

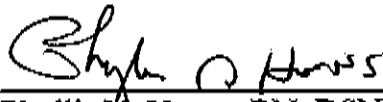
# RADIATION SAFETY MANUAL

## FOREWORD

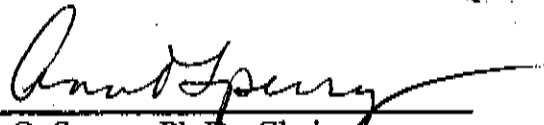
This manual is issued as a means of providing users of radiation sources with information on the radiation safety policies and procedures of East Carolina University. The responsibilities placed on the University by Public Law make it mandatory that all departments and their activities conform to the intent of this manual.

The Radiation Safety Committee, through its two Subcommittees, establishes University radiation safety policies. This includes reviewing each proposal to use radioactive material or install and operate radiation producing electronic equipment. Consultation and service necessary to insure proper radiation protection and adherence to the regulation is provided by the Office of Prospective Health-Radiation Safety Section.

All users of radioactive material and radiation producing electronic equipment must be familiar with the requirements set forth in this manual, including all applicable Public Laws, and conduct their operation in accordance with them.



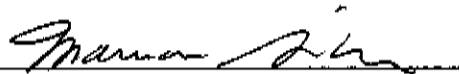
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# **ADMINISTRATION**

## **ADMINISTRATION**

### **Purpose of This Manual**

With the increasing use of both ionizing and non-ionizing radiation sources at East Carolina University, it has become necessary to provide a single document covering all radiation safety procedures and regulations.

The regulations and procedures outlined in this guide are intended to protect all individuals with a minimum of interference in activities. They are consistent with Federal and the State of North Carolina regulations but in general, the specific Federal and State regulations are not restated in this manual. Nevertheless, all such regulations are assumed to be applicable and are binding on personnel working with and using radioactive material or electronic equipment emitting radiation.

Regulations and recommendations stated within this document represent and reflect the most recent requirements of the University. This manual has been submitted for approval to the Radiation Protection Division of the North Carolina Department of Environment and Natural Resources.

The major purposes of this manual are summarized below:

- Clearly outline the responsibilities of all parties involved in obtaining and using radioactive material and radiation producing equipment at East Carolina University.
- Clearly state the training required by all radiation workers.
- Advise all individuals working with radiation producing equipment and radioactive material of their rights and responsibilities under Federal and State laws.
- Discuss fundamental dose-effect relationships and place radiation exposure risk into perspective with other risks encountered in daily life.
- Prescribe the use and interpretation of personnel dosimetry devices.
- Outline the special considerations involved with the exposure to radiation during pregnancy.
- Provide the radiation worker with a reference so as to assist in the safe handling of radioactive material and radiation producing equipment.
- Provide information on the proper disposal of radioactive waste.
- State the steps to be taken in case of any radiation emergency.

## ORGANIZATION/POLICY

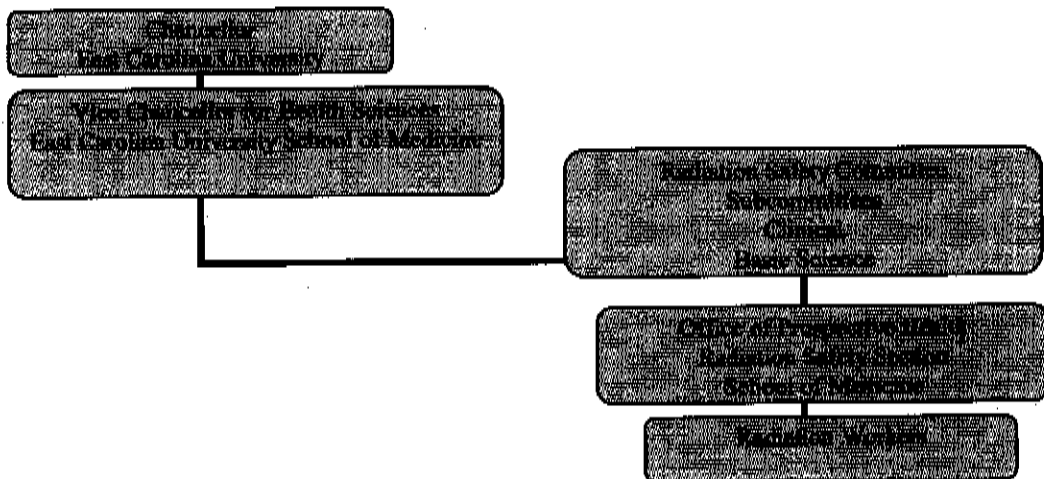
Whenever sources of radiation are used at any institution, the safety of personnel and the general public becomes a prime consideration. To insure this, safety, federal and state governments have developed regulations designed to protect the public health as related to radiation sources. Consequently, state regulations in agreement with federal standards require the existence of an adequate radiation safety program.

The Radiation Safety Committee and the Office of Prospective Health-Radiation Safety Section have been established to provide a quality radiation protection program for East Carolina University. The committee has been authorized by the University Chancellor to review and approve proposals that utilize sources of radiation. The Office of Prospective-Health Radiation Safety Section provides for the daily program operation. The Radiation Safety Committee is divided into two independent subcommittees: Basic Science Subcommittee and Clinical Subcommittee.

### Radiation Safety Organization

Where unsafe practices involving the use of products producing radiation or practices in violation of established regulation are observed, the Radiation Safety Officer has the authority to require cessation of the use of the radiation sources until thorough review can be made by the appropriate subcommittee. If the committee, at any time, is not satisfied with the adequacy of the radiation safety practices employed in a procedure, they may require all use of radiation to be stopped until satisfactory procedures have been adopted.

The University policy is to limit exposure to personnel from ionizing and non-ionizing radiations As Low As Reasonably Achievable (ALARA). However, under no circumstances is exposure to exceed federal and state regulations. The Radiation Safety Committee will allow the responsible use of radiation providing the use is in agreement with the safety procedures set for by the University, State and Federal requirements.



## **RESPONSIBILITIES**

### ***Radiation Safety Committee***

The Radiation Safety Committee is separated into two subcommittees: Basic Sciences and Clinical. The subcommittees meet at least three times during the year or as needed to discuss various aspects concerning the safe use and disposition of radioactive material and electronic equipment emitting ionizing and non-ionizing radiation.

#### ***Responsibilities of the Radiation Safety Committee: (Basic Sciences, Clinical, Non-ionizing)***

- Develop policies and guidelines for East Carolina University concerning the safe use of all radioactive material and radiation producing equipment.
- Review for approval all proposals for the use of radioactive material or radiation producing equipment.
- Review plans for all new buildings and modification to existing structures where ionizing and non-ionizing radiation is used.
- Provide technical advice to the Radiation Safety Officer.
- Review periodic reports from the Radiation Safety Officer
- Review all instances of alleged infractions of the use of ionizing and non-ionizing radiations or safety rules with the Radiation Safety Officer and responsible personnel and take necessary steps to correct such infractions.
- Ensure that in regard to radiation safety, all license obligations, regulations, and standards from the Nuclear Regulatory Commission (NRC), Occupational Safety and Health Administration (OSHA), Food and Drug Administration (FDA), Environmental Protection Agency (EPA), Department of Transportation (DOT), and the State of North Carolina Radiation Protection Division are reasonably met.

### ***Radiation Safety Officer***

The Radiation Safety Officer manages the Office of Prospective Health-Radiation Safety Section for East Carolina University.

#### ***Responsibilities of the Radiation Safety Officer:***

- Furnish consulting services to any potential user of ionizing or non-ionizing radiation and provide advice on radiation safety procedures.
- Ensure that in regard to radiation safety, all license obligations, regulations, and standards from the Nuclear Regulatory Commission (NRC), Occupational Safety and Health

Administration (OSHA), Food and Drug Administration (FDA), Environmental Protection Agency (EPA), Department of Transportation (DOT), and the North Carolina Department of Environment and Natural Resources are reasonably met.

- Review for approval all applications to use radiation sources prior to being sent to the Radiation Safety Subcommittees.
- Provide general surveillance of all radiation safety related activities including providing assistance to all personnel in discharging their responsibilities.
- Receive and ship all radioactive materials coming to or leaving the facility.
- Provide personnel and laboratory monitoring.
- Instruct personnel in radiation safety.
- Administer a radioactive waste disposal program.
- Perform leak tests on all sealed sources and provide radiation surveys on radiation producing equipment.
- Supervise decontamination in case of accidental spills of radioactive materials.
- Provide a continuous program of environmental radiation monitoring and hazard evaluation.
- Provide advice and assistance in the acquisition of dosimetry and monitoring equipment.
- Provide first echelon maintenance and calibration of survey equipment.
- Maintain all centralized records pertinent to the radiation safety program.
- Develop and refine radiation detection, shielding, and health protection techniques.
- Administer the overall day-to-day operation of the radiation safety program at the East Carolina University.
- Serve as a member on each of the Radiation Safety Subcommittees.
- Hire and train the staff of the Office of Prospective Health-Radiation Safety Section.
- Provide and maintain information on radiation protection, radiation safety supplies and equipment, and applicable federal and state regulations.
- Suspend any operation causing excessive and/or unnecessary radiological hazard as rapidly and as safely as possible and subject to review by the Radiation Safety Committee. (In carrying out this duty, the Radiation Safety Officer will report directly to



the Director of Prospective Health, the Vice Chancellor for Health Sciences, and the Radiation Safety Committee.)

### ***Department Chairs and Administrators***

The Department Chairs and Administrators are in charge of all uses of radiation sources in their department or area. The Chairs and Administrators are an integral part of the Application process that each Approved User must follow in order to use radioactive material and each review process conducted prior to the use of radiation producing electronic equipment.

### ***Responsibilities of the Department Chairs and Administrators***

- Ensure that staff members who desire to use ionizing or non-ionizing radiation contact the Office of Prospective Health-Radiation Safety Section and also secure a copy of this Radiation Safety Manual (on the web) <https://www.ecu.edu/cs-dhs/prospectivehealth/radiation.cfm>.
- Have permanent plans for all new buildings and modification of existing structures where ionizing and non-ionizing radiations are to be used submitted for approval by the Radiation Safety Committee through the Radiation Safety Officer prior to construction or modification.
- Notify the Radiation Safety Section of any transfer of radioactive material or radiation producing equipment to/or from East Carolina University.
- Have any area where radioactive material has been used surveyed by the Office of Prospective Health-Radiation Safety Section before any modifications are performed.
- Inform the Office of Prospective Health-Radiation Safety Section of the final disposition of any radioactive material, radioactive waste, or radiation producing electronic equipment in the possession of a terminated employee.

**NOTE:** The Radiation Safety Officer will keep each Department Chair and all Administrators informed of the Approved Users in the department who are conducting projects approved by the Radiation Safety Committee.

### ***Approved User:***

The approved user is a physician or faculty member who has been approved by the Radiation Safety Committee to use or supervise the use of radiation sources. The Approved User is **fully responsible** for adherence to all regulations and the safe use of ionizing and non-ionizing radiation sources by themselves and those under their direction.

