetings, including members in attendance and members absent, discussions, action, recommendations, decisions and numerical results of all votes taken; and
- Ensure that the byproduct material license is amended if required prior to any changes in facilities, equipment, policies, procedures and personnel.

To the extent that they do not interfere with the mission of the Committee, management may assign other responsibilities such as x-ray radiation safety, quality assurance oversight and research project review and approval.

The Committee shall meet in formal session on a monthly basis (minimum quarterly) to review pending NRC License Applications, Byproduct Material Authorization Applications or other matters that may come before it, except when there are no matters to discuss. **One meeting each quarter will be designated to cover the human use license**. These meetings are scheduled for January, April, July and October. The agenda will list discussion items related to Howard University and University Hospital licensed activities. The minutes of these meetings will be sent to all the Radiation Safety Committee members for their review.

At least one half of the membership, including the Chair of the Committee, a representative of management, the Radiation Safety Officer and a representative of nursing administration shall constitute a quorum. The entire Committee shall take action on matters that come before the Committee. The **President** or **Provost and Chief Academic Officer** of Howard University shall appoint the members of the Radiation Safety Committee.

1.2.3 Selection of RSC Chairperson

The selected RSC chairperson shall be an individual whose knowledge and leadership skills shall promote the effectiveness of the RSC. The selection of the RSC chairperson must be a significant task for executive management and other existing RSC members. Such individual candidate must have adequate time to devote to the RSC chairperson position in addition to other job responsibilities or assignments. The prospective candidate shall not be coerced into taking the position, but one who wants the position, is knowledgeable, and has leadership skills and adequate time to devote to accomplishing the goals of the RSC and fulfilling the role as chairperson.

1.2.4 Selection of Other RSC Members

The Radiation Safety Committee characterizes a cross-section of medical use areas, expertise, scholars (researchers), and management, and serves as an effective collegial group to develop and promote a quality radiation safety program. The RSO and the RSC chairperson shall work together to appoint other people who have knowledge, experience, and are interested in serving on the RSC. The RSC

members shall have adequate training or possess an appropriate level of knowledge of radiation safety issues, medical uses, and research uses of radioactive material and radiation producing machines (10 CFR Part 33, 10 CFR Part 35, NUREG 1516). The NRC regulations require that the RSC for a limited specific medical license, should include, a minimum, a representative from each authorized area of medical use, the RSO, executive management, and a nursing representative.

The NRC regulations also stipulate that the management representative cannot be the authorized user or RSO. User group representatives, such as radiation oncology, nuclear medicine, radiology, cardiology, and research, should also be active members. Additionally, NRC regulations require that a quorum be present for each meeting of at least one-half of the RSC membership, including the RSO and executive management. Typically, the nursing representative on the RSC is a nurse with administrative authority and responsibility to ensure that facility nurses who care for patients undergoing therapy procedures receive required radiation safety training and are aware of relevant radiation safety issues that may affect them or the patients under their care. This individual should have, or should be provided with, a general knowledge of the institution's radiation and radioactive material uses for patient procedures (e.g., diagnostic, radiopharmaceutical therapy, teletherapy, and brachytherapy uses, especially where patients are required to be confined). The membership term is extended for 3 years.

1.3. ROLE OF EXECUTIVE MANAGEMENT IN RADIATION SAFETY PROGRAM

The "Executive Management" refers to an individual at the provost or chief executive officer level who is responsible for oversight of the facility's radiation safety program, have the authority to manage, direct, or administer the licensee's activities or that person's delegate or delegates (10 CFR 35.2). The executive management at Howard University shall be acquainted with the types of radiation sources used at the Howard University and Howard University Hospital facilities, and where they are used, received, and stored. The executive management shall appoint the RSO and describe in detail, the responsibilities and authority to the RSO for the implementation of radiation safety program.

The "management triangle" concept was developed by the US NRC (NUREG -1516) to stress the three entities responsible for management of radiation safety program (Figure below). In this concept, no one element is considered more important than the others; rather, the management triangle represents a team approach in which the success of the team is dependent upon the contribution of each element.

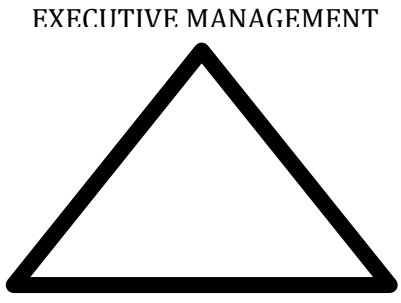

Figure 1.1: Management Triangle (Emphasis on Executive Management) (NUREG 1516)

1.3.1 Executive Management Representative to Radiation Safety Committee

As required by NRC (10 CFR 30.9, 10 CFR 35.12, I0 CFR 35.24, NUREG 1516, NUREG 1556 Vol. 9), Howard University shall appoint a representative of executive management who will actively participate as a member of the Radiation Safety Committee and has the authority to delegate necessary resources to the radiation safety program, as identified by the RSC. Hence, selection of individual to represent executive management and oversee the radiation safety program shall be deemed with high priority.

Moreover, executive managers shall be well-informed of their role, the roles of the RSC and RSO, and their interrelationship. The radiation safety program may have substantial financial needs and the executive manager shall have authority (and ability to negotiate the needs with various parties and departments) to appropriate funds in a timely manner as required by the NRC.

1.3.2 Management, Attendance and Participation In Meetings

Howard University's Radiation Safety Committee (RSC) meetings shall be conducted periodically to discuss radiation safety issues at the Howard University and Howard University Hospital facilities under the leadership of the RSC Chairperson and RSO. All RSC members are required to attend all meetings, especially, the executive management representative. To establish a quorum, the regulations require that at least one half of the members be present, including the Radiation Safety Officer and executive management representative [10CFR 35.22 (a) (3)]. In the absence of the designated executive management representative, an alternate individual representing the executive management shall attend the meeting in an event where the meeting cannot be postponed, to ensure that the radiation safety program receives the support it needs from licensee management.

1.3.3 Radiation Safety Committee Support to Executive Management

The Radiation Safety Committee (RSC) shall periodically give all relevant information regarding the radiation safety program to the executive management to allow the management for making decisions that shall not affect the radiation safety program. After careful deliberation and collective decision-making between management, RSO and the RSC, the RSC (including the RSO) shall support and implement the final management decision. For effectiveness of the management team, the RSC must ensure that the management team reviewed all relative information and arrived at a consensus to support the final decision. The RSC functions as a "window" to the licensed program through which management gains an overall picture of its activities and the respective roles of the RSO, RSC and other responsible individuals, including authorized users. The RSC serves to offer guidance and information on the radiation safety program to executive management to ensure that adequate resources are provided by licensee management, and assist the Radiation Safety Officer in the development, implementation and maintenance of the radiation safety program.

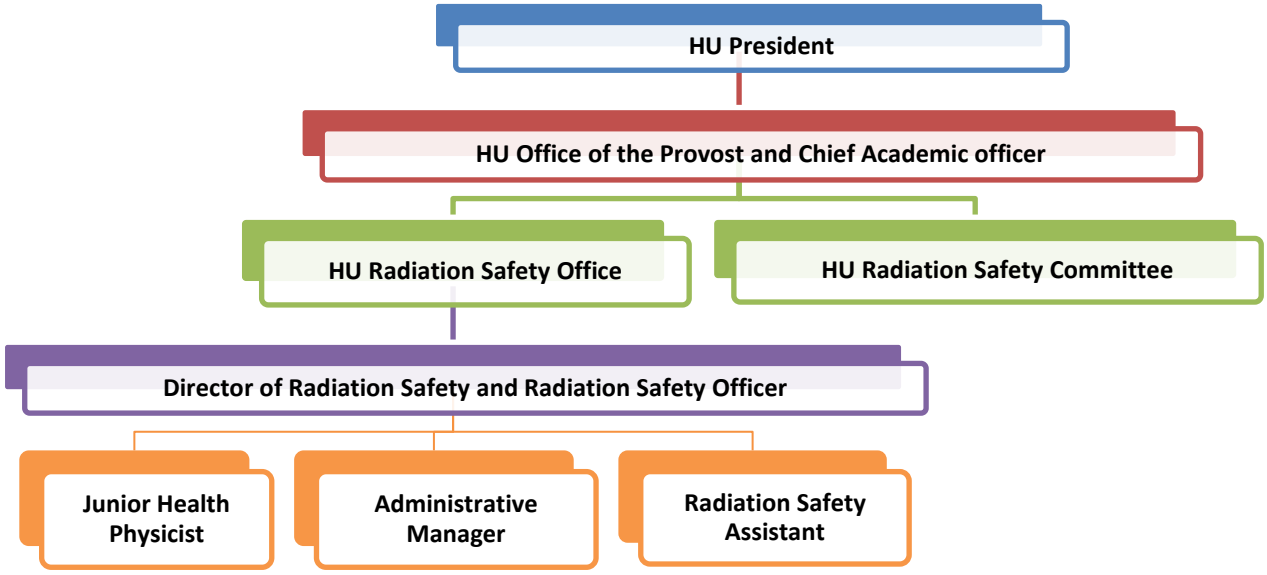

Figure 1.2: Current Organization Structure of Radiation Safety Office

1.4. RADIATION SAFETY OFFICE

Administratively, the Howard University Radiation Safety Office is under the direction of the Provost and Chief Academic Officer. The Radiation Safety Office perform its duties and responsibilities under the direct supervision of the Office of the Provost and Chief Academic Officer in consultation with the RSC.

Radiation Safety Office Staff:
Director of Radiation Safety & Radiation Safety Officer
Jr. Health Physicist
Administrative Manager
Radiation Safety Assistant

HOWARD UNIVERSITY
Radiation Safety Office
Cancer Center, Room 323
806-7216 (Voice)
234-1375 (Fax)

1.5 RADIATION SAFETY OFFICER (RSO)

1.5.1 Authority, Responsibilities and Duties

The Radiation Safety Officer (RSO) is responsible for the implementation, coordination, and day-to-day oversight of the Radiation Safety Program (RSP). In addition, the RSO has the authority to enforce radiation policies and procedures regarding radiation safety and regulatory compliance of the use of ionizing radiations.

The Director of Radiation Safety and Radiation Safety Officer, per U.S. NRC regulation 10 CFR 35.24, is responsible for ensuring the safe use of radiation at Howard University and Howard University Hospital. As the Radiation Safety Officer, he/she is responsible for managing the radiation safety program; identifying radiation problems, initiating, recommending, or providing corrective actions; verifying implementation of corrective actions; and ensuring compliance with U.S. NRC and DC Health regulations. The current RSO for Howard University Radiation Safety Program is Satya R. Bose, Ph.D., DABR. The RSO is delegated the authority necessary to meet these responsibilities.

In his/her capacity as Radiation Safety Officer of the Howard University Radiation Safety Program, RSO will ensure compliance with the rules and regulations set forth in the U. S. Nuclear Regulatory Commission Broad Scope and Human Use Licenses issued to Howard University and the University Hospital. In addition, RSO is responsible to oversee the radiation safety policy and procedures as applicable for safe use of devices producing radiation for regulatory compliances set forth by the District of Columbia Health, Radiation Protection Division.

The Radiation Safety Officer shall:

- Implement and oversee the operational aspects of the Radiation Safety Program (RSP);
- Ensure that radiation safety activities are being performed in accordance with licensee-approved procedures and regulatory requirements;
- Review and approve (with RSC) RSP changes before implementation;
- Help identify and investigate radiation safety problems;
- Initiate, recommend, or provide corrective actions for identified safety problems;
- Verify implementation of corrective actions;
- Stop operations identified as unsafe;
- Immediately suspend faulty work of staff/technicians that jeopardizes integrity of radiation safety program;
- Notify management of radiation safety problems, unsafe operations, and corrective actions
- Provide a link between the RSC and the users of ionizing radiation;
- Provide the contact between the licensee and the regulatory agencies;
- Investigate over-exposures, accidents, spills, losses. Thefts, unauthorized receipts, uses, transfers, disposals, misadministration and other deviations from approved radiation safety practices and implement corrective actions as necessary;
- Establish, collect in a file, and implement written policy and procedures for:
  a) Authorizing the purchase of byproduct materials;
  b) Receiving and opening packages of byproduct materials;
  c) Storing byproduct materials;
  d) Keeping inventory records of byproduct materials;
  e) Using byproduct materials safely;
  f) Taking emergency action if control of byproduct material is lost;
  g) Performing checks of survey instruments and other safety equipment;

h) Disposing of byproduct materials;
i) Keeping a record of all records and reports required by the U.S. NRC regulations, a copy of these regulations, a copy of each licensing request and license and amendments and the written policy and procedures required by the regulations.

- Brief HUH management once each year on the byproduct material program;
- Establish personnel exposure investigational levels that, when exceeded, will initiate a prompt investigation by the Radiation Safety Officer of the cause of the exposure and a consideration of actions that might be taken to reduce the probability of recurrence;
- Survey all activities involving radioactive materials, including routine monitoring and special surveys of all areas in which radioactive materials are used;
- Determine compliance with rules and regulations, license operations and the conditions of the project approval specified by the Radiation Safety Committee;
- Monitor and maintain absolute and other special filter systems associated with the use, storage or disposal of radioactive materials;
- Furnish consulting services on all aspects of radiation protection to personnel at all levels of responsibility;
- Conduct training programs and otherwise instruct personnel in the proper procedure for the use of radioactive materials prior to use, at periodic intervals (refresher training) and as required by changes in procedures, equipment, regulations, etc.;
- Supervise and coordinate the radioactive waste disposal program, including maintaining waste storage and disposal records and monitoring effluents;
- Store all radioactive materials not in current use, including wastes;
- Perform leak tests on all sealed sources at the University and Hospital;
- Perform or arrange for calibration of radiation survey instruments;
- Supervise decontamination in case of accidental spills with radioisotopes;
- Maintain an inventory of all radioisotopes at the institution and limit the quantity of radionuclides at the institution to the amounts authorized by the licensee. The inventory should include the name of the person responsible for each quantity of radioisotopes, where it will be used or stored, and the date the quantity was delivered to that person. Items are removed from the inventory by showing how and when the radioisotope was disposed of;
- Terminate immediately a project that is found to be a threat to health or property;
- Maintain all records as required under 10CFR Part 30.51 and assist investigators in their program by:
  a) Providing aid to users in the development of safety procedures which will meet all applicable regulations and policies;
  b) Performing periodic inspections of all programs where radiation sources are used;
  c) Reviewing all applications for new or amended radiation programs and submitting comments and suggestions to the Howard University Radiation Safety Committee;

d) Recommending remedial action to correct safety infractions.

In addition to the responsibilities listed above, the Radiation Safety Officer has the authority to:

- Enter, in order to inspect any laboratory or area where ionizing radiation sources are used or stored;
- Suspend, pending Howard University Radiation Safety Committee review, any project or procedures, which is believed to be a threat to health or property;
- Take immediate possession of any radiation source which is being used or stored in any unsafe manner. Such action is subject to review by the Howard University Radiation Safety Committee.

1.6 CORRESPONDENCES

All correspondences and applications to the U.S. Nuclear Regulatory Commission must be sent through the Howard University Radiation Safety Office. This correspondence should be sent to the Director of Radiation Safety and Radiation Safety Officer for consideration by the Howard University Radiation Safety Committee.

Chapter - 2

SCIENCE OF IONIZING RADIATION

2.1 IONIZING RADIATION

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

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

Ionized atoms (free radicals), regardless of how they were formed, are much more active chemically than neutral atoms. These chemically active ions can form compounds that interfere with the process of cell division and metabolism. Also, reactive ions can cause a cascade of chemical changes in the tissue. The degree of damage suffered by an individual exposed to ionizing radiation is a function of several factors: type of radiation involved, energy, chemical form of the radiation, intensity of the radiation flux (related to the amount of radiation and distance from the source), duration of exposure and individual characteristics (age, sex, etc.).

2.2 NON-IONIZING RADIATION

Non-ionizing radiation do not have enough energy to remove electrons from atoms. Examples of non-ionizing radiation are sound waves, visible light, microwaves, radio waves, etc. The scope of non-ionizing radiation is not discussed in this manual.

2.3 EXPOSURE TO IONIZING RADIATION

Exposures to ionizing radiation occur either from radiation sources within work environment (occupational exposures) or from radiation sources outside the work environment (non-occupational exposures).

2.3.1 Occupational Exposure

Occupational exposure is the radiation exposure received by a person, as a result of working with or near radiation sources (radioactive material or radiation-producing devices). Occupational exposure is received during 40-hour work per week, hence the need to closely monitor and control exposure to

Howard University workers.

2.3.2 Non-Occupational Exposure

Non-occupational exposure is received from 168 hour per week from our homes or outside work environment. The means of exposure can be classified into two groups: those from natural sources (e.g. cosmic radiation, terrestrial radiation comprising of mainly radon and its isotopes,) and those resulting from man-made sources (medical procedures such as diagnostic x-ray and nuclear medicine procedures, etc.). The radiation from natural sources is generally referred to as the "natural background radiation". The background radiation and the related dose vary significantly from one place to another in the United States.

2.4 ROUTES OF EXPOSURE TO RADIATION

There are three exposure pathways by which people are exposed to ionizing radiation, especially when the work involves radioactive materials. They are external, internal, and contamination. Each pathway must be carefully evaluated prior to working with radioactive materials or radiation producing machines and precautions must be taken to prevent these exposures.

2.4.1 External Radiation Exposure

External exposure occurs when radiation from a source external to the body penetrates the body and causes a radiation dose to the body tissue/organ. Exposure from X-ray machines and radioisotopes which are gamma emitters are of greatest concern, followed by beta emitters, and alpha emitters are of least concern. The effect (hazard) of external exposure is dependent upon both the type and energy of the radiation.

Most beta particles do not normally penetrate beyond the skin, but when sufficiently intense, can cause skin and/or eye damage. Very energetic beta particles, such as those emitted by 32P, can penetrate several millimeters into the skin. Shielding is needed to reduce the external radiation exposure. Typically, a maximum of 1/2 inch thick sheet of Plexiglass is an effective shield for most beta particles.

Alpha particles, because of higher mass, slower velocity, and greater electrical charge compared to beta particles, are capable of traveling a few inches in air and rarely penetrate the outer dead skin layer of the body. Therefore, alpha particles are not typically an external radiation hazard. X-rays and gamma rays, along with neutron radiation, are very penetrating, and are of primary importance when evaluating external radiation exposure and usually must be shielded.

Exposure to external radiation may be controlled by limiting the working time in the radiation area, working at a distance from the source of radiation, and by inserting shielding between the worker and the source.

2.4.2 Internal Radiation Exposure

Radioactive materials may be internally deposited in the body when an uptake occurs through one of the four routes of entry: inhalation, ingestion, injection, and absorption (via skin pores or wounds when radioactive material is in contact with skin).

a) **Inhalation** occurs when radioactive material is airborne, and a person breathes into the lungs (absorbed by the lungs and deposited in the body). The major concerns are gaseous radioisotopes (e.g. radon, iodine-129, H-3 (airborne)) or radioactively contaminated dust, and smoke. The particles of radioisotope can remain in the lungs for a long time, until they decay. Hence, inhalation of radioisotopes that are alpha or beta particle emitters, is of much concern.

b) **Ingestion** occurs when a person swallows' food, drink or other consumable items which contain radioactive materials. Radioisotopes may release enormous amounts of energy directly to tissue, resulting damage to the DNA and other cells. Alpha and beta emitting radioisotopes are of greatest concern.

c) **Absorption** occurs when radioisotope on the skin surface is absorbed via skin pores or wounds (cuts or scratches). It is advisable to avoid working with radioactive materials if you have an open wound.

d) **Injection** occurs when a person accidentally injects himself/herself with radioisotopes during normal job activity.

Once radioisotopes get into the body, it can damage cells/tissues or organs since there are no protective layer to shield the organs and tissues. Internal exposures are not limited to the intake of large amounts at one time (acute exposure). Chronic exposure may arise from an accumulation of small amounts of radioactive materials over a long period of time.

2.4.3 Exposure to Radioactive Contamination

This occurs when radioactive material is present on a person (body/skin or clothing), floor, bench top, equipment or other surfaces. It is either transferable (removable) or non-transferable (fixed). Contamination may lead to internal exposure via absorption process. *Internal deposition may also result from contaminated hands, with subsequent eating or rubbing of eyes.*

2.5 RADIOACTIVE DECAY

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

This is important for many reasons. When deposited in the human body, the half-life of the radioactive material present in the body affects the amount of the exposure. If the radioactive material contaminates a workbench or equipment, and is not removable, the amount of time before the contaminated items may be used again is determined by the radioactive half-life. Radioisotope decay using half-life minimizes costs and concerns in radioactive waste management.

The equation used to calculate radioactive decay is as shown:

$$A = A_0 e^{-\lambda t}$$

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

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

2.6 BASIC RADIATION TERMS AND UNITS

The basic terms used are:

Radioactive material may be solid, liquid or gas compound or mixture in which some of the atoms present are radioactive.

Radioactivity is the process by which certain nuclides spontaneously emit energy, in the form of ionizing radiation, in an attempt to become more stable.
Activity is the amount or quantity of radioactivity in a material; that is the rate of disintegration (transformation) or decay of radioactive material per unit time. The SI unit for activity is the *Becquerel* (Bq), defined as one disintegration per second. Another unit is Curie (Ci).

$$1 \text{ Ci} = 3.7 \times 10^{10} \text{ Bq}.$$

Exposure is defined as the charge produced in air by ionizing radiation per unit mass. Exposure is measured in units of Roentgens, R (mR, μR), or C/kg. 1 R corresponds to approximately 2.58 x 10^{-4} C/kg in dry air at standard temperature and pressure. Exposure is typically applied to gamma and X-rays.

Exposure rate is the exposure delivered per unit of time. The unit is R/hr (mR/hr, μR/hr).

Absorbed dose: Absorbed dose is the amount of energy imparted to the matter by ionizing radiation per unit mass of irradiated material. The traditional unit of absorbed dose is rad (1 rad = 100 ergs/gm). The SI unit is Gray (Gy); 1 Gy = 100 rad.

Dose rate is the absorbed dose (or dose equivalent) delivered per unit of time. The units: rad/hr, Gy/hr, or rem/hr, and Sv/hr.

Dose equivalent (or ***effective dose***) describes the amount of radiation absorbed from different type of radiation and the medical effects of that type of radiation. The traditional unit is rem (roentgen equivalent man), the SI unit is Sievert (Sv); 1 Sv = 100 rem.
Dose equivalent takes into account the biological damaging effects of different types of radiation. For beta and gamma radiation, the dose equivalent is the same as the absorbed dose. However, the dose equivalent is larger than the absorbed dose for alpha and neutron radiation, because these types of radiation are more damaging to the human tissue or organ. For practical purposes, exposure and dose for both gamma and X-rays are considered equal.

Thus,

1 R (exposure) = 1 rad (absorbed dose) = 1 rem or 1000 mrem (dose equivalent)

To account for these differences, a quantity called radiation weighting factor W_R (formerly called quality factor, Q), is used in conjunction with the radiation absorbed dose in order to determine the dose equivalent in rem:

Dose equivalent (rem) = Absorbed dose (rad) x W_R

However, the target organ which is exposed to radiation is important when assessing radiation exposures and a modifying factor is used in radiation protection to correct for the biological damaging effectiveness. Also, the chemical form of the radiation producing the dose is of critical importance in assessing internal doses, because different chemicals bind with different cell and/or organ receptor sites.

Tissue weighting factors, W_T, are modified factors used for incorporating the actual risk to tissues for different radioisotopes and tissues in dose calculations. These tissue weighting factors assign multiplication factors for increasing or decreasing the actual biological risk to a given tissue.

Another way to evaluate risk to an individual for internal intakes of radioactive material is the use of body retention class, D, W or Y. These classes stand for days, weeks or years of retention time in the human body and are specified in the Title 10 CFR 20 limits in the Appendix. This classification is based on the chemical form of the radioactive material, which affects the biochemical pathway and resultant target organ, therefore determining the retention time.

Please refer to Appendix A for the list of units and associated conversion factors.

2.7 BIOLOGICAL EFFECTS OF IONIZING RADIATION

Injury due to irradiation is caused mainly by ionization within the tissues of the body. When radiation interacts with a cell, ionizations and excitations are produced in either biological macromolecules or in the medium in which the cellular organelles are suspended, predominantly water. Based on the site of interaction, the radiation-cellular interactions may be termed as either direct or indirect.

Direct action occurs when an ionizing particle interacts with and is absorbed by a macromolecule in a cell (DNA, RNA, protein, enzymes, etc.). These macromolecules become abnormal structures, which initiate the events that lead to biological changes.

Indirect action involves the absorption of ionizing radiation in the medium in which the molecules are suspended. The molecule that most commonly mediates this action is water. Through a complex set of reactions, the ionized water molecules form free radicals that can cause damage to macromolecules.

The most important target for radiation in the cell is DNA in the nucleus. Biological effects result when DNA damage is not repaired or is improperly repaired. Extensive damage to DNA can lead to cell death. Large numbers of cells dying can lead to organ failure and death of the individual. Damaged or improperly repaired DNA may develop into lymphoma and cancers in somatic cells. Two kinds of effects of radiation exposure may result; acute and delayed.

Acute, or non-stochastic, effects are health effects, the severity of which varies with the dose and for which a threshold is believed to exist. Radiation-induced cataract formation is an example of a non-stochastic effect (also known as a deterministic effect). The onset of first observable effects of acute radiation exposure, diminished red blood cell count may occur at a dose of approximately 100 rads of acute whole-body radiation exposure. The LD_{50} for humans (lethal dose where 50% of the exposed population may die from a one-time exposure of the whole body) is about 500 rads, assuming no medical intervention.

Delayed, or stochastic, effects, are health effects that occur randomly and for which the probability of the effect occurring, rather than the severity, is assumed to be a linear function of the dose without threshold. Genetic effects and cancer incidence are examples of stochastic effects.

Various degrees of sensitivity to radiation exist due to the type of tissue which receives the exposure, as depicted in Table 2.1

Table 2.1: Classification of major types of tissue based on their radio-sensitivity.

Radiosensitive	Radioresistant
Breast tissue	Heart tissue
Bone marrow cells	Large arteries
Mucosa lining of small intestines	Large veins
Sebaceous (fat) glands of skin	Mature blood cells
Immune response cells	Neurons
All stem cell populations	Muscle cells
Lymphocytes	

A rule of thumb used to assist in biological risk assessment for radiation is the 'Law of Bergonie and Tribondeau'. It states that most mature cells are radioresistant; all immature cells are very radiosensitive. It is very important for radioactive material users to be aware of the target organs for the nuclides they handle. Precautions may then be taken to prevent exposures.

It is important, when considering the real versus the perceived risk of radiation exposures, to be aware of the acute effects of large radiation exposures. Without this information, one has no comparison to determine whether the radiation the individual is handling presents an actual risk or not. Often fear exists, that because the radiation is present and is measurable, a serious risk is present. The fact that we cannot see, smell, hear or feel the radiation sometimes magnifies the fear. Table 2.2 shows the effect of various types of high radiation exposure.

Table 2.2. Effects of acute radiation exposure in humans

Exposure (R)	Occurrence of Exposure	Part of Body Exposed	Effects
10000	Single dose	Whole body	Death occurs within hours from apparent neurological and cardiovascular breakdown (Cerebrovascular syndrome)
500 – 1200	Single dose	Whole body	Death occurs within days and is associated with bloody diarrhea and destruction of the intestinal mucosa. (Gastrointestinal syndrome)
250 – 500	Single dose	Whole body	Death occurs several weeks after exposure due to damage to bone marrow (Hematopoietic syndrome). 50% death rate
50 – 350 or higher	Single dose	Whole body	Can produce various degrees of nausea, vomiting, diarrhea, reddening of skin, loss of hair, blisters, depression of immune system
100	Single dose	Whole body	Mild radiation sickness, depressed white blood cell count
400 – 500	Local, Low energy x-ray		Temporary hair loss
600 – 900	Local	Eye	Cataracts
500 – 600	Local single dose, 200 keV	Skin	Erythema, blistering, residual smooth soft depressed scar
1500 – 2000	Local single dose, 200 keV	Skin	Erythema, blistering, residual smooth soft depressed scar
25	Single dose	Whole body	Lymphocytes temporarily disappear from circulating blood
10	Single dose	Whole body	Elevated number of chromosomal aberrations in peripheral blood; no other detectable injury or symptoms

2.8 GENERAL WORKPLACE SAFETY GUIDANCE

Safe use of hazardous materials in the workplace depends on the cooperation of individuals who have been educated in the science and technology of the materials, who have technical training specific to their application, and who follow administrative and technical procedures established to ensure a safe and orderly workplace.

Chapter - 3

REGULATIONS FOR SAFE USE OF IONIZING RADIATION

3.1 INTRODUCTION

During its first fifty years of use, ionizing radiation, whether from X-ray tubes or radioactive materials, was applied in a variety of research, medical, industrial, and consumer products and services. Some applications were well founded, and some were frivolous. Some of them resulted in injury or death to radiation workers and members of the public. By the 1960's, the state and federal regulatory frameworks governing radiation were established. Their goal was to provide adequate assurance of public health and safety in the presence of ionizing radiation. Today, the use of ionizing radiation is one of the most stringently regulated activities in our society.

Howard University is authorized to procure and use radioactive materials under the following two licenses:

- Human Use License # 08-03075-07(Limited), for clinical applications for patient treatments or diagnostic purposes
- Research & Development License # 08-00386-19(Broad Scope License), for conducting research activities

These license activities are regulated by the US Nuclear Regulatory Commission, as stated in Part 10 of the Code of Federal Regulations.

3.2 10 CFR PART 19—*Notices, Instructions, And Reports to Workers; Inspections*

This part establishes requirements for notices, instructions, and reports by licensees to individuals participating in licensed activities, and options available to those individuals in connection with inspections of licensees, as well as, reports to workers regarding their radiation exposures.

All personnel who work in a restricted area must be provided radiation safety training, informed of the risks associated with their work, instructed to observe regulations and proper operating procedures, report any unsafe conditions and provided with protective action that should be taken.

At any time, an employee may request a copy of their radiation exposure history. Each employee will be able to view their monthly dosimetry report and receive a copy of their yearly radiation exposure history, per NRC regulations.

3.3 10 CFR PART 20—*Standards for Protection Against Radiation*

The purpose of this section is to control the receipt, possession, use, transfer and disposal of licensed material, in such a manner that the total dose to an individual doesn't exceed the standards for protection against radiation.

The licensee shall use procedures and engineering controls based upon the sound radiation protection principles to achieve ALARA occupational doses.

The licensee shall ensure that instruments and equipment used for quantitative radiation measurements are calibrated periodically.

3.4 10 CFR PART 30 –*"Rules of General Applicability to Domestic Licensing of Byproduct Material"*

This part prescribes rules applicable to all persons in the United States governing domestic licensing of byproduct material under the Atomic Energy Act of 1954, as amended (68 Stat. 919), and under title II of the Energy Reorganization Act of 1974 (88 Stat. 1242), and exemptions from the domestic licensing requirements permitted by Section 81 of the Act. This part also gives notice to all persons who knowingly provide to any licensee, applicant, certificate of registration holder, contractor, or subcontractor, components, equipment, materials, or other goods or services, that relate to a licensee's, applicant's or certificate of registration holder's activities subject to this part, that they may be individually subject to NRC enforcement action for violation of § 30.10.

3.5 10 CFR PART 35— *Medical Use of Byproduct Material*

There are extensive regulations governing medical use and human research. They cover general administrative and technical requirements and prescribe detailed precautions for specific diagnostic and therapeutic clinical procedures.

Chapter - 4

APPROVALS TO USE LICENSE MATERIALS

4.1 APPROVALS FOR USE OF RADIOACTIVE MATERIALS

All programs involved in the use of radioactive materials at Howard University and Howard University Hospital must be approved by the Howard University Radiation Safety Committee (RSC) prior to procurement, receipt or use of radioactive materials at the University and Hospital.

All applications for non-human use of byproduct materials will be considered by the Howard University Radiation Safety Committee under the licensing authority granted to the Howard University RSC in a broad scope license issued by the U.S. Nuclear Regulatory Commission. All non-human use of byproduct materials at Howard University and Howard University Hospital must be conducted under the provisions of the broad scope license.

Approval for the use of radioactive materials is given by the RSC for a period of three years and is reviewed annually. Approval may be obtained by submitting a Byproduct Material Application, describing the requested material and quantity to be used, the location, individuals who will handle the material, the training and experience of the applicant, the training of workers, the protective equipment to be used, if any, monitoring equipment, a description of experimental procedures with emphasis on potential safety concerns, and waste disposal information. Applicants must have faculty status, assistant professor or greater, experience in the use of radioactive materials and must be trained by the Radiation Safety Officer (RSO) prior to approval. The application will be reviewed by RSC members, wherein approval may be granted.

The RSC may impose additional conditions under which the use of the radioactive material must be conducted. The approved principal investigator may then order, receive and use the requested materials, but must do so according to the statements and representations made in the application, and any conditions set forth by the RSC and all applicable U.S. NRC and DC Health law, regulations and license conditions. Violations or infractions of these conditions may be a cause for suspension or termination of the approval to receive and use radioisotopes.

For most applications to use radioactive materials, interim approval may be given by the RSO until the RSC gives final approval. This precludes a long waiting period for approval. Principal Investigators who are currently approved and have a good safety record may be given interim approval to initiate a new use, except for the work that involves a significantly higher risk. The applications for new principal investigators must be approved directly by the RSC, regardless of the previous approvals at other institutions.

New applications are required for the use of a new radionuclide, for a change in experimental procedures which have an impact on safety, a change in chemical or physical form of a material previously approved, and for substantial increases in the quantity. The amendments to current approvals are given for slight increases in quantity or moderate changes in chemical form and may be obtained by submitting a short memo stating the desired change and the reason for the change, referencing the original approved application to be amended. Applications for approval or amendments should be directed to the RSO.

Prior to preparing an application, the RSO should be consulted. An application, for approval of a radioisotope program, must be submitted in the appropriate format as shown in Appendix B of this manual. These forms can be obtained from the Radiation Safety Office. If the request for the use of byproduct materials is based upon an application to a funding agency, that protocol must be submitted with the application. If a researcher allows his/her authorization to use radioactive materials to lapse (6 months after the expiration date), a new application requesting the use of radioactive materials must be submitted for review by the RSC.

4.2 DURATION OF AUTHORIZATION

The maximum period for which an authorization will be granted for byproduct materials is three (3) years. However, the authorization may be renewed upon approval from RSC.

4.3 RENEWAL OF AUTHORIZATION

An authorized user may apply for renewal when his/her authorization expires. A written notice shall be sent to the authorized user three months (3) in advance prior to the expiration date. The authorized user must complete and file a renewal application to use radioactive materials, in accordance with the guidelines and policies established by the Howard University and regulations set by the U.S. NRC. The applicant must use the format for the submission of applications as shown in Appendix B.

Review of Applications for Non-Human Use

Upon receipt of an application, the Howard University Radiation Safety Committee evaluates the proposed use to determine:

a. Whether the applicant has the necessary training and qualifications to safely conduct the proposed operation;

b. Whether the applicant has specified the necessary procedures and has access to the necessary facilities and equipment to use the radioactive materials safely and in a manner, which will comply with applicable Regulations.

All requests to use byproduct materials at Howard University (new, amendments, renewals and reactivations) must be submitted on a formal application for Byproduct Material Authorization (see Appendix B). If the request for the use of byproduct materials is based upon an application to a funding agency, that protocol must be submitted with the application. The maximum period for which an authorization will be granted for byproduct materials is three (3) years. In the event the research project is for a shorter period, the RSC will grant the authorization for the projected project period.

The Howard University Radiation Safety Committee is scheduled to meet on the second Wednesday of each month. The application must reach the Office of Radiation Safety at least ten (10) working days prior to the Committee meeting.

All applications are to be submitted to:

Radiation Safety Office
Cancer Center – Room 323
ATTN: Administrative Manager

A new application is considered as a request by a researcher who has never used radioactive materials at Howard University or Howard University Hospital. The applicant must complete an Application for Byproduct Materials Authorization and use the format for the submission of applications as shown in Appendix B. All new applications, including support staff, must successfully complete the Howard University Basic Radiation Safety Course, regardless of prior training and/or experience in the use of radioactive materials. The Howard University RSC does not issue an opinion on the technical merit of any proposed use of radioactive materials - it is concerned only with safety and regulatory compliance.

Applicants for non-human use of byproduct materials which are approved by the Howard University Radiation Safety Committee will receive a written authorization from the Committee. This authorization will list, either directly or by reference, the conditions and limits applicable to that particular program.

4.4 AUTHORIZED USER'S QUALIFICATIONS AND DUTIES

4.4.1 Qualifications

Investigators applying for non-human use of radioactive materials must have the following qualifications:

- A working knowledge of the principles and practices of radiological safety, radioactive measurements, standardization and monitoring techniques, instrument use, biological effects of radiation and the basic mathematics related to radioactivity;
- Experience in the use of radioactive materials that are listed on the applications.

4.4.2 Duties

Authorized Users must:

- Notify the Radiation Safety Officer immediately of any termination of employment of radiation workers who are listed on the authorization to use byproduct materials by submitting written notification. The personnel monitoring equipment should be returned to the Radiation Safety Office at that time.
- Notify the Radiation Safety Officer if work with radioisotopes is terminated.
- Maintain complete and accurate records of all radioisotopes received, used and disposed. Each authorized user should have an up-to-date record of the quantity of radioisotopes in hand at any given time.
- Assume the responsibility for the proper segregation of radioactive waste for disposal and maintain exposures **ALARA** through laboratory procedures, shielding, and the use of gloves and other protective clothing.
- Instruct laboratory personnel in the proper use of personnel monitoring equipment and confirm that this equipment is always worn in the laboratory where any procedures involving radioactive materials are performed.

The authorized user should familiarize himself/herself with the radiological properties of the radioisotopes used in his/her lab. The properties of common radionuclides used in biomedical

research are listed in **Appendix C**.

4.5 AMENDMENTS OF AUTHORIZATION

If an authorized user finds a need to amend his/her authorization, to include any of the following:

- additional isotope(s)
- increased possession limit for an existing isotope
- change in laboratory location,

a complete application to amend the existing authorization must be submitted to the Radiation Safety Office.

If the research work involving radioactive materials shall continue during the absence of the principal investigator (by support staff and/or graduate students), a request must be made, at least one month in advance, for another authorized user to supervise the use of radioisotopes, in the form of an amendment application. However, if the radioactive materials are not to be used during the investigator's absence, a request must be made to transfer the radioactive materials to the possession of the Radiation Safety Officer or another authorized user.

4.6 RESPONSIBILITIES OF THE PRINCIPAL INVESTIGATOR

Principal Investigators (PI) are directly responsible for compliance with all regulations governing radiation safety in the laboratory, and for safe practices of individuals working under their supervision. Principal investigators are obligated to:

- Ensure that individuals working under their control are properly supervised and trained to enable safe working habits and prevent exposures to themselves and others and/or contamination of the work areas or environment. Inadequate supervision and lack of training have been cited as indicative of negligence in lawsuits involving radiation.
- Be aware of the potential radiation hazards inherent in a proposed activity; be responsible for instructing personnel in safe practices or directing personnel to sources of information concerning safe practices.
- Maintain inventory and knowledge of the various forms (physical and chemical) and quantities of radiation which are present in their work areas.
- Avoid any unnecessary exposure, either to themselves or to other workers.
- Understand the risks associated with the possession, use and shipment of all radioactive materials. Federal and state regulations control the use and shipping of radioactive materials and certain other hazardous materials.
- Keep current records of the receipt and the disposition of radioactive material in their possession including use in research, waste disposal, transfer, storage, etc.
- Maintain constant surveillance and immediate control of radioactive materials to prevent unauthorized removal or tampering, and/or assure that all of the workers occupying the area maintain security.

- Post warnings and restrict entry to areas that contain potentially hazardous radioactivity or chemicals. Label radioactive use equipment and work areas.

- Notify the Radiation Safety Office if any personnel changes, including addition or termination of employees, or changes of areas where radioactive materials may be used or stored.
- Assure instruction of female radiation workers of the risks associated with working with radioactive materials during pregnancy. (NRC Reg. Guide 8.13).
- Assure designation of a responsible individual to oversee radioisotope work during short absences, and of a stand-in principal investigator with the required committee approvals during extended absences (greater than 60 days).
- Ensure that radiation safety surveys and audits in the laboratory are conducted and maintain records for review.
- Be aware of regulations and requirements pertaining to the use of radioactive materials, maintain compliance and a safe working area.
- Use radioactive materials according to statements, representations and conditions set forth in the radioactive materials use approval given by the Radiation Safety Committee. **Changes from the approved procedures must be approved by the Committee in an amendment or new application prior to the implementation of the change.**
- Maintain use logs for radioisotopes with half-lives of 120 days.

Failure to comply with the rules and regulations set forth above and throughout this manual may lead to disciplinary actions and/or the cessation of radioisotope shipments and experiments. The Radiation Safety Officer and/or the Radiation Safety Committee may terminate any radioisotope use and/or research if deemed necessary. Suspension or termination of approval to use radioactive materials may result from situations jeopardizing health and safety, the environment or the HU/HUH U.S. NRC licenses.

Radioactive shipments which are ordered during a principal investigator's absence will be tracked under the absent principal investigator's inventory.

4.7 PRINCIPAL INVESTIGATOR ABSENCES

Principal investigators may be occasionally absent from the laboratory for various reasons. During such absences, another individual must be named to assume the responsibility for the correct usage and management of radioactive materials. When the absence is less than 60 days, a responsible graduate student or technician may be appointed to assume responsibility. If the absence is greater than 60 days, an alternate principal investigator with the appropriate radioisotope approvals must be designated and must agree to assume responsibility.

The Radiation Safety Officer must be notified in writing of the absence, duration and the name of the alternate principal investigator who will oversee the uses of radioactive materials during the absence prior to departure. The stand-in PI must have all the authorizations necessary to oversee the uses of the radioactive materials possessed by the absent. The Radiation Safety Office must be notified in

advance of the intended absence. During the absence, shipments will still be logged under the absent principal investigator's inventory, but all oversight will be conducted by the stand-in PI.

4.8 RESPONSIBILITIES OF RADIATION WORKER

Individuals who use radioactive materials, assume certain responsibilities in their work. The individual worker is the "first line of defense" in protection of people and the environment against undue risks of radiation exposure and/or contamination. Since the workers, themselves, are the direct handlers of the radioactive material, the final responsibility lies with them for safety and compliance with 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.

The term "worker" is used by HU/HUH to identify an individual who uses radioactive material in the course of his/her employment or study at HU/HUH. Workers may be principal investigators, graduate students, undergraduate students, technicians, post-doctorates, visitors, or any other individual who will handle radioactive material. The following items are to be always adhered to by the radiation workers.

- Each worker must attend a radiation safety training class prior to working with radioactive materials or devices producing radiation. Workers are prohibited from handling radioactive materials until this training has been completed. Radiation workers must attend a refresher session each year (Annual Refresher Radiation Safety Training held in March of each year).
- The worker must complete the radiation safety examination and pass with a score of 75% or better. Workers are prohibited from handling radioactive materials until this test hasbeen passed.
- Workers are responsible for adhering all laws, rules, regulations, license conditions and guidelines pertaining to the use of radioactive materials.
- Workers must wear their assigned radiation dosimeter while working with radioactive materials. (See Personnel Monitoring for details on dosimeter requirements.)
- Workers must practice ALARA (As Low As Reasonably Achievable) in their work, and minimize the potential for exposures, contamination or release of radioactive materials.
- Radiation work areas must be monitored by the user after each use of radioactive material. If contamination is found, it must be cleaned up. The Radiation Safety Officer must be notified immediately.
- No changes in experimental procedures using radioactive materials are allowed without the approval of the principal investigator. Do not take short cuts. Changes in experimental procedures impacting upon safety (higher quantities, higher risk, use in animals, etc.) must be approved by the HU Radiation Safety Committee.
- Any abnormal occurrence must be reported immediately to the principal investigator, such as spills, significant contamination, equipment failure, loss of radiation dosimeters and unplanned release. If the principal investigator cannot be reached, contact the Radiation Safety Office.
- It is the responsibility of the worker to clean any contamination or spills that occur in their work area. DO NOT LEAVE IT FOR ANOTHER PERSON TO CLEAN UP. Notify the RSO of the incidence.

- Workers are responsible for returning the radiation dosimeter on time and reporting any loss or contamination of the dosimeter to the Radiation Safety Office.
- Workers are responsible for informing the RSO of any exposures which have occurred at a previous employer when beginning employment at HU/HUH. They are also responsible for notifying the Radiation Safety Office of termination of employment and returning the radiation dosimeter at the end of their employment.
- Workers are responsible for maintaining security of radioactive materials. (See section on Security of Radioactive Materials).

4.9 SUPPORT STAFF WORKING WITH RADIOACTIVE MATERIALS

All support staff working with radioactive materials must work under the direct supervision of an authorized user approved by the Howard University Radiation Safety Committee. Support staff must successfully complete the Howard University Basic Radiation Safety Course and attend the annual sessions of the Radiation Safety Refresher Course. The names of all support staff must be listed on the Application to Use Byproduct Materials with written documentation of the formal radiation safety courses attended, including the name and location of training and dates of attendance.

4.10 NON-RADIATION WORKERS

Non-Radiation Workers are individuals who work in laboratories or areas where radioactive materials or radiation producing equipment are used, but do not handle or work with those materials or equipment. All Non-Radiation Workers must attend basic radiation safety training conducted by Radiation Safety Office. This training will help them understand their working environment and the scope of the hazards present in the work area without unnecessary fear of radiation, as well as preventing radiation accident in the ignorance of dealing with radioactive materials or radiation producing machines.

4.11 TERMINATION OF EMPLOYMENT

If a principal investigator terminates employment at HU/HUH, the Radiation Safety Officer shall be notified at least two weeks beforehand. Arrangements must be made to remove or reassign any radioactive materials according to the requirements of the Radiation Safety Program. Before the termination date, the radiation safety staff will conduct a final radiation survey of the radioisotope laboratory to determine the presence of unused radioisotopes and/or the presence of contamination.

Radiation workers who terminate their education and/or employment at HU/HUH shall notify the Radiation Safety Office, and must return their badges. Federal law mandates that new workers who will use radioactive materials must supply the current year's exposure report to the safety office prior to beginning work with radioactive materials. The HU Radiation Safety Office maintains badge records for all radiation workers. To meet this requirement at future locations, this information will be supplied to a worker leaving HU/HUH after the radiation detection badge has been returned to the Radiation Safety Office.

4.12 TERMINATION OF AUTHORIZATION

An Authorized User may request termination of Authorization after all radionuclides are properly disposed of or transferred to another Authorized User via Radiation Safety Office. A final survey will be made to ensure that there is no contamination or radioactive materials present in the lab. An authorization may be revoked by the RSC for deliberate disregard of the radiation safety guidelines or for repeated or intentional violation of the NRC regulations.

4.13 TERMINATION OF LABORATORY

An Authorized User may request termination of laboratory after all radionuclides are properly disposed, removed or transferred to another Authorized laboratory or Authorized User via Radiation Safety Office and a final survey of that laboratory or facilities indicate that there are no contamination or presence of radioisotope. The lab will be released for unrestricted use and no longer be under the supervision of the Radiation Safety Office. If you have any question, please contact the Radiation Safety Office at 806-7216.

4.14 DISCIPLINARY ACTIONS

The Howard University Radiation Safety Committee has the authority to terminate any authorization to use radioactive materials if the authorized user or anyone under his/her supervision fails to comply with the Federal Regulations. Howard University policies or conditions of use as specified in the authorization or license, which may include, but is not limited to:

1. Failure to correct and/or respond to deficiencies found during a routine laboratory inspection;
2. Failure to submit quarterly reports;
3. Failure to purchase film badges for personnel working with radioactive materials;
4. Failure to perform routine monitoring tests;
5. Failure to notify the Radiation Safety Committee of changes in the radioisotope program, i.e., use of an unauthorized radioisotope, new employee working without receiving the training provided by the Radiation Safety Office;
6. Failure to notify the Radiation Safety Office of official leave from the University.

The Howard University Radiation Safety Committee may alter an authorization in order to maintain a program in compliance with applicable regulations or policies. Programs found to be in violation of applicable regulations or policies will be subject to administrative discipline through the Office of the Provost for the Health Sciences to the Office of the President, Howard University.

4.15 APPROVAL FOR USE OF RADIATION PRODUCING DEVICES

Prior to the use of any radiation producing equipment (X-ray devices, electron microscopes, etc.) for medical purposes (diagnostic or therapeutic) or research purposes at the University and Hospital, the equipment must be registered with the DC Department of Health, and a copy of the registration must be submitted to the Radiation Safety Office. The user must be certified personnel and receive radiation safety training prior to the use of the equipment. It is the responsibility of the owner of the equipment (Principal Investigator or the Department) to maintain annual Quality Assurance (QA) of the

equipment. A copy of the QA must be submitted to the Radiation Safety Office. Details of radiation producing equipment are discussed in Chapter 9 (*Radiation producing equipment*).

Chapter - 5

PROCUREMENT OF RADIOACTIVE MATERIALS

5.1 ORDERING RADIOACTIVE MATERIALS

Any receipt of radioactive materials must be authorized by the Radiation Safety Officer. Authorization is based on prior approval by the Radiation Safety Committee as described earlier. Radioactive materials are not to be ordered using PeopleSoft, online or purchasing card systems. All requisitions should be sent to the purchasing department directly, after contacting the RSO to obtain authorization to order. The purchase department / materials management will not process purchase requests for radioactive materials without the signature/approval of the RSO. The information that purchasing needs from the approved user is the name of the principal investigator ordering the material, account number, element and mass number, chemical form, activity and company from which the radioisotope will be purchased. Every shipment of radioactive material received must be inventoried.

The person initiating requests for purchases of radioactive materials shall request for a Purchase Form. This form is distributed from the Radiation Safety Office only. The Materials Management Department will no longer distribute these forms to authorized users or designees.

Each shipment received by project leaders, such as gifts, electron capture devices, or any other device containing a radioactive source or radioactive material must be reported to the Radiation Safety Office so that the material may be tracked in the inventory database and summed with the campus/hospital totals. This is to prevent an individual principal investigator or the campus from exceeding individual approval or HU/HUH license possession limits.

5.2 RECEIVING AND MONITORING OF RADIOACTIVE MATERIALS

All shipments of radioactive materials must be delivered directly to:

Howard University Hospital
Radioactive Material Receiving Vault
Shipping and Loading Dock
Howard University Hospital
2041 Georgia Avenue, NW
Attn: (Name of Authorized User and Radiation Safety Officer)
Washington, DC 20060

The shipments are monitored by the Radiation Safety Office staff, and records of monitoring are maintained for review. The results are indicated on the shipping papers delivered to the laboratory with the shipment.

5.2.1 Receiving Radioactive Packages

Except radioactive packages for Nuclear Medicine Division, all packages containing radioactive materials are received by the Shipping and Receiving Area, Mail Room Services Office and Security Office (Howard University Hospital) personnel during regular working hours (8:00 a.m. to 5:00 p.m.).

Due to the nature and number of the radioactive packages received by the Nuclear Medicine, the division is authorized to directly receive radioactive material packages from the vendor during regular working hours.

Inspection of any package containing radioactive material delivered to Howard University and Howard University Hospital facilities which appears to be crushed, wet, damaged or otherwise suggests likelihood of contamination, shall follow the instructions mentioned on the "Procedure for Receiving and Opening Incoming Radioactive Packages". Packages containing radioactive material must be recorded in the receiving (package receipt) logbook located in either the Security Office or Shipping and Receiving Areas and the Mail Room Services Office. The Radiation Safety Officer shall review the logbook in the Security Office to ensure that all deliveries, containing radioactive materials, are properly accounted.

The packages containing exempt quantities of radioactive materials are received in the Howard University Hospital Mail Room via the U.S. Postal Service. These packages are picked up by authorized individuals from the Radiation Safety Office immediately following the appropriate notification from the Mail Room personnel.

5.2.2 Accessing Loading Dock Vault

Packages received (by Mail Room Services) are then stored in an approved vault located in the loading dock area of the Hospital until picked up by Radiation Safety Office staff. There are two keys for the loading dock vault. One is kept by the Radiation Safety Officer and the other remains in possession of the Security Office. Authorized personnel from the Radiation Safety Office, Mail room, Nuclear Medicine, Radiation Oncology and respective vendors may obtain the key from Security Office to gain access to the vault. All persons who use the key must complete an entry on the receiving vault log sheet.

5.2.3 Receiving and Monitoring of High Dose Rate Source

For the delivery of High Dose Rate (HDR) (^{192}Ir) source, the vendor notifies the Radiation Safety Officer of the shipment date and expected delivery date. The Radiation Safety Office then notifies the mail room of the expected delivery date of the HDR source. The mail room immediately contacts the Radiation Safety Office upon arrival of the source. The HDR package with Ir-192 source is shown in Figure 5.1 as a reference.

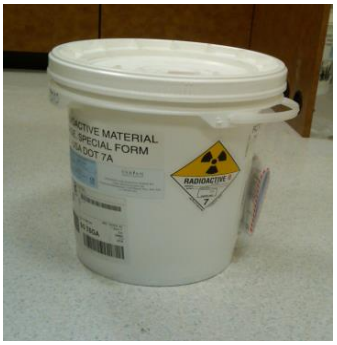

Figure 5.1: HDR Package with Ir-192 source

During off-duty hours, weekends and/or holidays, no radioactive packages should be scheduled for delivery. In the event of being presented with a radioactive package as shown above during off-duty

hours, weekends, and/or holidays – **Do not receive/accept the delivery**. Instruct the courier to return on the next business day.
When in doubt, or should you have any questions or concerns, you may contact the Director of Radiation Safety & Radiation Safety Officer at (202)373-4161 or (202)806-7216

All packages will be inspected for damage and surface contamination. If contamination is found, the Radiation Safety Office will take the proper action to prevent the spread of contamination. This procedure does not relieve the purchaser and user of radioactive materials from the responsibilities of monitoring as described in 10 CFR 20.1906, "Procedures for Receiving and Opening Packages".

The purchaser will be notified by the Radiation Safety Office upon arrival of the radioactive material shipment. The purchaser will be requested to arrange a suitable time to accept the delivery of the shipment from the Radiation Safety Office. Delivery will be made only upon the presentation of a copy of the purchase order.

A detailed procedure for receipt and opening of radioactive packages is provided in Appendix D. This procedure is instituted to assure that:

1. only radioisotopes authorized for use by a principal investigator are ordered and received at the University;
2. only authorized personnel received radioactive materials;
3. proper records are maintained for receipt and distribution.

5.3 TRANSFER OF RADIOACTIVE MATERIALS

Transfer of radioactive material between authorized users or principal investigators must be reported (in writing) and approved by the RSO prior to the transfer to ensure compliance with NRC regulations. Radioactive materials received by any means other than through a purchase order must also be approved by the RSO prior to receipt. This includes transfers of radioactive material between on campus users or off campus users. When transfer is approved, an inventory number may be assigned for control and tracking purposes.

5.3.1 On Campus Transfers (HU/HUH)

Transfer of radioactive material between RSC approved principal investigators of different projects or laboratories or buildings within Howard University must be approved by the RSO prior to the transfer. These transfers must be within the limits of the approved radioisotope(s) and approved quantities (activity). The transfer should not take place until the authorized by the Radiation Safety Officer.

It is required to document any transfers of radioactive materials by reassigning the shipment in the inventory database. For transfer or shipment, contact the Radiation Safety Office and supply the information to the Radiation Safety Officer, who will approve transfer of material and document the change in the inventory database.

Radioactive materials must **NEVER** be transferred to individuals who are not certified or approved to use radioactive material at Howard University. Qualified workers are trained and have passed the certification examination. This transfer notification must include the following:

1. Chemical Name of radioisotope
2. Physical/ Chemical Form
3. Activity in μCi or mCi
4. Number of radioactive materials receiving/sending
5. Name of Principal Investigator receiving material
6. Name of person transferring radioisotope, department, telephone number, fax number and / or e-mail address

5.3.2 Off Campus Transfers

Transfers of radioactive material to or from off campus (other institutions) must be approved by the RSO prior to the transfer. On March 26, 1998, the Radiation Safety Committee adopted the policy entitled, "Procedures for Receiving Radioactive Materials from Other Institutions". The Radiation Safety Office must be notified prior to the receipt of ALL radioactive materials to include transfers, gifts, etc. This notification must include the following:

1. Chemical Name of radioisotope
2. Physical/ Chemical Form
3. Activity in μCi or mCi
4. Number of radioactive materials receiving/sending
5. Name of Principal Investigator receiving material
6. Name of person sending radioisotope, institution, telephone number and the Radiation Safety Officer's name, telephone number, fax number and / or e-mail address

The Radiation Safety Officer of the transferring institution must call the Howard University Radiation Safety Officer and notify him/her of the anticipated date of shipment to the University. All packages of radioactive materials must adhere to the U.S. Department of Transportation and U.S. Nuclear Regulatory Commission regulations for shipping. The package must be wipe tested and surveyed by the shipper and the results of these tests must accompany the package with the appropriate label affixed to the package. All packages of radioactive materials must be addressed and shipped to:

Howard University Hospital
Radioactive Material Receiving Vault
Shipping and Loading Dock
Howard University Hospital
2041 Georgia Avenue, NW
Attn: (Name of Authorized User and Radiation Safety Officer)
Washington, DC 20060

Upon arrival of the package, the Howard University Radiation Safety Officer will perform the survey and wipe test the package. If no contamination is revealed, the Authorized User will be contacted, and arrangements will be made to deliver the package. The Howard University Radiation Safety Officer will notify the shipper of the receipt of the radioisotope shipment.

5.4 SHIPMENT AND TRANSPORTATION OF RADIOACTIVE MATERIALS

Shipment or transportation of radioactive material within HU campus or outside HU must be done in accordance with the regulations.

5.4.1 On-Campus Transportation

Transportation may involve walking or driving radioactive materials across campus; in either case Radiation Safety Officer must be notified prior to transporting. This is to ensure that proper procedures are followed and the movement of radioactive materials within the university can be tracked. The package must be wipe tested for removable contamination before it leaves its place of origin and after it reaches its destination. Whenever radioactive materials are to be transported from one building to another, the following information must be provided to the Radiation Safety Office.

1. Date the radioactive material(s) to be transported
2. Names and contacts of the person sending and receiving the material
3. Sending and receiving locations including the lab and building
4. Chemical name of radioisotope and the total activity
5. Physical/chemical form of the radioisotope
6. Number of containers to be transported
7. Any special conditions of the radioactive material

5.4.2 Off-Campus Shipment

Shipments of radioactive materials leaving HU/HUH must have prior authorization of the Radiation Safety Officers at both the sending and the receiving institutions. Federal and District of Columbia law requires that the shipper must obtain the receiver's approval and the respective Nuclear Regulatory License number or the District/State License number prior to the shipment of the material.

All shipments must be in accordance with the packaging and labeling requirements set forth by the Department of Transportation (DOT). An appropriate record must be made of the radiation levels on surface of the package and at three feet from the package using an ion chamber. Also, the record must contain information on the shipper, receiver, nuclide(s) and activity, phone numbers of shipper and receiver, and performance of a survey for removable radioactivity. Contact the Radiation Safety Office well in advance of the desired shipping date to assure that all the required license exchanges, shipping papers and monitoring records are completed, as the package will not be shipped until these requirements are met.Refer to **Appendix E** for detailed instructions on transportations of radioactive material.

5.5 SECURITY OF RADIOACTIVE MATERIALS

All shipments of radioactive materials received at Howard University must be secured or under constant surveillance at all times. The Radiation Safety Office staff is prohibited from delivering a package with radioactive materials unless there is an authorized person (authorized user designated support personnel) at the location who will accept it, exchange a copy of the purchase order and secure the radioactive materials. The authorized person receiving the shipment must immediately secure the package in the laboratory or storage room designed for work with radioactive materials. If the Radiation Safety Office staff cannot find an authorized person to receive the shipment, the package will be returned to the Radiation Safety Office Laboratory where it will be secured in a locked area until delivery can be completed. **Radioactive materials are not to be left unsecured at any time.**

Any radioactive material in use in a laboratory must be attended at all times or secured by locking the

laboratory when not attended. Radioactive materials may not be left unsecured even momentarily. Radioactive materials in storage, i.e., not being used, must be secured when the room in which it is stored is unoccupied. The required security may be accompanied by locking the room while unoccupied, or by locking the radioactive materials in refrigerators, freezers, cabinets or lock boxes. Only authorized persons may have access to radioactive materials. Radioactive materials that are stored or used in areas common to both authorized and unauthorized personnel must be secured at all times from unauthorized personnel.

Corridors (hallways, elevator lobbies and utilities chases, etc.) are not secured areas. Therefore, use and storage of radioactive materials in these areas are prohibited.

All radioactive wastes are considered as radioactive materials. Radioactive wastes, including dry waste, liquid waste, medical pathological waste and mixed waste must be secured at all times. Radioactive waste may be placed in the approved containers provided by the Radiation Safety Office.

Persons performing work in the area, such as engineering or maintenance personnel, contractors (i.e., janitorial staff, telephone or computer support personnel) or commercial service representatives must be accompanied by an authorized person at all times. The persons unknown to the occupants of an area where radioactive materials are used or stored, should not be permitted into the area without proper identification and a legitimate reason for entry.

Federal law requires that NRC licensed material must be under the immediate control and constant surveillance of the licensee, or otherwise be locked and secured to prevent tampering or unauthorized removal. NRC has cited many facilities for violations of this law; therefore, precautions must be taken to prevent this from occurring. This means that radioactive materials in storage or unattended should be kept in locked containers or in areas that are not readily accessible to unauthorized individuals.

When working with radioactive materials, the room must be secured whenever a radiation worker is not present, or the radioactive materials must themselves be secured. Refrigerators or cabinets containing radioactive materials that are located outside a lockable room must be locked to prevent access. **Any loss of radioactive materials must be reported to the Radiation Safety Officer immediately**.

The personnel present in the laboratory may provide security for radioactive materials by challenging unauthorized entry into the room. Staff members who are not radiation workers may be among those in immediate control of the materials if they are trained by the principal investigator according to the items on the PI Training Checklist.

Appendix M contains further information on maintaining the security of radioactive materials.

5.6 INVENTORY OF RADIOACTIVE MATERIALS

Under the provisions of the broad-scope license issued to Howard University, the University must ensure that the total University-wide inventory of radioisotopes does not exceed licensed limits. Each user is required to keep an inventory of the radioisotope he/she currently possess. The inventory should show the activity received, used and discarded for each radioisotope indicated on the authorization.

The Howard University Radiation Safety Committee may request periodic written reports on the

current inventory from each authorized user. A current inventory report is required on quarterly reports. No radioactive materials shall be transferred to other departments, programs, users, individual or institutions without the prior knowledge and approval of the Howard University Radiation Safety Office.

5.7 LEAK TEST OF SEALED SOURCES

Each sealed source containing licensed material (other than tritium) with a half-life greater than thirty days, and in any physical form other than gas, shall be periodically tested for leakage. The test shall be capable of detecting 0.005 μCi. Sources are exempt from testing if they contain <10 μCi of an alpha emitting material or <100 μCi of a beta or gamma emitting radionuclide. Sources that are being stored and not being used must be tested at least once every ten years, except for alpha emitting sources. Alpha emitting sources must be tested every quarter, regardless of their use.

A stored source is the one that has not been used for six months and will not be used in the coming six months. It must be removed from its functional position (i.e., electron capture devices removed from gas chromatographs) and secured. Stored sealed sources must be leak-tested before being returned to service. The broad license requires that sealed beta or gamma emitting sources be leak tested every six months. Alpha emitting sealed sources must be leak tested every three months.

Principal investigators must have approvals to possess, and use sealed radioactive sources. Users must have been trained, sources must be labeled, and security must be in place. It is the principal investigator's responsibility to assure that the sources are used according to the laws and regulations pertaining to the source. In particular, the leak tests must be performed before the required deadline. If non-compliances are found with the sealed sources, sanctions may be imposed.

Chapter - 6

RADIATION EXPOSURES AND ALARA

6.1 MAXIMUM PERMISSIBLE EXPOSURES

Occupational dose limits have been established by the NRC (10 CFR § 20.1201) and set at a level where apparent injury due to ionizing radiation during a normal lifetime is unlikely. This limit is called the "maximum permissible exposure". However, personnel should not completely disregard exposures at or below these limits. It is the responsibility of each individual to keep his/her exposure to all radiation as low as reasonable, and to avoid all exposures to radiation when such exposures are unnecessary.

The exposure limit for whole body exposures is lower than that for a single organ because all organs and tissues are exposed in a whole-body exposure, while only a single organ is involved in the single organ exposure limits. The risk to the organ is incorporated in the exposure calculations which must be done if organs or tissues are exposed. Maximum permissible exposure limits to external radiation for adult and minor radiation workers are given in the table 6.1 below. The dose limits for minors (persons under 18 years of age) are 10% of the adult occupational dose limits. HU dose limits are 10% of the adult occupational dose limits.

Table 6.1: Occupational Radiation Exposure Limits

Part of Body	Federal & Sate Dose Limits		HU Dose Limit
	Adult Yearly mrem (mSv)	Minors Yearly (<18 yrs. Old) mrem (mSv)	Adult ALARA Yearly mrem (mSv)
Whole Body (Head and Trunk) (TEDE)	5,000 (50)	500 (5)	500 (5)
Lens of Eye (LDE)	15,000 (150)	1,500 (15)	1,500 (15)
Extremities (SDE) (Elbows, Forearms, Hands, Knees, Lower Legs, Feet)	50,000 (500)	5,000 (50)	5,000 (50)
Single Organ Dose (TODE)	50,000 (500)	5,000 (50)	5,000 (50)
Skin of Whole Body (SDE)	50,000 (500)	5,000 (50)	5,000 (50)
Embryos/Fetus (during 9-month gestation)	500 (5)*	N/A	50 (0.5) *
Member of the General Public	100 (1)	N/A	10 (0.1)

* 500 millirem for the fetus is during the *gestation period* of a declared pregnancy.
It is important to note that, for these purposes only, a woman is considered pregnant ***only if she declares herself so, in writing, to the radiation safety officer.*** A woman may declare or undeclared her pregnancy at any time; it must be in writing to the RSO.

Definition of Dose quantities

Notice that each of the following quantities are types of dose equivalents. The following definitions describe the quantities. (Note: the types of doses are quantities; the units used for these quantities are the rem or the sievert.)

DE: Dose Equivalent. The product of the absorbed dose in tissue, weighting factor, and all other necessary modifying factors at the location of interest. The units of dose equivalent are rem and sievert.

CDE: Committed Dose Equivalent. Means the dose equivalent to organs or tissues of reference that will be received from intake of radioactive materials by an individual during the 50-year period following the intake.

EDE: Effective Dose Equivalent. It is the sum of the products of the dose equivalent to the organ or tissue and the weighting factors applicable to each of the body organs or tissues that are irradiated.

CEDE: Committed Effective Dose Equivalent. It is the sum of the products of the weighting factors applicable to each of the body organs or tissues that are irradiated and the committed dose equivalent to these organs or tissues.

DDE: Deep Dose Equivalent. Apply to external whole-body exposure. It is the dose equivalent at a tissue depth of 1 centimeter (1000 mg/cm^2).

TODE: Total Organ Dose Equivalent. The sum of the CDE and DDE for the maximally exposed organ.

SDE: Shallow Dose Equivalent. Applies to the external exposure of the skin or an extremity, is taken as the dose equivalent at a tissue depth of 0.007 centimeter (7 mg/cm^2), averaged over an area of 1 square centimeter.

LDE: Lens of Eye Dose Equivalent. Applies to the external exposure of the lens of the eye and is taken as the dose equivalent at tissue depth of 0.3 centimeter (300 mg/cm^2).

TEDE: Total Effective Dose Equivalent. The sum of the deep dose equivalent (for external exposures) and the committed dose equivalent (for internal exposures).

6.2 POLICY FOR MINORS WORKING WITH RADIOACTIVE MATERIALS

Radiation exposure limits exist for minors, (individuals under 18 years of age) who work with radioactive materials. These limits are 10% of all the occupational limits for adult radiation workers. For these workers, safety training must be completed prior to work with radioactive materials as with other occupational workers. It is university policy that an informed parental consent form must be completed and kept on file for purposes of liability and risk management.

Due to university policy and legal requirements, principal investigators must notify the Radiation Safety Office before allowing minors to enter laboratories with radioactive materials.

HU Policy was instituted for minors working with the radioactive materials. The policy can be found in ***Appendix F***.

6.3 EXPOSURE LIMITS FOR THE PUBLIC

Visitors to a radiation laboratory who are not classified as radiation workers by their employers, laboratory workers who are not trained in radiation safety, custodial staff, and any other non-radiation workers are all members of the general public under the law. They must not receive a radiation dose in excess of either 2 mrem (0.02 mSv) in any one hour or 100 mrem (1 mSv) in any one year.

Since most radiation use facilities frequently have members of the general public visit their work areas, HU/HUH has elected to maintain unrestricted area contamination limits as part of the ALARA program.

6.4 ALARA Philosophy

6.4.1 What is ALARA?

ALARA is an acronym for **A**s **L**ow **A**s **R**easonably **A**chievable. This is a radiation safety principle for minimizing radiation doses and releases of radioactive materials by employing all reasonable methods. ALARA is not only a sound safety principle but is a ***regulatory requirement*** for all radiation safety programs.

6.4.2 What is the basis for ALARA?

Current radiation safety philosophy is based on the conservative assumption that radiation dose and its biological effects on living tissues are modeled by a relationship known as the "*Linear Hypothesis*". The assertion is that every radiation dose of any magnitude can produce some level of detrimental effects which may be manifested as an increased risk of genetic mutations and cancer. Thus, the Howard University Radiation Safety Program attempts to lower doses received by radiation.

6.4.3 How is ALARA Implemented?

An effective ALARA program is only possible when a commitment to safety is made by all those involved. This includes the Radiation Safety Office staff, the Radiation Safety Committee, research faculty and all radiation workers. This manual provides the guidelines for the responsibilities and good practices which are consistent with both the ALARA concept and the regulatory requirements of the District of Columbia Health and United States Nuclear Regulatory Commission. These guidelines and regulations require not only adherence to legal dose limits for regulatory compliance, but also ALARA investigation dose levels, which serve as alert points for initiating a review of the work practices of a radiation worker.

6.4.4 Radiation Safety Committee and ALARA

The Howard University Radiation Safety Committee (RSC) is an essential element in the successful application of the ALARA proposed experimental protocols and the qualifications of the Principal Investigator (PI) before authorization is granted for the possession of radioactive materials or radiation-producing devices. The RSC delegates authority to the Radiation Safety Office through the Radiation Safety Officer (RSO) for implementation of the ALARA concept. The RSO is responsible for reviewing the occupational radiation doses of all workers with particular attention to those workers

for which the ALARA investigation level is exceeded. The RSC performs an annual review of the radiation safety program regarding operating procedures and dose records, which reflect the efficacy of the ALARA effort.

10 CFR Parts 20 and 35 require the establishment of an ALARA program and Part 35 requires that the RSC periodically reviews the program. The ALARA program should be reviewed at each RSC quarterly meeting and summarized at the end of every year. The RSC should also review recommendations (e.g., from employees) on ways to maintain individual and collective doses ALARA. In addition, as part of the annual review, a determination should be made regarding whether the radiation safety program needs to be modified to keep exposures ALARA. (NUREG -1516, Regulatory Guide 10.8).

6.4.5 Radiation Safety Office and ALARA

The RSO provides guidance for the ALARA program as the manager and technical supervisor of the Radiation Safety Office. In turn, the Radiation Safety Office staff is responsible for contributing to the success of the ALARA program in the following ways:

1. Providing technical support and guidance to the PIs and their staff of implementation of the ALARA concept.
2. Performing routine lab inspections to identify possible ALARA issues.
3. Monitoring of worker radiation doses with the assignment of dosimetry and use of bioassays as deemed appropriate.
4. Reviewing occupational doses and responds to situations in which the investigation levels are exceeded.
5. Providing training and consultation to workers' concept. The RSC has the responsibility to review to ensure doses are maintained ALARA.

6.4.6 Principal Investigator (PI), Radiation Workers and ALARA

The PI and research staff, with the support of the Radiation Safety Office, should ensure that the ALARA principle is being implemented in all lab operations. This includes proper use of shielding and dosimetry combined with contamination control techniques. All employees bear a responsibility for their own personal safety in such work areas as:

1. Awareness of potential radiation hazards, exposure levels and safety controls in their work areas.
2. Awareness of operating and emergency procedures.
3. Awareness of practices that do not seem to follow the ALARA philosophy.
4. Compliance with reporting incidents and possibly unsafe working conditions to their supervisors and, if appropriate, to the Radiation Safety Office staff.
5. Compliance with wearing personnel dosimetry and ensuring its return to the Radiation Safety Office at the proper exchange frequency.
6. Compliance with providing bioassay samples to the RSO as needed.

6.4.7 Mitigation of External Radiation Exposures

The three (3) major principles to assist with maintaining doses ALARA are:

1. **TIME** – minimizing the time of exposure directly reduces radiation dose.
2. **DISTANCE** – doubling the distance between your body and the radiation source will divide the radiation exposure by a factor of four (4)**.**
3. **SHIELDING -** using absorber materials such as Plexiglas for beta particles and lead for X-rays and gamma rays' exposures.

6.4.8 Mitigation of Internal Radiation Exposures

The following practices are effective for reducing potential internal exposures:

1. Good hygiene techniques that prohibit the consumption of food and drink in the lab and the control of personal gestures that involve "hand-to-mouth" contacts.
2. Frequent swipe surveys and lab area monitoring of work areas, refrigerators, hoods, sinks, phones and computer keyboards, etc.
3. Control contamination with absorbent paper and spill trays, properly labeled waste containers, equipment, etc. and prompt decontamination of any detected contamination.
4. Use fume hoods for materials which could become airborne (e.g., vapors, dust, aerosols, etc.) and present an inhalation hazard to workers.
5. Use proper protective equipment (PPE) such as disposable gloves, safety glasses, lab coats, etc. to reduce the possibility of ingestion or absorption of radioactive materials.

6.4.9 How are Annual Occupational Dose Limits related to the ALARA concept?

The annual occupational dose limits have been derived from a study of the observed biological effects of radiation on humans and animals during the 20th century. These maximum limits are promulgated on the basis that when applied to occupationally exposed radiation workers they will result in a level of risk no greater than that in other occupations which are deemed to have high safety standards. The ALARA concept imposes lower operational dose limits that are even more restrictive than the maximum legal dose limits in the table above. This ensures an enhanced safety factor for what are already considered to be safe annual doses for radiation workers.

6.4.10 What are the ALARA Investigation Levels?

There are two types of ALARA investigation levels for external occupational radiation exposure as indicated by a dosimeter. If a radiation worker's dose for any calendar quarter (3 months) or calendar year (12-month period) exceeds these values, an investigation is conducted by the RSO to determine if there are reasonable ways to reduce the dose levels. Quarterly investigation levels I and II are based on 2.5% and 7.5% of the annual regulatory limits respectively.

Table 6.2: Regulatory Limits and ALARA Investigational Levels

Part of Body	Regulatory Limit mrem/yr (mSv/yr)	ALARA (Level I) mrem/qtr (mSv/qtr)	ALARA(Level II) mrem/qtr (mSv/qtr)
Whole Body	5,000 (50)	125 (1.25)	375 (3.75)
Lens of Eye	15,000 (150)	375 (3.75)	1125 (11.25)
Skin and/ or Extremities	50,000 (500)	1250 (12.5)	3750 (37.5)
Minors (whole body)	100 (1)	10 (0.1)	30 (0.3)
Embryos/Fetus (during 9-month gestation)	500 (5)	11 (0.1)	31 (0.3)
Member of Public onsite (EPA)	100 (1)	5 (0.05)	15 (0.15)
Member of Public offsite (EPA)	10 (0.1) with less than 3 (0.03) due to radioiodine from airborne releases	1 (0.01)	3 (0.03)
Environmental Releases	10 CFR 20 averaged over one year at the unrestricted area boundary.	10% of 10 CFR 20 averaged over the calendar quarter at the boundary; or listed value at the stack.	30% of 10 CFR 20 averaged over the calendar quarter at the boundary; or listed value at the stack.

6.4.11 Personnel dose less than Investigational Level I

Except when deemed appropriate by the RSO, no further action will be taken in those cases where an individual's dose is less than Table 1 values for the Investigational Level I.

6.4.12 Personnel dose equal to or greater than Investigational Level I, but less than II

The RSO will review the does of each individual whose quarterly dose equals or exceeds Investigational Level I and will report the results of the reviews as the first RSC meeting following the quarter when the dose was recorded. If the dose does not equal or exceed Investigational Level II, no action related specifically to the exposure is required unless deemed appropriate by the RSC. The RSC will, however, review each such dose in comparison with those of others performing similar tasks as an index of ALARA program quality and will record the review in the RSC meeting minutes.

6.4.13 Personnel dose equal to or greater than Investigational Level II

The RSO will investigate in a timely manner the causes of all personnel doses equaling or exceeding Investigational Level II and, if warranted, will take action. A report of the investigation, any actions taken, and a copy of the individual's Form, NRC-5 or its equivalent will be presented to the RSC at its

first meeting following completion of the investigation. The details of these reports will be included in the RSC meeting minutes.

6.4.14 Pregnant Worker and ALARA

Licensees are required to attempt to prevent pregnant workers from exceeding ~ 55 millirem (0.55 mSv) during any one month. The desire is to avoid a large dose to the fetus during the 8th to the 15th weeks of the pregnancy as this is the period during which it is most sensitive to potential radiation-induced effects. Thus, it is incumbent upon the pregnant employee to strongly consider officially notifying the Radiation Safety Division as soon as she is aware of her pregnancy.

6.5 PERSONAL MONITORING

Radiation detection dosimeters (badges) must be worn routinely by personnel when exposure to penetrating radiation is possible. At HU/HUH, this means that workers handling radiation that is energetic enough to penetrate and cause exposures, need to wear a dosimeter. Dosimeters are exchanged monthly or quarterly. Each individual is responsible for seeing that his/her badge has the current dosimeter within the holder.

These badges provide legal documentation of external radiation exposure received while working with radioactive materials at a given facility. They are not to leave your immediate work area; they are not to be taken home or to any other location, since non-occupational exposures may occur (e.g., a dentist's office or another laboratory). Badges are heat and light sensitive, and if left in a car where the temperature may be high, a false exposure will be recorded. It will then become difficult to distinguish a true radiation dose from a dose caused by exposure to excessive heat or light.

Personnel monitoring film badges are given to those adults who are likely to receive, in one year from sources external to the body, a dose in excess of 10 percent of the occupational radiation exposure limits (10 CFR 20.1201(a) as shown in table 6.2). Radiation detection dosimeters are not assigned to work with certain radionuclides, since the energies are beneath the detection limit of the badge. This is not a risk to the workers, however, because these kinds of radiation are not strong enough to penetrate leading to deep radiation dose. Examples of these radionuclides are ^{3}H, ^{14}C, ^{35}S, ^{45}Ca, ^{33}P and ^{63}Ni.

For those individuals who use X-ray equipment and/or high energy beta or gamma emitters, extremity (ring) badges should be used in conjunction with the whole-body dosimeter. **It is a legal requirement that workers handling ≥1 mCi (≥ 37 MBq) of ^{32}P must wear extremity badges.** The whole-body badge should be worn on the torso with the name tag facing the suspected source of radiation. With finger ring badges, the name tag must face the radiation source.

Care must be taken to ensure that the badges do not become contaminated with radioactive materials. Lost or misplaced badges should be reported immediately to the Radiation Safety Office in order to receive a replacement. Under no circumstances should workers wear a dosimeter belonging to another individual. It is a legal requirement that doses be tracked for the worker to whom the dosimeter is assigned.

When terminating employment with HU/HUH, badges must be returned to the Radiation Safety Office. If badges are not returned and proper notification of termination of employment/study has not

occurred, it is a non-compliance with regulatory requirements. A termination report will be supplied when a worker leaves, since the next place of employment must be supplied with this report before the individual will be allowed to work with radioactive materials.