### *Responsibilities of the Approved User*

- Control personnel, student, employee, and visitor radiation exposure as low as reasonably achievable and below the maximum permissible limits.
- Request and insure proper use of dosimetry for laboratory personnel.
- Provide suitable laboratory radiation monitoring instruments and supplies for students, employees, and visitors.
- Follow correct procedures for procurement of radioactive material and radiation producing electronic equipment.
- Ensure that radioactive wastes are properly prepared for disposal and inventory records are current and accurately maintained.
- Report immediately to the Office of Prospective Health-Radiation Safety Section any hazardous spills, suspected overexposures, theft of material, or other incidents regarding radiation safety.
- Operate safely all radiation producing equipment in their possession.
- Properly test all radiation sources for contamination, and maintain all records required by the Office of Prospective Health-Radiation Safety Section.
- Train and supervise students, employees, and visitors in:
  - a) general procedures for laboratory personnel
  - b) operating procedures for radiation producing equipment
  - c) radiation emergency procedures

### ***Radiation Worker:***

The individual radiation worker is the person who deals with the radioactive material or radiation emitting equipment on a regular basis. This is the person who should be most familiar with the potential hazards and radiation safety procedures involved with a procedure.

### *Responsibilities of the Radiation Workers*

- Keep your own radiation exposure As Low As Reasonably Achievable (ALARA) and always below 5000 millirem.
- Assist the Approved User in keeping all postings and labels of laboratories, material and equipment current.
- Properly secure radiation sources, dispose of all radioactive wastes, and maintain accurate disposal records.
- Report immediately to the Office of Prospective Health-Radiation Safety Section of all spills, suspected overexposures, theft of materials and any other radiation related accidents.
- Properly use all dosimetry equipment.

- Properly test and care for all radiation sources and maintain all records required.
- Have a working knowledge of the radiation emergency and decontamination procedures.
- Be familiar with the radiation safety precautions in the specific areas of:
  - a) procedures for laboratory personnel
  - b) operating procedures for radiation producing equipment
- Attend the Basic Radiation Safety Course or provide documentation of radiation safety training.

### **RIGHTS OF THE RADIATION WORKER**

The rights of each radiation worker are defined by the State of North Carolina Department of Environment and Natural Resources on a form titled "Notice to Employees". This form is posted throughout the work areas involving sources of radiation at East Carolina University.

*A radiation worker has a right to:*

- Apply all state and federal regulations to your work involving sources of radiation.
- View a copy of the N.C. Department of Environment and Natural Resources Regulations for Protection Against Radiation and operating procedures that apply to your work.
- An explanation of the state regulations and instructions in basic radiation safety.
- View any violations issued involving radiological working conditions and orders.
- Be advised of your radiation exposure at any time upon receipt of your written request.
- Upon termination of your employment, a written report of radiation exposures received during your employment.
- Request an inspection by the North Carolina Department of Environment and Natural Resources if you believe that there is a violation of the North Carolina Regulations for Protection Against Radiation, or the terms of the University Licenses or Registrations with regard to radiological working conditions. The North Carolina Department of Environment and Natural Resources will respect requests for confidentiality.
- Not be discharged or be discriminated against in any manner because you have filed a complaint with the North Carolina Department of Environment and Natural Resources.

### **TRAINING**

This manual **DOES NOT** provide detailed training in conducting specific laboratory and clinical tasks and their associated radiation safety procedures. Instruction concerning individual laboratory procedures and techniques as well as radiation safety is the responsibility of the Approved User.

The Office of Prospective Health-Radiation Safety Section provides general training and training materials in all areas of radiation safety. Attending the Basic Radiation Safety Course is required of all new radiation workers. The course is offered quarterly and details can be obtained by calling the Office of Prospective Health-Radiation Safety Section. All students and staff working with radioactive material are required to attend this course. An individual may work for 90 days under the direct supervision of an approved user or a radiation worker who has attended the Basic Radiation Safety Course. Documentation of training from another institution, university, or hospital may be substituted for the Basic Radiation Safety Course. Several different radiation safety technique courses may be obtained by contacting the Office of Prospective Health-Radiation Safety Section.

### **STANDARD OPERATING PROCEDURES**

More specific and detailed procedures than provided in this manual are available as Standard Operating Procedures for the Office of Prospective Health-Radiation Safety Section. These procedures are changed and updated frequently as required. A complete listing of the procedures may be obtained from the Office of Prospective Health-Radiation Safety Section.

### **APPLICATION PROCEDURES**

The application procedures stated in this manual apply to all persons who receive, possess, or otherwise use radioactive material or radiation producing electronic equipment at East Carolina University.

In order to use radiation sources, an application must be submitted to the proper subcommittee of the Radiation Safety Committee. Applications are required prior to any radioactive material use and in some instances prior to use of electronic equipment. Application forms and procedures specific for each of the Radiation Safety Subcommittees are available from the Radiation Safety Section. Applications are approved **indefinitely** unless there is a major change in protocol.

The Office of Prospective Health-Radiation Safety Section will review each application prior to it being submitted to the proper Radiation Safety Subcommittee. During the period between completion of the Office of Prospective Health-Radiation Safety Section review and final action by a Radiation Safety Subcommittee, the Radiation Safety Officer **MAY** grant temporary interim approval to a user of radiation sources pending final action by the committee.

Approval of any proposed use of radioactive material or electronic equipment producing radiation will be based on the adequacy of the safety measures to be exercised.

Three principal factors are considered by the Radiation Safety Subcommittees in evaluating the adequacy of the safety provisions in a proposed usage. First, the ability and experience of the applicant to cope with the hazards involved in the particular application. Second, the adequacy of the facilities and equipment for the proposed usage. Third, the thoroughness and attention given to the safety precautions applied to the proposed experimental or clinical procedures.

The Subcommittees may specify further precautions for certain types of operations and particular projects. To assist personnel in observing safety precautions and to satisfy itself that the adequate measures of safety are being practiced, the Radiation Safety Subcommittees directs the Office of Prospective Health-Radiation Safety Section to serve as a liaison between the committee and the individual projects.

## GENERAL INFORMATION

### Risks

Man, living in an environment that is naturally radioactive, is exposed to low levels of ionizing radiation every day. The sources of this natural radiation include cosmic rays from the sun, and even the earth itself. Man also receives exposures from manufactured sources of ionizing and non-ionizing radiation such as medical x-rays, fallout from nuclear weapons testing and radio-frequency and microwave radiation. Since each of us is already being irradiated by these means, it is then generally difficult to detect any additional detrimental effects that may occur due to any occupational radiation exposures.

Although the amount of risk associated with low level ionizing radiation exposures is a subject of great debate, certain fundamental conclusions can be drawn from the data collected:

- Low level background radiation has been a part of man's environment since the beginning of time. Any man-made radiation exposure merely adds to that already being received.
- The average individual in the United States receives approximately 200 millirem of radiation exposure per year from a variety of sources collectively referred to as "background radiation". Listed below are typical radiation exposures from a number of common sources.

SOURCE OF EXPOSURE	APPROXIMATE EXPOSURE (mR/yr)
Cosmic Radiation	38 to 75
Terrestrial	15 to 140
Radionuclides in the Body	15 to 20
Medical and Dental Radiation	90
Fallout	5 to 8
Nuclear Power	0.3
Consumer Products	0.3
Video Display Terminal (2000 hrs at 5 cm)	0.0018
<b>TOTAL</b>	<b>160 to 330</b>

*NOTE: Wide variations are noted because a multitude of factors can influence exposures such as altitude, soil composition, food intake, etc.*

# **GENERAL INFORMATION**

A study was conducted on two large population groups (approximately 80,000 individuals in each group). Epidemiological records were available for up to 16 generations. One group was exposed to an average exposure of 200-400 millirem from natural sources, while the other was exposed to 96-150 millirem. No significant differences between the two population groups were found with respect to cellular abnormalities, incidence of chromosomal aberrations, occurrence of peripheral lymphocytes, frequency of 31 different kinds of hereditary diseases and congenital deformities, spontaneous abortion rate, frequency of malignancies, or mortality rate from malignancies (from Science, Vol. 209, 22 Aug. 1980).

The degree of risk associated with exposure to low level ionizing radiation is thought to be low. Disagreement exists between experts about the precise magnitude of this risk. In the general population, approximately 25% of all individuals will die from cancer regardless of any exposure to radiation. If this same population were exposed to 1000 millirem per year for 45 years, the risk of death is increased to approximately 25.08%.

It is often helpful to compare the risk from radiation exposure with that of other activities. Numerous common activities involve increased risk of fatality from cancer or other causes.

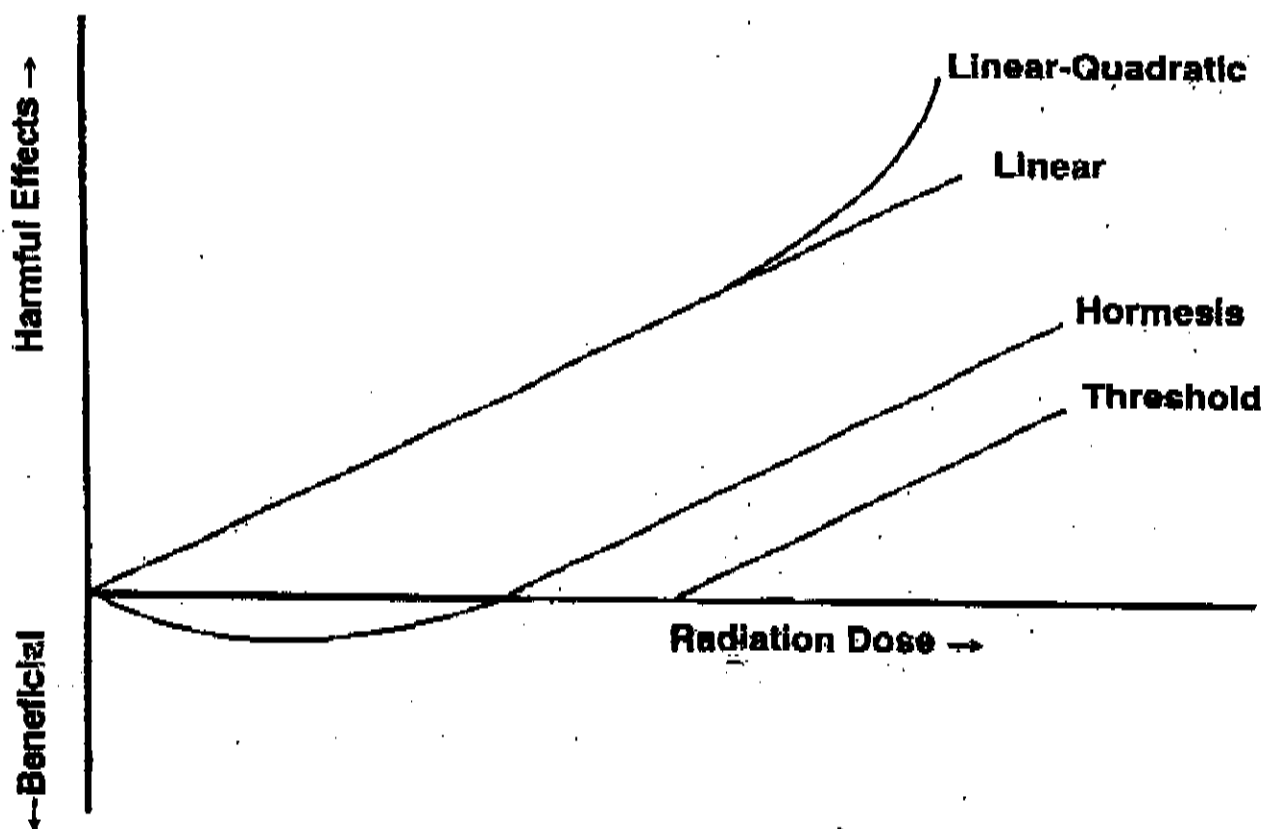
The following have each been calculated to result in an additional fatality risk of one in one million:

- Eating 40 teaspoons of peanut butter increases the risk of liver cancer caused by Aflatoxin\_B.
- Eating 100 charcoal broiled steaks increases the risk of cancer from benzopyrene.
- Living for two days in New York City increases the risk of cancer or fatal respiratory disease from air pollution.
- Smoking 12 cigarettes increases the risk of cancer and heart disease.
- Driving 300 miles by car or flying 1,000 miles by commercial aircraft increases the risk of an accident.
- 10 millirems of radiation exposure increases the risk of cancer (Wilson, R., "Analyzing the Daily Risks of Life", Technology Review, Feb. 1979.)