It is important to return your badge at the proper time. Delays in processing and reading the badge may invalidate the results. Chances of the badge being lost are increased with late badge returns. At any time, individuals can contact the Radiation Safety Office for their radiation exposure data. It typically takes 4 to 6 weeks to receive the processed dosimeter reports. The badge vendor will call the Radiation Safety Office to report any doses that are significantly higher than normal (i.e., greater than 200 mrem/ 2 mSv on a badge) and the worker will be notified by the Radiation Safety Officer. **If you suspect that you have received a significant exposure, contact the Radiation Safety Officer immediately**. Potential exposure will be evaluated, and the badge may be sent immediately for an emergency reading. A temporary badge will be issued for the interim period. On an emergency basis, results can be obtained within a few days.

6.6 RADIATION MONITORING AND TRAINING REQUIREMENTS FOR CONTRACTED EMPLOYEES

1. All employees and staff members whose work involves devices producing radiation at HUH will need to complete the appropriate radiation safety training, including training related to safety procedures related to the devices producing radiation.
2. If the employee is hired by a third-party contracting company, and has been provided with Radiation Safety training beforehand, the HUH RSO will require a copy of his/her radiation safety training documents.
3. Additionally, this office will require a copy of the exposure history report for the employee from their previous employers.
4. Furthermore, if the contracting company will be monitoring the agency employee's radiation exposure, the RSO will require a copy or access to the individual's ongoing monthly/quarterly dosimetry exposure reports for the period they work at HUH.
5. In this case, the contracted employee will need to fill out an exposure report release authorization form, for the RSO to receive a copy of the exposure history, while working at Howard University or University Hospital.

For more information on personnel monitoring and film badge dosimetry services, refer to **Appendix H.**

6.7 BIOASSAY

Conditions of the broad license issued by the Nuclear Regulatory Commission (NRC) mandates that bioassays are required for workers using certain types and amounts of radioisotopes.

Individuals performing or observing iodination where 1 mCi (37 MBq) or more of ^{125}I is used, are required to obtain a thyroid scan after the iodination or use of the sodium iodide or potassium iodide stock solution. A baseline thyroid scan should be conducted on workers who have not previously used

these kinds of ^{125}I at HU/HUH. Individuals must receive a thyroid scan bioassay with the HU/HUH at least 24 hours after each iodination or use of free radioiodine, but not more than one week afterwards.

Also, individuals handling $\geq$100 mCi ($\geq$ 3700 MBq) of tritium (^{3}H) must submit a urine sample to the Radiation Safety Office for bioassay within 24 hours of the handling. This bioassay must be performed each time this amount of tritium is handled. Contact the Radiation Safety Office for further details prior to urine bioassays.

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

Chapter - 7

QUALITY ASSURANCE POLICY ON LEAD/LEAD-FREE LEAD EQUIVALENT APRONS

7.1 INTRODUCTION

Lead or lead equivalent aprons are used to protect radiation workers from unnecessary X-ray radiation exposure during diagnostic radiology procedures. These aprons may reduce the dose received by over 99%, making them the most effective personal radiation protection equipment. However, they are only effective when worn properly, and when matched with the appropriate energy of X-rays and the lead equivalent thickness of the apron, as well as, when used in a safe and regulated environment.

Radiation workers who are required to wear lead/lead equivalent aprons should visually inspect these devices prior to each use for obvious signs of damage such as tears or sagging of lead. All employees working with fluoroscopic units must wear a lead apron. If the operator's eyes or thyroid are likely to receive dose from radiation, it is advisable to wear additional protection for these organs. Personnel working in a radiographic room during X-ray exposure must stand behind a protective barrier or use protective aprons or whole-body protective barriers of not less than 0.25 mm of lead equivalent. Aprons and gloves must have radiation attenuation of no less than 0.5 mm lead equivalence at 150 kilovoltage peak. Full aprons should cover the front of the body from the throat to within 10 cm of the knees as well as the sides of the body.

Gonadal shielding should be used for all patients, of atleast 0.25 mm of lead equivalence. Exceptions occur only when gonadal shielding may interfere with the diagnostic procedures.

Human holders can be used and must be provided with adequate protection, 0.5 mm lead when standing in the primary beam and 0.25 for scatter (secondary radiation). The minimum requirement is 0.25 mm of lead equivalent shielding for an occupational worker, not standing in the primary beam.

When wearing a lead apron, the badge should be placed on the collar outside the apron. For radiation workers using two film badges, one should be worn on the collar (outside the apron) and the other should be worn at the waist level under the apron. Except for the patient, only the staff and ancillary personnel required for the medical procedure, or training, shall be in the room during the radiation exposure.

According to the International Atomic Energy Agency (IAEA), lead aprons with 0.35 mm lead thickness equivalence should be sufficient for most fluoroscopic procedures. For high workload, a wrap-around lead apron with 0.25 mm lead equivalence that overlaps on the front and provides 0.25+0.25=0.5 mm lead equivalence on the front and 0.25 mm on the back would be ideal. For a low workload, a 0.25 mm lead equivalence apron, should do well.

However, based on the Burlington Medical, LLC., report, it was recommended by the Radiation Safety Officer (RSO) to utilize lead equivalent aprons with a 0.50 mm thickness.

7.2 USE OF APRONS DURING FLUOROSCOPY

Transparent upper body shields are usually suspended from the ceiling and protect the upper torso, face, and neck. The shield is contoured so that it can be positioned between the irradiated patient and the operator.

Mobile flat panel shields must be placed between personnel and the sources of radiation when used. Mobile shields are recommended for the operator and ancillary personnel, who must be in the room but do not perform patient-side-work.

When used correctly, X-ray attenuating surgical gloves can help to reduce the risk of radiation dermatitis in a physician's hands from exposure to scattered radiation. When wearing shielded surgical gloves, the operator must make sure his hands are not in the primary X-ray beam. The shielded surgical gloves are highly X-ray attenuating. If the gloves are in the primary beam, the glove will cause a substantial X-ray tube output boost to correct for the attenuation of the beam, which will cause an increase in dose to both the patient and the operator. Leaded eyewear and thyroid shields are recommended if the operator performs patient-side work during the procedure.

For the voltage ranges of the unattenuated beam of 70 – 50 kV, which are used in X-ray diagnostic practices such as traumatology and angiography, and also in Cardiology, the attenuation factor of the lead rubber aprons is in the range of 99-100 in the stray radiation field. With low lead- and lead-free material, the attenuation factor also varies between 99 and 100% (Xenolote). Additionally, a thyroid collar and leaded eye wear (or "radiation glasses") are recommended.

7.3 QUALITY ASSURANCE TESTS

According to DC Health regulations, lead aprons shall be checked annually for defects, such as holes, cracks, or tears. This check can be done by visual inspection, tactile evaluation (feeling the protective devices) or by X-ray imaging. A record of the date of the check, the type of check and who performed the check, shall be kept for three years. If a defect is found at the time of the annual check or on any other occasion, the device must be removed from service immediately. Any cracks or tear in the apron can make one vulnerable to the effects of radiation exposure. Defects arises when aprons are not stored properly as recommended but can also occur over time after its long use. Inspections should be carried out by each department (HUH/HU) when you first receive a new apron and yearly after that.

7.3.1 Survey Procedures

Using image intensified fluoroscopy units:

- Lay out the item on the table.
- Examine the entire item using the fluoroscope.
- Record results on the Annual Quality Control Checklist.

Using Radiographic Units:

- Closely inspect each item for irregularities.
- Take a radiograph of doubtful areas.

- Check film and look for breaks in the lead lining.
- Record results on the Annual QC Checklist.

7.3.2 Corrective Action

Any item displaying breaks in the lead lining should be replaced. When purchasing new lead aprons, gonadal shielding or gloves, make sure the lead equivalent is sufficient with the Regulations for Protection Against Radiation.

- Do not fold, crease, drape or sit down tightly on your garment. It is strongly recommended that the aprons be hung on a heavy-duty chrome hanger or equivalent and not on a hook.
- Don't fold or throw the lead apron on the floor in between procedures or after you are done wearing it.
- Do not sit on the apron or while wearing the apron. This may cause creases to the lead or core protective material.

7.3.3 Handling and Storage

The manufacturer's recommendations regarding the handling and storage of protective clothing must be strictly observed.

- Aprons should be hanged by shoulders or straps on hangers to prevent cracks in protective lead.
- Inspection and testing of protective clothing must be performed as described by manufacturer.
- Avoid heat and humidity.
- Avoid sitting while wearing an apron.
- Rejecting an apron depends on the location, area size and number of flaws. It is best to keep the number of flaws to a minimum.

7.3.4 Cleaning and Disinfecting Lead Apron

The cleaning guidelines and recommendations outlined by the Center for Disease Control (CDC) for the proper care of environmental surfaces (*https://www.cdc.gov/hicpac/pubs.html*) must be followed strictly. They advise that the surfaces be properly cleaned first, followed by sanitization.

- Do the spot cleaning with a damp cloth and dishwashing detergent.
- Dry the wet spot with a dry cloth and repeat the process until the soiled area is cleaned.
- Do not immerse the apron in water or under running water.
- Inappropriate cleaning of the lead apron will create creases or cracks in the surface which could also compromise the safety of your garment or even void the warranty.
- Prevent the use of harsh cleaning agents or other abrasive products. They could damage the outer material or make it age faster.
- Use a soft brush like a toothbrush. If you want to scrub the apron, avoid anything with rigid or tough bristles.
- Aprons can be cleaned periodically using sanitizers such as DisCide or SaniCloth.
- For disinfecting surfaces of an apron, use Clorox Wipes and allow a drying time of 5 minutes.

References: Burlington Medical https://burmed.com/a-guide-to-cleaning-storing-your-protective-garments/

Chapter - 8

DECLARED PREGNANT WORKER PROGRAM

8.1 INTRODUCTION

A special situation arises when a radiation worker becomes pregnant. Under such situation, radiation exposure could also involve exposure to the embryo or fetus. Several studies have indicated that the embryo or fetus is more sensitive than the adult, particularly during the first four months of pregnancy. This can be a problem since many workers are unaware of their pregnancy during the first month or two of gestation. Hence, the NRC and the District of Columbia Health require that all occupationally exposed workers be instructed concerning the potential health protection problems associated with prenatal radiation exposure.

The maximum permissible exposure for a declared pregnant worker during the gestation period is 500 mrem (5 mSv). The reason for lower dose limits is that the cells of a fetus replicate at a very high rate and therefore the possibility of doing damage to the cells is increased dramatically. Remember, it is more harmful to have a drink of alcohol than it is to get an X-ray of the chest.

There are relatively few research laboratories where radiation levels are high enough that a fetus would receive this dose before birth. If a radiation worker is pregnant, she may notify the Radiation Safety Officer, and then declare the pregnancy in writing for the prenatal exposure limits to take effect. The pregnant radiation worker will then meet with the Radiation Safety Officer and her supervisor. At that time, a complete assessment of her radiation exposure potential will be made. The written declaration is made by completing a Declaration of Pregnancy form, which is maintained in the records by the Radiation Safety Office.

If notification is not made in writing, the radiation exposure limits remain at the occupational level, that is, 5 rem (50 mSv) per year. An individual may "undeclare" her pregnancy at any time, but this also should be documented.

Declared pregnant workers (DPW) will be assigned two badges, one for the whole body, normally worn on the torso and one for the fetus, normally worn on the abdomen. The badges will be exchanged on a monthly basis. Exposures must be maintained beneath a cap of 50 mrem (0.5 mSv) per month in order to prevent exposure spikes.

Radiation workers at Howard University rarely accumulate any dose at all to their whole body; however, we do concern ourselves with this issue. At Howard University, we give the worker the choice of not working with radioactive material at all. If a student or other user of radioisotopes should become pregnant and wish to make that known, she may ask for someone else to do all work with radioisotopes. **This will not be held against her.**

8.2. EFFECTS 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 woman 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.

8.2.1 Radiation Risks

1. 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 re-evaluated the data from these studies and even re-analyzed the results. Some of the strongest support for a causal relationship is provided by twin data from an Oxford survey. 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 death per thousand children.

2. 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 rad. 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. For a radiation dose of 1,000 millirems at 4 to 7 weeks after conception, the excess cases of small head size were 5 per thousand; at 8 to 11 weeks, they were 9 per thousand.

In another study, the highest risk of mental retardation occurred during the 8 to 15-week period after conception. A recent EPA study has calculated that excess cases of mental retardation per live birth lie between 0.5 and 4 per thousand per rad.

3. 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 a negligible effect on her descendants.

8.2.2 Non-radiation Risks

1. Occupation

A recent study 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 mental industry, chemical industry, medical technology, wood industry, textile industry, and farms exhibited stillbirths (birth of a dead fetus after 28 weeks of pregnancy) 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.

2. Alcohol

It has been recognized since ancient times that alcohol consumption affects the unborn child. Carthaginian (site of an ancient city found by the Phoenicians on the northern coast of Africa) 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 may reduce 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. 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 full-blown 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.

3. 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.

4. 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 low-birth-weight children born, while an increase in Down's syndrome 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.

8.3 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." Since it is known that the unborn child is more sensitive to radiation than adults, particularly during certain stages of development, the NRC has established a special dose limit for unborn children. Also, since this dose limit could result in job discrimination for women of childbearing age and perhaps in the invasion of privacy (if pregnancy tests were required), the NRC has taken the position that the 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.

8.4 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 term. 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 an 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 nine-month 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 t the 500-millirem recommended limit.

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.

8.5 INTERNAL HAZARDS

This document has been directed primarily toward a discussion of radiation doses received from sources outside the body. The 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:

- Do not smoke, eat, drink, or apply cosmetics around radioactive material.
- Do not pipette solutions by mouth.
- Use disposable gloves while handling radioactive material when feasible.
- Wash hands after working around radioactive material.
- Wear lab coats or other protective clothing whenever there is a possibility of spills.

Remember that the employer is required to assure safe procedures and practices before the NRC issues him a license to use radioactive material. The workers are urged to follow the established procedures and consult the employer's radiation safety officer or health physicist, whenever problems or questions arise.

Further information on the declared pregnant worker program can be found in **Appendix G**.

Chapter - 9

RADIATION SAFETY TRAINING

9.1 REGULATIONS GOVERNING RADIATION SAFETY

The Nuclear Regulatory Commission (NRC), and the District of Columbia Health regulations require that licensees instruct individuals of licensed activities about the principles of radiation safety appropriate to that individual's use of radioactive material, and devices producing radiation. Regulatory agency inspectors and some licensees often find that the root cause of an incident or misadministration is a result of ineffective training or a lack of training. The RSO should dedicate adequate time to ensure that job-specific training and annual retraining is provided to all authorized users, physicians under the supervision of authorized users, and supervised individuals including technologists, physicists, nursing personnel, and ancillary personnel.

Before beginning work with or in the vicinity of licensed material, all individuals who are likely to receive an occupational dose in excess of 100 mrem (1 mSv) in a year must receive radiation safety training commensurate with their assigned duties and specific to the licensee's radiation safety program. Each individual should also receive periodic refresher training.

10 CFR 19.12(a) describes the training that licensees are required to provide individuals who, in the course of their employment, are likely to receive in a year an occupational does in excess of 1 mSv (100 mrem). 10 CFR 19.12 (b) requires that the licensee, in determining which individuals are subject to the training requirements of 19.12 (a), consider assigned activities during both normal and abnormal situations involving exposure to radiation and/or radioactive material that can reasonably be expected to occur during the life of a licensed facility. While many licensees can demonstrate that it is not likely during a normal situation for a laboratory worker, manufacturing technician, hospital technologist, or environmental services worker at their facility to receive in a year an occupational dose in excess of 100 mrem (1 mSv), these individuals and others could reasonably be expected to receive this level of exposure during abnormal situations (e.g. radioactive material left unsecured, a contamination event, or improper disposal of radioactive material in the regular trash) or, by their actions, cause others to receive this level of exposure. Untrained workers represent a potential hazard to themselves, other individuals, and property.

Licensees should not assume that safety instruction has been adequately covered by prior employment or academic training. Practical, site-specific training should be provided for all individuals prior to beginning work with or in the vicinity of licensed material. Periodic refresher training should also be provided. Topics covered should, at a minimum, include those described in 10 CFR 19.12 (a). The training may take any form. Many licensees utilize video tapes or interactive online or offline computer programs to provide training. The licensee should determine whether the training succeeded in conveying the desired information and adjust the training program as necessary. The person conducting the training should be a qualified individual who is familiar with the licensee's program.

Re-training should be performed whenever there is a change in duties or the work environment and at a frequency sufficient to ensure that all staffs are adequately trained.

Applicants should review the model training program described in the appropriate base NUREG corresponding to a particular type of license program. For example, NUREG-1556, Volume 7 describes a training program that is acceptable to NRC for licensees who are in research and development, and Volume 9 describes a training program that is acceptable to NRC for licensees who possesses radioactive material for medical use.

The applicant should also be aware of additional specific training requirements that may apply to their licensed program. For example, 10 CFR Part 35 contains specific requirements for the training of individuals who will work under the supervision of medical authorized users.

[Regulations: 10 CFR 19.11; 10 CFR 19.12; 10 CFR 19.13; 10 CFR 30.33(a)(3); and 10 FR 30.34(e)]

9.2 HOWARD UNIVERSITY RADIATION SAFETY POLICY

In October 1973, the Howard University Radiation Safety Committee adopted the policy requiring basic training in radiation safety for **ALL** persons who are involved in the handling of radioactive materials, as required by the U.S. Nuclear Regulatory Commission regulations (10CFR, Part 19.12, "Instructions to Workers"). Therefore, persons who are involved in the handling of radioactive materials must attend and successfully complete the Howard University Radiation Safety Course or provide documented evidence of the successful completion of an equivalent course at another institution and attend a one-day seminar designed to inform users of radioisotopes of the policies and procedures related to the use of radioactive materials at Howard University and Howard University Hospital. If individuals do not comply with the requirements, they will not be authorized to handle radioisotopes at Howard University until the time these requirements are fulfilled.

The Howard University Radiation Safety Course is offered by the Radiation Safety Officer as needed. Upon successful completion of this course a certificate of documentation will be awarded to each participant.

All persons who are authorized to use and possess radioactive materials and all others involved in their use must attend the Annual Radiation Safety Refresher Course. These sessions are designed to keep authorized users of radioisotopes informed of the current changes in the rules and regulations relevant to the use of radioactive materials at Howard University and Howard University Hospital. If individuals do not comply with this requirement, their authorization to use and possess byproduct materials shall be revoked until the time this requirement is fulfilled.

9.2.1 Specialized Courses

All ancillary non-laboratory personnel who frequent restricted areas, such as janitorial workers, secretarial/administrative staff, security guards, engineering service personnel and shipping and receiving workers, must receive instruction provided by the Radiation Safety Officer in accordance with 10 CFR Parts 19 and 20. These courses are conducted by the Radiation Safety Officer or his designee as needed, tailored to the needs of these occupational groups and are designed to inform the non-laboratory personnel about radiation hazards and appropriate precautions.

All personnel employed in the Howard University Hospital Shipping & Receiving Area and Mail Room Services must attend training sessions conducted by the Radiation Safety officer or his designee every six (6) months (Annual mandatory refresher course and the department specific make-up course). This training shall consist of:

- Information on the storage, transfer, receipt and uses of radioactive materials at Howard University Hospital;
- Instruction on the health protection problems associated with exposure to radioactive materials and in precautions or procedures to minimize exposure;
- Instruction on what is required, within the worker's control to observe the applicable provisions of the U.S. Nuclear Regulatory Commission Regulations for the protection of personnel from exposure to radioactive materials;
- Instruction on staff responsibilities to report immediately any condition which may lead to or cause a violation of the U.S. Nuclear Regulatory Commission and/or Howard University Radiation Safety office policies and procedures

Records of all training, including documentation of attendance are required to be maintained by the Office of Radiation Safety for review by the U.S. Nuclear Regulatory Commission representatives.

The checklist for training workers in radiation laboratories is provided in **Appendix I**.

Chapter - 10

LABORATORY DESIGN, EQUIPMENT AND POLICIES

10.1 LABORATORY DESIGN AND EQUIPMENT

Working with radioactive materials require the use of specially designed laboratories and equipment and may not be conducted in offices or other unapproved locations. In fact, rooms to be used for such work must be examined and approved for use of the types and quantities of radioactive materials to be used. This is part of the approval process. Most laboratories at Howard University Hospital and Howard University (HU & HUH) meet the requirements for use of radiation.

Smooth, contiguous and non-absorbent surfaces such as stainless steel or linoleum are required in a radiation work area. A properly working chemical fume hood with flow rates of at least 100 feet per minute is required, if fume hoods will be used for containing radioactive materials. Special filters and/or design are not generally necessary but may be prudent in special cases. The labs and/or rooms used must besecure; in other words, must be able to be locked, when unused/unattended, to maintain the security requirements for radioactive materials.

In areas where contamination is likely, surfaces should be covered with absorbent and disposable material, such as poly-backed absorbent lab paper. If you are in the process of designing a radioisotope lab, consult the Radiation Safety Office (RSO) staff, to obtain information regarding design and vendor catalogues. Work areas should be localized to minimize the possibility of contamination spread. Also periodic surveys must be conducted for all areas where radioactive materials are used, stored or disposed.

Equipment such as glassware, tools, syringes, etc. used in the handling of radioactive materials should not be used for other work or taken out of the lab unless it is ensured that the equipment is free from removable contamination. It is strongly recommended that a designated and labeled storage area be used to store this equipment. Fume hoods with flow rates of at least 100 linear feet per minute should be used whenever working with radioactive materials where the potential for vaporization/volatilization exists (e.g. during iodination), or when handling stock solutions of radiotracers, because of the high activity concentration.

10.2 CLEAN LABORATORY CONDITIONS AND CONTAINMENT

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

1. Maintain neat and clean work areas. Clutter, debris and crowded conditions interfere with the required careful handling of hazardous materials.
2. Follow experimental procedures carefully. Radioisotope approvals are contingent upon following the procedures, statements and representations made in the principal investigator's approval. Departures from the procedures may place the approval at jeopardy.

3. Use absorbent poly-backed laboratory paper, with the plastic side down and the absorbent side up, to protect surfaces from inadvertent spills or splashes. Laboratory benches, fume hoods, trays containing samples, waste areas and floors in the radioactive work areas are some of the locations where absorbent paper is useful.
4. Use secondary containment for all radioactive solutions, samples, liquid waste or any other hazardous materials that can be spilled. Use trays, boxes, bus trays and other types of secondary containment to catch spills, splashes and possible container ruptures.
5. When transporting radioactive materials, use a cart; this will prevent accidentally dropping or tipping the container.
6. Clean up the work areas and survey for contamination after work is completed. If contamination is present, decontaminate or dispose off the contaminated materials.
7. Use tightly sealed or capped containers when moving, heating, centrifuging or vortexing. Spills, evaporation, gases, container breakage or splashes may occur in any procedure where energy is put into the system.
8. Label all radioactive materials and areas where radioactive materials are used, stored or disposed.

10.3 MONITORING EQUIPMENT

Every laboratory using radioactive materials must possess or has available for immediate use, appropriate radiation monitoring equipment. This equipment must be in a good working order and calibrated yearly. Equipment that has not passed the annual examination must be removed from service until it is repaired or replaced. If there is a problem with your equipment, contact the Radiation Safety Office and arrange a time when the equipment can be inspected and calibrated. Radioactive monitoring instruments must be capable of detecting the radioisotopes being monitored at or below the contamination limits.

There are several types of monitoring instruments commonly used in teaching and research laboratories. The most widely used instrument is the Geiger counter, a portable instrument capable of detecting beta or gamma radiation. The Geiger counter is the least expensive, fastest and generally the most reliable means of detecting and measuring radioactive contamination.

The Beta Pancake detector is used with the Geiger counter for finding and measuring beta radiation and will detect all beta radioisotopes used at HU & HUH except ^{3}H and ^{63}Ni as their betas are too low in energy to penetrate the window of the detector. Radioisotopes which may be detected reliably with the beta pancake are ^{14}C, ^{35}S, ^{33}P, ^{32}P, ^{45}Ca, ^{36}Cl, and other beta emitting nuclides.

The Low Energy Gamma (LEG) probe is used with the Geiger counter to detect and measure gamma radioisotopes of various energies. It is most efficient for ^{125}I, but performs adequately for ^{51}Cr, ^{111}In, ^{60}Co and other gamma emitting nuclides. These detectors can also detect low energy X-rays, such as those emitted by beta emitters producing Bremsstrahlung radiation.

Another instrument in common use is the Liquid Scintillation Counter (LSC). It is necessary to use it in radiation safety surveys for ^{3}H and ^{63}Ni, since no other instrument will detect these nuclides. Liquid scintillation counters work for quantitative analysis of both beta and gamma nuclides in a sample. However, it is not an adequate primary method of evaluating contamination surveys, since samples

measured consist of wipes of the areas of suspected contamination; if the contamination is not removable, the wipe will not pick it up and contamination will not be detected. It is also possible for only a part of the contamination present to come up on a wipe, therefore, not providing an accurate measurement of the contamination present. Other instrument which may be used to evaluate contamination is the Gamma Well counter; again, this is used to gather data in samples, but for the same reasons as the liquid scintillation counter, it is not a good radiation survey instrument.

Ion Chambers are commonly used by the RSO staff and in locations where frequent and higher flux external radiation hazards are present; they are typically not used for contamination surveys by laboratory staff. These instruments measure the ions produced in air (of one sign) by gamma radiation and are a good indicator of radiation exposure fields. They are useful for exposure potential screening on shipments, hot parts at the cyclotron, drums of waste at the radioactive waste facilities, packages prior to shipment and sources and stocks of radioactive materials.

Other, more sophisticated, instrument used to detect and quantify radiation are the Gamma Spectrometers coupled to multi-channel analyzer, Neutron detectors, Alpha detectors, and a wide array of electronic dosimeters, area monitors, and even portal monitors (which a person walks through to detect any contamination on the body or clothing; these are used at reactors).

For effective and accurate data gathering in radiation, follow a few simple guidelines as given below:

1. Survey at the proper geometry. Hold the detector about 1 cm or 1/2 inch above the surfaces monitored. If the detector is too far away, serious underestimation of activity or no detection of activity present may occur. If the detector is too close, contamination of the detector may occur.
2. Use the correct detector. Do not survey for beta radiation with a gamma probe, or for gamma radiation with a beta probe. **No Geiger counter will detect tritium; liquid scintillation techniques must be utilized.**
3. Survey slowly. Do not race the detector over the surface or wave it like a magic wand; the sensitivity of the detection is inversely proportional to increasing survey speed.
4. Do not cover the detector while surveying. Covers decrease or eliminate detection, as they may act as a shield.

10.4 CALIBRATION OF INSTRUMENTS

Radiation detection instruments used for radiation surveys must be operable and capable of detecting the radioisotopes used in the laboratory. All exposure rate survey meter calibration services must be conducted annually by accredited national labs. The count rate meters can still be calibrated by radiation safety staff using a calibrated pulsar.

10.5 SURVEYS

The purpose of a physical survey is to identify potential problems, such as poor storage or handling practices, before they pose a hazard, and to demonstrate that contamination levels and dose rates are well below limits. Surveys should be done during the first week of each month to assure that they are not inadvertently omitted and must be done after each use in shared work areas.

Removable contamination surveys help identify areas where radioactivity has been spilled. Countertops, sinks, floors, refrigerators, centrifuges, fume hoods, and telephone handsets should all be considered for inclusion. Take a sample by making an "S" motion in a 100 cm long wipe of the surface with a small piece of filter paper. Count the sample in a Liquid Scintillation Counter.

Instrument surveys help identify areas where radioactive material has been spilled or where it is inadequately shielded. Survey bench surfaces, your hands, clothing, and shoes. Most researchers use a survey instrument with a speaker, which responds more quickly than the meter needle movement.

Perform a "battery check," and use either a radioactive check source or a known radiation area to confirm the instrument is working before you begin. Move the detector slowly to allow the instrument time to respond.

10.6 CONTAMINATION SURVEYS

The RSO will make independent surveys of all radioisotope labs at least quarterly. Such things as inventory assessment, contamination control, personnel monitoring, training and waste disposal practices will be addressed during these surveys. See the Radiation Safety Inspection checklist used by the Radiation Safety Office in **Appendix L**.

Copies of the results of surveys will be forwarded to the Principal Investigator (PI), and a recheck may be conducted in the event problems have been detected that need corrective action. HU Radiation Safety Committee (RSC) may accompany the RSO staff on surveys as deemed necessary for problem laboratories or for purposes of auditing the Radiation Safety program.

Surveys are to be conducted by the project investigator or his/her designee in conjunction with the Radiation Safety Office surveys. Each lab, that is actively using isotopes, must conduct radiation surveys weekly, monthly or quarterly, depending on the types and quantities of radioactive materials present in the laboratory. By doing this, the potential for exposures can be evaluated and reduced, if necessary. Records of these surveys must be maintained for review.

When removable radioactivity is found, the area must be decontaminated and then re-surveyed and documented. Detectable levels of removable contamination should be removed, and non-removable contamination should be labeled and shielded whenever possible in order to maintain ALARA limits.

It is understood that certain areas may be routinely contaminated, such as internal parts of equipment and the inside areas of glassware, and that it may not be practical to decontaminate these surfaces. If this occurs, signs must be posted, and protective clothing and gloves should be used when in contact with these areas. In some cases, such as ^{32}P contaminated equipment, shielding is required. The limits for removable contamination are listed in the table 10.1 below.

Radioactive contamination found at or above these levels must be decontaminated or shielded and labeled. One of the advantages of using disposable lab paper on the benches is that the user must dispose the contaminated area of the paper in the radioactive waste, rather than decontaminating or shielding.

Radioisotope-authorized labs at HU & HUH are treated as restricted areas and are characterized as locations with controlled access and have proper radiation safety controls in place.

Radioisotopes classified as high risk include ^{45}Ca, ^{22}Na, and ^{60}Co. Low/moderate risk radioisotopes include ^{32}P, ^{3}H, ^{14}C, ^{35}S, ^{125}I, ^{51}Cr and ^{111}In. Remember that the ALARA requirement must be adhered to in the above limits, meaning 10% of the limits, where possible**.** For some radionuclides, it is impossible to achieve less than the contamination limits, since the instrumentation and normal background prevent any increased sensitivity. For others, sensitivity may exist where it is realistic to achieve 10% of the contamination limits.

Table 10.1: Radioactive Contamination Limits

Type of Area	Alpha Emitters (DPM/100 cm^2)	High Risk Beta or Gamma Emitters (DPM/100 cm^2)	Low/Moderate Risk Beta or Gamma Emitters (DPM/100 cm^2)
Unrestricted Areas	22	220	2,200
Controlled Areas	22	220	2,200
Restricted Areas	220	2,200	22,000
Personal Clothing	22	220	2,200
Outside Restricted Areas			
Skin	22	220	2,200

10.7 FOOD AND DRINK POLICY

Due to the number of U.S. NRC violations cited at numerous institutions, the HU Radiation Safety Committee and Radiation Safety Office have developed a policy regarding food and drink. The following policy must be adhered to by PI's and users of radioactive labs:

1. There shall be no food, drink, smoking or applying cosmetics in the laboratories which have licensable radioactive materials, bio-hazardous materials or hazardous chemicals present. There shall be no storage, use or disposal of any "consumable" items in laboratories (including refrigerators within laboratories). Rooms which are adjacent, but are separated by floor to ceiling walls, and do not have any chemical, radioactive or bio-hazardous agents present, may be used for food consumption or preparation at the discretion of the PI's responsibility for the areas.
2. It is important to be aware that even the presence of empty food and drink containers in the normal trash may cause a violation, since it is construed as "evidence of consumption" by regulators, and the burden of proof to the contrary then lies with the licensee. Please also note that gum and tobacco chewing are prohibited in the laboratories.
3. Floor to ceiling enclosures must separate food areas from hazardous material areas, due to the potential release of a hazardous material into the air and then possibly into a food area, if only partial barriers are present.
4. If empty food or drink containers are used for storage or disposal of laboratory waste, pipette tips, or other laboratory equipment, reagents or materials, they must be clearly labeled. If used for disposal of items contaminated with radioactive materials, the containers must be clearly labeled

with the radioactive material warning symbol, the nuclide, the quantity of activity and the date of disposal.

10.8 LABELING AND POSTING REQUIREMENTS

Work areas, trays, racks, stock solutions, tools, equipment, etc., which contain radioactive material or are contaminated, must be labeled with a tape that reads radioactive material. The label must contain the radioisotope present, date, and the total activity in disintegrations per minute (dpm) or microcuries. It is not reasonable to expect that each tube or vial be labeled, but the container, tray or rack that holds them must be labeled; for example, scintillation vials do not need to be individually labeled, but the tray or box that they are stored in must have the above-described label. The "rule of thumb" is that if there is radiation above the background level in or on something, it must be labeled.

For contaminated equipment which is in frequent use, the isotope, date and maximum activity which may be present at any given time is to be written on the radioactive warning label. For equipment, which is used for radioactive materials, but is not contaminated (equipment which the staff wishes to identify for radioactive use), a label with the radioactive material warning, "**Caution, Radioactive Materials**", may be used. Labels are not required if the equipment is not contaminated.

All radioactive waste must be similarly labeled with the above-described information. Bench top waste containers are to be labeled in the same method as for radioactive materials in use or storage. As soon as radioactive waste is placed in the radioactive waste container, all information on the waste tag must be filled out.

Work areas must be labeled with the “Caution Radioactive Materials” sign or marked off with the radioactive warning label tape. If the area is seldom used for radioactive materials, the area may be labeled only for the duration of the use, providing that it is surveyed for contamination and is free of contamination the labels are removed. If the work area is frequently used, it is best to label the area permanently. For work areas frequently used for radioactive materials work, and which may contain contaminated equipment, the area may be labeled with a maximum reasonable amount of activity, the radioisotope, the date and the "Caution Radioactive Materials" warning.

Each room in which radioactive materials are used must bear a label on doors to the room. These labels must have the radioactive warning symbol, and the name and telephone numbers of the PI and one other person who is knowledgeable about the radioactive materials used in the room(s). These labels are for emergency response purposes and should have the non-working hours telephone numbers where a responsible and knowledgeable individual may be reached in the event of an emergency. These labels shall not be disposed in the regular trash.

Each authorized user of radioactive materials shall have posted in their respective laboratory the current copies of the following documents:

- Part 19 and 20 of the U.S. Nuclear Regulatory Commission’s Regulations;
- A copy of the authorization to use and possess byproduct materials from the Howard University Radiation Safety Committee;
- A copy of Form NRC-3 entitled, “NOTICE TO EMPLOYEEES”:
  A notice indicating where the U.S. Nuclear Regulatory Commission regulations and the Howard

University Authorization to Use Byproduct Materials may be examined can be posted in lieu of Part 10 and 20 and the Authorization to Use Byproduct Materials at Howard University.

10.9 AREA RESTRICTIONS

All rooms or areas in which licensed quantities of radioactive materials are used or stored must be posted with a "Caution Radioactive Material" sign, an "NRC Licensing and Regulation Information Bulletin" sign, and a "Notice To Workers" sign. Door signs must include the PI's name and phone number, and where he or she can be reached in the event of an emergency. Postings can be obtained from the Radiation Safety Office.

Definition of area restrictions (10 CFR 20.1003)

The following chart definitions are set forth in the federal law for area restrictions.

Unrestricted Area: An area to which access is neither controlled nor restricted by the licensee.

Restricted Area: An area to which access is limited by the licensee for the purpose of protecting individuals against undue risks from exposure to radiation and radioactive materials. A restricted area does not include areas used as residential quarters, but separate rooms in a residential building may be used as a restricted area.

Controlled Area: An area outside of a restricted area but inside of the site boundary, to which access can be limited by the licensee for any reason.

Radiation Area: An area accessible to individuals, in which radiation levels could result in an individual receiving a dose equivalent in excess of 5 mrem (0.05 mSv) in 1 hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates.

High Radiation Area: An area accessible to individuals, in which radiation levels could result in an individual receiving a dose equivalent in excess of 100 mrem (1 mSv) in 1 hour at 30 centimeters from the radiation source or from any surface that the radiation penetrates.

Very High Radiation Area: An area accessible to individuals, in which radiation levels could result in an individual receiving an absorbed dose in excess of 500 rads* (5 Gy) in 1 hour at 1 meter from a radiation source or from any surface that the radiation penetrates.

(*The exposure rates for Very High Radiation areas are in rads rather than rems, because of the potentially life-threatening exposures that could result in areas with these fluxes of radiation.)

At HU & HUH most of the radiation use areas are managed as 'restricted areas'. Some radiation use areas are open to the public and may have both radiation workers and other individuals present often or all of the time. Members of the public are permitted to be present, as long they are escorted by a trained worker while in the restricted area or have been trained in radiation safety to work independently. Principal Investigator training accomplishes training requirements for workers frequenting the laboratory but not handling radioactive materials.

Within the restricted areas, it is imperative that strict surveillance be maintained to assure that significant exposure levels are not present, whether in the form of contamination, airborne levels of radiation and/or external exposure levels. For this reason, unrestricted area limits for contamination, exposures and/or releases must be adhered to at all times, rather than restricted area limits. We have

been using the unrestricted area limits for several years at HU & HUH as a part of our ALARA program management.

Another very important requirement for restricted areas is the security of radioactive materials. It is the responsibility of all workers frequenting a restricted area to maintain security. This is discussed in the section on security of radioactive materials.

Other radiation area restriction categories (radiation area, high radiation area, etc.), exist only in a few specific locations, which are typically not accessible to the general public. In the event of emergency or other unusual situations, any of the restricted areas may be restricted to a more secure level to protect against radiation and/or any other hazard which may be present. If this were to occur, the area(s) would be clearly marked and posted with warning signs or barriers.

Warning signs and labels are available from the Radiation Safety Office. Indiscriminate use of warning signs and/or labeling of non-radioactive materials with "Radioactive" stickers or labels are prohibited.

10.10 WASTE STORAGE IN LABORATORY

Radioactive waste must be stored in a controlled and secure place. Never dispose radioactive waste in regular trash cans or pour it down drains or sinks. Ensure that all waste containers are labeled with radiation warning signs.

General Radiation Safety Rules for Waste Storage in Lab:

1. Separate all wastes by radioisotope and physical form.
2. Designate a specific location for radioactive waste storage.
3. Post the area and label each container with a RADIOACTIVE warning symbol.
4. Use appropriate shielding when relevant, especially when handling high-activity or high-energy radioisotopes.
5. Attach a completed radioactive waste tag to each container in the radioactive waste storage.
6. Keep containers closed, except when material is being added. Make sure the container and bag exteriors are free of contamination.
7. Radioactive waste must not be stored in the lab for a long time. Place the waste container in the local waste room if applicable, if not, request waste pickup frequently to minimize radiation exposure in the lab.
8. Request radioactive waste collection when ready for a waste pick up.
9. If the waste has high-activity or high-energy radioisotopes, notify the Radiation Safety Office so that an appropriate shielded container may be brought for pickup.

Detailed guidelines are described in the Waste Management Section (Chapter 12).

Chapter - 11

LOADING DOCK RADIATION SURVEY POLICY

11.1 INTRODUCTION

Most facilities generate regulated medical waste, which includes items saturated with blood or body fluids and needles or other sharps instruments/devices that have been used on a patient or been contaminated with blood or body fluids. Organizations should dispose of this kind of waste using red bags (for non-sharp items) and sharps containers (for needles and other sharp elements). When it comes to hazardous waste, organizations must be scrupulous about disposal. If these dangerous materials are not handled appropriately, they can be toxic not only to the staff and patients, but also to the environment and surrounding community.

The first step in proper hazardous waste disposal is determining what types of waste are present in a facility as defined by the Resource Conservation and Recovery Act (RCRA) of 1976. Generators need to determine if their waste is listed (found on the U, P, F, or K lists) and/or if the waste exhibits hazardous characteristics – ignitable, corrosive, reactive, toxic.

Another type of hazardous waste frequently found in healthcare organizations is radioactive hazardous waste. Healthcare facilities employ radioactive materials in both diagnostic and therapeutic treatment procedures. Most of the radiation therapy takes place in the nuclear medicine section of a hospital.

Radioactive waste can come in many forms: medical equipment contaminated with trace amounts of certain isotopes, clothing, or the actual radiation sources (e.g. a cobalt block). When radioactive materials are inserted inside patient bodies (for instance iodine to treat a diseased thyroid gland or iridium pellets to destroy prostate tumors) body parts and fluids can become radioactive. The patient's urine and feces can end up being radioactive pathological waste. Tericycle is the vendor in-charge of picking up all non-radioactive hazardous waste from Howard University Hospital.

11.2 DAILY LOADING DOCK RADIATION SURVEY

The loading dock is surveyed twice a day, every day. Once in the morning (9:00 a.m.) and once in the afternoon (2:00 p.m.) by the Radiation Safety Office staff. This is to ensure that no "Hot Trash" has been put in any of the waste containers or compactors and to ensure that the radiation monitors and detectors are functioning correctly.

The loading dock monitors and detectors are checked by using a radioactive check source. When checking the detectors, the radioactive check source shall be placed in front of the detector. You shall then pause 5 seconds to ensure that the alarm does go off. This process must then be repeated with all the remaining radiation detectors (there are a total of 4 radiation detectors in the loading dock area).

The waste containers and compactor are then surveyed as well, using a survey meter. The survey meter must be checked for proper functionality before each use. The waste containers and compactor shall then be surveyed slowly in a "S" motion, up and down, in order to allow the survey meter sufficient time to detect any contamination or "Hot Trash".

A loading dock survey log sheet is then filled and signed by the Radiation Safety Office staff member, completing the loading radiation survey during each round daily.

11.3 SURVEY METERS

Survey meter operation should be checked prior to each use by comparing the current reading of the dedicated check source with the expected reading as printed on the meter. On an annual basis, all meters are sent out to be calibrated by an accredited national lab. Following pre-operational checks of survey meters must be performed:

Step 1 – Battery Check

- Turn the knob to the 'Bat' position.
- Make sure the needle is within the 'Bat Test' region.
- If necessary, replace the batteries with two D cells.

Step 2 – Background Check

- Turn the knob to the lowest scale (X0.1 scale).
- The purpose of the background check is to make sure that the detector is not contaminated or that there are no unusual radiation readings before you begin your survey.

Step 3 – Source Check

- Determine the expected reading using a check source.
- Place the detector in the closest contact with the source. The meter reading should be within the specified range written on the side of the meter.

11.4 DISPOSING OF WASTE THROUGH LOADING DOCK AREA

When taking waste containers out onto the loading dock area, be sure to:

1. Pause 5 seconds at the monitor station.
2. If no alarm goes off, you may proceed.
3. If an alarm does go off, the container or bin you are transporting is considered radioactive.
4. Take the container to the HUH Hot Trash room (BG-03)
5. Notify your supervisor.
6. Monitor the radioactive waste bags **at least**once a day.
7. Check radiation levels with the survey meter (located in the HUH "Hot Trash" room).
8. If the content in the hot trash bag shows a reading similar to the background level, you may remove the trash and dispose in the corresponding disposal bin.
9. However, when removing the waste through the loading dock, if the alarm continues to go off, it means the contents in the bags are still radioactive. Place the waste back in the "Hot Trash" room until it has decayed to a background level.

11.5 RECEIVING RADIOACTIVE MATERIAL

All shipments of radioactive materials coming into Howard University and Howard University Hospital are monitored by the Radiation Safety Office (RSO) staff; records are maintained in the RSO for review.

Shipments of radioactive materials must be delivered directly to:

HOWARD UNIVERSITY HOSPITAL
RADIOACTIVE MATERIAL RECEIVING VAULT
Shipping and Loading Dock
Howard University Hospital
2041 Georgia Avenue, NW
Attn: (Name of Authorized User and Radiation Safety Officer)
Washington, DC 20060

11.6 SOURCE RECEIVING VAULT

Packages received (by Mail Room Services) are stored in an approved vault located in the loading dock area of the Hospital until picked up by Radiation Safety Office staff. There are two keys for the source receiving vault. One is kept by the Radiation Safety Officer and the other remains in possession of the HUH Security Office.

Authorized personnel from the Radiation Safety, Mail room, Nuclear Medicine, Radiation Oncology department/office and respective vendors may obtain the key from the security office to gain access to the vault. All persons who request and utilize the key must register their information on the source-receiving vault key log sheet.

11.7. AREA SURVEYS AND WIPE TESTS

A. Daily

- All areas will be surveyed daily with a low-range, thin-window G-M survey meter (mR/hr) to monitor for contamination. A reading of >0.05 mR/hr above room background in non-restricted areas and > 0.5 mR/hr above room background in a restricted area is considered contaminated and must be decontaminated. The loading dock areas are surveyed twice daily once in the morning and again in the afternoon by the radiation Safety Office staff.
- All trash in both the regular trailer and the bio-medical waste trailer will be monitored before the trash is disposed of. All the trash needs to go through the radiation monitors which are installed at the entrances of the loading dock. Any trash with a high reading will be separated and stored in the "Hot trash" room until it decays to background level prior to disposal by RSO.
- If "Hot Trash" is already in the trailer, the Radiation Safety Officer (RSO) must be notified immediately. No further trash shall be put into the trailer/compactor. The RSO will then survey the contaminated trailer/compactor and monitor the radiation exposure periodically, until the radioactive waste has decayed to a background level; in the case of a high reading, the RSO may

also decide to relocate the trailer/compactor until the radioactive waste has decayed to a background level.

- Once the trailer/compactor has been cleared, it may continue to be used to dispose of waste.

B. Weekly

- The loading dock area will be surveyed with a low-range thin-window GM survey meter (mR/hr.). The areas of use will be wipe tested covering a 10 cm × 10 cm area. The wipe samples will be counted and recorded as net cpm. The sample count must be converted to dpm. A count of >200 dpm/100 cm^2 above background and/or a sample with an identifiable peak is considered contaminated and must be decontaminated and re-wiped.

C. Quarterly

- The quarterly inspection includes the radiation survey of the loading dock area as well as wipe tests which are carried out to rule out any radiation contamination.

11.8 SPILL PROCEDURES

A spill is to be considered "Major" if the exposure level at 30 cm from contamination is greater than 5 mR/hr. The following documentation must be completed for all spills:

1. Radiation Incident Report
2. Patient Safety Report (regardless of whether or not a patient was directly implicated)

The following procedures are recommended for minor and major spills:

A. <u>Minor Spills</u>

1. Notify all people in the area that a spill has occurred. No personnel may leave thespill area until they have been surveyed and found to be free of contamination.
2. Prevent the spread of contamination by covering all visibly 'wet' areas with absorbent paper.
3. Monitor the area(s) and define the borders of the contamination with markers or barriers. Ensure to cover the detector so as to prevent contamination.
4. Wear gloves and protective clothing such as a lab coat and booties, and clean up the spill using an absorbent paper, working from the edges of the spill towards the center. Carefully fold the absorbent paper with the clean side out and place in a bag labeled, "Caution Radioactive Material" for transfer to a radioactive waste container. Also put contaminated gloves and any other contaminated disposable material in the bag.
5. Perform follow up wipe tests and decontaminate as necessary. Document all results in the Radiation Incident report. If the radiation levels cannot be reduced to less than 2 mR/hr at 1meter, or if there is removable contamination >200 dpm resulting from a wipe over an area of 100 cm^2, the area must remain secure to prevent entry until decontaminated and released by RSO. The area should be clearly marked with appropriate signage.
6. Contaminated clothing should be removed and placed in a plastic bag for decay in storage. If contamination is suspected in the person's eyes, they shall proceed to use the designated eyewash

station. If one is not present, eyes may be washed over the sink, allowing water and contamination to flush down the drain.

7. If the spill is on the skin, the following steps may be taken:
   a. Flush skin surfaces with tepid water and re-monitor.
   b. If contamination persists, the area may be washed with mild soap and lukewarm water.
   c. A soft brush may be used; do not scrub hard enough to abrade the skin, as this may degrade the skin's natural ability to act as a barrier.
   d. If residual activity persists, consult the RSO for further steps. Adding moisture (lotion) to the skin may aid in removing persistent contamination.
8. Report the incident to the Radiation Safety Office. A Radiation Incident Report will need to be completed and submitted to the Radiation Safety Office.

B. Major Spills

1. Clear the area. Notify all persons not involved in the spill to vacate the room. No personnel may leave a spill area until they have been surveyed and found to be free of contamination.
2. Call for help; notify the Radiation Safety office as soon as possible. The Radiation Safety Office will advise on the clean-up and surveying of the area and any contaminated personnel.
3. Prevent the spread of contamination by covering the spill with absorbent paper labeled, "Caution Radioactive Material," but do not attempt to clean it up. Also, clearly indicate the boundaries of the spill and limit the movement of all personnel who may be contaminated.
4. Shield the source if possible. Do this only if it can be done without further contamination or a significant increase in personnel radiation exposure.
5. Secure the area to prevent entry.
6. Contaminated clothing should be removed and placed in a plastic bag for decay in storage. If contamination is suspected in the person's eyes, they shall proceed to use the designated eyewash station. If one is not present, eyes may be washed over the sink, allowing water and contamination to flush down the drain.
7. If the spill is on the skin, the following steps may be taken:
   a. Flush skin surfaces with tepid water and re-monitor.
   b. If contamination persists, the area may be washed with mild soap and lukewarm water.
   c. A soft brush may be used; do not scrub hard enough to abrade the skin, as this may degrade the skin's natural ability to act as a barrier.
   d. If residual activity persists, consult with the RSO for further steps. Adding moisture (lotion) to the skin may aide in removing persistent contamination.
8. A Radiation Incident Report will need to be completed and submitted to the Radiation Safety Office.

Chapter – 12

RADIATION PROTECTION GUIDELINES AND DOSIMETRY

12.1 GENERAL RADIATION SAFETY RULES IN RADIATION LABORATORIES

1. Wear a lab coat, gloves and safety glasses when working with radioactive materials. Lab coats should be buttoned up and never be worn open.
2. Do not eat, drink or smoke in radioisotope use, storage or disposal areas. "Eating" includes chewing gum, candy, consuming medication, drinking beverages and/or chewing tobacco. Do not apply cosmetics in the laboratory. Do not dispose of food, empty food wrappers or containers anywhere in the laboratories.
3. Never store food, drinks, or any item for consumption in the lab nor the lab refrigerators.
4. Gloves should be worn during all operations to avoid contamination of hands.
5. Never pipette radioactive liquids by mouth.
6. Store and transport radioactive materials in containers which will prevent breakage and spillage. Secondary containment is important; when transporting radioactive materials, use trays and carts.
7. Use ventilation hoods or glove boxes if the radioactivity may become airborne and for high activity uses, such as stock solutions.
8. The individual(s) responsible for any contamination will be required to decontaminate the area of concern.
9. Regularly survey your hands, clothing and shoes for contamination while working with radioactive material, and prior to leaving the work area.
10. Always dispose of radioactive waste in a radioactive waste container.
11. Always wear your assigned radiation badge(s) when working with radioactive materials. If assigned, ring badges must be worn at all times when handling radioactive material if assigned.
12. Users of high energy beta or gamma radionuclides should wear eye protection, such as safety glasses or a face shield.
13. Work areas should be covered with plastic backed absorbent material and/or use a nonporous tray to contain any spill that may occur when using unsealed radioisotopes.
14. Spend less time, increase distance, and apply shielding when necessary to reduce exposure to radiation.
15. DO NOT work with radioactive materials if you have an open wound.

12.2 MONITORING OPERATIONS INVOLVING RADIOACTIVE MATERIALS

Due to the potential for contamination of work areas during use of radioactive materials, it is necessary to monitor, as much possible, the operations performed. Work areas should be checked

before use to determine background or prior contamination. The survey instrument should be turned on and placed proximal to the work area in order to check radiation levels and alarm the worker if radiation levels rise significantly; hands should be checked frequently for presence of contamination due to splashing or aerosols; at the end of the use of the work area each day, work areas should be monitored to determine the presence of contamination. Note that worker clothing and shoes should also be monitored.; if contamination is found, the area or equipment must be decontaminated. The general guidelines for conducting surveys are given in **Appendix L.**

12.3 PERSONAL PROTECTIVE EQUIPMENT

In order to prevent contamination of skin, eyes or personal apparel, protective equipment should be utilized during the use of radioactive material. The specific types of protective equipment needed are dictated by the nuclide, level of activity, chemical form and experimental procedures.

Two main categories of protective equipment are personal protective equipment and engineering controls. Personal protective equipment is protective equipment worn by the workers. Examples are gloves, laboratory coats, safety glasses and shoes (water-resistant shoes that covers the foot; *NO slippers, half-shoes or open toes*). Engineering controls are external equipment designed to protect the workers or are a part of the design of the work area. Examples are fume hoods, biological safety cabinets, building ventilation systems and shields.

Individuals using radioactive materials must wear laboratory coats, gloves and eye protection. Additional protective equipment may be necessary or prudent. Contact the Radiation Safety Office if you have any questions about protective equipment.

12.4 RADIATION PROTECTION PRINCIPLES

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

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

Distance:
Maximize the distance from the radioactive materials. Dose is inversely proportional to distance; therefore, greater distance leads to less dose. Do not increase the distance to the point wherein dexterity or control of the materials is jeopardized.

Shielding:
Use shielding wherever necessary to reduce or eliminate exposure. By placing an appropriate shield between the radioactive source and the worker, radiation is attenuated, and exposure may be completely eliminated or reduced to an acceptable level. The type and amount of shielding needed to achieve safe working level varies with the type and quantity of radioactive material used. The HVL (half-value layer) may be used as a guide to the thickness of the shielding necessary to block the radiation. The HVL is the thickness of the shielding necessary to reduce the radiation dose rate to half

of the original, or unshielded dose rate. Refer to the HVL information in the appendices on specific nuclides.

Above all, minimizing the amounts of radioactive materials handled in each experiment will reduce potential exposure, since exposure is directly related to the amount used and how it is handled. Following the precautionary measures discussed in this manual will be of great help toall radiation workers.

12.5 AIRBORNE RADIOACTIVITY

Radioactive materials have a potential risk of being released into the air, causing the workers to uptake the material through one or more routes of entry into the body, particularly inhalation. Numerous situations may cause airborne release of radioactive materials.

Contamination present in a room may create airborne radioactivity by simple movement of the air over the contamination, spreading it around in the air. Most radioisotopes are picked up by air and spread through this mechanism. This is another good reason to keep areas free of contamination.

The use of **volatile forms of radionuclides**, such as ^{125}I for iodination's or ^{3}H-sodiumborohydride may generate airborne radioactivity. Any chemical or physical form which readily volatilizes or evaporates into the air must be considered a potential airborne radioactivity risk.

Chemical reactions may generate radioactive gases or other airborne contaminants. An example is the labeling reaction for ^{35}S methionine, which generates a methyl mercaptan reaction which liberates HCl and $^{35}SO_2$ gas. Airborne radioactivity has resulted in unnecessary intakes and area contamination in laboratories, where the users were unaware of this risk and did not take precautions to trap or contain the liberated $^{35}SO_2$.

Heating or incubating may cause evaporation or chemical reactions which release radioactive materials into the air. **Aerosols** (tiny droplets or particles) are present with all materials and pose an increased risk when handling stock solutions or other high concentrations of radionuclides. Use chemical fume hoods or biological safety cabinets for high activity, concentrated or potentially volatile radioactive materials manipulations.

Materials which have been frozen may release substantial quantities of aerosols or gaseous radioactive material when the containers are opened. There have been numerous incidents at various institutions where such contamination occurred and caused significant contamination of work areas, equipment and clothing following opening of the containers.

Another cause of airborne radioactivity is media or solutions containing **cells, bacteria or other living organisms**. The living organisms metabolize the radioactive substrates and may produce radioactive gases or vapors as a byproduct.

When **hazardous chemical forms of the radionuclides** are used, such as radiolabeled carcinogens or toxins, increased risks are presented by the vapors, aerosols or gases present or generated in the use. In this case, the hazard present is not only radioactive, but may also pose airborne chemical risks.

In order to prevent uptake in these increased risk situations, fume hoods, biological safety cabinets or other containment must be used to protect the worker from uptake and internal deposition. Do not use clean benches (tissue culture hoods) for use of radioactive materials, or any other hazardous

material. While the product is kept sterile by these hoods, the hazardous material present in the materials used are blown into the face of the worker, and into the room. Therefore, there is no protection for the worker.

In certain rare cases, respiratory protection may be necessary for certain radioisotope uses. However, respiratory protection should only be used when other means of control and containment do not provide enough protection. Respirators must be chosen carefully to ensure the proper fit and type of cartridge, and the use must be monitored carefully. For this reason, use of respirators for radioactive materials use must be pre-approved by the Radiation Safety Office, documented and monitored. Prior to using respirators for any reason, fit testing and medical monitoring are required.

If you are concerned that an intake has occurred, contact the Radiation Safety Office. Bioassays (urine samples) or other investigational methods may be employed to determine whether an intake has actually occurred and to recommend ways to avoid such undesirable situations in the future.

12.6 SAFETY PROCEDURES FOR USERS OF DIAGNOSTIC RADIOGRAPHIC AND FLUOROSCOPIC DEVICES

Patients - It is the responsibility of the X-ray technologist to use the proper radiographic techniques and to ensure that the X-ray beam is well collimated. Gonadal shielding should be provided when indicated. Lead aprons shall be provided for all dental patients. Technologists should always ask female patients if they are pregnant before beginning the examination. Signs advising declaration of pregnancy before X-ray procedures are also posted. If a patient is pregnant, a radiologist should be informed and consulted.

The patient's region of interest should be calibrated correctly, and the appropriate technical factors should be selected/set properly on the control panel. The radiograph shall be accurately marked (patient ID, right/left marker, etc.) prior to the exposure so as to be visible on the processed radiographic image. The patient shall be given specific instructions (holding breath, holding still, etc.) to minimize the number of exposures taken. During the exposure, the main entrance door to the radiographic room must be closed.

Patients should be immobilized as necessary to prevent retakes. Occupationally exposed personnel shall not hold patients except in a true emergency. In such emergency, or if a non-occupational exposed person (e.g. parent/guardian) holds the patient, that person shall not place any portion of their body in the useful beam. Appropriate protective clothing such as a lead apron and/or lead gloves shall be worn. Radiographic cassettes shall not be held by anyone other than the patient during the radiographic examination.

Visitors - Only necessary persons shall be in the room during the radiographic procedure. It is the policy of Howard University Hospital to embrace the principles of family-centered care and therefore the presence of non-occupationally exposed persons (e.g. parent or guardian) may be permitted in the radiographic room during their child's examination. However, it is the responsibility of the staff radiographer to assure that exposed persons are adequately protected from the radiation source. The exposed person shall also maintain a minimal distance of six (6) feet from the patient and the X-ray tube. Under no circumstance, shall the exposed person be permitted to stand in the primary beam. Protective lead aprons shall be worn by all persons in the room.

Employees **-** For general radiographic examinations, the technologist should be inside a shielded booth or behind an adequately protective screen and must wear a personnel monitor. For fluoroscopic examinations, protective devices normally supplied with the equipment, such as lead drapes, protective pull up panels, bucky slot covers, etc., should be used, whenever possible. Everyone in the room should be supplied with protective clothing and personnel dosimeters. The personnel dosimeters must be worn on the collar above the lead apron during the fluoroscopic examinations. Some personnel will be supplied with two dosimeters. If the employee is required to wear two dosimeters, the appropriate dosimeter should be worn as specified on the dosimeter - above the lead apron and the other underneath the apron at the waist area. Ring badges will be provided to employees whose hands may be exposed to radiation. Should any technical staff member be pregnant, she should contact her supervisor, or the medical physicist in that area to review special instructions and requirements.

When performing portable examinations, all employees should stand at least six (06) feet from the X-ray tube. If this distance cannot be maintained, a lead apron must be worn. Occasionally, a patient may have an employee hold them for/during an examination. This occurs when a patient's movement must be curtailed, and mechanical restrains are not possible. Technologists shall not hold patients during exposure under any circumstance. If non-technologist employees are asked to hold patients for X-rays, then following procedures should be followed:

1. A lead apron must always be worn by the person holding patient for X-rays.
2. No part of the body can be in the X-ray field. This is checked by the light localizer. If the individual's hands are close to the edges of the field, lead gloves must be worn.
3. Pregnant employees are not permitted to hold patient for X-rays.

Restricted Access

The X-ray room is a restricted area only during X-ray exposures. The authorized operator is responsible for controlling access to that room during exposures. The room is shielded so as to permit all adjacent areas to be treated as unrestricted areas. Most of the rooms have either radiation signs or warning lights above their entry doors that indicate radiation exposure is present. In addition, warning signs to alert potentially pregnant patients prior to exposure are dispersed through the department.

12.7 SAFETY PROCEDURES FOR USERS OF RADIOTHERAPY DEVICES

Patients **–** All radiotherapy patients are treated in accordance with the modern code of practice. Technologists should review the patient's chart for treatment times and instructions prior to each treatment.

Visitors- All treatment rooms and storage areas are restricted to all visitors. Only those under staff escort are permitted in these areas. Visitors are not allowed in the treatment room during patient treatments.

Employees- Employees are not allowed in the treatment room during the procedure. All patient monitoring must be performed via television cameras and intercoms. All pregnant employees should contact their supervisor of the teletherapy physicist to review special instructions and requirement.

12.8 SAFETY PROCEDURES FOR USERS IN OPERATING ROOM

Staff Radiographers

Medical X-ray procedures shall be performed only by a qualified Radiographer minimally holding an appropriate current license from the District of Columbia Health Department and only when and as authorized by a licensed physician. Preferred qualifications include documented graduation from an approved school of Radiologic Technology and/or registration with the American Registry of Radiologic Technologists (ARRT). Protective leaded aprons shall be worn by all operating room personnel who remain in the operating suite during a radiological procedure. In addition, thyroid shields, lead glasses, and lead gloves are available to be worn by the operating room personnel. When not in use lead aprons should be hung up or laid flat. Under no circumstance should they be folded. Shielded personnel remaining in the operating room during a radiologic procedure should be no closer than six (6) feet from the radiation source during the X-ray exposure.

Beam Restrictions and Gonadal Shielding

Radiation beam shall be limited to the area of clinical interest during both radiographic and fluoroscopic examinations. At no time should exposures be made where the Radiographer could come in contact with the direct beam. This requires "coning down" (restricting the field size) to the actual area of interest and/or the cassette size, whichever is smaller.

Shielding of the gonads on all patients, regardless of age, shall be employed for all radiographic procedures if the gonads are in the primary beam. Such shields mut not interfere with the examination.

Hand Controls

All hand exposure controls shall be mounted in the control booth in a way that prevents the operator from making/getting an exposure while in an unshielded position. This will be accomplished by permanent attachment of the hand control and/or by limiting the length of the exposure cord. No one shall make any alteration in attachment to the control or length of the cord without prior approval by the Diagnostic Imaging Supervisor, or Specials Imaging Supervisor. If through wear or any other reason, a hand control is found to be removable, the Diagnostic Imaging Supervisor or Specials Imaging Supervisor shall be notified at once.

Unshielded Personnel

All unshielded staff/student radiographers shall stand in such a position as to ensure that their entire body is shielded by the control booth barrier or by a portable protective barrier during radiographic examinations involving stationary X-ray units.

12.9 DOSIMETRY

12.9.1 Radiation Badges

There are mainly two types of radiation badges worn by radiation workers in HU and the University Hospital:

1. *Collar Badges:* They shall be worn by all occupationally exposed personnel at all times while in the department and/or orthopedic office(s). When a lead apron is worn, the radiation badge shall be worn on the collar outside of the lead apron.

2. *Ring Badges:* Individuals are issued ring badges as deemed appropriate by the Radiation Safety Officer. Ring badges are worn during fluoroscopic procedures and during the preparation and injection of radiopharmaceuticals. The ring badge shall be worn with the detection crystal visible on the side of the hand that is primarily exposed to the radiation source (e.g., Nuclear Medicine would be volar side while fluoroscopy would be dorsal side, etc.).

Badge Submission

Both the radiation collar badge and the ring badge must be submitted for processing monthly/quarterly. Any user who loses or destroys a radiation badge must contact the Radiation Safety Officer (RSO). All monitoring devices are submitted to Landauer, Inc. (Division of Tech/Ops, Inc.) for monthly, quarterly, yearly, and cumulative dosage readings.

Lost Radiation Badges

When an employee loses a badge, he/she must immediately bring it to the attention of his/her Supervisor, Program Coordinator, or Director. According to the Radiation Safety Committee (RSC) recommendations, there will be a $10.00 fee for first time incidents. The amount will be increased thereafter, every time a badge is lost. Such incidents will be documented on the employee's personal file. There will be a written policy in place, regarding the consequences of losing the dosimetry badge and/or not using it properly.

12.9.2 Exposure Reporting Policy

Landauer radiation badge reports are reviewed monthly, quarterly by the RSO. A summary of the review is presented to the Radiation Safety Committee in its quarterly meetings. The review is conducted to identify at least the following areas.

1. Radiation badge readings that exceed the allowable ALARA limit
2. Persistently high radiation readings that are within allowable ALARA limits
3. Actions taken to follow ALARA principles

ALARA is an acronym for **A**s **L**ow **A**s **R**easonably **A**chievable. This is a radiation safety principle for minimizing radiation doses and releases of radioactive materials by employing all reasonable methods. ALARA is not only a sound safety principle, but a ***regulatory requirement*** for all radiation safety programs.

An effective ALARA program is only possible when a commitment to safety is made by all those involved. This includes the Radiation Safety Office staff, the Radiation Safety Committee, research faculty and all radiation workers. The **HU Radiation Safety Manual** provides the guidelines for the responsibilities and good practices which are consistent with both the ALARA concept and the regulatory requirements of the D.C. Health and U.S. Nuclear Regulatory Commission. These guidelines and regulations require not only adherence to legal dose limits for regulatory compliance, but also ALARA investigation dose levels which serve as alert points for initiating a review of the work practices of a radiation worker.

12.10 EQUIPMENT SAFETY

12.10.1 Performance Testing

All radiography/fluoroscopy units will be surveyed, at least on an annual basis. In accordance with DC Health rules and regulations, a qualified Physicist, who is certified by the American Board of Radiology (ABR) in Radiological Physics (includes all areas) or in the area of Diagnostic Radiological Physics, shall perform these tests.

Evidence of such certification shall be on file in the form of a photocopy of the ABR certificate. The survey shall include analysis of mR/mA variations with time and current, determination of congruence of light localizer with the x-ray beam, measurement of half-value layers to determine filtration, and any other studies which may be necessary to meet the District, and federal requirements and recommendations, as well as to assure the personnel and patients

12.10.2 Quality Assurance

Since quality assurance results in lower patient and personnel exposure, an important part of the radiation survey is the assurance of proper operation of the unit including checks of kVp, linearity of exposure with time, current, and focal spot size. These checks are also made on all radiographic units annually. All lead aprons and lead gloves shall be inspected at least annually for integrity. There must be documentation available suitable for review, that deficiencies found during the survey have been corrected or are in the process of being corrected.

Covered under section 12.6 Para 2
Covered under section 12.6 Para 3

Chapter - 13

RADIATION PRODUCING EQUIPEMNT

13.1 INTRODUCTION

Radiation producing equipment are devices that generate ionizing radiation for medical (diagnostic or therapeutic) or research purposes. The medical equipment includes medical X-ray machines, dental X-ray machines, etc., while the analytical equipment includes X-ray diffraction, electron microscope, etc. All the equipment is regulated by the District of Columbia's Department of Health (DC Health), Radiation Protection Division. The principal investigator (PI) possessing the machine is responsible for the registration of the device with DC Health. The registration shall be done through Office of Radiation Safety. The installation and operation of all equipment must be inspected periodically and approved by the RSO.

13.2 ANALYTICAL X-RAY EQUIPMENT

Analytical X-ray equipment is equipment used for X-ray diffraction or fluorescence analysis. Analytical X-ray systems are a group of components utilizing X-rays or gamma-rays to determine the elemental composition or to examine the microstructure of materials. Hence, analytical equipment used for research purposes at Howard University, which include X-ray diffraction units, spectrographic equipment, fluoroscopy, radiography, electron microscope (e.g. scanning electron microscope (SEM), Transmission electron microscopy (TEM), others), electron spectroscopy for chemical Analysis Systems (ESCA), cabinet X-ray equipment, medical radiograph and fluoroscope systems, X-ray photoelectron spectroscopy systems (XPS), X-ray vacuum spectroscopy systems, as well as any X-ray producing devices used for research purposes. For analytical X-ray equipment, a very narrow collimated X-ray beam of high intensity is used; hence exposure of primary X-ray beam to the skin or eyes may result in severe radiation burns in a matter of seconds. These burns heal poorly, and on rare occasions have required amputation of fingers.

The potential sources of radiation exposures from analytical X-ray equipment may include:

- Exposure to an intense, localized primary X-ray beam
- Exposure to diffracted and/or scattered portions of the primary X-ray beam
- Exposure to X-ray leakage from the X-ray tube/tube housing

13.2.1 Purchase and Installation of Analytical X-ray Equipment

All purchases of radiation-generating equipment and all changes in such equipment must be approved by a Radiation Safety Officer in advance. For such equipment, the Radiation Safety Officer will, prior to installation, determine if and how much shielding is required prior to putting the equipment into service.

13.2.2 Registration of Analytical X-ray Equipment

All analytical X-ray equipment must be registered with D.C. Health, and a copy of the registration certificate must be submitted to Radiation Safety Office (RSO) including description of the machine and its proposed use, standard operating procedure (SOP), training requirements for workers and

students under the PI and other information deemed necessary by the RSO. It is the responsibility of the individuals to contact DC Health to obtain registration of the equipment.

13.2.3 Authorization of Analytical X-ray Equipment

All analytical X-ray equipment at Howard University and Howard University Hospital (HU & HUH) must be approved by the Howard University Radiation Safety Committee (RSC) prior to procurement, receipt or use of analytical X-ray equipment at the University or Hospital. Contact the Radiation Safety Office for purchase request form. The RSO shall ensure that the equipment is installed properly in accordance with the requirements established by the DC Health regulations and the radiation safety rules, and that safe operation and emergency procedures are posted conspicuously near the X-ray equipment prior to its use.

13.2.4 Training Requirement

It is the responsibility of authorized user/PI to ensure that all users (workers and their respective students) have received training on proper operation and emergency procedures of the analytical X-ray equipment. All users must also attend a radiation safety training course prior to the use of X-ray equipment. Contact the Radiation Safety Office for training information.

No individual shall be permitted to operate or maintain analytical X-ray equipment unless he/she has received instruction in and demonstrated competence as to:

1. Theory of operations;
2. Normal and emergency operating procedures;
3. Function of installed safety devices such as interlocks;
4. Requirements for personal protective equipment and radiation dosimeters, if applicable;
5. Any routine maintenance suggested or required by the manufacturer.
6. Identification of radiation hazards associated with the use of the equipment;
7. Significance of the various radiation warning, safety devices, and interlocks incorporated into the equipment, or the reasons they have not been installed on certain pieces of equipment and the extra precautions required in such cases;
8. Recognition of symptoms of an acute localized exposure; and
9. Proper procedures for reporting an actual or suspected exposure incidence.

13.2.5 Labeling

The Authorized User must ensure that each analytical X-ray equipment is labeled in a visible way to caution individuals that radiation is produced when unit is energized. The label must be affixed in a noticeable place on the front of the control unit, with a sign such as "**CAUTION: X-RAY EQUIPMENT**," or words having a similar intent.

13.2.6 Machine Security

Analytical X-ray equipment must be secured from unauthorized removal. Devices and administrative protocols must be used to prevent unauthorized use. Moveable or hand-held analytical X-ray equipment must be kept in a secured (locked) room to prevent unauthorized removal.

13.2.7 Equipment Safety Requirement

a) **Ports**
All unused ports must be securely closed to prevent accidental opening.

b) **Interlocks**
All interlocks must be well-designed and in operation for X-ray production. Bypassing must only be done by the designated responsible operator and only during alignments and equipment changes as required.

c) **Alignments**
Alignments must be performed at minimal settings and only by specially trained personnel.

d) **Maintenance**
Equipment maintenance must be done by trained qualified persons and at the manufacturer's recommended time intervals.

e) **Warning Lights**
The analytical X-ray device warning lights must have fail-safe characteristics.

f) **Beam Stops**
The X-ray beam must be terminated within the enclosure at all times.

g) **Shutters**
In an open-beam configuration, each port on the radiation source housing must be equipped with a shutter that cannot be opened unless a collimator or a coupling has been connected to the port.

h) **Tube Housing**
The X-ray tube housing (radiation source housing) must be equipped with an interlock that shuts off the tube in case it is removed from the radiation source housing or if the housing is stripped.

i) **Generator cabinet**
The X-ray generator must have a protective cabinet that limits leakage radiation, such that the measured dose does not exceed 0.5 mrem/hour at a distance of 5 centimeters from its surface.

13.2.8 Radiation Protection Principles

Analytical X-ray users must minimize their exposures to radiation As Low As Reasonably Achievable (ALARA), by following the safety principles:

- **Time** -The shorter the time spent around an X-ray source, less the radiation dose.
- **Distance** - Radiation exposure decreases considerably with an increase of distance (one of the easiest and most effective radiation protection technique).
- **Shielding** - Lead shielding must be used to reduce radiation levels to less than 2 mR/hr.

13.2.9 Area Requirements

1. The room where an analytical x-ray machine or system is located must be labeled. The analytical X-ray unit must be labeled.
2. Adequate shielding must be such that no radiation levels outside or surrounding the local component group does not exceed regulatory dose limits for uncontrolled area.

3. Radiation surveys must be done in the room and around the analytical X-ray equipment to assure compliance upon:

    a) Installation of the equipment
    b) Any change in the initial arrangement, number, or type of local components in the system
    c) Any maintenance requires the disassembly or removal of a local component in the system
    d) Maintenance and alignment procedures
    e) Visual inspection of the local components reveals an abnormal condition
    f) Personnel monitoring devices indicate a significant increase from the previous monitoring period or the readings approaching the radiation dose limits.

13.2.10 Operating Requirements

1. Operating and safety procedures must be written and available to all machine operators.
2. Never operate analytical X-ray equipment in any manner other than that specified in the procedures, unless you have obtained written approval of the RSO.
3. Never bypass a safety device unless such person has obtained the approval of the RSO.

13.2.11 Responsibility of Authorized Users

The Principal Investigator or Authorized User (AU) must ensure that the analytical X-ray equipment meets all applicable radiation safety standards. The PI or AU must:

1. Ensure that all users (associated workers and students) have received training on proper operation and X-ray hazards fitting to the X-ray equipment installed.
2. Ensure that radiation safety rules, safe operating, and emergency procedures are posted conspicuously near the analytical X-ray equipment.
3. Make readily available a copy of manufacturer's manual of the equipment for reference by users and maintenance personnel.
4. Make plans for verification, supervision and periodic review to ensure that all users have received adequate training and understood the relevant radiation safety rules, safe operating and emergency procedures before using the X-ray equipment.
5. Establish maintenance program, considering the age and frequency of use that ensures all safety devices and components, critical to both X-ray production and shielding, are routinely checked and defective parts replaced or repaired.
6. Have an appropriate survey meter and ensure that it always functions properly.
7. Report all radiation overexposures and accidents and submit appropriate reports to Radiation Safety Office.

13.2.12 Responsibilities of Workers

All users (workers and students) using analytical X-ray equipment must:

1. Receive approval, and training on the operation and X-ray hazards relevant to the specific analytical X-ray equipment intended for use.

2. Read, understand and follow all applicable radiation safety rules and emergency procedures before operating the analytical X-ray equipment.
3. Wear personal radiation monitors approved by RSO.
4. Review his/her own personal dosimetry report and identify unexpected radiation exposures, explore the root cause(s) and implement suitable corrective plan(s).
5. Survey critical areas (e.g., tube housing, beam ports, shutters, analysis accessories, etc.) of the equipment during set up and beam alignment procedures, and following modifications and alterations to the device or its accessories, and to ensure compliance with the dose limit (0.5 mR/hr at 5.0 cm from any external surface).
6. Stop working with the X-ray equipment if any unsafe operating conditions arise and notify the PI or designee of such conditions immediately.

13.2.13 Personal Monitoring

Finger (ring), and body (film badge) dosimeters shall be provided by RSO to all users. Users must wear them while:

1. Using analytical X-ray equipment with an open-beam configuration and not equipped with a safety device; and
2. Maintaining analytical X-ray equipment; if the maintenance procedures require the presence of a primary X-ray beam when any local component in the analytical X-ray system is disassembled or removed.

13.3 ELECTRON MICROSCOPES

The electron microscope uses the wave characteristics of electrons that have been accelerated by an electric field to visualize the microscopic structure of material. Electron microscopes must be registered with DC Health. All persons using electron microscopes must attend the radiation safety training specific to this type of equipment. The original unit design must not be modified unless permitted by the RSO with the approval from the DOH.

Electron microscopes emit a low amount of radiation, and therefore, personnel dosimetry is not required during routine procedures use unless specified otherwise by RSO. However, precautions and requirements list for analytical X-ray machines, and ALARA principle, limiting time near the unit, switching off the unit when not in use, should be followed while operating electron microscopes to minimize personal dose.

13.3.1 Radiation Survey of Electron Microscopes

Radiation protection survey shall be performed to ensure that the X-ray exposure rate dose does not exceed 0.5 mR/hr at 5 cm form all external points of the microscope, including column, high voltage cable, high voltage tank, console (top, sides, and beneath), and power supply cabinet. Particular attention shall be paid to the areas immediately opposite the operator (the viewing chamber and the pot chamber). The radiation survey shall be done annually to ensure safe operation of the unit as well as the users.

13.4 MEDICAL X-RAY EQUIPMENT

On an annual basis, equipment performance testing muat be conducted on all portable X-ray units, Cysto unit, C-arms, Cardiac Cath lab units and diagnostic X-ray tubes to conform with requirements of Federal and District of Columbia Health regulations, as well as recommendations from the Joint Commission. The Radiation Safety Office at Howard University controls and supervises the safety and guidance of all X-ray equipment used at the Howard University Hospital and College of Dentistry for healing arts, research, and educational activities involving X-ray equipment. This includes all medical, dental and teletherapy (e.g., linear accelerators) X-ray machines, and all other X-ray machines used at the Howard University Hospital.

13.4.1 Machine Security and Access Restriction

All the X-ray equipment must be secured from unauthorized removal. Special devices and/or administrative measures must be used to prevent unauthorized use of radiation producing machines. Mobile X-ray machines must be kept in a secured room after use to prevent unauthorized removal. During exposure, no person other than the operator, ancillary personnel, and patient shall be in the X-ray room or area unless that individual's assistance is required. Mechanical supporting or restraining devices must be used when a patient or image receptor must be held in a position during radiography. If a patient or image receptor must be held by an individual during an exposure, that individual must be protected with appropriate shielding devices and protective equipment. Windows, mirrors, closed circuit television, or provisions should be made for the operator to constantly observe the patient during irradiation, as well as be able to maintain verbal, visual, and aural contact with the patient.

13.4.2 Shielding

Shielding is required in an area where an X-ray machine is installed to ensure that machine operators, staff, patients, and members of the general public are not unnecessarily exposed to radiation and are kept below their respective legal dose limits. The purpose is to adequately shield the X-ray beams and scattered radiation produced by the X-ray machines. Shielding requirements are determined by this potential exposure to humans and must take into consideration occupancy factors, distance, workload, energy, and direction of the primary beam, and other related factors. The area of concern may be the employee work area, the employee lounge area or an area that the public has access to such as a waiting room or a sidewalk.

Additional protective devices should be available in fluoroscopy and interventional radiology rooms which include ceiling suspended protective screens, protective lead curtains mounted on the patient table, protective lead curtains for the operator if the X-ray tube is placed in an over couch geometry and if the radiologist must stand near the patient.

13.4.4 Warning Lights

A clear visible warning light labeled with the words "**X-RAY ON**," or words having a similar intent, must be located outside (e.g. upper door post) or in front of any room that have an X-ray machine and shall be illuminated only when the machine is in use or operation. The X-ray machine warning lights must have fail-safe characteristics.

13.4.5 Authorized User

Only persons authorized and who have received radiation safety training from the RSO shall operate any radiation producing machine. The operator must have training and certifications deemed necessary for the specific machine operation. A resident or fellow must work under the supervision of a certified supervisor operator.

13.4.6 Written Operation and Safety Procedures

In addition to the X-ray machine's user guidelines, all departments using X-ray machines must have written operating and safety procedures, which include a list of circumstances in which mechanical holding devices cannot be routinely utilized; and a procedure for selecting an individual to hold or support the patient or image receptor. The written operating and safety procedures must adhere to DC Health regulatory standards.