Because it only takes a single interaction between a photon or particulate radiation and a cell nucleus to cause a chromosomal change or other damage, unnecessary radiation exposure should be avoided.

Three major dose-effect models have been proposed: Linear, Linear-Quadratic, and Threshold. Each is depicted in graphic form below. Although many authorities feel that the linear-quadratic form, (i.e. there is a certain amount of dose that can be received before any detrimental effect can be observed), all radiation protection practices are based on the linear form (i.e. any exposure results in some detrimental effect).

## DOSE EFFECTS MODEL



### IN SUMMARY

- 1) Linear Response
- 2) Linear-Quadratic Response
- 3) Threshold Response
- 4) Hormesis

- All exposures should be kept as low as reasonably achievable (ALARA), therefore reducing any associated risks.
- Any risk from radiation exposure must be balanced against the benefits provided by the activity producing the exposure.



## **PERSONNEL MONITORING/DOSIMETRY**

East Carolina University uses several different methods of personnel monitoring in order to evaluate the amount of ionizing radiation that a worker has been exposed to. It is important to note that any type of personnel monitor merely records the amount of exposure received. It in **NO WAY** protects the wearer from the radiation and its associated effects.

Before explaining the various types of personnel monitors, it is helpful to answer some basic questions:

### **What is the maximum "legal" exposure a person can receive in a given period of time?**

- All work must be conducted in such a manner that no member of the general public could receive a dose in excess of 100 millirem in one year.
- All work must also be conducted in a manner such that no individual receives a dose exceeding:
  - The Total Effective Dose Equivalent (TEDE) is the sum of Internal and External Dose.
  - 15,000 millirem in one year to the lens of the eye.
  - 50,000 millirem in one year to the hands and forearms, feet and ankles.
  - 15,000 millirem in one year to the skin of the whole body.

### **When is an individual issued a personnel monitor?**

Federal and State regulations state that personnel monitors must be issued whenever it is likely that an individual will receive in excess of 10% of the above stated limits. Radiation workers at ECU will be issued a whole body monitor if they are in one of the following categories:

- Clinical staff/faculty using a radiation producing device or source material to diagnose or treat patients.
- Basic Science's faculty/staff/students that are using x-ray, irradiator or sealed sources of radiation.
- Declared pregnant radiation workers at their request.
- If RSO determines a person could potentially exceed 10% of annual limit, a badge will be issued.

## **What is a typical exposure for an individual working with radiation at East Carolina University?**

Because of the wide variety of working circumstances there is no single answer to this question. Most individuals working with radiation sources at the University receive doses so low that they are not measurable with normal personnel monitoring devices. Individuals working in areas where their exposures may be considered appreciable are monitored on bimonthly basis in order to assure that exposures are kept As Low As Reasonably Achievable.

### ***Types of Personnel Monitors***

Two types of personnel monitors are used at the East Carolina University to evaluate radiation exposures:

**Luxel™ Badges:** These monitor Beta, Gamma, X-ray, and in some cases Neutron. They use optically stimulated luminescence (OSL) technology to measure radiation through a thin layer of aluminum oxide. A laser light stimulates the aluminum oxide after use, causing it to become luminescent in proportion to the amount of radiation exposure. Typically these badges are used for whole body, collar, fetal, and area monitoring.

**Finger Ring Badges:** These smaller TLD badges are designed to be worn on the finger to record exposures to the hands. They record Gamma, X-ray, and high energy Beta exposures (see "criteria for requiring extremity monitoring").

Other Dosimeters will be issued at the discretion of the Radiation Safety Officer and the Radiation Safety Committee.

### ***General Rules for Use of Personnel Monitors***

Some basic guidelines must be followed in order for the Office of Prospective Health-Radiation Safety Section to accurately evaluate personnel exposures:

- **Always wear your own badge. Never allow another person to wear your badge and never wear a badge assigned to an individual other than yourself. Do not take your badge off the premises.**
- Badges are designed to monitor exposures for the wearing period beginning with the date shown on the badge. All badges must be returned to the Office of Prospective Health-Radiation Safety Section for processing promptly at the end of each wearing cycle, even if not worn during that period.
- Never wear your badge when undergoing any type of medical or dental radiographic procedure as a patient. Do not expose badge to airport X-ray machines. Badges are intended to measure occupational exposures only.

- In the event that your badge is lost, damaged, or the film is missing from the holder, notify the Office of Prospective Health-Radiation Safety Section immediately to arrange for a replacement. No work with radiation should take place until the personnel monitor is replaced.
- Remember that these devices do not act as warning devices when an individual receives exposure. They do not change color, beep, or in any other way visually indicate that exposure has been received. Their sole function is to document whatever exposure an individual may receive as part of their work with radiation sources.
- During special procedures in diagnostic radiology and cardiac catheterization, collar badges should be worn outside the lead apron and whole body badges beneath the apron.
- ***Criteria for Requiring Extremity Monitoring***

Personnel monitors are issued in accordance with North Carolina Regulations for Protection Against Radiation. The need for badges, including extremity monitors such as finger rings, is evaluated on a case-by-case basis, taking into consideration factors such as radioisotope usage and extremity exposure in x-ray.

Extremity monitoring (normally finger ring badges) is required when an individual uses certain radionuclides in amounts greater than those listed in the following table, or when work is performed in a radiation field where it is likely that 10% of the allowable annual exposure limits for the extremities will be exceeded. (The annual limit for extremities is 50,000 millirem.)

RADIONUCLIDE	AMOUNT IN mCi*
I-125	5
I-131	2
P-32	1
Betas > 1 MeV**	1
Gamma Microspheres	0.5

\* Usage level above which extremity monitoring is required.

\*\*  $\beta$  emitters with predominant  $E_{max}$  of 1 MeV or greater.

Those who routinely draw up doses of radiopharmaceuticals into syringes will normally be required to use extremity monitors.

After a suitable period of time, individual dosimetry data may be reviewed and extremity monitoring for an individual discontinued if deemed no longer necessary based on actual doses

received. Extremity monitoring may be provided for individuals who are working with amounts less than those listed above if review of the proposed usage indicates that such monitoring would be beneficial.

Workers will be notified by the Office of Prospective Health-Radiation Safety Section when a whole body personnel dosimeter reading of greater than 2% (100 millirem) of the annual limit in a one month period is recorded. During this notification, an inquiry will be made to determine if techniques or devices are available to reduce this level of exposure in the future. The notification limits for skin and extremity dosimeter readings are set at 2% (300 and 1,000 millirem, respectively) of the annual limit.

### ***Obtaining Personnel Monitoring Devices***

Individuals who need personnel monitors for their work must apply to the Office of Prospective Health-Radiation Safety Section. Specifically requesting and obtaining these monitors is a separate step from the actual application process to work with radiation sources. The following information is needed for each individual who is to receive a monitor:

- 1) name
- 2) social security number
- 3) date of birth \*
- 4) sex

\* Birth date is needed to assure that cumulative exposures do not exceed established limits.

Upon receipt of this information, monitors will be issued and the individual will be notified of their frequency of exchange (monthly or quarterly). Monitors are normally issued automatically, shortly before the end of the wearing period. If for some reason an individual does not receive a replacement, the Office of Prospective Health-Radiation Safety Section should be notified. The Office of Prospective Health-Radiation Safety Section should also be notified if the monitoring service is to be discontinued.

### ***Bioassay Program***

The State of North Carolina requires that bioassay be performed on individuals who work with amounts of radioactive materials greater than those listed below. Bioassay techniques to measure radionuclide uptake normally involve urinalysis or thyroid uptake analysis.

It is important to note that in the context of the regulations, "working with" includes withdrawing any amount of material from a stock solution containing an activity equal to or greater than the specified amounts listed, even though the activity to be used in the experiment is below the levels which warrant bioassay.

### ***Tritium***

- Urinalysis is required within three (3) working days after any individual works with 100 mCi or more of tritiated water or sodium borohydride.

- Urinalysis is required within three (3) working days after any individual works with 25 mCi or more of organically bound tritium.

### *Iodine*

- Each individual handling I-125 or I-131 labeled materials in an unsealed form and using an activity greater than or equal to those listed below, must undergo a thyroid bioassay within ten working days for I-131 or twenty-five working days for I-125 after the end of the work period during which radioactive iodine was handled:
- Processes in open room or bench with possible escape of I-125 or I-131 from process vessels:
  - 1 mCi if volatile
  - 10 mCi if bound to nonvolatile agent
- Processes with possible escape of I-125 or I-131 carried out within a fume hood of adequate design:
  - 10 mCi if volatile
  - 100 mCi if bound to nonvolatile agent
- Processes carried out within glove boxes ordinarily closed but with possible release of I-125 or I-131 from the process and occasional exposure to contaminated box and box leakage:
  - 100 mCi if volatile
  - 1,000 mCi if bound to nonvolatile agent

*Note: All individuals routinely handling I-125 or I-131 in activities equal to or greater than those specified above must undergo thyroid bioassay on a monthly basis unless specified conditions are met, in which case thyroid bioassay may be performed once every three months. (Such cases are the exception rather than the rule.)*

### *Other Radionuclides*

The Nuclear Regulatory Commission and the State of North Carolina specify that, where necessary or desirable, in order to aid in determining the extent of an individual's exposure to concentrations of radioactive material, provisions of appropriate bioassay services may be required as a condition of a license.

## **RADIATION EXPOSURE TO MINORS**

In some instances, individuals under the age of 18 may encounter situations where exposure to radiation may be involved. Radiation exposures to those under 18 years of age require special attention because, from a regulatory standpoint, these individuals are considered to be minors.

Most radiation exposures to minors are the result from teaching laboratories or advanced placement summer science learning programs. The Office of Prospective Health-Radiation Safety Section and the State of North Carolina Division of Radiation Protection recognize the benefits that arise from exposures in controlled settings in the form of education, and permit minors to receive whole body radiation doses up to 10% of the levels established for occupationally-exposed individuals. Authorized Users with minors under their direction must be aware of the following special provisions established for the safety of individuals under 18 years of age:

- As with all other radiation workers in the laboratories, it is the responsibility of the Approved User to fully adhere to all regulations applicable is the safe use of any radiation sources under their direction, with special attention given to the consideration of minors.
- No minor shall be permitted to work with open containers or dispersible forms of radioactive material. It is strongly recommended that minors not work directly with any sources of radiation, if at all possible.
- No minor shall work in the vicinity of any source of radiation without the immediate and constant supervision of an adult who is familiar with all applicable safety practices.
- Any exposure to minors shall be maintained ALARA. In no instances shall a minor receive a whole body radiation exposure in excess of 10% of the allowable adult exposure limit, which is 5,000 millirem per year. The 10% limit for minors shall also be imposed for all of the other established dose limits (e.g. extremities, skin, etc.)
- Even with the precautions listed, personnel dosimeters must be issued to minors who are working in laboratories where the devices will effectively record doses. Dosimeters may also be issued if penetrating radiations are not used directly, but are used in the area. The decision to issue dosimetry in this case will be made on a case-by-case basis, with input from the minor, the parent or guardian, the Authorized User and/or the Radiation Safety Officer.