13.4.7 Monitoring and Exposure Assessment

All workers, and other frequent users of X-ray systems who are usually exposed to radiation in controlled areas, such as radiologists, medical physicists, radiographers, nurses, endoscopists, anesthetists, cardiologists, surgeons etc., as well as ancillary workers who work in controlled areas, shall be monitored. All radiation workers must be assigned personal dosimeter(s) accordingly.

13.4.8 Safety Guidelines for Medical X-ray Machine Workers

All users (operators and other workers) of X-ray equipment must:

1. Receive job specific training, and radiation safety training prior to operating or working with radiation producing equipment.
2. Read, understand and follow all applicable radiation safety rules and emergency procedures before working at radiation producing equipment area.
3. Wear personal radiation monitors approved by RSO.
4. Wear protective equipment which includes lead aprons, thyroid protectors, protective eyewear and gloves.
5. Review their own personal dosimetry report and identify unexpected radiation exposures, explore the root cause(s) and implement suitable corrective plan(s).
6. Use appropriate shielding if present in the room when the X-ray machine is "ON".
7. Stop working with X-ray equipment if any unsafe operating conditions arise and notify your supervisor or department chair or designee of such conditions immediately.

13.4.9 Machine Relocation, Disposal or Transfer

Notify DC Health via RSO prior to relocation, disposal, or transfer of ownership of X-ray machines (medical x-rays, dental x-ray and analytical x-ray which includes an electron microscope). Relocation includes moving equipment to a different room within the same building. The Radiation Safety Office shall ensure records are kept in accordance with the state regulations.

Notifications

- Notify the RSO if X-ray unit or tube is moved or modified before resuming the machine usage.
- Notify the RSO if new X-ray equipment is installations before use.
- Notify the RSO if X-ray equipment is removed from the University, becomes inoperable for a long period of time, or is placed into long-term storage.
- Report any real or suspected radiation exposure to supervisor and Radiation Safety Office.
- In case of a medical emergency, call 911 immediately.

13.4.10 Quality Assurance

Departments or divisions conducting medical imaging procedures using radiation-generating equipment or radioactive materials or using radiation-generating equipment or radioactive materials for therapeutic purposes shall adopt written quality assurance procedures in accordance with the requirements of applicable DC Health and U.S. NRC regulations.

The goal of these procedures is to ensure the equipment provides quality images and to ensure radiation doses to patients and staff are maintained at ALARA levels at all times. Testing and inspections required by these procedures shall be overseen by the Radiation Safety Officer. Quality assurance programs must be conducted at intervals not to exceed 12 months by an authorized medical physicist.

A Radiation Safety Officer or his/her designee must ensure that the individuals who conduct the audit prepare and deliver a report that contains an assessment of the effectiveness if the quality assurance program and makes recommendations for any needed modifications or improvements.

A Radiation Safety Officer or his/her designee must promptly review the audit findings, address the need for modifications or improvements, and document actions taken. If recommendations are not acted on, documentation of the underlying reasons and any alternative actions taken to address the audit findings must be drafted and maintained.

Chapter - 14

RADIOACTIVE MATERIALS IN ANIMAL RESEARCH

14.1 INTRODUCTION

The use of radioactive materials (RAM) in animals for research purposes or for any study at Howard University must be approved by the Radiation Safety Committee (RSC) before commencing any work. Any work involving radioactive material in animals must be done by or under the direct supervision of an approved Authorized User. The animal housing/cage/area must also be approved by Radiation Safety Officer. The care and management of the radioactive animals are the responsibility of the Principal Investigator and his/her research group. However, there are additional precautions required when animals with RAM are to be returned to an animal facility.

14.2 TRAINING

All persons providing animal care to animals with radioactive materials shall be trained in the appropriate protective measures required for safe use of radioisotopes. Training includes the following subject areas:

1. Principles and practices of radiation protection
2. Biological effects of radiation
3. Measurements and monitoring of radioactivity
4. Knowledge of Howard University policies and procedures for controlling radioactive materials
5. Procedures and concerns specifically for the animal research project.

14.3 POSTING OF SIGNS AND LABELS

Radiation signs and symbols must be posted in a visible location on the cage/room/area/facility. The signs must remain on the cage until the animal has been removed and the cage has been decontaminated. Personnel providing care to animals with radioactive materials must be informed of the significance of various radiation warning signs and labels. They must also be instructed to follow all written precautionary measures as indicated on such signs. The Radiation Safety Officer shall inspect each cage/room/area/facility where animals injected with radioactive materials are housed to determine security precautions and suitability of warning labels. The entrance to these areas must be posted with a sign bearing the radiation caution symbol and the words, "**CAUTION – RADIOACTIVE MATERIALS**".

14.4 POSTMORTEM EXAMINATION (NECROPSY)

Necropsy of animals containing radionuclides can present both contamination and irradiation hazards. The experimental protocol, procedures for radiation protection, sample collection, and waste disposal procedures must be discussed with the Radiation Safety Officer prior to implementation of the animal studies.

14.5 RESPONSIBILITIES OF AUTHORIZED USER

The Authorized User is responsible for ensuring:

1. Animal rooms or cages are properly labeled to indicate the use of radioactive materials in that location.
2. Animal care personnel are properly trained in the use of radioactive materials.
3. Proper safety procedures are followed for the hazard(s) involved.
4. Radioactive animals are not moved to unauthorized facilities.
5. Suitable ventilation must be provided in the area where animals are administered radioactive materials that may be volatile (e.g., I-129, H-3 (airborne)).

14.6 GENERAL RADIATION SAFETY RULES

The risk of equipment and surface contamination using radioactive materials require extra caution by all individuals working in the area to prevent the release of radioactive materials and avoid unnecessary exposure. Personnel must adhere to standard laboratory safety policies and procedures. The following are general precautions that must be followed:

1. Wear lab coat (knee-length), impermeable gloves, and eye protection.
2. Wear personnel monitor (film badge, ring, etc.) while working with animals with RAM.
3. Personnel must not work with animals with RAM if there are open cuts or abrasions on their body (e.g., finger, hands, or arms).
4. Survey hands, shoes, and clothing for contamination using an appropriate survey instrument before leaving the working area.
5. Animals with RAM must be housed in cages or stalls separated from other animals without RAM.
6. The facilities, stalls, or cages are to be secured to prevent unauthorized access to the animals.
7. Do not eat, drink, apply cosmetics or smoke in areas designated for use of radioactive materials.
8. Appropriate contamination techniques should be followed in the work area regularly and consistently for contamination. Document carefully the wipe test results and meter readings.
9. Label and isolate radioactive waste and equipment.
10. Ensure that the equipment used for radioactive materials is not used for any other work removed from the area until it is cleaned (decontaminated) and surveyed to prove absence of radioactive material. Be aware of decontamination procedures.
11. All cages housing animals with RAM must be labeled with the sign - "**Caution, Radioactive Materials**".
12. Follow laboratory safety procedures and guidelines for RAM use to prevent or minimize spread of contamination.
13. Any animal excreta or litter that is radioactive must be treated as biological waste (biohazard).

14. Maintain accurate and legible records of radioactive materials used and methods for their disposal.
15. All surfaces - benches, cabinets, counter-tops, and shelves in animal cages must be lined with absorbent paper/ chucks or a protective layer.
16. Report all incidents involving radioactive materials to the Radiation Safety Office.

14.7 GENERAL RADIATION SAFETY RULES FOR ANIMAL CARE WORKERS

To minimize and protect animal care workers against ingestion, inhalation, or absorption of radioisotopes, the following rules must be observed:

1. Wear protective clothing (lab coats, cover-gowns, etc.), gloves, and eye protection gear.
2. Protective dust masks must be worn when dealing with radioactive animal bedding.
3. Wear personnel monitor (film badge, ring, etc.) while working with animals with RAM.
4. Personnel must not work with animal with RAM if there are open cuts or abrasions on their body (e.g., finger, hands, or arms).
5. Never store food nor beverages in the same storage location (refrigerator, freezer, etc.) as the radioactive materials.
6. Eating, drinking, smoking, food preparation, food storage, and application of cosmetics is strictly prohibited in laboratories or facilities where radioactive materials are used or stored.
7. Monitor hands, feet, and clothing after working with animals with RAM.

14.8 SAFETY GUIDELINES FOR ANIMALS WITH RADIOACTIVE SEALED SOURCES

For any procedure involving the use of sealed sources in animals, the authorized user must:

1. Retain source inventory of the account for all sealed sources (records shall demonstrate at least each time the animal(s) are moved from one cage/room/area/facility to another while the sources are still in the animal).
2. Perform survey in rooms where the animal is housed regularly as deemed by RSO.
3. Perform surveys to ensure that radiation exposure level in all adjacent areas are within legal limits, less than 100 mrem/yr and 2 mrem/hr.
4. Each cage housing animal with RAM must be labeled as follows:
   a. "**Caution - Radioactive Materials**" Label.
   b. Radioisotope amount implanted, and the date Implanted.
   c. Name and phone number of authorized users.
5. Animal wastes must be surveyed before disposal or stored appropriately (hold the waste) until the end of the experiment when all sources are accounted for. Survey all other materials before removal from the animal housing area.
6. Animal must be surveyed after the sources have been removed.

7. Ensure that all personnel working with or caring for animals have received required Radiation Safety training (emphasis on animal use).
8. When any animal is moved to a different authorized cage/room/area/facility, survey the vacant cage/room/area/facility to confirm that no sources are left behind.
9. The animals must be retained or marked until the sources are tested for leakage. If the sources are found leaking, the animal must remain marked and must be disposed of through Radiation Safety Office upon death or sacrifice.

14.9 SAFETY GUIDELINES FOR ANIMALS WITH RADIOACTIVE UNSEALED SOURCES

Radiation safety guidelines for work involving radioactive material (RAM) in animals other than sealed sources are:

1. Perform radiation survey (wipe test and meter survey) after high energy beta or gamma emitters are administered in rooms where the animal is housed to ensure the exposure levels for appropriate labeling of the room.
2. After high energy beta or gamma emitter is administered, perform surveys to ensure that radiation exposure level in all adjacent areas is within the legal limits (less than 100 mrem/yr and 2 mrem/hr).
3. Each cage housing animal with RAM must be labeled as follows:
   a. "Caution - Radioactive Materials" Label
   b. Radioisotope amount implanted, and the date Implanted.
   c. Name and phone number of authorized users.
4. All animal waste, urine, feces, blood contaminated beddings must be treated and handled as contaminated until surveys show otherwise.
5. Ensure that all personnel working with or caring for animals have received required training.
6. When any animal is moved to a different authorized cage/room/area/facility, survey the vacant cage/room/area/facility to ensure that the room is not contaminated.
7. Any animal with RAM must be marked and must be disposed of through Radiation Safety Office upon death or sacrifice.

14.10 RELEASE CRITERIA

Any animals injected with radioactive material must not be released to unrestricted areas before an evaluation of the public dose due to the animals retained radioactive material has been performed. The release criteria are based on the allowable dose to members of the public due to the exposure from the animal(s). The criteria for release of animal with RAM is that the radiation exposure level at the distance of one (01) foot must be within legal limits or less than 100 mrem/yr, and 2 mrem/hr. (uncontrolled area). All cages must be monitored for radioactive contamination after the animals are removed and decontaminated using the criteria above.

The authorized user must provide detailed instructions to the animal's caretaker regarding the methods to keep doses ALARA. An additional assessment must be performed based on the impact of

the byproduct material on the environment as this assessment may be required. All procedures involving animals injected with radioactive materials must be approved by the Radiation Safety Officer.

Responsibilities of the Principal Investigator before Release of Animals

Before any animal with RAM is returned to an animal facility, the PI is responsible for:

1. Posting the room where the animals are housed
2. Providing information about the administered materials
3. Performing the required periodic radiation surveys
4. Properly handling and disposing of radioactive material waste, e.g., contaminated bedding
5. Providing husbandry for the animal(s) until the exposure rate is less than 1 mrem/hr at 1 foot from the cage(s).
6. Each cage housing animal with RAM must be labeled as follows:
   a. Animal name
   b. Radionuclide, activity and half–life
   c. Injection Date
   d. Measure and record exposure rate at 1 foot from the cage, ensuring the exposure does not exceed 1 mrem/hr.
7. Date anticipated to be free from radioactivity, if applicable
8. Research contact person and telephone number
9. Date anticipated for routine care by animal facility
10. Contact person's name and telephone number at the animal facility

14.11 GUIDELINES FOR X-RAY USE IN PROCEDURES INVOLVING ANIMALS

To ensure unnecessary exposure to X-rays, the operators and the animal caretakers assisting authorized users in radiographic procedures must follow the guidelines given below:

1. Personnel operating the X-ray machines must receive radiation safety training by RSO prior to operating them.
2. Only essential personnel must be permitted in the radiographic area during an exposure.
3. Protective clothing (e.g., lead aprons, leaded glasses, thyroid collars, etc.) must be worn by all personnel required to be in controlled radiographic areas while the machine is energized except:
   a. When ancillary personnel are wholly behind protective barriers.
   b. When a radiation protection survey indicates that the exposure rate in the occupied area is less than 5 mR per hour and the individuals are wearing personnel monitoring devices.
4. Personal monitoring devices (dosimeters) must be worn by all personnel performing and/or assisting in radiographic procedures.
5. Entrances to radiographic room(s) must be locked when performing X-ray exposures.

6. Never hold or support animals or film during X-ray exposures.
7. No part of a personnel's body should be exposed to the primary X-ray beam. Personnel must be adequately protected from scatter radiation.
8. Slings, sandbags, V-troughs, or other appropriate ancillary devices must be used to assist positioning animals for X-ray exposures.
9. If an animal must be held or positioned manually, the individual holding the animal must wear protective gloves, a protective apron, and must ensure all body parts remain out of the beam.

14.12 WASTE COLLECTIONS AND DISPOSAL

The Principal Investigator must make arrangements with the Radiation Safety Office for waste storage of any animal work (large or small scale) well in advance. Personnel involved with the handing of excreta, bedding or carcasses of animals used in radionuclide research projects must take specific precautions to control contamination from these types of waste and ensure the proper disposal. Waste from animal experiments must be clearly labeled with the radionuclide and the activity. Animal care personnel must place the waste in designated labeled containers and freezers and notify the Radiation Safety Office for pickup. Any excreta or litter that is radioactive must be disposed in the same manner as biological radioactive waste. Carcasses and tissues of animal with RAM must be frozen and stored in designated radioactive freezers until they are ready to be disposed of by RSO as 'solid radioactive waste' when the exposure level is less than or equal to the background. Additional details about the proper disposal of animals, bedding, food, and waste are discussed in **Appendix K**.

14.13 TRANSPORTATION OF RADIOACTIVE ANIMALS

Transporting animals with RAM from one building/facility to another must be done in a way to prevent any contamination of hallways, elevators, etc. The cage or the housing must have a solid bottom and must be such that animal excretes can be contained in case of transfer. Animals with RAM may not be transported across public streets or sidewalks without approval from the RSO. Contact Radiation Safety Office before any animal with RAM is transported and provide the following information for approval:

1. Authorized User - Sender of the animals
2. Recipient Authorized User
3. Recipient Location (room and building)
4. Radioisotope(s), activity (μCi or mCi)
5. Animal species & type of transport cage
6. Date & time of transfer

14.14 RULES FOR MINORS WORKING WITH RADIOACTIVE ANIMALS IN LABORATORIES AND FACILITIES

1. Follow University policy on minors as described in **Appendix F.**
2. Never work alone in any laboratory environment without direct supervision from the PI,
3. Always follow the instructions of the PI or laboratory supervisor.

4. Always report any accidents (regardless of severity) immediately to the PI or laboratory supervisor.
5. Always wear the personal protective equipment as directed and dispose of it appropriately. This personal protective equipment includes glasses, gloves, coats/gowns, and other face/body protection as dictated by the hazard being worked with or around.
6. Always keep your hands away from your face and wash them well with soap and water prior to leaving any laboratory area.
7. Never eat, drink, chew gum, apply lip balm, or touch contact lenses while in any laboratory environment.
8. Always wear closed-toe shoes while in any laboratory.
9. Always tie back long hair.
10. Always wear clothing that reduces the amount of exposed skin. Shorts and sandals are prohibited in the laboratory.
11. Always ask questions if you don't understand the safety requirements.

Chapter - 15

RADIATION INCIDENTS AND EMERGENCIES

15.1 DEFINITIONS

Incidents may occur while working with radioactive materials, such as spills, accidental releases into the air, contamination of the worker or the work area, and numerous other possible problems. When an incident occurs, the worker must first make a judgment as to whether the incident is a minor incident, major incident or an emergency. Subsequent actions are based on this decision.

A ***minor incident*** with radioactive materials is an abnormal occurrence involving low amounts of radioactive materials, where the worker handling the spill knows how to clean it up, has the decontamination materials on hand, and can respond without incurring risk of exposures or spread within a reasonably short time.

A ***major incident*** is an abnormal occurrence involving high amounts of radioactive materials, high risk nuclides, large area contamination, contamination of skin, airborne radioactivity, or any situation where contamination may have been spread outside the authorized area. Major spills must be reported to the Radiation Safety Officer immediately, as required by the federal law. Call the Radiation Safety Office (202) 806-7216 during working hours; dial 911 during non-working hours.

An ***emergency*** is an incident which involves serious injury or death, fire, explosion, or significant release of a health or life-threatening material, which may be coupled with a minor or major radiological incident. **DIAL 911 IMMEDIATELY IF AN EMERGENCY HAS OCCURRED!!**

15.2. HANDLING OF RADIATION INCIDENTS AND EMERGENCIES

In the event of a **MINOR** incident, following procedures must be observed:

1. Notify the principal investigator and persons in the area where the incident has occurred.
2. Contain the spill. Cover with absorbent paper or dike with absorbent.
3. Isolate the area to prevent unnecessary spread and personnel exposures.
4. Survey using the appropriate monitoring equipment to evaluate the presence of contamination on an individual's skin and clothing and on lab equipment. If skin or clothing are contaminated, a major spill has occurred. Contact the Radiation Safety Office immediately.
5. Using disposable gloves; carefully fold up the absorbent paper and pad and deposit them in an appropriate radioactive waste container.
6. Survey the area of the spill to determine the extent.
7. Decontaminate the spill using decontaminant detergent/solution and resurvey.
8. Continue step 7 until the area is decontaminated completely.
9. Document spill in radiation survey logbook.

In the event of a **MAJOR** incident, following procedures should be instituted:

1. Notify all persons in the area that a major spill or incident has occurred and evacuate unnecessary personnel. Notify the principal investigator.
2. If possible, prevent the spreading of the radioactive material by using absorbent paper. Do not attempt to clean it up. Confine all potentially contaminated individuals to prevent the further spread of contamination.
3. If possible, shield the source, but only if it can be done without significantly increasing your own radiation exposure.
4. Leave the affected room and lock the doors in order to prevent entry. Attempt to prevent further contamination or spreading to unrestricted areas. (Hallways, non-radiation laboratories, etc., are unrestricted areas.)
5. Contact the Radiation Safety Officer if the spill occurs during normal work hours. Call the Department of Police and Public Safety, 911, after normal working hours.
6. Remove all contaminated clothing and await instructions concerning cleanup from the Radiation Safety Officer.
7. If skin contamination has occurred, measure levels of contamination with a survey meter, record, and begin decontamination by gentle washing with warm water and soap, washing downwards towards extremities, not upwards.

In the event of an **EMERGENCY** in which radioactive materials are involved, the following procedure should be instituted:

1. Notify all people in the area that an **EMERGENCY** has occurred and evacuate the area if considerable risk to the people present exists.
2. Dial **911** and notify of the nature of emergency, using the reporting guidelines previously listed in this section.
3. **AWAIT THE EMERGENCY RESPONDERS** who will assist and provide direction, as well as contact any other necessary responders.

All incidents involving radioactive materials must be reported as soon as possible to the Principal Investigator and Radiation Safety Officer. If the Principal Investigator is not available, the Radiation Safety Officer will advise and assist with the problem.

15.3 REPORTING INFORMATION

Following are the reporting information necessary to evaluate and respond properly to an abnormal occurrence involving radioactive materials:

- Radionuclide involved
- Amount of radioactivity
- Chemical form of released material, other hazardous chemicals involved
- Volume or released material
- Location of incident (building and room number)
- Persons contaminated or exposed, estimate of amount (e.g., 2,000 CPM, ^{32}P, 10 cm^2 on skin of arm)

- Any injuries, their type and gravity
- Air borne radioactivity, present or not
- Steps taken so far
- Principal investigator's name
- Name of the person reporting the incident
- Telephone number where you can be reached

Some radiological incidents involve serious risk to life, health or property. In the event of serious injury coupled with an exposure to radiation, fire, explosion, major release of health-threatening materials or serious radiation exposure, an ambulance will be dispatched, and victims will be transported to a hospital for treatment. Upon arrival at the hospital, the victims(s) will be met by appropriate radiation safety personnel who will monitor their treatment and decontamination procedure.

15.4 DECONTAMINATION

When radioactive material is present in any unwanted or unplanned location, it is called contamination. This contamination may be on floors, equipment, work areas, storage areas, people or areas outside the authorized radiation using laboratory. Fortunately, most radioactive contamination and/or spills are easy to clean to background levels in a reasonable time and with reasonable cost. Some methods of decontamination are as follows:

1. **Liquid Radioactive Decontaminant:** Concentrated liquid decontaminating agents are available from general stores and most scientific suppliers. This detergent is diluted with water and rapidly and easily cleans radioactive contamination without excessive effort. Mild wiping or scrubbing will remove most contamination using this detergent. Note that these detergents contain a carcinogen, so the Material Safety Data Sheet should be read by new radiation users so that they are aware of the hazards. In dilute liquid form, radioactive decontaminants do not present a significant hazard to handlers unless ingested or splashed in eyes. Avoid prolonged skin contact with the concentrated material.
2. **Foam Spray Decontaminant:** A variety of foam spray decontamination products are available which are marketed as radioactive decontaminants. However, many other foam cleaning products accomplish decontamination just as effectively at a much lower cost; most of these are marketed in any store as bathroom or kitchen cleaning agents. Spray the foam on the contaminated areas, let it sit for a few minutes, and then wipe off with a dry paper towel.
3. **Other Decontaminating Agents:** Many other agents will work to clean radioactive contamination that has been resistant to the above methods. Contact the Radiation Safety Office for assistance with difficult to remove contamination. We will help identify a method of decontamination which will work effectively for your particular surface, nuclide, chemical form and location.

Contamination on Skin: Use lukewarm (not hot or cold) water and a mild cleaning agent, such as soap. Do not rub hard or scrub with abrasives, which may break the surface of the skin. Clean the affected area in a downwards fashion, with the grain of the skin and hair, not against it, and towards the tips of extremities, not upwards. Check the area after gentle drying. If still contaminated, use a cream hand cleaner which does not contain abrasives. Remember to notify the Radiation Safety Officer

immediately, if personnel contamination occurs or is suspected. Also, note the readings of radioactive contamination detected with the survey instrument and the times that it was discovered and then removed.

Chapter - 16

RADIOACTIVE WASTE MANAGEMENT

16.1 INTRODUCTION

Radioactive waste is the leftover from the use of radioactive materials for research, diagnosis and treatment of disease, and other purposes. In other words, it includes any waste that contains, or is contaminated with any radioactive material use. This includes liquids, solids, trash, animal carcasses and excreta, used scintillation counting vials, etc. Under no circumstances shall any radioactive waste be incinerated or placed in the conventional solid waste disposal system. Waste and trash which are not radioactive must never be mixed with radioactive waste.

The Radiation Safety Office supplies the solid and liquid waste containers to laboratories upon request. It is the responsibility of the laboratory to supply secondary containers, such as a plastic bus tray, to prevent the waste from leaking or contaminating the surfaces. Laboratories must supply their own shielding for waste that may cause external exposures to workers in the area. Bench top waste containers are considered part of the experiment, and must be labeled with the isotope, activity in dpm or μCi and the date. It is not necessary to attach a waste tag until the waste is placed in the permanent waste container.

In order to dispose of waste under the current regulatory constraints, it is necessary to segregate all radioisotopes from each other (except ^{3}H and ^{14}C), and to segregate chemically hazardous waste from other radioactive waste.

It is important that workers only place the waste which is contaminated with radioactive materials in the radioactive waste containers. This can be achieved by carefully monitoring potential radioactive waste with an appropriate survey meter prior to disposal. Since radioactive waste must be stored for some period of time prior to disposal, it is critical that the date(s) the waste was deposited in the container be mentioned; radioactive decay is one means of effectively managing and minimizing radioactive waste.

Due to the problems in radioactive waste management and legal requirements, no radioactive waste may be removed from the laboratory without complete information on the tag. Failure to thoroughly fill the radioactive waste manifest may result in suspension of permission to use radioactive materials.

16.2 WASTE SEGREGATION

Radioactive wastes generated at Howard University must be segregated into solids, liquids, or gases as per the protocol. Each laboratory generating radioactive liquid or solid waste must be equipped with at least one approved container for solid and one for liquid waste. However, long-lived radioisotopes must be separated from short-lived radioisotopes for better storage and disposal processes. All waste containers must be labeled with a standard "**CAUTION – RADIOACTIVE MATERIAL**" sign and a warning to housekeeping personnel indicating the container shall not be handled for any reason.

Solid Waste. It consists of all items contaminated with radioactive material (e.g., absorbent paper, gloves, etc.), which are not in liquid form. The container for solid waste must be fitted with a disposal

plastic liner and a securely fitting cover. The cover will prevent the waste from spilling out if the container tipped over. Carbon-14 and Tritium wastes are processed similarly and may be packaged together. Wastes from all other isotopes must be packaged separately. Since wastes containing lead, including lead "pigs" or containers, radioactive lead ores, are very difficult to dispose, they should be separated from solid waste generated.

Sharps and Broken glass. Sharps such as broken glassware, syringes, needles, pasteur pipette tips, sharps, blades etc. contaminated with radioactive materials must be separated from the solid waste. All sharp waste must be placed in a sharps waste container. All sharp objects (needles, glass, metal, etc.) must be protected so that they do not penetrate the container when being handled.

Liquid waste. All liquid waste must be placed in containers approved by the Office of Radiation Safety Office. This container shall be enclosed in a sealed five (05) gallon plastic bag.

Stock solution vials and sealed sources. Stock solution vials, all sealed sources for education, calibration and quality assurance (QA), exit signs, and other sealed sources due for disposal should not be mixed with solid waste. Contact Radiation Safety Office for their collection and safe disposal.

Liquid Scintillation Vials. Liquid scintillation vial (LSV) wastes must be separated from other wastes. LSV wastes must be segregated by cocktail type, that is, sewer disposable or organic hydrocarbon. All liquid scintillation vials containing liquid scintillation cocktail must be contained in a sealed five (05) gallon plastic bag. No more than one hundred vials should be packaged in each bag.

16.3 MIXED WASTE

Mixed waste such as mixed chemical-radioactive waste or mixed infectious-radioactive waste must be segregated, and properly stored according to the prescribed procedure. For mixed chemical-radioactive waste, store in a container made of material(s) compatible with the chemical(s) to be stored in it. A brief guideline for mixed waste is provided below:

16.3.1 Mixed Chemical-Radioactive Waste

1. Use container made of material(s) compatible with the chemical(s) for storage.
2. Attach a completed hazardous waste tag to the waste container. Include this information:
   a. All chemical constituents and their percentages.
   b. Concentrations of different chemicals in the waste (**NO** abbreviations or chemical formulas)
   c. Name and activity of the radioisotope in the waste
3. The container must be stored in the radioactive waste storage area of the lab.
4. For liquid waste, store in a secondary container.
5. Request waste collection when ready for a waste pick up.

16.3.2 Mixed Infectious-Radioactive Waste

1. Decontaminate infectious waste at the source of generation, when possible.
2. Keep infectious-radioactive waste separate from other wastes.
3. Store the waste applicably as waste categorized (dry, liquid, sharps, etc.).

4. Add absorbent material to the second bag, sufficient to absorb fluids which may leach from the waste.
5. Seal the outer bag and make sure it's free of contamination.
6. Attach a completed hazardous/radioactive waste tag to the container, including:
   a. List all hazardous constituents (chemical, infectious)
   b. Specify that the container or bag contains infectious waste and the decontamination method used.
   c. Name and activity of the radioisotope in the waste
7. Request waste collection when needed for a waste pickup.

16.4 WASTE INVENTORY

Prepare a written inventory of the radioactive materials contained in the waste. The inventory must list the date, radioisotope, chemical form and activity.

RADIOACTIVE WASTE SHALL NEVER BE STORED OR PLACED IN HALLWAYS OR OTHER PUBLIC AREAS

16.5 QUANTIFYING LEVELS OF RADIOACTIVITY IN WASTE

Radioactive and other hazardous materials must be completely mentioned in the waste manifest. In order to accurately list levels of radioactivity on the tags, it is necessary to assess the levels which are disposed in both liquid and solid waste. Some methods to quantify the waste are as follows:

1. During a given experiment, it is known that a certain quantity of radionuclide is used. At the end of each of several similar experiments, take a sample of liquid waste and count the activity with the appropriate counting equipment. The activity in the sample per unit volume is then multiplied by the total volume of the liquid waste generated. For the solid waste, the quantity of radioactivity in the liquid is subtracted from the total quantity used in the experiment, and the remainder is then the quantity in the solid waste.

   Example:

   - Total activity used in experiment: 500 µCi
   - Liquid Sample Volume: 1 mL
   - Total Liquid Waste Volume: 4000 mL
   - Activity in Liquid Waste Sample: 8×10^{-2} µCi/mL
   - Liquid Waste Total Activity: 8×10^{-2} µCi/mL × 4000 ml. = 320 µCi in liquid waste
   - Solid Waste Total Activity: 500 µCi - 320 µCi = 180 µCi in solid waste
2. After the first few experiments, or when the waste carboy is full, take a sample of the pooled liquid waste, and count it as above. Multiply the activity of the sample per unit volume by the total volume in the carboy to obtain the total activity in the carboy. Quantify the solid waste as above by subtracting the liquid waste activity.

16.6 RADIOACTIVE WASTE PICKUP

All authorized users/principal investigators or their designee should contact the Radiation Safety Office for waste "pick up" when needed. All radioactive waste generated must be kept in appropriate containers until request is made for "pick-up" and the integrity of the waste containers must be assured in accordance with the regulatory guidelines.

16.7 RADIOACTIVE WASTES DISPOSAL

For the disposal of radioactive waste including radioactive veils, liquid scintillation vials, used or unused radioactive materials, unusable items contaminated with radioactive material (e.g., absorbent paper, gloves, etc.), animal waste, liquid waste, and solid waste of all forms, contact the Radiation Safety office. There are specific procedures for the correct management and disposal of radioactive waste. All radioactive waste shall be separated from non-radioactive waste. Under no circumstances, it is permissible to dispose of any radioactive material into the non-radioactive trash or into any drains. The issue of radioactive waste disposal is very complex, not only due to the radioactive nature of the waste and its inherent disposal problems, but also the recent concerns with the chemical hazards associated with the same waste. Hence, it is possible to have mixed waste, which contains not only radioactive waste, but Resource Conservation and Recovery Act (RCRA) hazardous chemical waste. Liquid scintillation vials are an example, as toluene is hazardous under RCRA laws, due to flammability. As a result, radioactive waste must be properly manifested for the isotope and activity, and any other hazardous constituents, including chemical or bio-hazardous components.

Radioactive waste must be completely labeled at all times, from the time it is deposited into a container until the final disposal. Records of radioactive waste disposal must be maintained by the Radiation Safety Office for NRC review, so this labeling or "manifesting" is critical. Tags must be completely filled out at all times after any radioactive waste is placed in the container. (Note: The radiation warning label and certain other information on the tag must be present according to NRC regulations).

A brief outline of proper management of radioactive waste is provided in **Appendix K**.

Radioactive wastes disposal at Howard University are done as Follows:

A. ***Liquid Waste***- All liquid radioactive waste must be disposed in an approved sink by the Radiation Safety Office. Liquid radioactive waste may be disposal via the Radioactive Waste Disposal Facility located in Room B-101 of the Cancer Center. Records of all waste disposals must be maintained for inspection to comply with the U.S. NRC regulations, Procedure for estimating of radioactivity in Liquid Waste prior to sewage disposal is provided in **Appendix K**.

B. ***Liquid Scintillation Vials***- Ensure liquid scintillation vials (LSV) wastes are separated by cocktail type, that is, sewer disposable or organic hydrocarbon. Vials kept separate by size and type (e.g., plastic, glass, film). Sewer disposable LSV solutions may be kept in a sealed five (5) gallon plastic bag packaged in boxes for pick up. Organic hydrocarbon cocktails (e.g. toluene, xylene) must be kept in their original counting vials and packaged in boxes for pick up. Place a completed radioactive waste label on each box. Indicate the cocktail brand name and any biological or chemical hazard that might make sewer disposal inappropriate. Ensure radioactive waste disposal form is completed and contact the Radiation Safety Office for pickup.

C. ***Dry and Solid Waste***- All forms of solid radioactive material wastes, including sharps, stock solution vials, sealed sources, etc. which are segregated into "compactible" and "non-compactible solid wastes (e.g. of compactible solid waste are: paper, towels, gloves, rags, cardboard boxes, etc.), are collected and stored in the waste facility. Afterward they are given to vendor(s) for appropriate disposal. **ALL SOLID WASTE MUST BE EMPTIED OF ANY LIQUID.**

D. ***Radioactive Animal Cadavers and Wastes Disposal-*** All radioactive animal carcasses or radioactive animal wastes MUST be disposed of through Radiation Safety Office. Animal cadavers must be preserved in formaldehyde or formalin, drained of all liquids and sealed in five (5) gallon bags. Every effort should be made to de-aerate the bags before sealing. The guidelines for disposing of animal carcasses, tissues, or animal wastes which contain radioactive materials are provided in **Appendix K.**

E. ***Hospital/Patients-*** Wastes from a room of patient who have received radioactive material are classified as biological waste, which may undergo decomposition (e.g. patient food,). Radioactive patient waste, bed linen and clothing from hospital wards must be stored at Howard University Radioactive Waste facility.

A radioactive waste pick-up receipt tag must be affixed to each bag of waste showing the name of the authorized user, radioisotope, type of waste, date of disposal and approximate activity of the waste.

16.8 DECAY-IN-STORAGE OF RADIOACTIVE WASTE FACILITY

The Howard University holds only radioactive waste material with a physical half-life of less than 120 days for decay-in-storage (DIS) in storage facility before giving to vendors for disposal. All the radioactive waste from the Howard University and the Hospital (Nuclear medicine and Radiation Oncology) are stored in the radioactive waste facility. The Radiation Safety Office staff monitors the waste containers at the surface before disposal and determine that its radioactivity cannot be distinguished from the background level with an appropriate radiation detection survey meter set on its most sensitive scale and with no interposed shielding. Ensure that all radiation signage, labels, except for radiation labels on materials that are within containers, are removed or obliterated.

The Radioactive Waste Facility is located on:

W Street

Adjacent:

Radiation Safety Office
Howard University Hospital
Cancer Center, 3rd Floor, Room 323

APPENDIX A:

RADIOLOGICAL UNITS

RADIOLOGICAL UNITS

Quantity	Symbol	Unit	Symbol	Brief Description	Use
Activity	A	Curie	Ci	Equal to 3.7×10^{10} disintegrations per second (2.22×10^{12} DPM)	Special unit of activity
		Becquerel	Bq	1 disintegration per second	SI unit of activity
Exposure	X	Roentgen	R	The amount of radiation traveling through the air; 2.58×10^{-4} C/kg.	Applies only to gamma and x radiation
*Absorbed Dose	D	Rad	rad	0.01 J/kg (100 ergs/g)	Special dose unit; applies to any radiation
		Gray	Gy	1 J/kg	SI unit of dose (Equals 100 rad)
Dose Equivalent	H	Rem	rem	Rad dose x Q x any other modifying factors	Special unit of human dose equivalent
		Sievert	Sv	Gy x Q x any other modifying factors	SI unit of human dose equivalent (Equals 100 rem)
**Quality Factor	Q	***Rem/Rad	rem/rad	A measure of effect of radiation on tissue/organ related to type of radiation	To assess biological damage to the exposed tissue

*Absorbed Dose is simply referred to as "Dose"

**Quality factor, has now been replaced by "radiation weighting factor" W_R

***Quality factor, Q, has **no** unit, unit was added for simplicity

Table: Radiation Weighting factors (*ICRP Publication 103*)

Radiation type	w_R
Photons	1
Electrons and muons	1
Protons and charged pions	2
Alpha particles, fission fragments, heavy ions	20
Neutrons	A continuous function of neutron energy

Note: All values relate to the radiation incident on the body or, for internal radiation sources, emitted from the incorporated radionuclides

Table: Organ Dose Weighting factors (*ICRP Publication 103*)

Organ or tissue	**w_T**
Gonads	0.25
Breast	0.15
Red bone marrow	0.12
Lung	0.12
Thyroid	0.03
Bone surfaces	0.03
Remainder	[1]0.30
Whole Body	[2]1.00

[1] 0.30 results from 0.06 for each of 5 "remainder" organs (excluding the skin and the lens of the eye) that receive the highest doses.

[2] For the purpose of weighting the external whole body dose (for adding it to the internal dose), a single weighting factor, $w_T = 1.0$, has been specified. The use of other weighting factors for external exposure will be approved on a case-by-case basis until such time as specific guidance is issued.

Relationship between Special & SI Units

Activity:	1 Ci = 3.7 x 10^{10} Bq = 2.22 x 10^{12} dpm
Exposure:	1 R = 2.58 x 10^{-4} C/kg
	The special unit for exposure is the Roentgen. There is no SI unit for exposure; it is simply expressed in C/kg.
Dose:	100 rads = 1 Gy
Dose Equivalent:	100 rems = 1 Sv
KeV:	Kilo (1000) electron volts
MeV:	Mega (1,000,000) electron volts
	1 MeV = 1000 keV
	1 KeV = 0.001 MeV
	1 Ci = 3.7 x 10^{10} Bq = 37 GBq
	27 μCi = 1 x 10^{6} Bq = 1 MBq
	1 rad = 0.01 Gy = 10 mGy
	1 rem = 0.01 Sv = 10 mSv
	1mCi = 37MBq (most commonly used in radiation therapy industry)

APPENDIX B:

APPLICATION FOR BYPRODUCT MATERIALS USE AUTHORIZATION

FORMAT FOR THE SUBMISSION OF APPLICATIONS FOR BYPRODUCT MATERIAL AUTHORIZATION

This narrative should include items 1-5 listed below. If your request for the use of byproduct materials is based upon an application to a funding agency, that protocol must be submitted with this application in lieu of the following outline; however, item E **must** be addressed and **must not exceed five (5) pages.**

1. **Abstract of Research Plan** – Briefly summarize the objective of the research and the methods to be employed. Provide a short statement of the nature of the involvement in the use of radioisotopes.

2. **Biographical Sketch** – (not to exceed two (2) pages).

3. **Research Plan**
   a. *Specific Aims* – List the broad, long-term objectives and describe concisely and realistically what the specific research described in this application is intended to accomplish and any hypotheses to be tested.

   b. *Background and Significance* – Briefly sketch the background to the present proposal, critically evaluate existing knowledge and specifically identify the gaps, which the project is intended to fill. State concisely the importance of the research.

   c. *Preliminary Studies (if applicable)* – A report of the principal investigator's preliminary studies is recommended. Summarize the specific aims and provide a succinct amount of published and unpublished results indicating progress toward the achievement. Summarize the importance of the findings. Discuss any changes in the specific aims since the project was last reviewed competitively.

   d. *Research Design and Method* – Describe the research design and the procedures to be used to accomplish the specific aims of the project. Include the means by which the data will be collected, analyzed and interpreted. Describe any new methodology and its advantage over existing methodologies. Discuss the potential difficulties and limitations of the proposed procedures and alternative approaches to achieve the aims. Provide a tentative sequence or timetable for the investigation. Point out any procedures, situations or materials that may be hazardous to personnel and procedures to be exercised. Outline the proposed experiment and give the specific amount of isotope(s) to be used in each experiment.

   e. *Radiation Safety Aspects (should not exceed five [5] typewritten pages*)

      i. A diagram of laboratory area(s) must be attached, indicating dimension and room numbers. Drawing should be to scale. If more than one laboratory will be used, provide telephone numbers of each area, including the office. Describe the availability of hoods, sinks, storage areas and other areas that would ensure safe use of

      ii. radioisotopes.

      iii. Verification that a source of funds is available to purchase film badges.

iv. Complete the request for previous radiation exposure history form, if applicable.

v. Verification of the availability of a properly functioning survey meter and any other instruments to be used during research (include special shielding apparatus, etc.).

vi. Verification of compliance with radioactive waste disposal procedures.

vii. Describe procedures for handling volatile isotope(s) or procedures that would release airborne contamination in the atmosphere; list references.

viii. Briefly point out any procedures, situations or materials that may be hazardous to personnel and precautions.

ix. State the previous accomplishments involving the use of radioisotopes for which you are authorized at Howard University.