The information listed above is also provided to the individuals who will be providing the minor with immediate supervision, and to any minor who might be working in the lab.

### **PRENATAL RADIATION EXPOSURE**

Ever since 1906, when the Law of Bergonie and Tribondeau was published, it has been known that cells are more sensitive to radiation damage when they divide rapidly and when they are relatively unspecialized in their function. Therefore, children are more sensitive to radiation than adults, and the unborn are more sensitive than children, especially during the first 2 to 3 months after conception.

This principle of increased sensitivity has long been a factor in the development of radiation exposure standards. Because the risks of the harmful effects from radiation may be greater for young people, the Nuclear Regulatory Commission and the State of North Carolina have placed different exposure limits on minors than on adult workers. Specifically, it limits anyone under 18 years of age to exposures not exceeding 10% of the annual limit for adult workers.

When a woman is pregnant and is exposed to radiation, exposure of her abdomen to sufficiently penetrating radiation from either external or internal radiation sources would also involve exposure to her unborn baby. A number of scientific studies have shown that the unborn are more sensitive than the adult, particularly during the first 3 months after conception. During a large part of these critical three months, a woman may not know that she is pregnant.

The North Carolina Regulations for Protection Against Radiation states, **the licensee or registrant shall ensure that the dose to an embryo/fetus during the entire pregnancy, due to occupational exposure of a declared pregnant woman, does not exceed 0.5 rem (500 millirem)."**

***Prenatal Radiation Exposure as Compared to Other Risks***

Many common activities have been shown to be harmful during pregnancy. It is helpful to view the risk associated with radiation exposure by comparing it to the risks associated with these other activities. For instance, cigarette smoking during pregnancy can cause reduced birth weight and infant death. Alcohol consumption during pregnancy can cause growth deficiencies, brain dysfunction, and facial signs on the infant. A radiation exposure of 1000 millirem may cause childhood cancers. For a listing of the rates of occurrence of these various types of maladies, see the following table.

FACTOR	PREGNANCY OUTCOME	RATE OF OCCURRENCE
German Measles	Birth Defects	2 in 3
<i>Cigarette Smoking</i>		
<1 Pack/day	In general, babies weigh 5-9 ounces less than average	1 in 5
>1 Pack/day	Infant Death	1 in 3
<i>Alcohol Consumption</i>		
2 drinks/day	Babies weigh 2-6 ounces less than average	1 in 10
2-4 drinks/day	Fetal Alcohol Syndrome	1 in 5
>4 drinks/day	Growth Deficiency, Brain Dysfunction, Facial Signs	1 in 3 to 1 in 2
<i>Maternal Age</i>		
20 Years	Down's Syndrome	1 in 2300
35-39 Years		1 in 74
40-44 Years		1 in 39
<i>Radiation exposure to 1000 millirem</i>		
Childhood cancer	Death before age 12	1 in 3333
Death form other childhood		1 in 3571

cancers before age 10		
<i>Bomb exposure at 4-14 weeks gestation</i>		
Hiroshima (15>100 rads)		1 in 4
Nagasaki (>150 rads)		1 in 4

It is the responsibility of the mother to decide whether the risks to a known or potential unborn child are acceptable. The Nuclear Regulatory Commission recommends that the mother consider the following facts:

- The first 3 months of pregnancy are the most important, so the decision to avoid risk should be made early.
- In most work situations, the actual dose received by an unborn child would be less than the dose to the mother, because some of the dose is absorbed by the mother.
- The dose to the unborn child can be reduced by: (A) reducing the amount of time actually exposed to the source of radiation, (B) increasing the distance of the mother and the source of radiation, and (C) shielding the abdominal area.
- If a woman becomes pregnant, she can ask her employer to reassign her to areas involving less exposure to radiation.
- When occupational exposures are kept below the regulatory limit of 5000 millirem per year, the risk to the unborn child is thought to be small. By following North Carolina Regulations for Protection Against Radiation, a dose to an embryo/fetus of 500 millirem for the entire pregnancy period, the amount of this risk is thought to be reduced. **Experts disagree on the exact amount of risk these actions eliminate.**

### ***The Decision of the Mother***

There is no need to be concerned about sterility, i.e. the loss of the ability to bear children. The radiation dose required to produce this effect is more than 100 times greater than the 5000 millirem per year.

Remember that the limit stated in the North Carolina Regulations for the Protection Against Radiation is **500 millirem for the entire nine months of pregnancy.**

Any female radiation worker who knows, suspects, or is trying to become pregnant should contact the Office of Prospective Health-Radiation Safety Section as soon as possible to obtain information on pregnancy and radiation risks. A confidential meeting will be scheduled between The Radiation Safety Officer and the woman upon notification.

It is up to the mother to consider the possible risks involving occupational radiation exposure to a known or potential unborn child. The mother should know that the Pregnancy Discrimination Act, an amendment of Title VII of the Civil Rights Act of 1964, states that "*women affected by*



*pregnancy, childbirth, or related medical conditions shall be treated the same for all employment related purposes, including the receipt of benefits under the fringe benefits programs, as other persons not so affected but similar in their ability or inability to work."* In addition, the Equal Employment Opportunity Commission (a Federal Agency) is responsible for examining cases for compliance with this act.

## GENERAL RADIATION SAFETY GUIDES

The body may be irradiated in two general ways; **externally** from radioactive material or other radiation sources, or **internally** from radioactive material deposited in the body.

External exposures can be the result of exposure to gamma, x-ray, or high energy beta emitters. Low energy beta and alpha emitters lack the energy needed to penetrate the outer layer of skin and subsequently present less of an external hazard but more of a concern when ingested. The amount of exposure an individual receives depends on the following factors:

**Amount:** The "*strength*" of the radiation source. When the amount (activity) of radioactive material is reduced or the settings on a radiation producing machine are lowered, this can result in a reduction of exposure.

**Time:** The total dose received from an external source is also dependent on the amount of time actually exposed to the source. Therefore, any time that is spent near a source should be kept as short as possible, and used as effectively as possible.

**Distance:** By increasing the distance between the source of exposure and the individual, one can significantly reduce the dose received. If an individual doubles his distance from a point source, the dose rate will drop by 1/4.

**Shielding:** When large radiation sources are being used, absorbing material, or shields, can be incorporated to reduce exposure levels. The specific shielding material and thickness is dependent on the amount and type of radiation involved.

Internal exposure results from the ingestion of radioactive material. This material can be incorporated in the body in several ways:

- Breathing radioactive vapors or dust.
- Consuming radioactive material located on contaminated hands, tobacco products, food, or water.
- Entering through a wound.
- Absorption through the skin.

The **fundamental objectives** of radiation protection measures are:

- To limit exposure to external radiation to as low as reasonably achievable, and always within the established exposure limits.
- To limit entry of radionuclides into the human body via ingestion, inhalation, absorption, or through open wounds when unconfined radioactive material is handled, and always within the established limits.

An important **secondary objective** is to obtain reliable results from experiments and clinical procedures. To accomplish these objectives, positive planning and following of procedures beyond the usual care taken in work with other materials is required. It is necessary to (1) analyze in advance the hazards of each job, (2) provide safeguards against foreseeable accidents, and (3) use protective devices and planned emergency procedures in accidents that do happen.

#### ***General Radiation Safety Guides for Radioactive Material Use***

- Before starting any work with radioactive material, a full understanding should be reached between all laboratory and clinical personnel as to the work to be done and the safety precautions to be taken.
- The procedure for each project should be well outlined in writing for all laboratory personnel. Necessary equipment, waste containers, and survey instruments must be available.
- Characteristics of the radioactive material such as type of radiation, half-life, significant and typical amounts, Annual Limit of Intake (ALI), Derived Air Concentration (DAC), Total Effective Dose Equivalent (TEDE), and chemical form should be known.
- In some cases, before the procedure is actually performed with radioactive material, a "dry run" of the procedure may be needed so as to avoid any problems.
- Visitors and students in a laboratory that uses radioactive material should be supervised by a radiation worker. No visitor or student shall be permitted to work with radiation sources without first contacting the Office of Prospective Health-Radiation Safety Section.
- Radioactive material must not be left unattended in places where it may be handled or removed by unknowing or unauthorized persons. **Radioactive material must be secured at ALL times.**
- As a general practice, work with radioactive material should be confined to only the areas necessary. This simplifies the problem of confinement and shielding, and aids in limiting the affected area in case of an accident.
- All work surfaces and storage areas (table tops, hoods, floors, etc.) should be properly covered. Some facilities, especially in older buildings, are very difficult to decontaminate.

- Absorbent mats or paper should be used. Protective absorbent with a plastic back and paper front is especially useful. If contaminated, it can simply be discarded in the radioactive waste container.
- Plastic or metal trays (stainless steel washes easily) should be placed on the surface when liquids are to be used. The edge of tray serves to confine a spill.
- Good housekeeping should be practiced. If an area is kept neat, clean, and free from equipment not required for the immediate procedure, the likelihood of accidental contamination or exposure is reduced.
- Radioactive material, especially liquids should be kept in unbreakable containers whenever possible. If glass is used, a secondary container should be provided.
- **Never pipette by mouth!** Always use some type of pipette filling device.
- Eating, drinking, or storing of food is prohibited in areas where work with unsealed radioactive sources is taking place or where contamination may exist.
- Refrigerators in laboratories with radioactive material **shall not** be used for the storage of food or drinks.
- Smoking is not permitted in areas where work with unsealed radioactive sources is in progress or where contamination may exist. Under no circumstances should cigarettes, cigars, or pipes be laid on tables or benches where radioactive work has been performed or is in progress.
- Before eating, drinking, or smoking, personnel working in areas where work with radioactive material is performed should wash their hands thoroughly.
- Gloves must be worn any time an unsealed source is being used, or whenever contamination is likely. Do not use the phone, handle books, open cabinets, or anything else with contaminated gloves. If there is a break in the skin on the hand, be sure to cover with a band-aide.
- Laboratory coats should be worn by all individuals handling radioactive material.
- All reusable glassware and tools used with radioactive material should be thoroughly cleaned after use and kept separate from noncontaminated items. It is recommended that a marked container or area be provided for glassware and tools used in radioactive work.
- Wear your personnel radiation monitoring device(s) if issued one.
- Pay attention to activity levels by using a radiation detection instrument. If unusually high, find out why and correct the problem.

- Patient requisitions must be approved by a physician before dispensing doses.
- Record all doses dispensed in a log book.
- Never return unused doses of radiopharmaceuticals to the stock solution.
- Observe strict sterile techniques at all times while drawing up injectable doses. Work behind a shield at all times.
- Shield all doses as required.
- Discard radioactive waste in the shielded containers provided.
- Safety glasses with protective side shields should be used when working with all dispersible radioactive material.

***General Radiation Safety Guides for Use of Radiation Producing Electronic Equipment***

- Each individual intending to operate any radiation producing machine should be properly trained by an individual familiar with the system.
- Each individual working with radiation producing electronic equipment should know exactly what work is to be done and which applicable safety precautions should be used.
- Written operating and safety procedures should be available to personnel **before** operating the equipment.
- Visitors and students in the area of work should be supervised by the equipment operator.
- Radiation producing machines should not be left unattended in an operational mode.
- Structural shielding requirements for any new installation, or any modifications to an existing unit or room should be reviewed by a qualified expert before the machine is used.
- When the safe use of the equipment depends on the mechanical set up of the unit or on technique factors, these restrictions should be rigidly followed.
- Under no circumstances should any shutter mechanism or interlock be defeated or in any way modified unless prior approval is obtained from the Radiation Safety Section.
- All warning lights should be of the "*fail safe*" type.
- A cumulative timing device that can be manually reset should be used to indicate elapsed exposure time and to turn off the machine when the total exposure reaches the planned amount.

- Some larger irradiators and accelerators require their own separate licenses from the North Carolina Department of Environment, and Natural Resources. Contact the Office of Prospective Health-Radiation Safety Section for information. Detailed operating and emergency procedures should be posted and followed.
- Proper maintenance on all radiation producing equipment is essential. All repairs to the equipment should be performed **ONLY** by properly trained technical personnel.
- The equipment **will not** be moved from the original installation site without written permission by the Office of Prospective Health-Radiation Safety Section. Permission must be also be granted if the equipment is intended to be sold, is surplus, or donated to another individual or institution.

### ***Radiological Health Surveys***

It is necessary to perform radiological health surveys whenever radiation sources are used. Surveys must be designed for the specific sources involved. Radioactive material and radiation producing electronic equipment must be considered.

Routine monitoring of laboratories containing radioactive material is necessary for the protection of radiation workers, compliance with regulations, and prevention of the contamination of experiments.

Each laboratory using radiation sources is assigned a survey frequency by the Radiation Safety Survey staff based on a variety of factors, including the type and amount of radiation used and the experimental techniques employed. At the discretion of the Office of Prospective Health-Radiation Safety Section, the assigned survey frequency of any laboratory may be changed to reflect the needed level of surveillance. Laboratories that work with radiation sources intermittently may be completely removed from the routine survey schedule providing a survey is performed and documented after the last work with the radioisotope.

### ***Corrective Actions for Violations***

Surveys performed by the Office of Prospective Health-Radiation Safety Section are comprehensive in nature, evaluating items ranging from ambient radiation levels to observance of prudent laboratory safety practices. Any radiation safety violations observed during a routine survey are documented on the survey form, and a formal set of steps are initiated to correct the problem. The procedure that is used to correct radiation safety violations involves a series of notifications:

#### **Verbal**

**warning:** If, during any routine inspection of a radiation laboratory, a problem involving radiation safety is found, written verbal warning will be issued to the technician staff, and the warning recorded on the Office of Prospective Health-Radiation Safety Section survey report form. Upon receipt of this verbal warning, the laboratory staff should take immediate steps to correct the problem. No verbal or written response is required from the laboratory.

- Step One:** If, within a six month period, the same radiation safety problem is discovered during an inspection, a written notification of the problem will be sent to the Approved User responsible for the laboratory. The Approved User will then be charged with correcting the situation. Although no verbal or written response is required by the Approved User for a Step One notification, a copy of the notification will be retained in the Authorized User's inspection file.
- Step Two:** If within a six month period, a second survey reveals that the same problem still exists, notification of this situation will be sent to both the Approved User and the Department Chair. No further orders of radioactive material will be placed for the Approved User until a **written response** concerning the item is received by the Radiation Safety Section. This response shall include the specific steps taken to ensure that the problem does not reoccur.
- Step Three:** If within a six month period, a third survey indicates a persistence of the problem, both the Approved User and the Department Chair will be given a final written account of the situation. No more orders for radioactive material will be placed for the Approved User by the Radiation Safety Section, and procedures will be initiated to remove existing inventories of radioactive materials. The entire case history of the event will also be presented to the appropriate Radiation Safety Subcommittee.

Any operation causing an **excessive** radiation hazard will be suspended immediately by the Office of Prospective Health-Radiation Safety Section without regard to the above procedure. Any such actions will also be promptly reviewed by one of the Radiation Safety Subcommittees.

In addition to the routine surveys performed by the Office of Prospective Health-Radiation Safety Section, each laboratory is responsible for performing their own contamination surveys of their work areas. **A documented survey is expected to be maintained for each month** that radioactive material is in use. The Basic Radiation Safety Course offered by the Office of Prospective Health-Radiation Safety Section, will instruct workers on how to properly survey for specific radioisotopes, and how to properly interpret the results.

## **RADIOACTIVE WASTE**

All radioactive wastes must ultimately be disposed of by the Office of Prospective Health-Radiation Safety Section. Any disposal of material not specifically approved by the Radiation Safety Officer may result in the loss of permission to use radioactive material at East Carolina University.

Radioactive waste is collected weekly by the Office Prospective Health-Radiation Safety Section. You may schedule pickup of waste by calling the **Radioactive Waste Line** at **744-DUMP** and following the instructions on the recorded message.

Different types and physical forms of radioactive waste material warrant different methods of disposal. As an example, liquid scintillation vials containing Carbon-14 must be handled

differently than solid wastes contaminated with Phosphorous-32. For this reason, each laboratory will be provided with separate waste containers for each type and isotope of waste. **All waste should be segregated by isotope and waste type.** The physical form of a radioactive waste can be classified as solid, liquid, biological, or scintillation vials. The proper disposal technique for each physical form is listed below.

**Solid Waste:** Solid waste should be placed in the proper radioactive waste container, each lined with two plastic bags. When filled, the accompanying radioactive waste tag must be completed before the waste will be removed. Special care should be taken with glassware. No liquid or biological waste should be placed in the solid waste containers, and under no circumstances may infectious biological material be disposed of as solid radioactive waste. Syringes **must** be placed in a separate and appropriate container.

**Liquid Waste:** Liquid radioactive waste shall be placed in the containers provided by the Office of Prospective Health-Radiation Safety Section. Only liquid waste shall be placed in the container. Emulsified tissue, feces, or biological waste that will support microbiological growth at room temperature shall not be placed in the liquid container. The liquid containers should be filled in such a manner so that a majority of the liquid is absorbed by the material in the jugs. Each filled container should be properly labeled and tagged, making sure to include isotope and amount. When washing containers that were used with radioactive material, the first rinse is usually retained as liquid radioactive waste. Any subsequent rinses may be allowed to go down the drain as long as the wash is performed in the designated radioactive waste sink. Any glassware that is contaminated as a result of work with radioactive material should be properly labeled as such.

**Biological Waste:** All biological waste must be properly contained in plastic bags. Infectious biological waste should not be available for disposal until special precautions and warnings have been considered. Each bag should be properly labeled and tagged with the completed radioactive waste tag. Biological waste should be refrigerated until picked up by the Office of Prospective Health-Radiation Safety Section. Adequate storage facilities for refrigeration of biological waste must be provided by the individual generating the waste until the ultimate disposal by the Office of Prospective Health-Radiation Safety Section.

**Scintillation Vials:** All liquid scintillation vials containing radioactivity shall be placed in the designated containers provided by the Office of Prospective Health-Radiation Safety Section. In certain cases, some combinations of isotopes (namely H-3 and C-14) can be placed into one container due to their similar disposal requirements. This disposal technique requires special permission from the Radiation Safety Officer. It is important to note that each isotope and its respective quantity must be recorded on the waste tag which accompanies each container.

Individuals using scintillation cocktails are asked to utilize fluids that do not contain hazardous constituents as identified in the Resource Conservation and Recovery Act. These cocktails are typically marketed as "environmentally safe" or "biologically safe".

**Sharps:** All syringes, needles and Pasteur pipettes or other materials that could potentially pierce the surface of the skin causing inoculation of radioactive or Biological/Infectious material will be

placed in a red sharp container. The appropriate radioactive material tag will also be fixed to the sharps container.

All of the different types of radioactive wastes are normally picked up by the Office of Prospective Health-Radiation Safety Section once a week. Each individual who needs a waste pick up should call the **Radiation Safety Radioactive Waste Line (744-DUMP)**. Special collection can be arranged if the amounts of waste are large or if the activity in the waste presents an exposure hazard. It is requested that individuals keep this in mind when planning their work.

Each laboratory should designate an area for the location of their waste containers. When choosing this area, several items should be kept in mind:

- The area should be obviously labeled so that the waste in this area is not inadvertently discarded as normal trash.
- The information concerning the waste should be readily available for the individual who picks up the waste.
- Consider any exposures that may result from the accumulated waste, (i.e. is shielding required?)
- Adequate spill and leakage protection should be provided, such as absorbent paper or collection trays.

Under no circumstances should any radioactive wastes be removed from the controlled area or delivered to the Office of Prospective Health-Radiation Safety Section unless specifically requested by the Office of Radiation Safety technical staff.



# **Emergencies**

## EMERGENCIES

***Important!*** Emergencies involving radiation should be treated as any other emergency with respect to bodily injuries, fires, and explosions. Any radiation exposures and contamination will be addressed after the physical hazards are contained. **DO NOT PANIC** - when properly handled, almost any accident or emergency occurring at the University involving radiation will add little or no immediate danger to the situation.

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# NOTIFICATION

## PHONE NUMBERS

Office of Prospective Health-Radiation Safety Section.....744-2070

The Office of Prospective Health-Radiation Safety Section is open during normal working hours. During all off hours call Public Safety at 744-2246. They will call the appropriate Radiation Safety Personnel on-call in case of emergencies or problems.

## RADIATION SAFETY PERSONNEL

## PHONE NUMBERS

(Call in order until contact is made)

Radiation Safety Officer.....744-2070

Public Safety.....744-2246

### Notify the Office of Prospective Health-Radiation Safety Section immediately if:

- There is a spill involving radioactive material.
- Any accident occurs involving radioactive materials producing airborne material, dusts, fumes, mists, organic vapors, or gases.
- Injuries occur involving radiation sources.
- There is a fire involving radiation sources.
- Any radioactive material is lost or stolen.
- Any radiation producing equipment malfunctions or is lost or stolen.

### I. MINOR SPILLS (material contained in a small area)

#### *NOTIFY OTHERS*

Inform others in the area that a spill involving radioactive material has occurred.

#### *PREVENT THE SPREAD*

Prevent the spread of the spill by containing it with absorbent material.

#### *CLEAN- UP*

Carefully dispose of all absorbent material in the radioactive waste container. Make sure to include in the waste all clean-up materials, gloves and other

disposable items. **NOTE:** If items are suspected to be contaminated and are not disposable, they should be placed in a plastic bag and held for decontamination. If broken glass is placed in the radioactive waste container, place a note on the top of the container so that the individual collecting the waste is aware that there are sharps inside.

### *CHECK YOURSELF*

If possible, check yourself and any others that may be contaminated with radioactive material. Use a radiation survey instrument if appropriate. Avoid touching your face, hair, etc.

### *REPORT THE INCIDENT*

Notify the Office of Prospective Health-Radiation Safety Section of the incident so that a thorough survey, if deemed necessary, can be conducted.

## **II. MAJOR SPILLS (Large quantity of radioactive material or/and spill is in many areas)**

### *NOTIFY ALL PERSONS*

Notify all individuals in the room that a spill has occurred involving radioactive material.

### *STOP THE SPILL*

If possible without causing further personnel contamination, stop the spill by up righting the container or containing it with absorbent material. If these actions will cause further personnel contamination or additional radiation exposure, leave the area.

### *FLUSH ANY CONTAMINATED SKIN WITH WATER*

If the spilled material is on the bare skin, flush the area with warm water. Avoid touching other parts of the body especially the mouth, eyes, and nose.