4. *Consultants/Collaborators (if applicable)* – List all consultants involved with the project. Attach appropriate letter from each individual confirming his or her role in the project. Also include a biographical sketch for each consultant and collaborator.

5. *Consortium/Contractual Arrangements (if applicable)* – Provide a detailed explanation of the programmatic, fiscal and administrative arrangements made between the applicant organization and the collaborating organization. Provide a statement that the applicant organization in the collaborating organization have established or are prepared to establish written inter-organizational agreements that will ensure compliance with all pertinent Federal, DC and University regulations and policies. Attach confirming letters countersigned by an authorized official of the collaborating institutions and authorized user or copies of written agreements.

6. *Literature Cited*- List literature citations at the end of the research plan. Each literature citation must include the title, names of all authors, book or journal, volume number, page number and year of publications.

7. *List of Radioisotopes in Human/Biohazards and/or Animals (if applicable)* – Material submitted to the respective risk committee may be submitted here for consideration.

8. For renewal applications, state the previous accomplishments involving the use of radioisotopes for which you are authorized at Howard University.

9. A completed Application for Material Authorization

PLEASE NOTE:
The maximum period for which an authorization will be granted for byproduct materials is three (3) years. In the event the research project is for a shorter period, the Radiation Safety Committee will grant the authorization for the projected period. The application must include the project period(s).

Application for Byproduct Material Authorization

The Radiation Safety Committee is scheduled to meet on the second Wednesday of each month. Applications must reach the Radiation Safety Office at least ten (10) working days prior to the Committee meeting.

APPLICATIONS ARE TO BE RETURNRED TO:
(One [1] original and three [3] copies)

Radiation Safety Office
Cancer Center, Room 323

Application for Byproduct Material Authorization

Please check one:

New Application Amendment Application Renewal Application Reactivation

Applicant (Proposed Authorized User):

Last Name First Name M.I.

Faculty Rank:

Department: **School/College:**

Telephone Numbers:

Office Laboratory

Email Address: **Fax Number:**

Title of Proposal:

Project Period:

Source of Funding (if applicable):

Signatures:

Signature of Applicant Date

Signature of Department Chair Date

Signature of Dean or Chief Medical Officer (HUH) Date

Application for Byproduct Material Authorization

INSTRUCTIONS:

Complete items 1 through 12. Use supplemental sheets where necessary. All applicants must complete item 8.

1. Name of Applicant (individual who will use or directly supervise the use of byproduct materials)

    a. Department.
    b. Location at which byproduct materials will be used (specify room number[s] and building).

    c. Telephone number(s), fax number and e-mail address.

2. Describe your formal experience in handling radioactive material, including locations, radioisotopes and amounts handled.

3. List the radiation safety courses you have attended.

Name of Course	Location/Institution	Month & Year

4. List other individuals who will be working with byproduct materials. Include formal radiation safety courses.

Support Staff	Name of Course	Location/Institution	Month & Year

Application for Byproduct Material Authorization

List byproduct material (element & mass number of each; chemical and/or physical form and maximum possession limit in mCi and mBq of each isotope listed).

Byproduct Material	Physical & Chemical Form	Maximum Possession Limit (mCi and mBq)

5. Attach four (4) copies of your research protocol(s) including this APPLICATION FOR BYPRODUCT MATERIAL AUTHORIZATION. This protocol should be prepared according to the document entitled, *"Format for the Submission of Application for Byproduct Material Authorization."*

   **If your request is based upon an application to a funding agency, that protocol must be submitted with this application.*

6. List all radiation detection equipment (i.e., liquid scintillation counters, survey meters, etc.). Include type of instrument, make, model number, radiation detection, use and location.

Instrument	Make	Model	Radiation Detection	Used For	Location

7. Describe laboratory facilities, storage containers, shielding, fume hoods, etc. Attach a sketch of the laboratory.

8. Describe the experimental procedures that will be utilized with the requested isotope(s). Emphasize aspects that pertain to safety issues. Add additional pages if necessary.

9. What amount of radioactivity will be used in a typical experiment?
   What is the frequency of experiments?

10. Describe the types of waste that will be generated in this research, including physical and chemical forms. List any other hazardous constituents, such as hazardous, chemical, biological hazards, etc. Identify the amounts, volumes and rates of disposal of waste.

11. Please describe any special hazards associated with the use(s) of radioactive materials requested in this application. (**THIS ITEM MUST BE ADDRESSED**)

Application for Byproduct Material Authorization

Did you complete the following items on your application?

- ☐ Signature of Applicant, Department Chair, Dean or Chief Medical Officer (if applicable) on cover sheet of application.
- ☐ Items 1-13 of Application
  - ☐ List names of all staff working with radioisotopes (Item 4)
  - ☐ Specifically state the possession limit for each isotope regardless of compound form (Item 5)
  - ☐ Sketch of laboratory must be included (Item 8)
  - ☐ Experimental procedures are to be written, not referenced per published article (Item 9)
  - ☐ Item 12 must be answered in writing. It must be indicated whether or not the radioactive waste is a biological hazard that would require special handling by the Office of Radiation Safety personnel.

Application Format

- ☐ Research Plan (Items 3a-3d)
- ☐ Research Plan/Radiation Safety Aspects (Items 3e {i-vii})
- ☐ Research Plan (Items 4-9)
- ☐ Does the research plan involve the use of radioactive materials in animals?
  - ☐ No
  - ☐ Yes
    - If yes, it is required to attach the approval from the Institutional Animal Care and Use Committee.
- ☐ Does the research plan involve the use of radioactive materials administered to humans?
  - ☐ No
  - ☐ Yes
- ☐ Does the research plan involve biohazardous conditions requiring approval of a risk committee?
  - ☐ No
  - ☐ Yes

CERTIFICATION

This application and any official executing this certificate on behalf of the applicant named in item 1, certifies that this application is prepared in conformity with Title 10, Code of Federal Regulations, Part 30 and that all information herein, including any supplements attached here to, is true and correct to the best of our knowledge and belief.

_____ _____

Applicant Date

_____ _____

Department Chair Date

APPENDIX C:

COMMON RADIONUCLIDES USED IN BIOMEDICAL RESEARCH

Hydrogen - 3
[^{3}H]

PHYSICAL DATA

- Beta Energy: 18.6 keV (maximum)
  5.7 keV (average) (100% abundance)
- Physical Half-Life: 12.3 years
- Biological Half-Life: 10 - 12 days
- Effective Half-Life: 10 - 12 days *
  * Forcing liquids to tolerance (3-4 liters/day) will reduce effective half-life of ^{3}H by a factor of 2 or 3. (Relatively easy to flush out of system with fluids.)
- Specific Activity: 9640 Ci/gram
- Maximum Beta Range in Air: 6 mm = 0.6 cm = 1/4"
- Maximum Beta Range in Water: 0.006 mm = 0.0006 cm = 3/10,000"
- Penetrability in Matter or Tissue: Insignificant*
  *0% of beta particle energy transmitted through dead layer of skin

RADIOLOGICAL DATA

- Least radiotoxic of all radionuclides
- Critical Organ: Body Water or Tissue
- Routes of Intake: Ingestion, Inhalation, Puncture, Wound, Skin Contamination (Absorption)
- External exposure from weak ^{3}H beta energy - not a radiological concern
- Internal exposure & contamination are primary radiological concerns
- Committed Dose Equivalent (CDE): 64 mrem/mCi (ingested)
  64 mrem/mCi (inhaled)
  64 mrem/mCi (puncture)
- Committed Effective Dose Equivalent (CEDE): 90 mrem/mCi (ingested)
  63 mrem/mCi (inhaled)
- Annual Limit on Intake (ALI)*: 80 mCi (ingestion or inhalation) [$^{3}H_2O$]
  * [1.0 ALI = 80 mCi (^{3}H) = 5,000 mrem CEDE]
- Skin Contamination Exposure Rate: 57,900 mrad/hr./mCi (contact)*
  * Exposure rate to dead layer of skin only
  * Skin contamination of 1.0 μCi/cm^2 = 0 mrad/hr dose rate to basal cells
- Rule of Thumb: 0.001 μCi/ml of ^{3}H in urine sample is indicative of a total integrated whole-body dose of approximately 10 mrem (average person) if no treatment is instituted (i.e., flush with fluids) [NCRP-65, 1980]

SHIELDING

• None required

SURVEY INSTRUMENTATION

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

RADIATION MONITORING DOSIMETERS

• Whole Body Badge or Finger Rings: Not needed (beta energy too low)

RADIOACTIVE WASTE

• Solid, liquids, scintillation vials, pathological materials, animal carcasses

REGULATORY COMPLIANCE INFORMATION

• Derived Air Concentration (DAC): 2.0×10^{-5} µCi/cc (occupational)

• Airborne Effluent Release Limit: 1.0×10^{-7} µCi/cc *

***** Applicable to assessment & control of dose to the public (10 CFR 20.1302). If this concentration was inhaled continuously for over one year, the resulting TEDE would be 50 mrem.

• Controlled Area Removable Contamination Limit: 2,200 dpm/100 cm^2

• Urinalysis (Byproduct License): Required when handling $\geq$100 mCi ^{3}H

GENERAL RADIOLOGICAL SAFETY INFORMATION

• Inherent Volatility (at STP): Substantial

• Experimental uses include total body water measurements & in-vivo labeling of proliferatory cells by injection of tritium-labeled compounds (i.e., thymidine). Tritium labeling is also used in a variety of metabolic studies.

• Oxidation of ^{3}H gas in air is usually slow (< 1% per day).

• Absorption of ^{3}H inhaled in air is much less when it is present as elemental ^{3}H than as tritiated water (HTO).

• Tritium penetrates the skin, lungs, and GI tract either as tritiated water or in the gaseous form.

• As gaseous hydrogen, ^{3}H entering the lung or GI tract is completely absorbed and rapidly dispersed within the body.

• Some ^{3}H is incorporated into cellular components and has a long turnover rate.

• Forcing fluids reduces integrated internal exposures from ^{3}H.

• Monitor for ^{3}H contamination using only wipe-testing (bench tops, floors, refrigerator/freezer handles, phone, etc.).

- Always wear a lab coat & disposable gloves when handling ^{3}H.
- Skin contamination, inhalation, ingestion, or absorption through the skin is assumed to be completely and instantaneously absorbed and rapidly mixed with total body water.
- The volume of total body water (standard man) is 42,000 ml.
- The concentration of ^{3}H in urine is assumed to be the same as in total body water.
- Detection limit of ^{3}H in urine: 1.08E-5 µCi/ml (approximately)
- For a continuous inhalation exposure at a rate of 1/365 of an ALI per day, the equilibrium concentration of ^{3}H in urine is 0.073 µCi/ml. [NOTE: 1/365 of 80 mCi (ALI) = 219 µCi]
- The predicted concentration activity normalized to unit intake from inhalation is 2.204×10^{-5} µCi/ml/µCi of ^{3}H.
- Beta dose rates from 1.0 mCi ^{3}H point source:

Distance (in cm)	**rad/hr**
0.25	10293.00
0.50	28.12
0.56	1.12

Carbon - 14
[^{14}C]

PHYSICAL DATA

- Beta Energy: 156 keV (maximum)
  49 keV (average) (100% abundance)
- Physical Half-Life: 5730 years
- Biological Half-Life: 12 days
- Effective Half-Life: 12 days (bound)
- Effective Half-Life: 40 days (unbound)
- Specific Activity: 4460 mCi/gram
- Maximum Beta Range in Air: 24.00 cm = 10 inches
- Maximum Beta Range in Water/Tissue: *0.28 mm = 0.012 inches
- Maximum Range in Plexiglas/Lucite/Plastic: 0.25 mm = 0.010 inches

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

RADIOLOGICAL DATA

- Critical Organ: Fat Tissue
- Routes of Intake: Ingestion, Inhalation, Skin Contact
- External exposure: Deep dose from weak ^{14}C beta particles is not a radiological concern
- Internal exposure & contamination: Primary radiological concerns
- Committed Dose Equivalent (CDE): (Fat Tissue)
  2.08 mrem/μCi (ingested)
  2.07 mrem/μCi (puncture)
  2.09 mrem/μCi (inhalation)
- Committed Effective Dose Equivalent (CEDE): 1.54 mrem/μCi (ingested)
- Annual Limit on Intake (ALI)*:
  2 mCi (ingestion of labeled organic compound)
  2000 mCi (inhalation of carbon monoxide)
  200 mCi (inhalation of carbon dioxide)

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

- Skin Contamination Dose Rate: 1090-1180 mrem per 1.0 μCi/cm^2 (7 mg/cm^2 depth)
- Dose Rate to Basal Cells from Skin Contamination, 1.0 μCi/cm^2 = 1400 mrad/hr
- Immersion in ^{14}C Contaminated Air = 2.183E7 mrem/year per μCi/cm^3 at 70 um depth of tissue and 4.07×10^6 mrem/year per μCi/cm^3 value averaged over dermis.

SHIELDING: None required (≤3 mm Plexiglas)

SURVEY INSTRUMENTATION

- Can detect ^{14}C using a thin-window GM survey meter; survey meter probe **must** be at a close range (1 cm).
- GM survey meters have very low counting efficiency for ^{14}C (5%).
- Liquid scintillation counter (indirect counting) may be used to detect removable ^{14}C on wipes.

RADIATION MONITORING DOSIMETERS

- Not needed (beta energy too low)
- ^{14}C Beta Dose Rate: 6.32 rad/hr at 1.0 cm in air per 1.0 mCi ^{14}C
- Skin Contamination Dose Rate: 13.33 mrad/hr per µCi on skin
- Dose Rate from a 1 mCi isotropic point source of ^{14}C:

Distance (in cm)	rad/hr
1.0	1241.4
2.0	250.4
15.2	0.126
20.0	0.0046

GENERAL RADIOLOGICAL SAFETY INFORMATION

- Urinalysis: Not required; however, prudent after a ^{14}C radioactive spill or suspected intake.
- Inherent volatility (at STP): Not Significant.
- Possibility of organic ^{14}C compounds being absorbed through gloves.
- Care should be taken NOT to generate $^{14}CO_2$ gas which could be inhaled.
- Internal Dose is the concern: Skin contamination, ingestion, inhalation, and puncture.
- Always wear a lab coat and disposable gloves when working with ^{14}C.
- The concentration of carbon in adipose tissue, including the yellow marrow, is about three times the average whole-body concentration. No other organ or tissue of the body concentrates stable carbon to any significant extent.
- The fractional absorption of dietary carbon (uptake to blood) is usually in excess of 0.90.
- Three main classes of carbon compounds may be inhaled: organic compounds, gases (CO or CO_2), and aerosols of carbon containing compounds such as carbonates and carbides.

Organic Compounds

Most organic compounds are NOT very volatile under normal circumstances; the probability of these being inhaled as vapors is therefore small. In circumstances where such substances are inhaled, it would be prudent to assume that once they enter the respiratory system they are instantaneously and completely translocated to the systemic circulation without changing their chemical form.

Gases

The inhalation of CO and its retention in body tissues has been studied extensively. Since gas has a relatively low solubility in tissue water, doses due to absorbed gas in tissues are insignificant in comparison with doses due to the retention of CO bound to hemoglobin. CO_2 in the blood exists mainly as a bicarbonate.

Carbonates & Carbides

It is assumed that inhaled or ingested ^{14}C labeled compounds are instantaneously and uniformly distributed throughout all organs & tissues of the body where they are retained with a biological half-life of 12-40 days.

Phosphorus - 32
[^{32}P]

PHYSICAL DATA

• Beta energy:	1.709 MeV (maximum) 0.690 MeV (average, 100% abundance)
• Physical half-life:	14.3 days
• Biological half-life:	1155 days
• Effective half-life:	14.1 days (bone) / 13.5 days (whole body)
• Specific activity:	285,000 Ci/gm
• Maximum range in air:	610 cm = 240 inches = 20 feet
• Maximum range in water/tissue:	0.76 cm = 1/3 inch
• Maximum range in Plexiglas/lucite/plastic:	0.61 cm = 3/8 inch
• Half-Value Layer (HVL):	2.00 mm (water/tissue)

RADIOLOGICAL DATA

- Critical organ (biological destination) (soluble forms): Bone
- Critical organs (insoluble forms or non-transportable ^{32}P compounds): Lung (inhalation) and G.I. tract/lower large intestine (ingestion)
- Routes of intake: Ingestion, inhalation, puncture, wound, skin contamination (absorption)
- External and internal exposure from ^{32}P

• Committed Dose Equivalent (CDE): (Organ Doses)	32 mrem/μCi (ingested) 37 mrem/μCi (puncture) 96 mrem/μCi (inhaled/Class W/lungs) 22 mrem/μCi (inhaled/Class D/bone marrow)
• Committed Effective Dose Equivalent (CEDE):	7.50 mrem/μCi (ingested/WB) 5.55 mrem/μCi (inhale/Class D) 13.22 mrem/μCi (inhale/Class W)

- Skin contamination dose rate: 8700-9170 mrem/μCi/cm^2/hr. (7 mg/cm^2 or 0.007 cm depth in tissue).
- Dose rate to basal cells from skin contamination of 1.0 μCi/cm^2 (localized dose) = 9200 mrad/hr
- Bone receives approximately 20% of the dose ingested or inhaled for soluble ^{32}P compounds.
- Tissues with rapid cellular turnover rates show higher retention due to concentration of phosphorous in the nucleoproteins.
- ^{32}P is eliminated from the body primarily via urine.

• Phosphorus metabolism; see ^{33}P Fact Sheet.

SHIELDING

• ≤3/8-inch-thick Plexiglas/acrylic/lucite/plastic/wood.

• Do not use lead foil or sheets! Penetrating Bremsstrahlung x-ray will be produced!

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

SURVEY INSTRUMENTATION

• GM survey meter and a pancake probe.

• Low-energy NaI probe is used **only to detect Bremsstrahlung X-rays.**

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

DOSE RATES

(from unshielded 1.0 mCi isotropic point source)

Distance	rad/hr
1.00 cm	348
15.24 cm	1.49
10.0 ft	0.0015

• 78,000 mrad/hr at surface of 1.0 mCi ^{32}P in 1 mL liquid.

• 26,000 mrad/hr at mouth of open vial containing 1.0 mCi ^{32}P in 1.0 mL liquid.

GENERAL PRECAUTIONS

• Because it is a bone seeker, special precautions must be taken to minimize any chance of introducing into the body.

• Airborne contamination can be generated through drying (dust), rapid boiling, or expelling solutions through syringe needles and pipette tips, due to aerosols.

• Personnel radiation monitors (whole body and finger rings) are **required** when handling > 1.0 mCi of ^{32}P at any time.

• Never work directly over an open container; avoid direct eye exposure from penetrating ^{32}P beta particles.

• Always wear a lab coat and disposable gloves when handling ^{32}P.

• Monitor personnel work areas and floors using a GM survey meter equipped with a pancake (beta) probe for surface contamination.

• Monitor for removable surface contamination by smearing or wiping where ^{32}P is used.

- Use low-density (low atomic number) shielding material to shield ^{32}P and reduce the generation of Bremsstrahlung X-rays. The following materials are low atomic number materials: Plexiglas, acrylic, lucite, plastic, wood, or water.
- Do NOT use lead foil, lead sheets, or other high-density materials (metals) to shield ^{32}P directly. Materials with atomic number higher than that of aluminum (Z = 13) should NOT be used. Penetrating Bremsstrahlung X-rays will be generated in lead and other high density shielding material.
- Safety glasses or goggles are recommended when working with ^{32}P.
- Typical GM survey meter with pancake probe efficiency is $\geq$45%. Typical liquid scintillation counter counting efficiency for ^{32}P (full window/maximum) $\geq$ 85%.
- Typical detection limit of ^{32}P in urine specimens using a liquid scintillation counter = 1.1×10^{-7} µCi/mL

Phosphorus - 33
[^{33}P]

PHYSICAL DATA

- Beta energy: 0.249 MeV (maximum, 100% abundance)
  0.085 MeV (average)
- Physical half-life: 25.4 days
- Biological half-life: 19 days (40% of intake; 30%rapidly eliminated from body, remaining 30% decays)
- Effective half-life: 24.9 days (bone)
- Specific activity: 1,000 - 3,000 Ci/millimole
- Maximum beta range in air: 89 cm = 35 inches = 3 feet
- Maximum range in water/tissue: 0.11 cm = 0.04 inch
- Maximum range in Plexiglas/Lucite/plastic: 0.089 cm = 0.035 inch
- Half-Value Layer (HVL): 0.30 mm (water/tissue)

RADIOLOGICAL DATA

- Critical organ (biological destination) (soluble forms): Bone marrow
- Critical organs (insoluble forms or non-transportable ^{33}P compounds): Lung (inhalation) and G.I. tract/Lower large intestine (ingestion)
- Routes of intake: Ingestion, inhalation, puncture, wound, skin contamination (absorption)
- Internal exposure and contamination are the primary radiological concerns
- Committed Dose Equivalent (CDE): 0.5 mrem/mCi (inhalation)
- Skin contamination dose rate: 2,910 mrem/hr/μCi/cm^2 (7 mg/cm^2 or 0.007 cm depth in tissue)
- Fraction of ^{33}P beta particles transmitted through the dead skin layer is about 14%.
- Tissues with rapid cellular turnover rates show higher retention due to concentration of phosphorus in the nucleoproteins.
- ^{33}P is eliminated from the body primarily via urine.
- Phosphorus metabolism: 30% is rapidly eliminated from body 40% has a 19-day biological half-life 60% of ^{33}P (ingested) is excreted from body in first 24 hrs.

SHIELDING

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

SURVEY INSTRUMENTATION

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

PERSONNEL DOSIMETERS

- Not required since they do not detect this low energy nuclide.

GENERAL PRECAUTIONS

- Inherent volatility (STP): Insignificant
- Skin dose and contamination are the primary concerns.
- Drying can form airborne ^{33}P contamination.
- Monitor work areas for contamination, using smears or wipes to check for removable contamination.

Sulphur - 35
[^{35}S]

PHYSICAL DATA

- Beta energy: 167 keV (maximum)
  53 keV (average) (100% abundance)
- Physical Half Life: 87.4 days
- Biological Half Life: 623 days (unbound ^{35}S)
- Effective Half Life: 44 - 76 days (unbound ^{35}S)
- Specific Activity: 42,400 Ci/g
- Maximum Beta Range in Air: 26.00 cm. = 10.2 in.
- Maximum Beta Range in Water or Tissue: 0.32 mm. = 0.015 in.
- Maximum Beta Range in Plexiglas or Lucite: 0.25 mm. = 0. 01 in.
- Fraction of ^{35}S betas transmitted through dead layer of skin = 12%

RADIOLOGICAL DATA

- Critical organ: Testis
- Routes of Intake: Ingestion, inhalation, puncture, wound, skin contamination (absorption)
- External exposure (deep dose) from weak ^{35}S beta particles is not a radiological concern.
- Internal exposure and contamination are the primary radiological concerns.
- Committed dose equivalent (CDE): 10.00 mrem/μCi (ingested)
  0.352 mrem/μCi (puncture)
- Committed Effective Dose Equivalent (CEDE): 2.6 mrem/μCi (ingested)*
  *(Assumes a 90-day biological half-life)
- Annual Limit on Intake (ALI)*: 10 mCi (ingestion of inorganic ^{35}S compounds)
  6 mCi (Ingestion of elemental ^{35}S)
  8 mCi (ingestion of sulfides or sulfates/LLI)**
  10 mCi (inhalation of ^{35}S vapors)
  20 mCi (inhalation of sulfides or sulfates)
  2 mCi (inhalation of elemental ^{35}S)

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

- Skin Contamination Dose Rate: 1,170 - 1, 260 mrem/uCi/cm^2/hr. (7.0 mg/cm^2 depth)
- Beta Dose Rates for ^{35}S: 14.94 rad/h (contact) in air per 1.0 mCi
  0.20 rad/h (6 inches) in air per 1.0 mCi

SHIELDING

None required (≤3 mm Plexiglas shields, shielding optional).

SURVEY INSTRUMENTATION

Can detect using a thin window G-M survey meter (pancake), however, probe **MUST** be at close range recommend 1 cm distance.
G-M survey meter has low efficiency, usually 4 - 6%.
Liquid scintillation counter (wipes, smears) may be used for secondary, **but will NOT detect non-removable contamination!**

RADIATION MONITORING DEVICES

- (Badges): Not needed, because ^{35}S beta energy is too low, and is not an external radiation Hazard
- Dose Rate from a 1 millicurie unshielded isotropic point source of ^{35}S:

Distance	Rad/hr.
1.0 cm	1173.6
2.5 cm	93.7
15.24 cm	0.2
20.00 cm	0.01

GENERAL RADIATION SAFETY INFORMATION

- Urinalysis: Not required but may be requested by the Radiation Safety Officer after a spill or personnel contamination involving ^{35}S.
- Inherent volatility (STP): Significant for ^{35}S methionine and cysteine.
- Radiolysis of ^{35}S amino acids (cysteine and methionine) during storage and use may lead to the release of volatile impurities. Volatile impurities are small (≤0.05%).
- Metabolic behavior of organic compounds of sulfur (cysteine and methionine) differs considerably from the metabolic behavior of inorganic compounds.
- Organic compounds of sulfur (cysteine and methionine) become incorporated into various metabolites. Thus, sulfur entering the body as an organic compound is often tenaciously retained.
- The fractional absorption of sulfur from the gastrointestinal tract is typically > 60% for organic compounds of sulfur. Elemental sulfur is less well absorbed from the GI tract than are inorganic compounds of the element (80% for all inorganic compounds and 10% for sulfur in its elemental form). Elemental sulfur is an NRC inhalation Class W (meaning it is retained for weeks in the body).
- Inhalation of the gases SO_2, COS, H_2S, and CS_2 must be considered. Sulfur entering the lungs in these forms are completely and instantaneously translocated to the transfer compartment; from there, its metabolism is the same as that of sulfur entering the transfer compartment following ingestion or inhalation of any other organic compound of sulfur.

- Contamination of internal surfaces of storage and reaction vessels may occur (rubber stoppers, gaskets or o rings).
- Vials of ^{35}S labeled cysteine and methionine should be opened and used in ventilated enclosures (exhaust hoods).
- The volatile components of ^{35}S labeled amino acids should be opened and used in ventilated enclosures (exhaust hoods).
- The volatile components of ^{35}S labeled cysteine and methionine are presumed to be hydrogen sulfide (H_2S) and methyl mercaptan (CH_3SH), respectively.
- ^{35}S vapors may be released when opening vials containing labeled amino acids, during any incubating of culture or cells containing ^{35}S, and the storage of ^{35}S contaminated wastes.
- Excessive contamination can be found on the inside surfaces and in water reservoirs of incubators used for ^{35}S work. Most notable surface contamination can be found on rubber seals of incubators and centrifuges.
- Radiolytic breakdown may occur during freezing processes, releasing as much as 1.0 µCi of ^{35}S per 8.0 mCi vial of ^{35}S amino acid during the thawing process.
- ^{35}S labeled amino acids work should be conducted in an exhaust hood designated for radiolytic work.
- Vent ^{35}S amino acid stock vials with an open-ended charcoal-filled disposable syringe. Activated charcoal has a high affinity for ^{35}S vapors.
- Place an activated carbon or charcoal canister, absorbent sheet, or tray (50-100 grams of granules evenly distributed in a tray or dish) into an incubator to passively absorb ^{35}S vapors. Discard absorbers which exhibit survey meter readings above normal area background levels in the solid radioactive waste.

Chromium - 51
[^{51}Cr]

PHYSICAL DATA

- Gamma Energy: 320 keV (9.8% abundance) *
- X-ray Energy: 5 keV (22% abundance) *

*[Percent of disintegration resulting in this radiation being emitted]

- No Betas Emitted
- Specific Gamma Constant: 0.017 mR/hr per mCi at 1.0 meter
- Physical Half-Life: 27.8 days
- Biological Half Life: 616.0 days
- Effective Half-Life: 26.6 days (whole body)
- Specific Activity: 92,000 Curies/gram
- Specific Activity (microspheres): 63.56 mCi/gram

RADIOLOGICAL DATA

- Critical Organ: Lower large intestine (LLI)
- Routes of Intake: Ingestion, inhalation, skin contact
- External & internal exposure and contamination are radiological concerns.
- Committed Dose Equivalent (CDE): (gonad & lung)
  0.15 mrem/μCi (ingested/gonad)
  1.41 mrem/μCi (inhalation/lung/Class W)
- Committed Dose Equivalent (CDE):
  1.20 mrem/uCi (ingested/GI tract/LLI)
  0.22 mrem/uCi (inhaled/LLI Wall/Class D)
- Committed Effective Dose Equivalent (CEDE):
  0.107 mrem/uCi (ingested)
  0.211 mrem/uCi (inhalation/Class D)
  0.211 mrem/uCi (inhalation/Class W)
- Annual Limit on Intake (ALI)*:
  20 mCi (inhalation/Class W & Y)
  52 mCi (inhalation/Class D/soluble)
  40 mCi (ingestion)

*[1.0 ALI = 40 mCi (^{51}Cr ingested) = 5,000 mrem CEDE (Whole Body)]

SHIELDING

- Use 1/4" - 1/2" lead shielding for ^{51}Cr

Half - Value Layer (lead):	2.0 mm = 0.07"
Half - Value Layer (concrete):	2.8 cm = 1.10"
Half - Value Layer (Plexiglas):	4.8 cm = 1.90"

Tenth - Value Layer (lead):	5.6 mm = 0.22"
Tenth - Value Layer (concrete):	9.3 cm = 3.66"
Tenth - Value Layer (Plexiglas):	17.2 cm = 6.80"
Maximum range in lead:	7 mm = 0.5"
Maximum range in Plexiglas:	65 cm = 22.0"

SURVEY INSTRUMENTATION

- Survey meter equipped with a NaI scintillation probe is recommended.
- Survey meter equipped with a G-M pancake/detector or standardized cylindrical probe is very **inefficient** for the detection of ^{51}Cr (very low counting efficiency).
- Smears or wipes counted in a liquid scintillation counter (indirect) is best for the detection of **removable** ^{51}Cr surface contamination.

PERSONAL RADIATION MONITORING DOSIMETERS

Whole body & extremity badges required.

REGULATORY COMPLIANCE INFORMATION

• Derived Air Concentration (DAC): (inhalation)	2.0×10^{-5} µCi/cc (Class D)
	1.0×10^{-5} µCi/cc (Class W)
	8.0×10^{-6} µCi/cc (Class Y)
• Airborne Effluent Release Limit*:	6.0×10^{-8} µCi/cc (Class D)
	3.0×10^{-8} µCi/cc (Class W & Y)

* Applicable to the assessment & control of dose to the public (10 CFR 20.1302). If this concentration was inhaled continuously for over one year the resulting TEDE would be 50 mrem.

- Urinalysis: Not required; however, may be requested in the event of a spill of ^{51}Cr.
- Whole Body Bioassay: May be prudent in the event of a suspected intake of ^{51}Cr through ingestion, inhalation, skin absorption, or a wound.
- Gamma (photon) exposure rates from 1.0 mCi ^{51}Cr point source:

Distance (in cm)	mrad/hr
1.0	160.0
5.0	6.4
10.0	1.6
100.0	0.016

- Inherent Volatility (STP): Insignificant/Negligible

Iodine - 125
[^{125}I]

PHYSICAL DATA

• Gamma Energies: (No betas emitted)	35.5 keV (7% abundance/93% internally converted, gamma) 27.0 keV (113%, X-ray) 27-32 keV (14%, X-ray) 31.0 keV (26%, X-ray)
• Specific Gamma Ray Constant:	0.27 to 0.70 mR/hr per mCi at 1 meter (Current literature indicates 0.27 mR/hr per mCi at 1 meter)
• Physical Half-Life:	60.1 days
• Biological Half-Life:	120-138 days (unbound iodine) - thyroid elimination
• Effective Half-Life:	42 days (unbound iodine) - thyroid gland
• Specific Activity:	17,400 Ci/gm (theoretical/carrier free)
• Intrinsic Specific Activity:	22.0 Ci/millimole

RADIOLOGICAL DATA

- Critical Organ (Biological Destination): Thyroid
- Routes of Intake: Ingestion, inhalation (most probable), puncture, wound, skin contamination (absorption)
- External and internal exposure and contamination concerns exist in use of ^{125}I

• Committed Dose Equivalent (CDE): (Organ Doses)	814 mrem/mCi (thyroid/inhalation/class "D") 1185 mrem/mCi (thyroid/ingestion/NaI form) 910 mrem/mCi (thyroid/inhalation) 1258 mrem/mCi (any organ/puncture/adult)
• Committed Effective Dose Equivalent (CEDE):	24 mrem/mCi (whole body/inhalation)

SHIELDING

- Lead foil or sheets (1/32 to 1/16-inch-thick): 0.152 mm lead foil
- Half Value Layer: 0.02 mm = 0.008 inches

SURVEY INSTRUMENTATION

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

DOSE RATES

(from unshielded 1.0 mCi isotropic point source)

Distance	mrad/hr
1.00 cm	156 - 275
10.00 cm	15.5 - 27.5
100.00 cm	0.156 – 0.28
6.00 in	6.5

(Some literature indicates 0.7 mrad/hr. per mCi at 100 cm)

- Individuals who will be using ^{125}I in the NaI or KI chemical form are required to obtain a thyroid scan to be used as a baseline reference prior to use.
- The thyroid gland accumulates 20 - 30% of the soluble radioiodine taken in by the body. All radioiodine's in the body can be assumed to be eliminated quite rapidly via the urine.
- Thyroid Bioassay is **required by law** when handling $\geq$ 1 mCi in the ^{125}I in the sodium or potassium iodide chemical form. In accordance with the NRC license and HU/HUH's commitment to ALARA, the threshold amount is taken to be 0.1 mCi. The thyroid scan is to be obtained not less than 24 hours but not more than one week after the handling or use of that quantity and form of ^{125}I. In addition, all workers who assist or observe in manipulations of the above quantity and type of ^{125}I, or are sufficiently close to the process so that intake is possible (within a few meters and in the same room) are required to obtain thyroid scans under the same conditions listed above.
- Fume hood sash glass provides adequate shielding for most iodination's. Extra shielding is not recommended, since it impedes air flow into the hood.
- Shielding is not required for most uses of this nuclide due to the low energy and low amounts typically used.
- Use a cannula adapter needle to vent stock vials of ^{125}I used for iodination's. This prevents puff releases.
- Segregate waste from iodination's (free) from other (bound) ^{125}I waste and store it in the fume hood, in tightly sealed zip lock bags (solid waste) or screw top containers (liquid waste) until waste pickup.
- Cover test tubes used to count or separate fractions from iodination's with parafilm or other tight caps to prevent release while counting or moving outside the fume hood.

IODINATION SAFETY TIPS

With safe practices, exposures do not occur when iodination is performed. Air monitoring may be done during iodination by the Radiation Safety Office staff to ensure that the room air is not contaminated. Additionally, bioassays detect any uptakes that may occur. These bioassays are required for all workers performing iodination.

Iodination labeling, however, can create potential exposures to thyroid in workers performing iodination if proper safety precautions are not followed explicitly. ^{125}I in the $Na^{125}I$ chemical form is volatile, and exposure through inhalation route can occur. Most iodinations are done with quantities of 1.0 mCi or greater, so very little airborne release of this concentrated material may cause a significant ^{125}I uptake.

The following list of safety precautions will assist workers in preventing unnecessary exposures to ^{125}I during iodinations. If you have questions, or would like assistance in iodination procedures, please call the Radiation Safety Office at (202) 806 -7216.

1. All iodinations and use of $Na^{125}I$ must be conducted in a fume hood certified room for radioisotope use. Work should be done at least 6 inches back from the front of the fume hood. Fume hoods should be free of clutter, and large objects should be placed on blocks to elevate them 2 inches from the floor of the fume hood. The sash of the fume hood should be brought down to the lowest possible height while still maintaining ample room for manual dexterity.
2. The fume hood should be covered with poly-backed absorbent paper to absorb possible spills, drips or airborne activity.
3. Double gloves should be worn. Latex or N-Dex gloves are preferable because they have a tighter fit, allowing good dexterity while wearing two or three pairs.
4. Poly-backed absorbent paper should be taped to the floor in front of the fume hood to prevent contamination and spreading in the event of an accidental spill or release.
5. Lab coats and film badges must be worn.
6. A GM rate meter with a low energy gamma probe must be used during the iodination. It should be placed near the iodination hood (not inside the hood) with the audio on. A noticeable and substantial change in the audible count rate during the iodination is an indicator that will alert the worker to possible release from the fume hood. Procedures should then be implemented to prevent further release into the breathing air in the room. Call the Radiation Safety Office at (202) 806-7216 for advice on handling the situation.
7. To remove the $Na^{125}I$ from the shipping vial, use an adapter to provide a conduit for the syringe used to withdraw the aliquot. A short 16-gauge cannula needle, available from General Stores, makes an excellent adapter. This prevents the syringe needles from bending, possible skin punctures and vents the fumes before withdrawing the solution.
8. Mix the reaction vial with a gentle tapping motion rather than shaking. Fumes are released in higher quantities with vigorous mixing; gently tap the reaction tube to provide gentle mixing. Hold the vial well up inside the hood so that fumes are drawn up through the hood, rather than into the room air.

9. NEVER collect iodination fractions outside the fume hood. High amounts of free iodine are contained in these fractions, and intakes can occur if the tubes are not collected in the hood.
10. NEVER count fractions from iodinations in tubes or vials which are not tightly capped. Dispose of counting tubes or vials with caps on in the iodination waste, not in the regular ^{125}I waste.
11. Contain all waste from the iodination as it is generated. Tape double plastic bags to the wall of the fume hood in an accessible location. Place dry waste in these bags. Deposit liquid waste in plastic bottles with screw-top caps to contain release. When the iodination is finished, place both dry and liquid waste in double zip lock plastic bags and label the waste with radioactive waste tags. Denote "**Free ^{125}I**" on the waste tag.
12. Store all syringes, glassware and other equipment that is reused in the iodination fume hood between uses. Label all iodination equipment thoroughly.
13. Thyroid scans must be performed on the workers after each iodination. A baseline thyroid scan is done to determine a background for each iodinater prior to conducting iodinations at HU/HUH. Post-iodination thyroid scans are done no less than 24 hours after the iodination, and no longer than 1 week after the iodination. Thyroid scans are required by law, and not obtaining them may cause a violation of our NRC license conditions. Call the Radiation Safety Office at (202) 806-7216 to obtain a thyroid scan.
14. If a spill occurs inside the fume hood during an iodination, close the hood sash completely. If a spill occurs outside the fume hood, place absorbent on the spill and evacuate personnel from the room. Call the Radiation Safety Office at (202) 806-7216 immediately to notify that the spill has occurred.
15. After every iodination, thoroughly survey the entire area, including floors, hood, equipment, outer waste container surfaces, hands, feet and clothing.

EMERGENCY PROCEDURES FOR FREE ^{125}I ACCIDENT

In the event of an accident with free iodine outside the hood, don't panic. Immediately get everyone out of the room. If possible, grab the rate meter on your way out. To minimize the spread of contamination, the people involved should go to a single, predesignated location and close the door. (A desirable location would have available a telephone, sink, hood and be in a "low traffic" area. The hallway outside the room may be the only choice if there are no adjacent rooms with closing doors.)

It is recommended that some disposable lab matting, or other absorbent paper be placed on the floor for people to stand on, until they can be surveyed and found free of contamination or decontaminated. If you have any contamination on your skin, wash it off. If your clothing is contaminated, remove the affected articles and place in the hood. Be sure the hood is turned on.

During regular workdays and hours call the Radiation Safety Office at (202) 806-7216 and request to speak to the Radiation Safety Officer. Tell the person answering the phone that you are reporting a radiation emergency. Then call your PI and let him/her know exactly what has happened and what you have done thus far.