### *REMOVE CONTAMINATED ARTICLES*

If the material is on any gloves, lab coat, or clothing, remove these articles. If the liquid has passed through the clothing, flush the area of skin with water as this area may possibly be contaminated.

### *CLOSE WINDOWS TURN OFF FANS AND LEAVE ROOM*

If able, close all windows, turn off any fans, leave and lock the room.

Do not wander, as this may spread any contamination that you may have brought outside the room. Access to the room should be denied to anyone except Radiation Safety personnel.

*CALL THE OFFICE OF PROSPECTIVE HEALTH-RADIATION SAFETY SECTION.*

Notify the Office of Prospective Health-Radiation Safety Section as soon as possible. Any major decontamination efforts must be performed under their direction.

**III. AIRBORNE MATERIALS (Dusts, Fumes, Mists, Vapors, Gases)**

Tell all individuals to vacate the room immediately.

*SECURE ROOM*

If possible, hold breath and close all windows, shut off all fans, close and lock the door. All individuals who were in the room at the time of the incident should remain in an assembled area outside the room. If the area of the door must be vacated, the door should be posted with a sign warning individuals not to enter.

*NOTIFY RADIATION SAFETY*

As soon as everyone is vacated, and the room secured, the Office of Prospective Health-Radiation Safety Section should be notified.

*REPORT SUSPECTED INHALATIONS*

Inform the Office of Prospective Health-Radiation Safety Section of any suspected inhalations of radioactive materials. Specific analysis must be performed in order to evaluate the extent of any internal deposition.

**IV. ELECTRONIC DEVICES**

*TURN MACHINE OFF*

Turn the machine off at both the control switch and the main power switch. **NOTE:** This must be done first in order to ensure that the event does not reoccur while assessing any injuries or damage.

*ATTEND TO ANY INJURIES*

Help any injured personnel.

### *NOTIFY RADIATION SAFETY*

Call the Office of Prospective Health-Radiation Safety Section as soon as possible. If injured personnel are involved, call for immediate medical attention.

### *DO NOT FIX*

Do not attempt to use, fix, or change in any way the electronic equipment involved in the incident.

### *SECURE AREA*

Make sure the area is secure and posted until the Office of Prospective Health-Radiation Safety Section can make a full evaluation of the accident.

## **V. INJURIES INVOLVING RADIATION**

### *FLUSH THE WOUND*

If the wound is minor, flush the wound immediately with generous amounts of water. Be sure spread the edges of the wound to permit thorough flushing. If the wound is a major one and bleeding is profuse, apply direct pressure and administer normal first aid. **Call for immediate medical attention if the injury is life threatening or requires medical care.**

### *NOTIFY THE OFFICE OF PROSPECTIVE HEALTH-RADIATION SAFETY SECTION*

Call the Office of Prospective Health-Radiation Safety Section immediately if there are any injuries, wounds, over-exposures, ingestions, or inhalations involving radioactive material.

### *SECURE THE AREA*

If a spill has occurred along with the injury, make sure that the area is secured so that contamination is not spread. The scene of the accident should be preserved so that the Office of Prospective Health-Radiation Safety Section can evaluate the accident in an attempt to prevent its recurrence.

### *DO NOT RETURN TO WORK*

No person involved in a radiation injury is to return to work without the approval of the Radiation Safety Officer and the attending physician.

**VI. FIRES**

*SOUND FIRE ALARM*

Sound fire evacuation alarm nearest you and call 911. You must also call the proper authorities. If at East Carolina University East Campus or East Carolina University Medical Complex, call the following:

ECU Public Safety Medical Complex.....	744-2246
ECU Public Safety East Campus.....	328-6150
Greenville Fire/Rescue.....	911
Greenville Police.....	911

*TURN OFF ALL EQUIPMENT*

If possible, turn off all equipment and machinery.

*EVACUATE THE BUILDING*

Do not attempt to fight the fire unless it is very small or if personnel are in immediate danger.

*NOTIFY RADIATION SAFETY*

Use an outside phone to notify the Office of Radiation and Biological Safety.

*APPROVED USER*

After evacuation, the Approved User should remain available to report to the Radiation Safety Officer and Fire Fighting Officials.

*FIRE FIGHTING*

The fire should be fought using normal procedures unless the Radiation Safety Officer advises otherwise. All radioactive material and contamination can be taken care of after the fire is under control.

**VII. LOST OR STOLEN SOURCES**

*NOTIFY OTHERS*

Inform others in the area that a radioactive source has been lost or stolen.

*IF A PATIENT IS INVOLVED*

If a patient is involved and must be moved, check clothing and bedding carefully in an attempt to locate the lost source.

### *LOCATING THE SOURCE*

Look quickly in the immediate area for the source. If found, use a long object to move the source away from the door. **Do not touch the source with your hands.** If the source cannot be located, secure all windows and doors and go **directly** to the nearest phone outside the room. Remain by the phone.

### *NOTIFY*

Call the Office of Prospective Health-Radiation Safety Section immediately  
744-2070.

## **VIII. EMERGENCY CARE OF RADIATION ACCIDENT PATIENTS**

### *GENERAL*

In addition to necessary medical treatment, the primary concern in a radiological emergency is minimizing contamination of attending personnel, equipment, and facilities.

### *TYPES OF CASUALTIES*

The following categories refer to the patient's radiological condition:

#### *Radiation Exposure*

Significant external exposure to radiation has occurred with no contamination. Blood samples should be taken.

#### *External Contamination*

Radioactive material is present on skin and/or clothing. Monitor and decontaminate the patient as necessary.

#### *Internal Contamination*

Internal deposition of radioactive materials has occurred. Urine and stool samples must be taken.

#### *Induced Activity*

Elements within the patient have become radioactive from exposure to neutrons. Monitor the patient for radiation exposure coming from the patient's body. Collect blood, urine, and stool samples.



## **INSTRUCTIONS**

- Notify the Radiation Safety Officer.
- Give life-saving assistance regardless of the radiological condition of the patient.
- If there is *no* possibility of radioactive contamination, no special precautions are required in the care of the patient.
- Monitor the patient to determine the extent of contamination.
- Monitor the ambulance personnel and equipment for contamination.
- If radioactive contamination is present, isolate patient, wear a gown, gloves, and mask or respirator during emergency first aid.
- Retain all patient effects, materials, and equipment that have come in contact with the patient; isolate in plastic bags if possible. These items must be monitored prior to release.
- Decontaminate the patient if necessary.
- Decontaminate the highest levels first.
- Pay special attention to the hair, body orifices, and body folds.
- Avoid cross-contamination.
- Use soap and water; avoid organic solvents and abrasives.
- Decontaminate the wound. Irrigation with simple debridement may be necessary to remove damaged tissue.
- Maintain isolation until patient has been found free of all contamination.
- Examine all personnel for contamination before allowing them to leave the area.
- Decontaminate personnel if necessary.
- On completion of emergency first aid, remain in the immediate area until monitored.

## **PLAN OF OPERATION**

- Monitoring and decontamination will be performed in the Emergency Room area.
- The radiological condition of each patient will be noted in their hospital chart.

- Monitoring priority is the same as treatment priorities: immediate, delayed, expectant, minimal, or deceased.
- Patients exhibiting dose-rates in excess of 100 mR/hr through induced activity will be placed in the Emergency X-Ray Room as soon as possible.
- All personnel entering the room containing contaminated patients will wear gowns, gloves and shoe covers which will be collected whenever personnel depart the area.

**USE OF RADIATION  
SOURCES IN THE BASIC  
SCIENCES**

## USE OF RADIATION SOURCES IN THE BASIC SCIENCES

Both radioactive material and electronic equipment emitting ionizing radiation can be used in a variety of ways in the basic sciences for research and teaching purposes. Radioactive material can be used in tracer studies, in irradiators, or as reference or calibration sources. Electronic equipment that can emit ionizing radiation includes x-ray systems, cabinet x-ray units, x-ray diffraction systems, and particle accelerators.

### RADIOACTIVE MATERIAL

#### *Tracer Studies*

Tracer studies in basic science research use radioactive isotopes in place of common elements, and use the subsequent radiation emissions to follow the labeled compound during various phenomena. This technique has the potential for causing contamination along with a substantial radioactive waste disposal problem. Due to the wide variety of isotopes available for use, a wide variety of radiation safety considerations exist. Therefore, every application to use radioactive material in tracer studies is reviewed by both the Radiation Safety Officer and the Basic Science Radiation Safety Subcommittee to ensure that the material will be handled properly and that the safety of the workers involved is addressed.

#### *Irradiator*

Irradiators can present serious exposure hazards if not handled properly. These units usually contain large quantities of radioactive material and are used to deliver large doses of radiation to cells and animals. All modern irradiator units are fitted with several safety interlock systems. These systems should **NEVER** be defeated. Serious exposures to radiation can result from individuals by-passing the interlocks and unknowingly exposing themselves.

#### *Reference and Calibration Source*

Reference sources are commonly used in the basic sciences for calibration and operational checks of instruments. These sources are normally sealed at the manufacturer in such a manner as to prevent any contamination from leakage. The Office of Prospective Health-Radiation Safety Section verifies the physical integrity of these sources twice each year.

Reference sources can also present an exposure hazard if improperly used and stored. Because of their small size, there is a potential for these sources becoming lost or misplaced. The possible hazards associated with reference sources should be emphasized to each worker, and care should be taken to have them replaced in their proper container.

### RADIATION EQUIPMENT

#### *Radiographic and Fluoroscopic*

Radiographic and fluoroscopic equipment which is used specifically for research on animals is not regulated as stringently as equipment used on humans. This does not mean, however, that the

equipment should not be inspected regularly. For the safety of personnel and quality of the examinations, all research equipment should be subjected to the same inspection and maintenance schedules as medical diagnostic equipment. Some general information on the use of radiographic and fluoroscopic equipment follows:

- ***Prior to purchase of any radiographic or fluoroscopic equipment, the Office of Prospective Health-Radiation Safety Section shall be contacted for a determination of room shielding requirements.***
- ***Upon installation of new equipment, a radiation survey of the machine and room shall be conducted prior to operational use.***
- All x-ray equipment must be properly labeled and proper room signs must be in place.
- All radiation producing machines and equipment shall be surveyed annually or after any major maintenance or modification.
- All personnel operating x-ray equipment must be thoroughly and properly trained. Operator manuals must be available.
- Personnel working with x-ray producing equipment shall be provided with and properly use a personnel monitoring device.
- ***The Office of Prospective Health-Radiation Safety Section shall assure that all radiation producing machines are registered with the State of North Carolina.***
- Only persons absolutely required for the radiographic and fluoroscopic examination shall be in the x-ray room during an exposure.
- Particular care should be taken to limit the useful beam to the smallest area consistent with research requirements.
- If an animal must be held during the x-ray exposure, persons performing this duty shall be provided with a protective apron and gloves and be positioned so that the primary beam will not strike any part of the body.
- Pregnant women shall not be requested to perform such holding.
- Whenever a lead apron is worn, the personnel monitoring badge shall be worn at the collar outside the apron. When personnel are provided with two monitoring badges, one is to be worn at the collar outside the apron and the other is to be worn on the trunk of the body under the apron. The location of these two badges shall not be interchanged.
- Any person assisting with the examination shall be provided with adequate shielding.

- Protective equipment supplied with the machine shall be used whenever possible. Any shielding devices, such as, lead drapes should be utilized during procedures.
- Everyone in the room shall be provided with protective clothing of 0.5 mm lead equivalent.
- Persons not required to attend the animal during the examination should be out of the room if these persons cannot be out of the room, they should stand as far as possible from the animal or stand behind a portable shield.
- Fluoroscopy should not be used as a substitute for radiography, but should be reserved for the study of dynamics or spatial relationships or for guidance in spot- film recording of critical details.
- Fluoroscopy should be performed only by faculty members properly trained in fluoroscopic procedures or by personnel under their direct supervision.
- No person shall be employed specifically to hold animals during radiographic procedures.
- Any person aiding the performance of a radiation procedure shall be appropriately attired in lead aprons and lead gloves, and instructed to keep all unprotected body parts out of the primary radiation beam. If the procedure involves a prolonged period or if this occurs with the same employee more than once a week, the Office of Prospective Health-Radiation Safety Section will be contacted for guidance as to the need for radiation monitoring.
- Under **NO** circumstances should attempts be made to fix or modify any x-ray equipment (especially interlocking devices).

### ***X-Ray Diffraction***

X-ray diffraction equipment can be particularly hazardous because of high exposure rates in the primary beam (e.g., in excess of 500,000 R per minute at the x-ray tube port). Operating procedures and safety requirements for all x-ray diffraction systems must be strictly followed. Under **NO** circumstances shall shutter mechanisms and interlocking devices be tampered with or defeated. Special care must be taken any time equipment is being repaired.

### ***Cabinet X-Ray***

Cabinet x-ray systems are generally safe to use as long as operating instructions are followed and the equipment is not tampered with in any way. Cabinet x-ray systems are certified by the manufacturer to meet strict federal performance standards. Standards cover leakage radiation, interlocks, warning lights and signs, as well as operating and maintenance instructions.

### ***Electron Microscope***

Modern electron microscopes present few radiation hazards as long as operating instructions are followed and no unauthorized modifications are made to the equipment. Particular attention should be paid to early types of equipment that are still in operation. These early types were made before manufacturers were required by Federal regulations to meet performance standards.

### ***Accelerator***

Detailed operating instructions and safety procedures for the East Carolina University Tandem van de Graff charged-particle accelerator are available at the University Accelerator Laboratory and at the Office of Prospective Health- Radiation Safety Section.

## **USE OF ANIMALS**

All use of radiation sources in or on animals must be under the direct supervision of an Approved User who has submitted the appropriate application forms to the Radiation Safety Committee detailing the proposed work involving the administration of radiation to animals.

East Carolina University policy also requires that the use of living vertebrate animals in teaching or research be reviewed for animal welfare concerns by the University Animal Care and Use Committee (ACUC). Applications to the Committee are made using the Animal Use Protocol (AUP) form.

Approved Users who require care for animals treated with radioactive materials must provide, by direct supervision or complete written instructions, the procedures which the Department of Comparative Medicine must follow with respect to cage handling and collection and disposal of radioactive waste. Investigators often house animals containing radioactive material in general animal care facilities which are used by several investigators at the same time. Such facilities, by necessity, are accessible to people with widely varied training in radiation safety. All investigators using radioisotopes are required to design and execute their studies in a manner which prevents unnecessary human exposure to radiation and keeps unavoidable exposure as low as reasonably achievable.

### ***Additional Requirements***

- Outside doors to animal rooms in which radioactive material is used **MUST** be posted with Caution-Radioactive Material sign as directed by the Radiation Safety Section.
- All live animals which have received radioactive materials and which are returned to the Department of Comparative Medicine for housing must be properly identified.
- Animals that have received radioactive material must be transported in such a manner as to prevent any contamination of hallways, elevators, etc. Solid bottomed transfer containers are **MANDATORY**. Such animals may not be transported across public streets or sidewalks except by the Office of Prospective Health-Radiation Safety Section.

- The potential hazard to animal care technicians and other persons entering the animal room must be evaluated before work begins. This evaluation must be based on the radiation dose rate in the work place, the excretion rate of the material, and any special hazard that may be associated with the radionuclide or its chemical form. Some examples of this include consideration of the volatility of iodine compounds or the anticipated very low excretion rate of microspheres.
- Written protocols for routine animal care and for emergency and special situations must be provided to the Chief of Laboratory Animal Sciences.
- Routine care includes feeding, watering, cage and pen cleaning, and the collection and labeling of radioactive animal wastes. Emergency or special situations include those requiring intervention by other personnel, such as post-op care, administration of medications, etc.
- Cage/pen wastes (i.e., animal excreta and bedding) must be collected in plastic bags and sealed with radioactive tape and properly labeled. Call the Office of Prospective Health-Radiation Safety Section for disposal.
- Carcasses and tissues removed from animals must be frozen and stored in designated freezers until they are picked up by the Office of Prospective Health-Radiation Safety Section. Carcasses must be placed in opaque bags, sealed with radiation tape, and properly labeled. Double bagging is often necessary, especially for heavy carcasses.



# APPENDICES

# **APPENDIX A**

## APPENDIX A

### Radiation Definitions and Units

**ABSORBED DOSE:** The amount of energy imparted to matter by ionizing radiation per unit mass of irradiated material (See Rad and Gray).

**ABSORPTION:** The phenomenon by which radiation imparts some or all of its energy to any material through which it passes.

**ACCELERATOR:** A device for imparting kinetic energy to charged particles, such as electrons, protons, deuterons and helium ions. Common types of accelerators are the cyclotron, synchrotron, synchrocyclotron, betatron, linear accelerator and Van de Graff electrostatic generator.

**ACTIVITY:** The number of nuclear disintegrations occurring in a given quantity of material per unit time (See Curie and Becquerel).

**ACUTE EXPOSURE:** Term used to denote a relatively high radiation exposure of short duration.

**AGREEMENT STATE:** Any state which the U. S. Nuclear Regulatory Commission has entered into an effective agreement under subsection 274b. of the Atomic Energy Act of 1954, as amended (73 Stat.689).

**ALARA:** Acronym for the radiation protection philosophy that radiation exposures and effluents to the environment should be maintained "As Low As Reasonably Achievable". The U.S. Nuclear Regulatory Commission requires that ALARA be considered in the design of all experiments where radioactive material is used. Also, a formal, written procedure has been incorporated into East Carolina University's license requiring that all reported personnel radiation exposures above specified administrative thresholds be investigated to determine their cause and that appropriate corrective actions be taken to maintain subsequent exposures to the same individuals ALARA.

**ALPHA PARTICLE:** A strong 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.

**ANGSTROM (A):** Unit of measure of wavelengths equal to  $10^{-10}$  meters or 0.1 nanometers (millimicrons).

**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 radio nuclide in a year by reference man that would result in a Committed Dose Equivalent of 50 rem (0.5 Sv) or a Committed Effective Dose Equivalent of 50 rem (0.5 Sv) to any individual organ or tissue.

**ANODE:** Positive electrode; electrode to which negative ions are attached.

**ATOM:** Smallest particle of an element which is capable of entering into a chemical reaction.

**ATOMIC NUMBER:** The number of protons in the nucleus of an atom.

**ATTENUATION:** The process by which a beam of radiation is reduced in intensity when passing through materials.

**APPROVED USER:** An individual member of the teaching or research faculty who has been approved by the Radiation Safety Committee to use or supervise the use of radioactive material under conditions specified in an application for authorization. All transactions involving radioactive material must be made in the name of an Approved User.

**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.

**BACKSCATTER:** The deflection of radiation by scattering processes through angles greater than 90 degrees with respect to the original direction of motion.

**BEAM:** A unidirectional or approximately unidirectional flow of electromagnetic radiation or particles. A USEFUL BEAM in radiology is that part of the primary radiation which passes through the aperture, cone or other collimator.

**BECQUEREL (Bq):** SI Unit of radioactivity. One Bq equals one nuclear transformation/second. One microcurie is equivalent to 37,000 Bq (37 kilobecquerels) (kBq).

**BETA PARTICLE:** Charged particle emitted from the nucleus of an atom, having a mass and charge equal in magnitude to that of the electron.

**BIOLOGICAL HALF-LIFE:** The time required for the body to eliminate one-half of an administered dose of any substance by regular processes of elimination. This time is approximately the same for both stable and radioactive isotopes of a particular element.

**BRACHYTHERAPY:** A method of radiation therapy in which sealed sources are utilized to deliver a radiation dose a distance of up to a few centimeters, by surface, intercavitary, or interstitial application.

**BREMSSTRAHLUNG:** Electromagnetic (X-ray) radiation associated with the deceleration of charged particles passing through matter. Usually associated with energetic beta emitters, e.g., phosphorus-32.

**CALIBRATION:** Determination of variation from standard, or accuracy, of a measuring instrument to ascertain necessary correction factors.

**CALORIE:** Amount of heat necessary to raise the temperature of one gram of water 1 0C (from 14.5 to 15.5 0C).

**CATHODE:** Negative electrode; electrode to which positive ions are attracted.

**COLLIMATOR:** A device for confining the elements of a beam within an assigned solid angle.

**COMMITTED DOSE EQUIVALENT (CDE):** The dose equivalent to organs or tissues of reference man that will be received from an intake of radioactive material by an individual during the 50 year period of intake.

**COMMITTED EFFECTIVE DOSE EQUIVALENT (CEDE):** The sum of the products of the weighting factors applicable to each of the body organs or tissues that are irradiated and the committed does 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 may be in violating the validity of an experiment or a procedure, or in actually being a source of excess exposure to personnel.

**COULOMB:** A unit of electrical charge in the practical system of units. A quantity of electricity equal to  $3 \times 10^9$  electrostatic units of charge.

**COULOMB-KILOGRAM (C-kg):** SI special unit of radiation exposure. One (1) coulomb-kilogram is equivalent to 3,876 Roentgens.

**COUNT (Radiation Measurements):** 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:** That organ or tissue, the irradiation of which will result in the greatest hazard to the health of the individual or his descendants.

**CURIE:** The quantity of any radioactive material in which the number of disintegrations is  $3.7 \times 10^{10}$  disintegrations per second. Abbreviated Ci. Microcurie: One millionth of a curie,  $3.7 \times 10^4$  disintegrations per second. Abbreviated  $\mu\text{Ci}$ .

**DAUGHTER:** A synonym for a decay product.

**DECAY, RADIOACTIVE:** Disintegration of the nucleus of an unstable nuclide by the spontaneous emission of charged particles and/or photons.

**DECLARED PREGNANCY:** a woman who has voluntarily informed her employer in writing of her pregnancy and the estimated date of conception.

**DEEP DOSE EQUIVALENT (DDE):** Which applies to external whole body exposure is the dose equivalent at a tissue depth of one (1) centimeter (1000mg/cm<sup>2</sup>).

**DERIVED AIR CONCENTRATION (DAC):** The concentration of a given radionuclide in air, if breathed by the reference man for a working year of 2000 hours under condition of light work, (inhalation rate 1.2 cubic centimeters of air per hour) results in an intake of one (1) ALI.

**DISINTEGRATION:** A spontaneous nuclear transformation (radioactive) characterized by the emission of energy and/or mass from the nucleus. When large numbers of nuclei are involved the process is characterized by a definite half-life.

**DOSE:** A general term denoting the quantity of radiation or energy absorbed in a specified mass. For special purposes it must be appropriately qualified, e.g., absorbed dose.

**DOSE ABSORBED:** The energy imparted to matter by ionizing radiation per unit mass of irradiated material at the place of interest. The unit of absorbed dose is the rad, which is 10<sup>-5</sup> J/gram.