If an accident occurs after regular working hours, dial 911, tell the dispatcher that you have a radiation emergency and need Radiation Safety assistance. (They will call the Radiation Safety Officer's cell phone.) Be prepared to provide the following information:

1. Medical services required, if any (paramedics, ambulance)
2. Your name
3. Building name and room number
4. Your phone number - where you can be reached
5. Name of lab's principal investigator
6. Isotope involved
7. Chemical form of isotope or say it is an iodination accident
8. Estimation of amount of activity involved
9. Number of people involved
10. Steps taken so far

    Then call your PI, if possible, and give the same information.

APPENDIX D:

PROCEDURE FOR RECEIVING AND OPENING RADIOACTIVE PACKAGES

HOWARD UNIVERSITY
1867
RADIATION SAFETY OFFICE

PROCEDURE FOR RECEIVING AND OPENING RADIOACTIVE MATERIALS PACKAGES

1. Scope

Most packages containing radioactive materials are received by the Shipping and Receiving Area, Mail Room Services Office and Security Office (Howard University Hospital) personnel during regular working hours (8:00 a.m. to 5:00 p.m.). These packages are then stored in an approved vault located in the loading dock area of the Hospital until picked up by individual from Radiation Safety Office.

For the delivery of High Dose Rate (HDR) (^{192}Ir) source, the vendor notifies the Radiation Safety Officer of the shipment date and expected delivery date. The Radiation Safety Office then notifies the Mail Room of the expected delivery date of the HDR source. The mail room immediately contacts the Radiation Safety Office upon arrival of the source.

Because of the nature and number of the radioactive packages received by the Nuclear Medicine, the division is authorized to directly receive radioactive material packages from the vendor during regular working hours.

The following procedure applies to all packages delivered to Howard University and Howard University Hospital facilities, which are either labeled as "containing radioactive material" or are crushed, wet, damaged or otherwise, suggesting likelihood of contamination.

2. Regulatory Requirement

10 CFR 20.1906 requires that each licensee monitor the external surfaces of a package labeled with Radioactive White I, Yellow II or Yellow III label for radioactive contamination and radiation levels. This monitoring shall be performed as soon as practicable, but not later than 3 hours after receipt of the package during the licensee's normal working hours, or not later than 3 hours from the beginning of the next working day if the package is received after working hours.

3. Materials Required

3.1. A calibrated dose-rate meter
3.2. Wipes
3.4. Gamma counter or liquid scintillation counter
3.5. Radioactive material receipt form (see attached form)
3.6. Radioactive material receipt logbook

4. Responsibilities

4.1. Personnel from Radiation Safety Office or department authorized by the Radiation Safety Office: See procedures from 5.1 through 5.13

4.2. Radiation Safety Officer (or Designated Alternate): See procedure 5.14

5. Procedure

5.1. Circle the type of package, note down the date and time of receipt, and the department the package was received for on line 1, 2 and 3 of the receipt forms respectively.

5.2. Visually inspect the package immediately upon receipt for integrity of the security seal and evidence of crushing, breakage or damage during transport. Look for stains that may indicate leakage. Circle the appropriate condition on line 4 of the receipt form.

5.1.1. If the package's integrity is not compromised, continue with the normal check-in procedures.

5.1.2. If the package is leaking, crushed or damaged, place the package in a secure area, and notify the Radiation Safety Officer (RSO) immediately.

5.5. Put on disposable gloves before proceeding with the package receipt.

5.4. Take measurements on the external surface of the package with a survey meter. Note the highest exposure rate reading on 5a of the receipt form.

5.4.1. If the radiation levels exceed 200 mR/hr at the surface, notify the RSO immediately.

5.5. Measure radiation levels at one meter from the package. Note the reading on 5b of the receipt form.

5.5.1. If the radiation levels exceed 10 mR/hr at 1 m, notify the RSO immediately.

5.6. Perform wipe test of the outside and inside of the package. The wipe should be counted with a source and background using an appropriate counter.

5.6.1. If the isotope received is gamma emitter, use a gamma-counter to count the wipe.

5.6.2. If the isotope received is beta emitter, use a liquid scintillation counter to count the wipe.

5.6.5. Record the removable contamination on line 6 of the receipt form.

5.6.4. If wipe test results show contamination in excess of 220 dpm/cm^2 (22 dpm/cm^2 for alpha emitting radionuclides other than low toxicity alpha emitters), stop the procedure and notify the radiation safety officer.

5.7. Verify that the contents agree with that listed on the packaging slip. If the contents do not correspond with the packaging slip, notify the radiation safety officer.

5.8. Note down the isotopes and corresponding activity on line 8 of the receipt form.

5.9. Deface or remove signs and labels from the package and monitor for contamination prior to disposal or return of the package.

5.10. Indicate the date and time the survey is complete on line 9 of the receipt form.

5.11. Print and sign the initials of the person performing the survey on line 10 of the receipt form.

5.12. Attach all necessary documentation with the cover-page, as applicable.

5.13. Fill in the appropriate areas in the radioactive materials receipt logbook.

5.14. The Radiation Safety Officer will notify the final delivery carrier and the NRC Operations Center (301)816-5100by telephone if the external radiation levels exceed the limits mentioned in 5.4.1 and 5.4.1 or if the surface contamination levels exceed the limits mentioned in 5.6.4.

6. References

6.1. 10 CFR § 20.1906, Procedures for receiving and opening packages

6.2. 10 CFR § 71.87, Routine determinations

6.3. 10 CFR § 71.47, External radiation standards for all packages

6.4. 49 CFR § 175.443, Contamination Control

HOWARD UNIVERSITY

RADIATION SAFETY OFFICE

RADIOACTIVE MATERIAL RECEIPT SURVEY/ INSPECTION REPORT

1. Type of package (Circle one):

   Excepted UN 2910 White I UN 2915 Yellow II UN 2915 Yellow III UN 2915

2. Date: _____ Time: _____ (am/pm)

3. Department/PI: _____

4. Condition of package: Complete/Undamaged__ Damaged___

   If damaged, describe condition_____

5. Radionuclide ordered: _____

6. Activity: _____ ○ µCi ○ mCi ○ Ci ○ Bq ○ KBq ○ MBq ○ GBq ○ TBq

7. Exterior radiation level of package:

Background: _____mR/hr	Surface: _____ mR/hr	3ft(1m): _____ mR/hr

8. Survey Instrument:

Meter #, S/N	Probe #, S/N	Calibration date:

9. Do packing slip and package contents agree? Yes_____ No_____ Note: If packing slip and contents disagree notify RSO immediately.

10. Wipe test result in DPM: _____

    Wipe all sides of the package, covering at least 100 cm² of the surface. Complete wipe test within 3 hours of receipt. Notify RSO if dpm is more than 220 dpm/cm².

11. Attach the following with this cover page, as applicable:
    ○ Packing slip ○ Wipe test result ○ DG declaration ○ Other

12. Surveyed by: Name: _____ Signature: _____

NOTE: If package is severely damaged, leaking or content is not as ordered, or radiation/contamination is significantly above background level, notify RSO immediately. Maintain original in Radioactive Package Receipt Logbook. Revised January 11, 2018

APPENDIX E:

TRANSPORTATION OF RADIOACTIVE MATERIALS

INSTRUCTIONS FOR TRANSPORTATION OF RADIOACTIVE MATERIAL

Requirements for the transportation of radioactive material on campus and to other institutions must comply with both the NRC and DOT regulations. Transporting may involve walking or driving radioactive material across campus or shipping off campus. The Radiation Safety Office must be notified before any transfers take place. This is to ensure that proper procedures are followed, and movement of radioactive material is tracked. Any transfers of radioactive material (possession transferred from one principal investigator to another) must be pre-authorized by the Radiation Safety Officer.

PACKAGE PREPARATION

All packages used to transport radioactive material must be strong, tight containers that do not leak under normal transportation conditions (such as dropping, jarring or temperature extremes). If liquid is shipped, use at least twice the amount of absorbent needed to contain the entire volume, in case the container should break or leak. If you are not sure whether the container you plan to use is adequate, contact the Radiation Safety Office.

TRANSPORTATION ON HU/HUH CAMPUS

Whenever radioactive material is transported from one building to another, the Radiation Safety Office must be notified of the following information:

- Date when the material needs to be moved
- Names of the person sending and receiving the material (if different)
- Sending and receiving locations
- Nuclide(s) being moved
- Chemical form of the isotope
- Total activity in mCi
- Number of containers
- Phone numbers of responsible persons
- Any special conditions

Walking to another building

Prepare to move your material using an appropriate container (see Package Preparation above). The package must have a radioactive warning label with the isotope, activity in DPM, µCi or mCi and date. Clearly identify the principal investigator and one other contact in case of an accident or loss of the package. The package must be tested for removable contamination before it leaves its place of origin and after it reaches its destination. Contact the ORCBS, if any removable contamination is detected.

Driving to another building

The transportation of radioactive material is regulated by the Nuclear Regulatory Commission (NRC) and the Department of Transportation (DOT). **You must not move any radioactive material on a public road without prior authorization by the Radiation Safety Officer.** Remember that all roads on the HU/HUH campus are public. The Radiation Safety Office will prepare documentation and

transport your material. The sender's responsibility is to contact the Radiation Safety Office in advance, and properly package the radioactive material.

Prepare to move your material using an appropriate container (see Package Preparation above). The Radiation Safety Office will determine what package labeling is required. Do not seal the package. The condition of the package must be checked, and a leak test performed by the Radiation Safety Office personnel. A radiation worker must be present at the receiving location to take possession of the material at the arranged time.

SHIPPING RADIOACTIVE MATERIAL

When preparing to ship radioactive material, whether it is radioactive samples or a piece of equipment being returned for repairs, the Radiation Safety Office must be informed in advance. **Do not expect to send shipments out immediately**. Federal regulations must be followed regardless of the quantity being sent.

Shipments can only be made to institutions that are licensed to possess radioactive material. When shipping to another licensee, it is required that prior authorization be obtained from the Radiation Safety Office at that location, preferably the Radiation Safety Officer. License information must be on record or obtained before the shipment can be sent. To initiate this process, the person sending the material must have the following information:

- Name of the person sending the material
- Facility name and address
- Name of the person receiving the material
- Radiation Safety Officer's (or other staff member) name and phone number
- Nuclide(s) being sent
- Chemical form of each isotope
- Total activity in mCi for each isotope
- Number of containers in the shipment
- Any special conditions

Remember that shipments of radioactive material must be planned well in advance; allow at least two weeks prior to the desired shipping date.

APPENDIX F:

POLICY FOR MINORS

HOWARD UNIVERSITY POLICY

Policy Number:	100-002
Policy Title:	MINORS IN RESTRICTED AREAS INVOLVING RESEARCH WITH RADIATION AND RADIOACTIVE MATERIALS
Responsible Officer:	Provost and Chief Academic Officer
Responsible Offices:	Office of the Deputy Provost for Health Sciences HU Radiation Safety Committee & Radiation Safety Office
Effective Date:	December 14, 2011 May 29, 2012 – Conforming Revisions

I. POLICY STATEMENT

Radioactive materials are potentially hazardous unless used with strict adherence to safety rules and regulations. Safety is the practice of a set of rules, guidelines and procedures which protect workers, facilities, the general public and the working environment. Regulatory compliance is the maintenance of such procedures, documents, and records which are not compromised. All administrators, radiation safety committee members, research investigators, students and other workers who are directly or indirectly involved in the management of radiation safety program at Howard University (the "University") must adhere to safety and compliance requirements. The safety rules in the research laboratories and clinical facilities govern the safe uses of ionizing radiation and radioactive materials and must provide guidelines on the biological effects of ionizing radiation.

II. RATIONALE

This policy prohibits individuals under the age of 18 years, from receiving unnecessary risks from exposure to radiation and radioactive materials. Radioactive research laboratories at the University must comply with the current license issued by the United States Nuclear Regulatory Commission (US NRC) to conduct research and development activities on non-human subjects.

According to the conditions of the current license, the byproduct, source and/or special nuclear material shall only be used by or under the direct supervision of individuals designated in writing by the Radiation Safety Committee [10 CFR Section 33.17 (b)], with access to research labs restricted to the authorized users whose names are in the license application. The Radiation Safety Committee acknowledges that there are justifiable and productive reasons for restrictions to the presence of minors in the laboratories where radioactive licensed materials are stored. Mentoring minors in University research laboratories where radioactive materials are used may pose liability risk issues for the University.

The mission of the Howard University Radiation Safety Committee is to support research and development activities by providing necessary training and services that enable limited access to minor students or visitors in the University's research laboratories. Because of concerns related to the exposure to radioactive hazards, the following guidelines are necessary to ensure that all potential exposure by minors is minimized.

III. ENTITIES AFFECTED BY THIS POLICY

This policy affects all faculty, students, staff and visitors of Howard University and Howard University Hospital.

IV. DEFINITIONS

A. **Minor** – a person under 18 years of age.

1. No minor shall work or volunteer in any capacity that is determined by the principal investigator of the laboratory where the minor is considering volunteering or work, or by determination of the Radiation Safety Committee to be hazardous or potentially detrimental to the minor's health or well-being.
2. No minor shall be allowed to enter any area where the radiation exposure may be potentially equal to or greater than a total dose of more than 0.1 rem (1 mSv) per year from both internal and external sources.
3. US NRC regulations (10 CFR Section 20.1201, 20.1207) require that the total effective dose equivalent to individuals not working with radioactive material may not exceed 100 mrem per year or 2 mrem in any one hour. These public exposure limits apply to anyone not explicitly trained to work with radioactive material or radiation producing equipment.

B. **Authorized Users of Radioactive Materials** – University employees who are on the current broad scope license and who plan to involve minors in activities in their laboratories. Authorized Users must notify the Radiation Safety Officer (RSO) prior to the beginning any work in the authorized research laboratory.

V. POLICY PROCEDURES

The privileges of using ionizing radiation require that each individual user strictly adheres to the regulations mandated by the regulatory agencies. All individuals who work with radioactive materials or radiation producing devices are required to receive radiation safety training to ensure adherence with the regulations. Training should include, but not be limited to, the following:

1. To ensure that researchers' and employee' exposure to ionizing radiation is kept *As Low As Reasonably Achievable* (ALARA). This means that the University must work to keep doses as far below the dose limits as can reasonably be achieved.
2. The University is committed to an effective radiation protection program to avoid unnecessary exposure to radiation and to reduce all exposures to levels that are ALARA, taking into account all social and economic considerations.
3. The ALARA principle is a formal requirement of the federal and District of Columbia Health regulatory agencies. To provide for compliance with all applicable regulations promulgated by the federal, state, and local agencies.

If there are compelling reasons for the proposed minor to volunteer or work in a research laboratory that uses any radioactive material, but not directly with radioactive materials or radiation producing machines, the following rules must apply:

a) Prior approval must be received from the Radiation Safety Committee.

b) The RSO must review and approve laboratory protocol.
c) The minor must receive work-related training provided by the laboratory supervisor/principal investigator.
d) Written consent waiver form has been completed by the minor's parent(s) or legal guardian. (This form is available on the University Policy Office website at www.howard.edu/policy.)
e) The minor must attend an approved radiation safety education program attended on safe laboratory techniques and emergency procedures. The minor must be approved by the RSO after completing the education program as able to comply with all laboratory safety rules to the reviewer's satisfaction; this must be documented in written form, with the document on file with the RSO.
f) Minor(s) will be held accountable for obeying all safety rules and practices of the laboratory.
g) Authorized users in the laboratory must complete any required accident reports.
h) All minors must keep their designated work areas safe from risks and hazards.
i) Minors must be supervised at all times in the laboratory by an authorized user of radioactive materials.
j) If appropriate, based on any level of potential radiation material exposure, the PI or lab supervisor must issue a temporary radiation monitoring dosimeter.
k) Minors are not allowed to work with or handle radioactive materials or radiation-producing machines at any time.
l) Minors are not allowed under any circumstances to enter a work area or laboratory where volatile forms of radioactive material are present, including iodine, volatile derivatives of ^{32}P, or irradiators, or where volatile forms of radioactive material are stored.
m) Minors are not allowed unsupervised access to a laboratory or work area where volatile, poisonous, or flammable chemicals are stored or used. In addition to the requirements itemized above, the minor must meet any conditions deemed necessary by the Howard University Radiation Safety Officer (RSO).
n) The Radiation Safety Committee will monitor compliance with this policy. Any incident or exposure to radiation involving a minor is required to be reported to the principal investigator or lab supervisor immediately. The minor is required to file an incident report under the guidance of the principal investigator or lab supervisor to document the event. The principal investigator or lab supervisor is required to sign the incident report. A copy of the completed report is to be sent to the Radiation Safety Officer immediately. The RSO will then review the report and follow regulations for reporting to the NRC, as permitted under the "Standard for Protection Against Radiation (10 CFR 20)", "NRC License Compliance & Enforcement Policy", and NRC Form 5– "Occupational Dose Record for a Monitoring Period." [Available on the University Policy Office website at www.howard.edu/policy.]

VI. INTERIM POLICIES

This policy supersedes any other written policy on areas contained herein.

VII. SANCTIONS

As with all other policies affecting the use of ionizing radiation, enforcement of this policy is the sole responsibility of the principal investigator or lab supervisor of the laboratory or work area where the minor is working. The professional judgment of the supervisor will be used to assure that the spirit of

this policy is appropriately followed. The failure or refusal to follow the policy and procedures as listed, or any other activities which violate the policy, will be referred to the Radiation Safety Committee for appropriate actions. Disciplinary measures available to the Radiation Safety Committee include the following:

1. Revocation of the minor's privilege to work in the laboratory.

2. Violations of this policy by supervisors/principal investigator(s) will result in:
   a) Termination of his or her privilege to work with minors in the laboratory.
   b) Retraining of the supervisor/principal investigators, with
   c) Reapplication to allow minors to work in the laboratory.

VIII. WEBSITE ADDRESS

www.howard.edu/policy

APPENDIX G:

POLICY FOR PREGNANCY

FETAL DOSE CONTROL PROCEDURES

1. The radiation worker will be assigned a monthly radiation monitoring badge, if one is not currently assigned and placed on a monthly basis program when radioactive materials are used within the guidelines of RSO Procedure.

2. A separate badge will be issued to wear near the abdomen to monitor embryo/fetus exposure throughout the use of radioactive material while pregnant. Records of this exposure will be kept in the worker's file.

3. The Howard University Hospital's responsibility to protect the embryo/fetus under the 500 millirem dose guideline begins only when the employee declares her condition to her supervisor and the Radiation Safety Officer. Control of the fetal dose will be carried out with full cooperation of the employee. Work assignment changes, consistent with the institution personnel policy, may be initiated, if necessary.

4. In conjunction with the 500 millirems fetal dose guideline limit, the 'As Low As Reasonably Achievable' (ALARA) radiation protection philosophy will be applied to maintain any dose to as low as practicable levels.

5. Pregnant radiation workers shall not participate in the following duties:

    a. In-room X-ray procedures or portable X-ray work, **without** adequate shielding.

    b. Other specific higher dose potential duties as determined on a case basis by the Radiation Safety Officer.

6. All radiation workers have an individual responsibility for adhering to the Howard University Hospital Radiation Safety policies and procedures.

7. **Reports** - Occupational radiation dose reports are maintained by the Radiation Safety Office in each user's history file. A copy of the report is available on request and is routinely sent to the individual yearly and upon termination. Each report includes the monitoring period, dose (millirems) for the immediate past period, current calendar quarter, calendar year and lifetime dose for each user.

8. **Investigation Levels** - Specific procedures for responding to any occupational radiation dose which exceeds established investigation levels are established in the Howard University and Hospital ALARA Program.

HOWARD UNIVERSITY

RADIATION SAFETY OFFICE

TO: Satya R. Bose, Ph.D., DABR
Director of Radiation Safety
Radiation Safety Officer
Howard University Health Sciences

SUBJECT: **NOTIFICATION OF PREGNANCY**

This is to inform you that I am currently pregnant or trying to get pregnant and would like to schedule a radiation safety consultation.

My approximate conceived date was _____

My expected delivery date is _____

I am currently working in the following laboratory and/ or department:

_____

Name of Supervisor: _____

Signature of Supervisor: _____

Department: _____

Telephone Number: _____

Email Address: _____

Employee Name: _____

Signature: _____ Date: _____

RECORD OF ATTENDANCE – PREGNANCY CONSULTATION

_____ has completed a session with the Radiation Safety Officer in which the risks of working with radiation were reviewed, the U.S. Nuclear Regulatory Guides:

8.13 – INSTRUCTION CONCERNING PRENATAL RADIATION EXPOSURE

8.36 – RADIATION DOSE TO THE EMBRYO/FETUS

The above were reviewed and an opportunity to ask questions was given. A copy of her previous radiation exposure history to date was handed to her at this time.

Receipt of dosimetry records is dependent on the prompt receipt of the badges by the Radiation Safety Office for processing; therefore, it is important that all badges be returned immediately upon receipt of the new monthly badges. This was stressed during the lecture.

Questions regarding the badges are to be directed to the Radiation Safety Office via your supervisor.

Date of notification of pregnancy: _____

Date of interview: _____

I hereby certify that I have attended the above referenced lecture and was informed according to the above statements. I understand it is my responsibility to notify the Radiation Safety Office in writing of any change in my status so that my personal dosimetry badges may be properly recorded or discontinued.

_____

Pregnant Worker Date

_____

Radiation Safety Officer Date

_____

Witness Date

HOWARD UNIVERSITY

RADIATION SAFETY OFFICE

MEMORANDUM

TO : Satya R. Bose, Ph.D., DABR
Director of Radiation Safety
& Radiation Safety Officer
Howard University Health Sciences

FROM : Name:_____
Department:_____

CC : Supervisor:_____
Department:_____

SUBJECT : **VOLUNTARY DECLARATION OF PREGNANCY WITHDRAWAL**

I am aware that the policy on pregnancy is covered under the Nuclear Regulatory Commission's (NRC) regulations on radiation protection as specified in 10 CFR Part 20, "Standards for Protection against Radiation;" and Section 20.1208.

I have been advised of the potential health risks to the embryo/fetus associated with radiation exposure. I have also been advised about the NRC requirements that the radiation dose to the embryo/fetus for occupational exposure of the expected mother be limited to 500 mR for the entire gestation period.

I hereby withdraw my request that the HU Radiation Safety Office limit my radiation exposure under the provisions of the Prenatal Radiation Exposure Policy.

I understand that, by withdrawing my request, the Radiation Safety Office will apply the NRC dose limits applicable to occupational workers. I make this decision voluntarily and have had the opportunity to ask questions concerning the potential health risks to me and to my embryo/fetus.

_____

Pregnant Worker's Signature Date

_____

Supervisor's Signature Date

_____

Radiation Safety Officer's Signature Date

APPENDIX H:

FILM BADGE DOSIMETRY MONITORING POLICY

HOWARD UNIVERSITY

RADIATION SAFETY OFFICE

FILM BADGE DOSIMETRY MONITORING POLICY

PERSONNEL MONITORING

- Personnel monitoring film badges/dosimeters are given to those adults who are likely to receive, in one year from sources external to the body, a dose in excess of 10 percent of the occupational radiation exposure limit (US NRC 10CFR 20.1201). Radiation detection dosimeters are not assigned to work with certain radionuclides, since the energies are beneath the detection limit of the badge. This is not a risk to the worker, however, because these kinds of radiation are not penetrating enough to cause a deep radiation dose. Examples of these radionuclides are ^{3}H, ^{14}C, ^{35}S, ^{45}Ca, ^{33}P and ^{63}Ni. **It is a legal requirement that workers handling ≥1 mCi (≥ 37 MBq) ^{32}P must wear extremity badges.** The whole-body badge should be worn on the torso with the name tag facing the suspected source of radiation. With ring badges, the name tag must face the radiation source.
- Each person assigned a dosimeter shall be responsible for assuring that it is returned to the departmental representative at the pre-arranged date. The Radiation Safety Office (RSO) will arrange for routine changes of dosimeters, evaluate exposures, and maintain and provide the records of radiation exposure. Any significant increase in the monthly exposure reading will be investigated to determine probable cause and the appropriate remedial measures to be taken.
- Radiation detection dosimeters (badges) must be worn routinely by personnel when exposure to ionizing radiation is possible. At HU/HUH, this means that the workers handling radioisotopes or devices producing radiation are required to wear a dosimeter.
- All individuals must receive radiation safety training before the film badges can be issued to ensure the badges are used properly. Training is to be provided upon initial hire for all new radiation workers and annually thereafter including the annual refresher course (regular/contractor).
- Film Badges will be issued after the film badge request form has been completed and submitted to the RSO. Once it is reviewed and approved by Radiation Safety Officer, then the badge will be requested from the vendor (Landauer Inc.)

EXCHANGE OF DOSIMETERS

- Film badges are distributed on a monthly or quarterly basis through the department managers or the designated personnel. The designees are responsible for the distribution and the return of the badges on a timely manner. The participants are responsible for the proper use of the badge to facilitate the legal responsibility of maintaining the accurate radiation dosimetry records. Each individual is responsible for seeing that his/her badge holder has the current badge.

CONTROL BADGES

Control badges provide a background measure of radiation exposure. Control badges should not be worn by a participant and should be stored in the same location as all other issued badges. Control badges should be rotated at the same time as the participant badges. Control badges are not area monitors and should not be used as an area monitor.

PROPER USE OF DOSIMETERS

- Only the person who is assigned a dosimetry badge shall wear it. Do not loan a badge or use it for monitoring an area. Under no circumstance should workers wear a dosimeter belonging to another individual. It is a legal requirement that doses be tracked for the worker to whom the dosimeter is assigned.
- The dosimetry badge should be worn such that monitoring is optimized when working with ionizing radiation. Acceptable locations include the trunk of the body, sleeves or shirt pocket. Ring dosimeters should be worn when there is a possibility of significant exposure to the hand. It is important to wear ring dosimeters on the hand that is favored. Usually, the index finger receives the greatest exposure. The ring dosimeter should be worn under gloves to protect it from contamination. The film badge (Optically Stimulated Luminescence - OSL) should always be turned to face the source of radiation. For monitoring radiation exposure from photons (X-rays or gamma rays) and beta particles, Landauer Inc. uses OSL dosimeters (Luxel+ and InLight) for whole body and area monitoring, and TLD (thermoluminescent dosimetry) based ring dosimeters for monitoring dose to the extremities.
- The radiation dosimeter should always be worn whenever there is a possibility of being exposed to ionizing radiation during the workday. The dosimeter should never leave the Howard University and University Hospital premises. It should be stored in a safe, radiation-free location when not in use. It should not be stored at high temperature or in areas of high humidity. The radiation dosimeter shall not be worn when receiving a medical radiation exposure for personal purposes.
- When wearing a lead apron, the badge should be placed on the collar or belt outside the apron. For individuals monitored using two dosimetry badges, one should be worn on the collar (outside the apron) and the other should be worn at the waist level under the apron.
- The dosimeter must be promptly returned for processing at the end of wear period. Delay in returning the dosimeter will result in considerable extra work and will further delay in obtaining dosimetry reports. A dosimeter which is returned late cannot be processed with the control badge supplied with the shipment.
- Care should be taken to make sure that badges do not become contaminated with radioactive materials. Lost or misplaced badges should be reported immediately to the Radiation Safety Office in order to receive a replacement.

REQUESTING RADIATION EXPOSURE RECORD

Radiation exposure history can be obtained from RSO by any individual with a written request. The written request must include the individual's name, date of birth, social security number, the department where the individual worked, and the dates that the dosimeter was worn at this location.

ABSENCES AND TERMINATIONS

If a badge has not been worn or used by a participant for any monitoring period, please notify the RSO for record. Also if a participant no longer requires a badge, please notify the RSO so that the badge for the individual can be cancelled.

EXPOSURE TO PREGNANT PERSONNEL

- The maximum permissible exposure for a declared pregnant worker during the gestation period is 500 mrem. If a radiation worker is pregnant, she has the option to notify the Radiation Safety Officer of her pregnancy in writing through her supervisor in order to monitor pre-natal radiation exposure during the gestation period. Upon declaration, the pregnant worker will then submit a Declaration of Pregnancy form. The pregnant radiation worker will then meet with the Radiation Safety Officer and her supervisor to receive additional radiation safety training.
- Declared pregnant workers (DPW) will be assigned two badges, one for the whole body, normally worn on the torso and one for the fetus, normally worn on the abdomen. The badges will be exchanged on a monthly basis. Regulations require that exposure must be maintained beneath a cap of 50 mrem (0.5 mSv) on a monthly basis.
- If not declared, the radiation exposure limits for the worker will remain at the occupational level, that is, 5000 mrem per year.

ALARA INVESTIGATION EXPOSURE LEVELS

- The Radiation Safety Office will investigate all exposures exceeding the guidelines below. **ALARA** is an acronym for **A**s **L**ow **A**s **R**easonably **A**chievable. This is a radiation safety principle for minimizing radiation doses and releases of radioactive materials by employing all *reasonable methods*. ALARA is not only a sound safety principle but is a **regulatory requirement** for all radiation safety programs.
- There are two types of ALARA investigation levels for external occupational radiation exposure as indicated by the dosimeter. If a radiation worker's dose for any calendar quarter (3 months) or calendar year (12-month period) exceeds these values, an investigation is conducted by the Radiation Safety Officer to determine if there are reasonable ways to reduce the dose levels. Quarterly investigation levels I and II are based on 2.5% (125 mrem) and 7.5% (375 mrem) of the annual regulatory limits respectively.

ALARA Level I

- No further action will be taken if an individual's dose is less than ALARA Level I value.

ALARA Level I but < ALARA II

- A timely investigation will be conducted to review the individual's dose history prior to the occurrence of the ALARA Level I dose and monitor the individual's doses for the next 3 months. No response will be necessary unless additional information is requested. Records are documented in ALARA investigation file.

ALARA Level II

- The Radiation Safety Officer (RSO) will investigate the causes of exceeding ALARA Level II; consider actions to reduce the probability of occurrence; and present a report on the ALARA Level II occurrences to the Radiation Safety Committee for review.

ALARA INVESTIGATION LEVELS

	Regulatory Limit	Level I	Level II
Whole Body Exposures	5000 mrem/year	125 mrem/quarter	375 mrem/quarter
Lens of the Eye	15000 mrem/ year	375 mrem/quarter	1125 mrem/quarter
Skin and/or Extremity	50000 mrem/ year	1250 mrem/quarter	3750 mrem/quarter
Minors (whole body)	100 mrem/ year	10 mrem/quarter	30 mrem/quarter
Embryos/Fetus	500 mrem/9-month gestation	10 mrem/quarter	30 mrem/quarter
Member of Public onsite (EPA)	100 mrem/year whole body	5* mrem/quarter	15* mrem/quarter
Member of Public offsite (EPA)	10 mrem/year with less than 3 mrem due to radioiodine from airborne releases	1* mrem/quarter	3* mrem/quarter
Environmental Releases	10 CFR 20 Appendix B averaged over one year at the unrestricted area boundary.	10% of 10 CFR 20 Appendix B averaged over the calendar quarter at the boundary; or listed value at the stack.	30% of 10 CFR 20 Appendix B averaged over the calendar quarter at the boundary; or listed value at the stack.

APPENDIX I:

RADIATION WORKER TRAINING

CHECKLIST FOR TRAINING WORKERS IN RADIATION LABORATORIES

The following is a list of information which should be reviewed by the principal investigator/department manager with all individuals frequenting any work area where there are radioactive materials/radiation producing devices. Please write a Y (Yes), N (No), or NA (Not Applicable) in the box provided next to the training item.

		Y/N/NA
1	Attended Radiation Safety Training from RSO.	
2	The exposure limits for radiation have been reviewed with the worker.	
3	Radiation warning symbols and their meanings have been reviewed with the worker.	
4	The locations of radioactive materials present in the laboratory have been pointed out to the worker.	
5	The location and types of wastes and containers for the wastes have been identified with the worker.	
6	The proper procedures for emergencies which may arise in the laboratory have been reviewed with the worker. This information includes the location of emergency spill kits, emergency response telephone numbers and immediate persons to contact in the laboratory if an emergency arises.	
7	Security requirements for radioactive material have been reviewed with the worker.	
8	I have reviewed or was informed where to access the HU/HUH Radiation Safety Manual	

Worker Consent:

I certify that I have been provided with and understand the information indicated above. I understand that this is a certification of principal investigator/department manager training and informed consent and does not constitute a waiver of my rights. I understand that I am responsible for adhering to all safety practices, laws, rules and guidelines.

_____ _____

Print Name Department & Job Title

_____ _____

Signature Date

Principal Investigator/Department Manager:

I certify that the above information was reviewed with or provided to the above certified worker.

_____ _____

Print Name Department & Job Title

_____ _____

Signature Date

INSTRUCTIONS FOR PRINCIPAL INVESTIGATOR TRAINING

1. Individuals frequenting an area where radioactive materials are used, stored or disposed should receive principal investigator training. This training may be documented with this checklist.
2. Training is function specific and site specific, meaning the content and depth of training is related to the duties of the person and the scope of the hazards present in the work area.
3. Exposure limits must be explained to workers. For persons who are not certified radiation workers, the exposure limits are General Public, or 100 mrem per year. For radiation workers, the limits are the occupational limits set forth in the 10 CFR 20 laws, or 5 rem per year TEDE (whole body), 50 rem per year to an organ, 15rem per year to the lens of the eye, 50 rem per year for the skin of the whole body and/or extremities. Radiation workers must have received introductory safety training at the ORCBS and must attend annual refreshers for radiation and hazardous waste.
4. Copies of the training records may be kept in the safety notebook.
5. Security and control of radioactive materials must be provided at all times, either with persons present or locking or securing to prevent tampering or unauthorized use or removal. Persons who are not radiation workers may provide this control if they are appropriately trained by the PI and/or the RSO's radiation safety training class.
6. This document serves as informed consent of the worker.

TRAINING OF STUDENTS WORKING WITH RADIOACTIVE MATERIALS

The principal investigator (Authorized User) is responsible for training students in the handling and safe use of radioactive materials. The training should include the basic safety precautions of working with radioactive materials. Upon request, a member of the Radiation Safety Office staff will present this information to your students. The student must also attend special training organized by Radiation Safety Office prior to working with radioactive material. Please contact the Radiation Safety Office for assistance in training or other matters pertaining to radioactive materials and radiation equipment.

APPENDIX J:

GUIDELINES FOR HANDLING RADIOACTIVE SPECIMENS

HOWARD UNIVERSITY POLICY

GUIDELINES FOR HANDLING AND PATHOLOGIC EXAMINATION OF RADIOACTIVE SPECIMENS

I. INTRODUCTION

The U.S. Nuclear Regulatory Commission has regulatory jurisdiction for the medical use of radioactive material. Title 10 CFR contains the relevant standards for protection against radiation. The maximum occupational exposure limit for radiation workers is 5000 mrem per year (total effective dose) or 50,000 per year for skin or extremities. Special training and individual radiation monitoring devices (film badges) are required only for those who are likely to be exposed to more than 10% of the annual exposure limits.

The exposure limit for the general public is 100 mrem per year. And the exposure limit for pregnant women is 500 mrem, throughout their entire pregnancy period. This, provided that the institution is authorized by the U.S. NRC and has procedures in place to maintain the dose As Low As Reasonably Achievable (ALARA).

II. SPECIMEN HANDLING AND LABELING (LABORATORY AD SURGERY PERSONNEL)

a) Handling

In general, exposure to radioactive material is reduced if movement of the material is minimized, if the storage site of the material is shielded, if the area of use has limited and controlled access, and if radioactive waste is appropriately handled. In addition, laboratories should have sufficient floor and workspace and have surfaces that can be decontaminated if necessary.

For example, doses of 0.4 to 1.0 millicuries of Tc-99m are typically used in sentinel lymphadenectomy (SLN) for melanoma and breast cancer. Mean radiation dose to the skin of a surgeon's hand during SLN procedures have been reported to be approximately 10 mrem for breast cancer and 2mrem for melanoma, whereas the total effective dose is estimated to be less than 0.1 mrem. At these measured exposure rates, a surgeon theoretically could perform several thousand such operations each year and not exceed statutory exposure limits.

Mean radiation dose to pathology staff exposed to these specimens has been rarely measured but is much lower than that to the surgeon because of the shorter time spent handling the specimens. Specimens obtained during sentinel lymphadenectomy have lower radiation levels than those of specimens obtained during radiation implant devices.

b) Labeling

The code of federal regulations states that containers of licensed radioactive material must be labeled

"Caution – Radioactive Material", unless they are in exempt quantity. The requisition slip that accompanies the tissue must indicate the nature of the specimen and include the date and time of surgery. If labels indicating radioactive material have been attached to the container, they must be removed before disposal.

III. TRANSPORTATION

Specimens containing radioactive materials should be promptly transported from the operating room to the laboratory, in a sealed, properly labeled specimen container. Under no circumstance should specimens be left unattended or in unsecured holding areas, before, during nor after transport to the laboratory or frozen section room. Only personnel who is properly trained in radiation safety should handle and/or transport radioactive specimens.

IV. SPECIMEN PROCESSING

Sentinel Lymph nodes, for example, shall not be held or quarantined prior to processing, as the radiation exposure levels are exceedingly low for the pathology staff. In fact, holding such specimens for one or more days may increase the risk of processing errors, such as misplaced specimens or suboptimal fixation.

However, quarantine of the primary tumor excision specimen may be considered because of the higher radioactivity levels in these specimens, as compared with the sentinel lymph node. The final decision on when to quarantine a radioactive specimen sample, shall be based on the determination of the RSO when measuring the exposure levels.

V. PROTECTIVE WEAR

Protective wear such as disposable surgical gloves (always use two pairs of gloves when handling RAM), surgical scrubs, and plastic aprons shall be worn when handling these specimens. Any protective wear used when handling radioactive tissue specimens shall be removed before leaving the laboratory.

VI. STORAGE

Radioactive specimens should be held in a secure location to prevent unauthorized access and premature disposal. The Radiation Safety Officer (RSO) will store all radioactive specimens/waste in a shielded container or in a secure location away from laboratory and other personnel, for decay-in-storage, until they reach a radiation level similar to that of the background radiation prior to disposal.

VII. DISPOSAL

The U.S. NRC regulations allows routine methods of solid medical waste disposal for radioactive specimens after they decay in storage, which requires 10 (ten) half-lives.

Because the half-life of TC-99m is 6 hours, sentinel lymphadenectomy specimens and related surgical materials can be disposed through ordinary medical waste disposal (Stericycle Waste) methods 60 hours after time of surgery. If specimen containers have been labeled as "Caution – Radioactive Material", U.S. NRC regulations requires that these labels be removed prior to disposal with regular medical waste.

VIII. RADIATION MONITORING AND FILM BADGES

Radiation monitoring devices and film badges are not necessary for pathology personnel, because of the low levels of radioactivity, rapid decay and limited time of exposure. However, upon request, the RSO will provide temporary radiation monitoring devices (such as pocket dosimeters), to monitor the radiation exposure for personnel handling radioactive specimens.

IX. RADIATION SAFETY OFFICER

The Radiation Safety Officer (RSO) has the overall responsibility for developing safety procedures, determining exposure risk to laboratory personnel, and determining whether wipe tests or other measurements of radioactivity are needed. The RSO is also responsible for overseeing that all surgical and pathology personnel are properly trained in regard to radiation safety issues.

APPENDIX K:

GUIDELINES FOR DISPOSING OF RADIOACTIVE WASTE

HOWARD UNIVERSITY POLICY

GUIDELINES FOR DISPOSING OF RADIOACTIVE WASTE

I. INTRODUCTION

Radioactive Material (RAM) Waste is any material that has been or is likely to have been contaminated with radioactive isotopes. Chemical and radioactive waste generated in laboratories is subject to U.S. NRC and D.C. Health regulations. At Howard University and Howard University Hospital, all chemical and radioactive waste disposal must be managed in accordance with the policies and procedures set forth by the Radiation Safety Office.

You are not allowed to dispose of any radioactive waste in a regular trash or disposal bins.
All RAM must be disposed of through the Radiation Safety Office.
There are no exceptions to this rule!

II. HANDLING RADIOACTIVE WASTE

1. A separate container must be used for each isotope used, with the exception of ^{3}H &^{14}C; these isotopes can be mixed in the same container.
2. You must separate the solids and the liquids. Under no circumstance should liquids be placed in the solid waste or solid material placed in the liquid waste.
3. You must have secondary containment for your liquid radioactive waste container(s), in case of a leak or some spillage when filling the container, or rupture of the container.
4. Record the isotope, activity, date and initials every time some material is added to the waste container(s). Each pair of gloves or pipette tip needs not be manifested, but there should be an entry for each experiment or day that material is added.
5. Be sure to list the chemical components of the liquid waste on the back of the waste tag. Put the chemical name followed by the percent "by volume" or other units to quantify that chemical. This helps the Radiation Safety Office personnel determine how to route the waste.
6. Fill the liquid container(s) only to 3 inches from the top. Overfilling the containers could present a hazard to the lab as well as the Radiation Safety Office personnel. When the container is full, contact the Radiation Safety Office to schedule a pickup. When scheduling your waste pick up, notify the Radiation Safety Office about each solid, liquid, animal or vial waste you want picked up, and be prepared to share the isotope and activity for each container.

III. DISPOSAL OF RADIOACTIVE ANIMAL WASTES

1. All animal feces (excrement except urine) and left-over food must be segregated based on radioisotope. However, wastes of C-14 and H-3 may be placed into one container (plastic bag).
2. All tissue and animal carcass wastes should be frozen prior to pick up.
3. Place animal carcass of C-14 and H-3 into one container (plastic bag) and put a label with combined total activity on the container including dates.
4. All animal tissues and bedding wastes must be double bagged and tied closed. Disposal bags provided by Radiation Safety should be used. Notify the Radiation Safety Office if biohazardous materials are in the wastes.
5. A completed radioactive waste label must be attached to the waste bag.
6. Filed the radioactive waste disposal form and contact the Radiation Safety Office to schedule a pickup.

IV. PROCEDURE FOR ESTIMATING RADIOACTIVITY IN LIQUID WASTE PRIOR TO DRAIN DISPOSAL

To ensure that the amount of each radioisotope does not exceed the monthly and annual discharge limits specified in 10 CFR 20.2003(a)(4) and 10 CFR 20, Appendix B, Table 3-

1. Record the volume of radioactive aqueous liquid kept in a suitable container.
2. Pipette 1 mL of the liquid waste into an empty scintillation vial and scintillation cocktail.
3. Run vial through the Liquid Scintillation Counter (LSC).
4. Obtain the LSC results (in cpm or dpm).
5. Convert the dpm to µCi/mL or cpm to mCi/mL using one of the following methods:

A. Method 1

$$(\text{dpm}) \times (4.545 \times 10^{-7}) = \mu\text{Ci/mL}$$

Convert µCi/mL to µCi by;

$$(\mu\text{Ci/mL}) \times (\text{total mL in waste bottle}) = \mu\text{Ci}$$

Convert µCi to mCi using;

$$(\mu\text{Ci}) \times (1.0 \times 10^{-3}) = \text{mCi}$$

B. Method 2

Converting **CPM** obtained from LSC result to µCi/mL using:

$$\mu\text{Ci/mL} = \text{cpm}/(\text{E} \times 2.22 \times 10^{6}(\text{dpm}/\mu\text{Ci}) \times \text{V(mL)})$$

Converting **DPM** obtained from LSC result to µCi/mL using:

$$\mu\text{C/mL} = \text{dpm}/(2.22 \times 10^{6}(\text{dpm}/\mu\text{Ci}) \times \text{V(mL)})$$

Where V =Total Volume of liquid waste in mL,

E = Efficiency will vary depending on radionuclide and instrument settings

Finally, compare the activity concentration (µCi/mL) obtained to the Monthly Average Concentration in accordance with 10CFR 20.2033, Appendix B, Table 3 before disposal.

APPENDIX L:

GUIDELINES FOR CONDUCTING CONTAMINATION SURVEYS

GUIDELINES FOR CONDUCTING CONTAMINATION SURVEYS

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

Isotope	Half-Life	Counting Method	Typical Efficiency*	Energy MeV (beta)	Energy MeV (gamma)
^{3}H	12.35 years	L.S.C.	50%	0.0186	None
^{14}C	5730 years	L.S.C., Pancake	75%, 5%	0.157	None
^{22}Na	2.6 years	2:2 Gamma, 1:1 Gamma	30%, 15%	0.546	0.511, 1.27
^{32}P	14.3 days	Pancake	50%	1.71	None
^{33}P	25.3 days	Pancake	15%	0.248	None
^{35}S	87.5 days	L.S.C., Pancake	75%, 5%	0.167	None
^{36}Cl	3.0E5 years	Pancake	30%	0.709	None
^{40}K	1.28E9 years	Pancake	50%	1.33	1.46
^{45}Ca	163 days	Pancake	15%	0.258	0.012 (X-ray)
^{46}Sc	84 days	Pancake, 1:1 Gamma	20%, 15%	0.357	1.12, 0.889
^{51}Cr	27.7 days	L.E.G.	20%	None	0.32
^{55}Fe	2.7 years	Pancake	15%	0.232	None
^{63}Ni	100 years	L.S.C.	50%	0.0669	None
^{65}Zn	243.8 days	1:1 Gamma, Pancake	15%, 15%	0.325	1.116
^{85}Sr	64.8 days	L.E.G.	15%	None	0.514
^{86}Rb	18.6 days	Pancake, 1:1 Gamma	50%, 20%	1.775	1.0771
^{111}In	2.8 days	L.E.G.	20%	None	0.245, 0.171
^{125}I	60 days	L.E.G.	50%	None	0.036
^{203}Hg	46.6 days	L.E.G., Pancake	25%, 10 %	0.213	0.279

Key

L.S.C.: Liquid Scintillation Counter
1:1 Gamma: 1" by 1" NaI – Scintillator
L.E.G.: Low Energy Gamma Scintillator
2:2 Gamma: 2" by 2" NaI – Scintillator
Pancake: Beta Pancake Detector

*These are not the efficiencies to use for your own laboratory surveys.
Obtain the correct efficiencies for your survey meter from the most recent calibration report supplied by the Radiation Safety Office

PROCEDURE

1. Use a Geiger counter rather than liquid scintillation counter for monitoring all nuclides except ^{3}H. Geiger counters detect both removable and non-removable contamination, whereas wipes and liquid scintillation counting detect only removable contamination. ^{3}H cannot be detected by any Geiger counter, so liquid scintillation counting is the only method to conduct a survey for that nuclide.
2. You must survey in all areas where radioisotopes are used, stored or disposed, and the floors adjacent to those areas. This includes centrifuges, incubators, cold rooms, sealing equipment, pipettes and any other equipment which has been used for radioisotope work.
3. Make a record of all laboratory surveys. The record should include a map of the room, marks to identify where you surveyed, nuclides surveyed for, equipment identification, background of the equipment, efficiency for each nuclide monitored, and results of the survey. Results include area of contamination, nuclide, CPM reading, DPM, µCi amount and corrective action taken. To convert CPM to µCi, the following equations may be used:

   $$\text{CPM}/\text{Efficiency} = \text{DPM} \qquad \text{DPM}/2.22\times10^{6} = \mu\text{Ci amount}$$

4. To monitor for ^{3}H, wipes of the area must be taken followed by the steps stated below:
   a. Use a cotton tip applicator dipped in methanol to wipe the work area being checked. You may wipe a large area, then count. If you find contamination, take wipes of smaller areas until you localize the contamination.
   b. Place the cotton tip applicator in a liquid scintillation vial.
   c. Add 10 -15 ml. of counting cocktail.
   d. Let the sample desorb for 30 minutes.
   e. Count in a liquid scintillation counter for 1 minute.
   f. Record the results on the laboratory survey record.
5. To monitor all other radioisotopes, use a Geiger counter with the correct probe. Follow these steps:
   a. Turn the meter on and first check the batteries by looking at the battery check reading. If the batteries are low, replace them before surveying. You may survey with the audio on or off. However, significant rate changes are easily detected by the audio.
   b. Set the meter to read on the lowest possible setting, e.g., 0.1X or 1X the count rate. Set the response to fast response.
   c. Check and record the background reading. (Note: Fast response mode gives a background range, which is needed to determine when contamination is present.)
   d. Slowly scan the area to be surveyed with the probe. Hold the probe about half an inch above the areas to maximize detection.
   e. If the needle reads above twice (rule of thumb for surveying) background, switch the response to slow response to accurately quantify the contamination. Check the suspected source of contamination from more than one direction to confirm the source of the response. The meter response may be due to waste, samples or other radioactive materials in the area and not due to contamination.
   f. Record the results of the survey on the record form.

g. Decontaminate or dispose of the contamination in the radioactive waste. If the contaminated area or equipment cannot be decontaminated, shield and label the contamination with the nuclide, date and activity in DPM or µCi.
h. Remember to turn the meter off after each use to save batteries.
i. If major contamination is found, report immediately to the principal investigator.

Table: Survey Frequency Guide

Amount Used	Documented Survey Frequency
Always less than 200 µCi in shipment	Monthly
≥200 µCi in shipment	After each use of ≥ 200 µCi (means each handling of shipment, even if using much less than 200 µCi), but not more than one per week, unless the Radiation Safety Officer deems otherwise (Certain high risk uses require more frequent surveys)
No use in a given period	No survey required, keep record of the dates of non-use in the survey book

APPENDIX M:

SECURITY AND STORAGE OF RADIOACTIVE SOURCES

SECURITY

It is required by U.S. Nuclear Regulatory Commission law that security of radioactive materials must be in place at all times. Violations of this regulation are frequently cited at institutions utilizing radioactive materials and place the license to use such materials in jeopardy. The Code of Federal Regulations, Title 10, Part 20.1801 and 20.1802, Storage and Control of Licensed Materials in Unrestricted Areas, reads:

(a) The licensee shall secure from unauthorized removal or access licensed materials that are stored in controlled or unrestricted areas.

(b) The licensee shall control and maintain constant surveillance of licensed material that is in a controlled or unrestricted area and that is not in storage.

This means that all locations where radioactive materials are present must be in constant attendance by the trained user, or otherwise locked or secured to prevent unauthorized removal or tampering.

STORAGE

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

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

All radioactive materials, whether in storage, waste or use, must be labeled with the radioactive warning symbol, the words "Caution, Radioactive Materials", the isotope, the date and the amount of radioactivity in DPM or microcuries.

APPENDIX N:

QUARTERLY INSPECTION FOR LABORATORIES

HOWARD UNIVERSITY

RADIATION SAFETY OFFICE

RADIOISOTOPE LABORATORY QUARTERLY INSPECTION REPORT

Section A: Contact Information (Authorized User)			
Last Name:	First Name:	Title:	
Department:	Building:	Room:	
Section B:			
Name of Inspector: Satya Bose, Ph.D., DABR		Date:	Time:
Inspection Period:		Phone: On file	

Section C: Postings and Hazard Communication				
Applicable		Yes	No	Comments
1	Radiation Warning Signs are used appropriately on entrance to the laboratory			
2	NRC Form 3 - Notice to employees posted			
3	Emergency procedure posted			
4	Current radioisotope permit is posted			

Section D: Laboratory Design and Physical Requirements				
Applicable		Yes	No	Comments
1	Access to laboratory is restricted to authorized personnel			
2	Radioactive materials and waste are adequately shielded and stored in a location taking ALARA principles in effect			
3	Area used for work and storage of radioactive materials are free of clutter, properly contained and labelled			
4	An emergency eyewash and shower station are available in the laboratory or in close proximity			
5	Laboratory supplies are available (absorbent pads, wipe test paper, decontamination solution etc..) and are in use			
6	All locations being used for handling and storing radioactive materials have been authorized by RSO			
7	Hand washing sink and soap are available in the laboratory			
8	Refrigerator, Freezer, hood, storage cabinet and waste receptacle are clearly and properly labelled			

Section E: Radioactive Laboratory Work Practices				
Applicable		Yes	No	Comments

1	Laboratory personnel are aware of Radiation Safety Manual and Standard Operating Procedures			
2	Lab coats, gloves and appropriate protective equipment are worn by radioisotope authorized users			
3	Any eating, drinking, storage of food or application of cosmetics noted in the laboratory			
Section F: Personnel Protective Equipment and Dose Control				
Applicable		Yes	No	Comments
1	Fume hood is available for volatile radionuclide work, functioning properly and certified within the last 365 days			
2	Dose rate from any working location does not exceed 2 mR/hr			
3	Radiation workers handling radioactive materials are using dosimeters			
4	Dosimeters are stored in a designated rack away from radiation sources			
Section G: Training and Regulatory Records				
Applicable		Yes	No	Comments
1	All authorized personnel listed on the license have completed “Radiation Safety” training			
2	All radioactive materials in storage and in use are within the possession limits as indicated on the permit			
3	All radioactive materials in storage and in use have corresponding inventory records			
4	Storage room, daily use, remaining quantities and final disposal are recorded on Inventory/Waste Record			
5	Inventory/Waste Records are available for review and kept for a minimum of three years			
Section H: Contamination and Laboratory Monitoring: Survey Meter				
Applicable		Yes	No	Comments
1	Wipe test is performed, recorded and are available for review			
2	Survey locations are identified on the map and results are kept for review			
3	Portable Survey meter is available for the type of radiation work and functioning properly			
4	Survey meter is calibrated within the year and pre-operation checks are done			
Section I: Waste Handling				
Applicable		Yes	No	Comments
1	Radioactive wastes are deposited into waste container, shielded, identified and recorded on the			

	Inventory/Waste Form			
2	Labels are obliterated on non-contaminated item prior to disposal			
3	Proper procedures for waste disposal are followed: sharps, liquid, solid			
Section J: Notes				
1				
2				
Section K: Completed by				
Name:		Title:		
Signature:		Date:		
Reviewed by: Satya Bose, Ph.D. DABR		Title: Radiation Safety Officer		
Signature:		Date:		

APPENDIX O:

RADIOACTIVE MATERIAL

RECEIVING VAULT LOG SHEET

RADIATION SAFETY OFFICE

HOWARD UNIVERSITY HOSPITAL

RADIOACTIVE MATERIAL RECEIVING VAULT LOG SHEET

Receiving Vault Instructions – There will be only 2 sets of keys for the Vault. One will be kept by the Radiation Safety Officer and the other will be in possession of HUH Security Office. Authorized Radiation Safety personnel (receiving instructions directly from the RSO) may obtain the key from HUH Security to gain access to the Vault. All persons who use the key from Security must complete an entry on this form.

Date	Staff Name	Time Key Retrieved	Time Key Returned	Description of Work	Monitors Source Checked	Signature

GLOSSARY

Absorbed Dose

the amount of energy imparted to matter by ionizing radiation per unit mass of irradiated material. The unit of absorbed dose is the rad, which is 100 ergs/gram.

Absorption

the phenomenon by which radiation imparts some or all of its energy to any material through which it passes.

Activation

the process of making a material radioactive by bombardment with neutrons, protons, or other nuclear radiation.

Activity

the number of nuclear disintegrations occurring in a given quantity of material per unit time.

Acute Exposure

the absorption of a relatively large amount of radiation (or intake of radioactive material) over a short period of time.

Acute Health Effects

prompt radiation effects (those that would be observable within a short period of time) for which the severity of the effect varies with the dose, and for which a practical threshold exists.

Adult

an individual 18 or more years of age.

ALARA

(acronym for As Low As Reasonably Achievable) making every reasonable effort to maintain exposures to radiation as far below the dose limits as is practical consistent with the purpose for which the licensed activity is undertaken, taking into account the state of technology, economics of improvements in relation to state of technology, the economics of improvements in relation to benefits to public health and safety, and other societal and socio-economic considerations, and in relation to utilization of nuclear energy and licensed materials in the public interest.

Alpha Particle

a strongly ionizing particle emitted from the nucleus during radioactive decay having a mass and charge equal in magnitude to a helium nucleus, consisting of 2 protons and 2 neutrons with a double positive charge.

Alpha Ray

a stream of fast-moving helium nuclei (alpha particles), a strongly ionizing and weakly penetrating radiation.

Anion

a negatively charged ion.

Annual Limit of Intake (ALI)

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 rems (0.05 Sv) or a committed dose equivalent of 50 rems (0.5 Sv) to any individual organ or tissue.

Atom

smallest particle of an element which is capable of entering into a chemical reaction.

Attenuation

the process by which a beam of radiation is reduced in intensity when passing through some material. It is the combination of absorption and scattering processes and leads to a decrease in flux density of the beam when projected through matter.

Background Radiation

ionizing radiation arising from radioactive material other than the one directly under consideration. Background radiation due to cosmic rays and natural radioactivity is always present. There may also be background radiation due to the presence of radioactive substances in other parts of the building, in the building material itself, etc.

Becquerel

the SI unit for radioactivity in which the number of disintegrations is equal to one disintegration per second. A charged particle emitted from the nucleus of an atom during radioactive decay.

Beta Particle

charged particle emitted from the nucleus of an atom during radioactive decay. A negatively charged beta particle is identical to an electron. A positively charged beta particle is called a positron.

Beta Ray

a stream of high-speed electrons or positrons of nuclear origin more penetrating, but less ionizing than alpha rays.

Bioassay

the determination of kinds, quantities or concentrations, and, in some cases, the locations of radioactive material in the human body, whether by direct measurement (in vivo counting) or by analysis and evaluation of materials excreted or removed from the human body.

Body Burden

the amount of radioactive material which if deposited in the total body will produce the maximum permissible dose rate to the critical organ.

Bremsstrahlung

electromagnetic (X-ray) radiation produced by the deposition of charged particles in matter. Secondary photon radiation (X-ray) produced by the deceleration of charged particles through matter. Usually associated with energetic beta emitters, e.g., ^{32}P.

Calibration

determination of variation from standard, or accuracy, of a measuring instrument to ascertain necessary correction factors. The check or correction of the accuracy of a measuring instrument to assure proper operational characteristics.

Cation

a positively charged ion.

Charged Particle

an ion. An elementary particle carrying a positive or negative electric charge.

Chronic Exposure

the absorption of radiation (or intake of radioactive materials) over a long period of time, i.e., over a lifetime.

Committed Dose Equivalent ($H_{T,50}$)

the dose equivalent to organs or tissues of reference that will be received from an intake of radioactive material by an individual during the 50-year period following the intake.

Committed Effective Dose Equivalent ($H_{E,50}$)

the sum of the products of the weighting factors applicable to each of the body organs or tissues that are irradiated and the committed dose equivalent to these organs or tissues.

Contamination, Radioactive

deposition of radioactive material in any place where it is not desired, and particularly in any place where its presence may be harmful. The harm caused may be a source of excessive exposure to personnel or the validity of an experiment or a procedure.

Controlled Area

an area, outside of a restricted area but inside the site boundary, access to which can be limited by the licensee for any reason.

Cosmic Radiation

penetrating ionizing radiation, both particulate and electromagnetic, originating in space. Secondary cosmic rays, formed by interactions in the earth's atmosphere, account for about 45 to 50 millirem annually.

Coulomb

the meter-kilogram-second unit of electric charge, equal to the quantity of charge transferred in one second by a constant current of one ampere.

Count

the external indication of a device designed to enumerate ionizing events. It may refer to a single detected event or to the total registered in a given period of time. The term is often erroneously used to designate a disintegration, ionizing event, or voltage pulse.

Critical Organ

the organ or tissue, the irradiation of which will result in the greatest hazard to the health of the individual or his descendants.

Curie

the activity of any radioactive material in which the number of disintegrations is 3.7×10^{10} per second. Abbreviated as Ci.

Daughter Products

isotopes that are formed by radioactive decay of some other isotope. In case of radium-226, for example, there are ten successive daughter products, ending in the stable isotope lead-206.

Decay, Radioactive

disintegration of the nucleus of an unstable nuclide by the spontaneous emission of charged particles and/or photons.

Declared Pregnant Worker

a woman who has voluntarily informed her employer, in writing, of her pregnancy and the estimated date of conception.

Delayed Health Effects

radiation health effects which are manifested long after the relevant exposure. The vast majority are stochastic, that is, the severity is independent of dose and the probability is assumed to be proportional to the dose, without threshold.

Decontamination

the reduction or removal of contaminating radioactive material from a structure, area, object, or person. Decontamination may be accomplished by (1) treating the surface to remove or decrease the contamination, (2) letting the material stand so that the radioactivity is decreased as a result of natural decay, and (3) covering the contamination to shield or attenuate the radiation emitted.

Deep Dose Equivalent (H_d)

applies to external whole-body exposure and is the dose equivalent at a tissue depth of one centimeter (1000 mg/cm^2).

Department of Transportation (DOT)

a governmental agency responsible for promoting the safe transportation of hazardous materials by all modes (land, air, water).

Depleted Uranium

uranium having a percentage of uranium-235 smaller than the 0.7% found in natural uranium. It is obtained from spent (used) fuel elements or as byproduct tails, or residues, from uranium isotope separation.

Derived Air Concentration (DAC)

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.

Disintegration

see decay, radioactive.

Dose or Radiation Dose

a generic term that means absorbed dose, dose equivalent, effective dose equivalent, committed dose equivalent, committed effective dose equivalent, or total effective dose equivalent, as defined in other paragraphs of this section.

Dose Equivalent (H_T)

the product of the absorbed dose in tissue, quality factor, and all other necessary modifying factors at the location of interest. The units of dose equivalent are the rem and the sievert (Sv). The ICRP defines this as the equivalent dose, which is sometimes used in other countries.

Dose Rate

the radiation dose delivered per unit of time. Measured, for example, in rem per hour.

Dosimeter

a portable instrument for measuring and registering the total accumulated exposure to ionizing radiation. (see dosimetry.)

Dosimetry

the theory and application of the principles and techniques involved in the measurement and recording of radiation doses. Its practical aspect is concerned with the use of various types of radiation instruments with which measurements are made (see film badge; thermoluminescent dosimeter; Geiger-Mueller counter).

Effective Dose Equivalent (H_E)

the sum of the products of the dose equivalent to the organ or tissue (H_T) and the weighting factors applicable to each of the body organs or tissues that are irradiated. ($H_E = \Sigma\, w_T\, H_T$)

Efficiency (radiation detection instrument)

a measure of the probability that a count will be recorded when radiation is incident on a detector. Usage varies considerably so be aware of which factors (window, transmission, sensitive volume, energy dependence, etc.) are included in a given case. HU/HUH, we are referring to the percent of

total activity present for a given nuclide detected by the radiation detection instrument being used.

Electromagnetic Radiation

a traveling wave motion resulting from changing electric or magnetic fields. Familiar electromagnetic radiations range from x-rays (and gamma rays) of short wavelength, through the ultraviolet, visible, and infrared regions, to radar and radio waves of relatively long wavelength. All electromagnetic radiations travel in a vacuum with the velocity of light (see photon).

Electron

negatively charged elementary particle which is a constituent of every neutral atom. Its unit of negative electricity equals 4.8 x 10-19 coulombs. Its mass is 0.000549 atomic mass units.

Electron Capture

a mode of radioactive decay involving the capture of an orbital electron by its nucleus. Capture from the particular electron shell is designated as "K-electron capture," "L-electron capture," etc. X-rays are produced.

Electron Volt

a unit of energy equivalent to the amount of energy gained by an electron in passing through a potential difference of 1 volt. Abbreviated eV. Radio isotopic energy is typically measured in MeV. (million electron volts).

Erg

the unit of energy or work in the centimeter-gram-second system; the work performed by a force acting over a distance of one centimeter so as to result in a one-gram mass being accelerated at a rate of one centimeter per second each second.

Exposure

(1) Being exposed to ionizing radiation or radioactive material. (2) a measure of the ionization produced in air by x or gamma radiation. It is the sum of the electrical charges on all ions of one sign produced in air when all electrons liberated by photons in a volume element of air are completely stopped in air, divided by the
mass of air in the volume element. The special unit of exposure is the Roentgen.

External Dose

that portion of the dose equivalent received from radiation sources outside the body.

Extremity

hand, elbow, arm below the elbow, foot, knee, or leg below the knee.

Eye Dose Equivalent

applies to the external exposure of the lens of the eye and is taken as the dose equivalent at a tissue depth of 0.3 centimeter (300 mg/cm^2).

Film Badge

a packet of photographic film used for the approximate measurement of radiation exposure for personnel monitoring purposes. The badge may contain two or more films of differing sensitivity, and it may contain filters which shield parts of the film from certain types of radiation.

Fission

the splitting of a nucleus into at least two other nuclei and the release of a relatively large amount of energy. Two or three neutrons are usually released during this type of transformation.

Gamma Ray

very penetrating electromagnetic radiation of nuclear origin. Except for origin, Identical to X-ray.

Geiger-Mueller (G-M) Counter

a radiation detection and measuring instrument. It consists of a gas-filled tube containing electrodes, between which there is an electrical voltage but no current flowing. When ionizing radiation passes through the tube, a short, intense pulse of current passes from the negative electrode to the positive electrode and is measured or counted. The number of pulses per second measures the intensity of radiation.

Gray

The standard international (SI) unit of absorbed dose in which the energy deposited is equal to one Joule per kilogram (1 J/kg).

Half-Life, Biological

time required for the body to eliminate 50 percent of a dose of any substance by the regular processes of elimination. This time is approximately the same for both stable isotopes and radionuclides of a particular element.

Half-Life, Effective

time required for a radioactive nuclide in a system to be diminished by 50 percent as a result of the combined action of radioactive decay and biological elimination.

$$\text{Effective half life} = \frac{\text{Biological half life} \times \text{Radiaoctive half life}}{\text{Biological half life} + \text{Radiaoctive half life}}$$

Half-Life, Radioactive

time required for a radioactive substance to lose 50 percent of its activity by decay. Each radionuclide has a unique half-life.

Half Value Layer

the thickness of any specified material necessary to reduce the intensity of an x-ray or gamma ray beam to one-half its original value.

Health Physics

a term in common use for that branch of radiological science dealing with the protection of personnel from harmful effects of ionizing radiation. The science concerned with the recognition, evaluation and control of health hazards from ionizing and non-ionizing radiation.

High Radiation Area

an area, accessible to individuals, in which radiation levels could result in an individual receiving a dose equivalent in excess of 0.1 rem (1 mSv) in one hour at thirty centimeters from the radiation source or from any surface that the radiation penetrates.

Hot Spot

the region in a radiation/contamination area in which the level of radiation/contamination is noticeably greater than in neighboring regions in the area.

Individual Monitoring Devices

devices designed to be worn by a single individual for the assessment of dose equivalent such as film badges, thermoluminescent dosimeters (TLDs), pocket ionization chambers, and personal air sampling devices.

Intake

quantity of material introduced into the body by inhalation, ingestion or through the skin (absorption, puncture, etc.)

Inverse Square Law

the intensity of radiation at any distance from a point source varies inversely as the square of that distance. For example: if the radiation exposure is 100 R/hr at 1 inch from a source, the exposure will be 0.01 R/hr at 100 inches.

Ion

an atom that has too many or too few electrons, causing it to be chemically active, such as an electron that is not associated (in orbit) with a nucleus. Ions may be positively or negatively charged and vary in size.

Ionization

the process by which a neutral atom or molecule acquires either a positive or a negative charge.

Ionizing Radiation

any radiation capable of displacing electrons from atoms or molecules, thereby producing ions. Examples, alpha, beta, gamma, x-rays, neutrons and ultraviolet light. High doses of ionizing radiation may produce severe skin or tissue damage.

Ionization Chamber

an instrument designed to measure the quantity of ionizing radiation in terms of the charge of electricity associated with ions produced within a defined volume.

Ionizing Radiation

alpha particles, beta particles, gamma rays, x-rays, neutrons, high speed electrons, high speed protons, and other particles or electromagnetic radiation capable of producing ions.

Isotopes

nuclides having the same number of protons in their nuclei, and hence having the same atomic number, but differing in the number of neutrons, and therefore in the mass number. Almost identical chemical properties exist between isotopes of a particular element.

Kinetic Energy

the energy that a body possesses by virtue of its mass and velocity, the energy of motion.

Joule

the standard international (SI) unit of work or energy; equal to the work done by a force of one Newton when its point of application moves through a distance of one meter in the direction of the force.

Labeled Compound

a compound consisting, in part, of labeled molecules. By observations of radioactivity or isotopic composition this compound or its fragments may be followed through physical, chemical or biological processes.

LD50/60

the dose of radiation expected to cause death within 60 days to 50 percent of those exposed.

Licensed Material

source material, special nuclear material, or byproduct material received, possessed, used, transferred or disposed of under a general or specific license issued by the Nuclear Regulatory Commission.

Licensee

the holder of the license.

Limits

the permissible upper bounds of radiation exposures, contamination or releases.

Member of the Public

an individual in a controlled or unrestricted area (who is not a radiation worker). However, an individual is not a member of the public during any period in which the individual receives an occupational dose.

Microcurie (uCi)

a one-millionth of a curie. (1/1,000,000), (0.000001 Ci) (See Curie.)

Millicurie (mCi)

a one-thousandth of a curie. (1/1000th), (0.001 Ci) (See Curie.)

Milliroentgen (mR)

a sub multiple of the Roentgen equal to one-thousandth (1/1000th) of a Roentgen. (see Roentgen.)

Minor

an individual less than 18 years of age, as pertains to radiation exposure limits, works with radioactive materials (not a member of the general public).

Molecule

a group of atoms held together by chemical forces. A molecule is the smallest unit of a compound that can exist by itself and retain all its chemical properties.

Monitoring

the measurement of radiation levels, concentrations, surface area concentrations or quantities of radioactive material and the use of the results of these measurements to evaluate potential exposures and doses.

Natural Radiation

ionizing radiation, not from manmade sources, arising from radioactive material other than the one directly under consideration. Natural radiation due to cosmic rays, soil, natural radiation in the human body and other sources of natural radioactivity are always present. The levels of the natural radiation vary with location, weather patterns and time to some degree.

Neutron

elementary particle with a mass approximately the same as that of a hydrogen atom and electrically neutral. It has a half-life in minutes and decays in a free state into a proton and an electron.

Non-Removable Contamination

contamination adhering to the surface of structures, areas, objects or personnel and will not readily be picked up or wiped up by physical or mechanical means during the course of a survey or during decontamination efforts.

NARM

any naturally occurring or accelerator produced radioactive materials. It does not include byproduct, source, or special nuclear material.

Neutron

an uncharged elementary particle with a mass slightly greater than that of the proton and found in the nucleus of every atom heavier than hydrogen.

NORM

naturally occurring radioactive materials.

Nuclear Regulatory Commission (NRC)

an independent federal regulatory agency responsible for licensing and inspecting nuclear power plants, universities and other facilities using radioactive materials.

Nucleus

the small, central, positively charged region of an atom that carries essentially all the mass. Except for the nucleus of ordinary (light) hydrogen, which has a single proton, all atomic nuclei contain both protons and neutrons. The number of protons determines the total positive charge, or atomic number; this is the same for all the atomic nuclei of a given chemical element. The total number of neutrons and protons is called the mass number.

Nuclide

a species of atom characterized by its mass number, atomic number, and energy state of its nucleus, provided that the atom is capable of existing for a measurable time.

Occupational Dose

the dose received by an individual in the course of employment in which the individual's assigned duties involve exposure to radiation and to radioactive material from licensed and unlicensed sources of radiation, whether in the possession of the licensee or other person. Occupational dose does not include dose received from background radiation, as a patient from medical practices, from voluntary participation in medical research programs, or as a member of the general public.

Particle Accelerator

any machine capable of accelerating electrons, protons, deuterons, or other charged particles in a vacuum and of discharging the resultant particulate or other radiation into a medium at energies usually more than 1 MeV. The National Superconducting Cyclotron Laboratory is a particle accelerator.

Photon

a quantum (or packet) of energy emitted in the form of electromagnetic radiation. Gamma rays and X-rays are examples of photons.

P i g

a container (usually lead or plastic) used to ship or store radioactive materials. Its thick walls protect the person handling the container from radiation. Large containers are commonly called casks.

Pocket Dosimeter

a small ionization detection instrument that indicates radiation exposure directly. An auxiliary charging device is usually necessary.

Positron

particle equal in mass, but opposite in charge, to the electron; a positive charge.

Principal Investigator (P.I.)

a faculty member, assistant professor or higher (no visiting faculty), appointed by the licensee, who has been approved through the Radiation Safety Committee for the purchase and use of radioactive materials.

Protective Barriers

barriers of radiation absorbing material, such as lead, concrete, plaster and plastic, that are used to reduce radiation exposure.

Proton

an elementary nuclear particle with a positive electric charge located in the nucleus of an atom.

Public Dose

the dose received by a member of the public from exposure to radiation and to radioactive material released by a licensee, or to another source of radiation. It does not include occupational dose or doses received from background radiation, as a patient from medical practices, or from voluntary participation in medical research
programs.

Quality Factor (Q)

a modifying factor that is used to derive dose equivalent from absorbed dose. It corrects for varying risk potential due to the type of radiation. The factor characterizing the biological effectiveness of a radiation, based on the ionization density along the tracks of charged particles in tissue.

Q has been superseded by the radiation weighting factor in the definition of equivalent dose, but it is still used in calculating the operational dose equivalent quantities used in monitoring.

Rad

the special unit of absorbed dose. One rad is equal to an absorbed dose of 100 ergs/gram or 62.4×10^6 MeV per gram.

A dimensionless factor by which the organ or tissue absorbed dose is multiplied to reflect the higher biological effectiveness of high-LET radiations compared with low-LET radiations. It is used to derive the equivalent dose from the absorbed dose averaged over a tissue or organ.

Radiation Area

an area, accessible to individuals, in which radiation levels could result in an individual receiving a dose equivalent in excess of 0.005 rem (0.05 mSv) in one hour at 30 cm from the radiation source or from any surface that the radiation penetrates.

Radiation Worker

an individual who uses radioactive materials under the licensee's control. Individuals must be trained and have passed a radiation safety examination prior to beginning work with radioactive materials.

Radiography

the making of shadow images on photographic film by the action of ionizing radiation.

Radioisotope

a nuclide with an unstable ratio of neutrons to protons placing the nucleus in a state of stress. In an attempt to reorganize to a more stable state, it may undergo various types of rearrangement that involve the release of radiation.

Radiology

that branch of medicine dealing with the diagnostic and therapeutic applications of radiant energy, including x-rays and radioisotopes.

Radionuclide

a radioactive isotope of an element.

Radio sensitivity

the relative susceptibility of cells, tissues, organs, organisms, or other substances to the injurious action of radiation.

Radiotoxicity

term referring to the potential of an isotope to cause damage to living tissue by absorption of energy from the disintegration of the radioactive material introduced into the body.

Reference Man

a hypothetical aggregation of human physical and physiological characteristics arrived at by international consensus. These characteristics may be used by researchers and public health workers to standardize results of experiments and to relate biological insult to a common base.

Relative Biological Effectiveness

for a particular living organism or part of an organism, the ratio of the absorbed dose of a reference radiation that produces a specified biological effect to the absorbed dose of the radiation of interest that produces the same biological effect.

Rem

the special unit of dose equivalent. The dose equivalent in rem is numerically equal to the absorbed dose in rad multiplied by the quality factor, distribution factor, and any other necessary modifying factors.

Removable Contamination

contamination deposited on the surface of structures, areas, objects or personnel that can readily be picked up or wiped up by physical or mechanical means during the course of a survey or during decontamination efforts.

Restricted Area

an area, access to which is limited by the licensee for the purpose of protecting individuals against undue risks from exposure to radiation and radioactive materials. Restricted area does not include areas used as residential quarters, but separate rooms in a residential building may be set apart as a restricted area.

Roentgen (R)

the quantity of x or gamma radiation such that the associated corpuscular emission per 0.001293 gram of dry air produces, in air, ions carrying one electrostatic unit of quantity of electricity of either sign. Amount of energy is equal to 2.58 x 10-4 coulombs/kg air. The Roentgen is a special unit of exposure.

Scintillation Counter

a counter in which light flashes produced in a scintillator by ionizing radiation are converted into electrical pulses by a photomultiplier tube.

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.

Shallow Dose Equivalent (H_S)

applies to the external exposure of the skin or an extremity and is taken as the dose equivalent at a tissue depth of 0.007 centimeter (7 mg/cm2) averaged over an area of one square centimeter.

Shielding Material

any material which is used to absorb radiation and thus effectively reduce the intensity of radiation, and in some cases eliminate it. Lead, concrete, aluminum, water and plastic are examples of commonly used shielding material.

Sievert

The standard international unit (SI) of dose equivalent (DE, human exposure unit), which is equal to 100 rem. It is obtained by multiplying the number of grays by the quality factor, distribution factor, and any other necessary modifying factors.

Site Boundary

that line beyond which the land or property is not owned, leased, or otherwise controlled by the licensee.

Somatic Effects of Radiation

effects of radiation limited to the exposed individual, as distinguished from genetic effects, which may also affect subsequent unexposed generations.

Source Material

1. uranium or thorium in any combination of uranium and thorium in any physical or chemical form; or
2. ores that contain, by weight, one-twentieth of 1 percent (0.05%), or more, of uranium, thorium, or any combination of uranium and thorium. Source material does not include special nuclear material.

Special Nuclear Material

1. plutonium, uranium-233, uranium enriched in the isotope 233 or in the isotope 235, and any other material that the Nuclear Regulatory Commission determines to be special nuclear material, but does not include source material; or
2. any material artificially enriched by any of the foregoing but does not include source material.

Specific Activity

total radioactivity of a given nuclide per gram of a compound, element or radioactive nuclide.

Stable Isotope

an isotope that does not undergo radioactive decay.

Stochastic Effects

health effects that occur randomly and for which the probability of the effect occurring, rather than its severity, is assumed to be a linear function of dose without threshold. Hereditary effects and cancer incidence are examples of stochastic effects.

Survey

an evaluation of the radiological conditions and potential hazards incident to the production, use, transfer, release, disposal or presence of radioactive material or other sources of radiation. When appropriate, such an evaluation includes a physical survey of the location of radioactive material and measurements or calculations of levels of radiation, or concentrations or quantities of radioactive material present.

Terrestrial Radiation

the portion of the natural radiation (background) emitted by naturally occurring radioactive materials in the earth.

Thermoluminescent Dosimeter (TLD)

crystalline materials that emit light when heated after being they have been exposed to radiation.

Tissue Weighting Factor (wT)

The factor by which the equivalent dose in a tissue or organ T is weighted to represent the relative contribution of that tissue or organ to the total health detriment resulting from uniform irradiation of the body (ICRP 1991b). It is weighted such that:

$$\sum w_T = 1$$

Total Effective Dose Equivalent (TEDE)

sum of the deep dose equivalent (for external exposures) and the committed effective dose equivalent (for internal exposures).

Tracer, Isotopic

the isotope or non-natural mixture of isotopes of an element which may be incorporated into a sample to make possible observation of the course of that element, alone or in combination, through a chemical, biological, or physical process. The observations may be made by measurement of radioactivity or of isotopic abundance.

Tritium

a radioactive isotope of hydrogen (one proton, two neutron). Because it is chemically identical to natural hydrogen, tritium can easily be taken into the body by any ingestion or inhalation path. Decays by beta emission. Its radioactive half-life is about 12.5 years.

Unrestricted Area

an area, access to which is neither limited nor controlled by the licensee.

Unstable Isotope

a radioisotope.

Uptake

quantity of material taken up into the extracellular fluids. It is usually expressed as a fraction of the deposition in the organ from which uptake occurs.

Very High Radiation Area

an area accessible to individuals, in which radiation levels could result in an individual receiving an absorbed dose in excess of 500 rads (5 grays) in one hour at one meter from a radiation source or from any surface that the radiation penetrates.

Weighting Factor (W_T)

for an organ or tissue (T) is the proportion of the risk of stochastic effects resulting from irradiation of that organ or tissue to the total risk of stochastic effects when the whole body is irradiated uniformly. Presently, the organ dose weighting defined by the NRC and the ICRP differ.

Whole Body

for purposes of external exposure, head, trunk (including male gonads), arms above the elbow, or legs above the knee.

Wipe (smear or wipe test)

a procedure in which a swab, e.g., filter paper or cotton tipped applicator, is rubbed on a surface and its radioactivity measured to determine if the surface is contaminated with loose (removable) radioactive material.

X-rays

Penetrating electromagnetic radiations having wave lengths shorter than those of visible light. They are usually produced by bombarding a metallic target with fast electrons in a high vacuum. In nuclear reactions it is customary to refer to photons originating in the nucleus as gamma rays, and those originating in the extra nuclear part of the atom as X-rays. These rays are sometimes called Roentgen rays after their discoverer, W.C. Roentgen.

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