**DOSE EQUIVALENT:** A quantity used in radiation protection expressing all radiation on a common scale for calculating the effective absorbed dose. The unit of dose equivalent is the rem, which is numerically equal to the absorbed dose in rads multiplied by certain modifying factors such as the quality factor, the distribution factor, etc.

**DOSIMETER:** An instrument used to detect and measure an accumulated dose of radiation. In common usage it is a pencil size ionization chamber with a built-in self reading electrometer, used for personnel monitoring.

**EFFICIENCY (Counters):** A measure of the probability that a count will be recorded when radiation is incident on a detector. Usage varies considerably so it is well to make sure which factors (window, transmission, sensitive volume, energy dependence, etc.) are included in a given case. Typically, efficiency is counts per minute/disintegrations per minute.

**ELECTRON:** Negatively charged elementary particle which is a constituent of every neutral atom. Its unit of negative electricity equals  $4.8 \times 10^{-10}$  electrostatic units or  $1.6 \times 10^{-19}$  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.

**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. Larger multiple units of the electron volt frequently used are: KeV for thousand or kiloelectron volts, MeV for million electron volts and BeV for billion electron volts.

**ENERGY DENSITY:** The intensity of electromagnetic radiation per unit area per pulse expressed as joules per square centimeter.

**EXCITATION:** The addition of energy to a system, thereby transferring it from its ground state to an excited state. Excitation of a nucleus, an atom or a molecule can result from absorption of photons or from inelastic collisions with other particles.

**EXPOSURE:** 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 (R).

**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.

**FLUX:** For electromagnetic radiation, the quantity of radiant energy flowing per unit time. For particles, the number of particles or photons flowing per unit time.

**GAMMA RAY:** Very penetrating electromagnetic radiation of nuclear origin. Except for origin, identical to x-ray.

**GEIGER-MUELLER (G-M) COUNTER:** Highly sensitive gas-filled detector and associated circuitry used for radiation detection and measurement.

**GENETIC EFFECT OF RADIATION:** Inheritable changes, chiefly mutations, produced by the absorption of ionizing radiations. On the basis of present knowledge these effects are purely additive, and there is no recovery.

**GRAY (Gy):** SI unit of absorbed dose. 1 Gy is 1 Joule of energy deposited per kilogram of absorber. 1 Gy is equivalent to 100 RADs.

**HALF-LIFE, EFFECTIVE:** Time required for a radioactive nuclide in a system to be diminished 50 percent as a result of the combined action of radioactive decay and biological elimination.

$$\text{Effective half-life} = \frac{\text{Biological half-life} \times \text{Radioactive half-life}}{\text{Biological half-life} + \text{Radioactive half-life}}$$

**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 (Half thickness):** 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.

**HARDNESS:** A relative specification of the quality or penetrating power of X-rays. In general the shorter the wavelength, the harder the radiation.

**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.

**HIGH RADIATION AREA:** Any area, accessible to personnel, in which there exists radiation at such levels that a major portion of the body could receive in any one hour a dose in excess of 100 millirems. High Radiation Areas must be posted and must be equipped with specified control devices, alarms, 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:** Atomic particle, atom, or chemical radical bearing an electrical charge, either negative or positive.

**IONIZATION:** The process by which a neutral atom or molecule acquires either a positive or a negative charge.

**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 EVENT:** Any occurrence of a process in which an ion or group of ions is produced.

**IONIZATION, SPECIFIC:** The number of ion pairs unit length of path of ionizing radiation in a medium, e.g., per centimeter of air or per micron of tissue.

**IONIZING RADIATION:** Any electromagnetic or particulate radiation capable of producing ions, directly or indirectly, in its passage through matter.

**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.

**JOULE (J):** Unit of energy. It is equal to 1 watt-second or 4.19 calories.

**JOULE/CM<sup>2</sup> (J/CM<sup>2</sup>):** Unit of energy density used in measuring the amount of energy per area of absorbing surface, or per area of a laser beam. It is a unit for predicting damage potential of a laser beam.

**KeV:** The symbol for one-thousand electron volts.



**LABELED COMPOUND:** A compound consisting, in part, of molecules labeled by radioactive material. By observations of radioactivity or isotopic composition this compound or its fragments may be followed through physical, chemical or biological processes.

**LASER:** Light amplifications by stimulated emission of radiation.

**LASER REGION:** A portion of the electromagnetic spectrum, which includes the ultraviolet, visible light, and infrared.

**LEAKAGE RADIATION:** The radiation which escapes through the protective shielding of an X-ray tube or teletherapy unit.

**MEMBER OF THE PUBLIC:** An individual in a controlled or unrestricted area. However, an individual is not a member of the public during any period in which the individual receives an occupational dose.

**MeV:** The symbol for one million electron volts.

**MICROWAVE:** An electromagnetic wave having a wavelength in the microwave region, usually in the frequency range above 1000 megahertz.

**MICROWAVE REGION:** A portion of the electromagnetic spectrum, which covers the approximate frequencies of 300 to 300,000 megacycles per second, with the corresponding wavelengths of approximately 1 meter to 1 millimeter.

**MILLIROENTGEN (mR):** A submultiple of the roentgen equal to one one-thousandth (1/1000th) of a roentgen (See Roentgen).

**MILLIWATT (mW):** A submultiple of the watt equal to one-thousandth of a watt.

**MONITORING, RADIOLOGICAL:** Periodic or continuous determination of the amount of ionizing radiation or radioactive contamination present in an occupied region as a safety measure for purposes of health protection. Area monitoring is routine monitoring of the level of radiation or of radioactive contamination of any particular area, building, room, or equipment. Personnel monitoring is monitoring any part of an individual, his breath, excretions, or any part of his clothing. (See Radiological Survey)

**NUCLEAR REGULATORY COMMISSION (NRC):** Federal agency established by the Atomic Energy Act of 1954 and the Energy Reorganization Act of 1974 to regulate the use of radioactive material through its Licensing, Inspection and Enforcement, and Standards Development activities.

**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.

**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 a restricted area or in the course of employment, the individual's assigned duties involved exposure to radiation, and to radioactive material from licensed and unlicensed sources of radiation, whether in the possession of the license 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.

**OUTPUT POWER AND OUTPUT ENERGY:** Power is used primarily to rate C.W. lasers since the energy delivered per unit time remains relatively constant (output measured in watts). However, pulsed lasers which have a peak power significantly greater than their average power, produce effects which may best be categorized by energy output per pulse. Pulsed energy output is usually expressed in joules.

**PLATED SOURCE:** Radioactive material permanently deposited on a surface or matrix such that there is no window or other covering between the radioactive material and the open air. (Essentially a "sealed source" with a zero thickness window.)

**POWER DENSITY:** The intensity of electromagnetic radiation present at a given point. Power density is the average power per unit area usually expressed as milliwatts per square centimeter.

**PROTECTIVE BARRIERS:** Barriers of radiation absorbing material, such as lead, concrete, plaster, and plastic, that are used to reduce radiation exposure. Protective Barriers, Primary: Barriers sufficient to attenuate the useful beam to the required degree. Protective Barriers, Secondary: Barriers sufficient to attenuate stray or scattered radiation to the required degree.

**QUALITY FACTOR (QF):** Linear-Energy-Transfer dependent factor by which absorbed doses are multiplied to obtain a quantity that expresses, on a common scale for all ionizing radiations, the biological effectiveness of the absorbed dose. As a rule of thumb, QF is 1 for X-rays, gamma rays, and Beta particles with  $E_{max} < 0.03$  MeV, 1.7 for Beta particles with  $E_{max} > 0.03$  MeV, 10 for neutrons and protons  $> 10$  MeV (30 for eyes), 10 for Beta particles, and 20 for heavy recoil nuclei.

**RAD:** Acronym for "Radiation Absorbed Dose." Unit used to describe dose in terms of energy deposited in any absorber.  $1 \text{ rad} = 100 \text{ ergs/gram}$ .

**RADIATION:** 1. The emission and propagation of energy through space or through a material medium in the form of waves, for instance, the emission and propagation of electromagnetic waves, or of sound and elastic waves. 2. The energy propagated through a material medium as waves; for example, energy in the form of electromagnetic waves or of elastic waves. The term "radiation" or "radiation energy," when unqualified, usually refers to electromagnetic radiation. Such radiation commonly is classified according to frequency as Hertzian, infrared, visible (light), ultra-violet, x-ray, and gamma ray. 3. By extension, corpuscular emissions, such as alpha and beta radiation, or rays of mixed or unknown type, as cosmic radiation.

**RADIATION AREA:** Any area, accessible to personnel, in which there exists radiation at such levels that a major portion of the body could receive in any one hour a dose in excess of 5 millirem, or in any 5 consecutive days a dose in excess of 100 millirems.

**RADIOLOGICAL SURVEY:** Evaluation of the radiation hazards incident to the production, use or existence of radioactive materials or other sources of radiation under a specific set of conditions. Such an evaluation customarily includes a physical survey of the disposition of materials and equipment, measurements or estimates of the levels of radiation that may be involved, and a sufficient knowledge of processes using or affecting these materials to predict hazards resulting from expected or possible changes in materials or equipment.

**RADIOACTIVITY:** Process whereby certain nuclides undergo spontaneous disintegration in which energy is liberated, generally resulting in the formation of new nuclides. The process is accompanied by the emission of one or more types of radiation.

**RADIOSENSITIVITY:** Relative susceptibility of cells, tissues, organs, or organisms to the injurious action of radiation. The term may be applied to chemical compounds or any other substances.

**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 (RBE):** 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 rems is numerically equal to the absorbed dose in rads multiplied by the quality factor, distribution factor, and any other necessary modifying factors.

**RESTRICTED AREA:** Any area, access to which is controlled for purposes of protection of individuals from exposure to radiation and radioactive materials. While any area except areas used for living quarters may be designated as a restricted area, every area in which there are radiation levels which, if an individual were continuously present in the area, could result in his receiving a dose in excess of two millirems in any one hour, or radiation levels which, if an individual were continuously present in the area, could result in his receiving a dose in excess of 100 millirems in any seven consecutive days MUST be established as a restricted area.

**ROENTGEN(R):** The quantity of x or gamma radiation such that the associated corpuscular emission per 0.001293 grams of dry air produces, in air, ions carrying one electrostatic unit of quantity of electricity of either sign. The roentgen is the special unit of exposure.

**SCATTER:** Change of direction of sub-atomic particle or photon as a result of a collision or interaction. **MULTIPLE:** Scattering of a particle or photon in which the final displacement is the vector sum of many, usually small, displacements.

**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 permanently enclosed inside a capsule or other holder such that there is no contact between the radioactive material and the open air. Sealed sources must be tested for leakage at intervals specified in the NRC license.

**SHALLOW DOSE EQUIVALENT (SDE):** Which applies to the external exposure of the skin or an extremity, is taken as the dose equivalent at a tissue depth of .007 centimeters (7 mg/cm<sup>2</sup>) average over an area of 1 cm<sup>2</sup>.

**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.

**SI:** Abbreviation for the international system of units. A system of units rapidly being adopted throughout the world. Forthcoming changes to NRC rules will incorporate SI units in addition to the "conventional" units presently used. The terms Gray, Sievert, Becquerel, and Coulomb-Kilogram are all SI units.

**SIEVERT (Sv):** SI unit of absorbed dose to the human body in terms of biological effect. (Sievert is Gray x Quality Factor). 1 Sv is equivalent to 100 Rem.

**SMEAR (Smear or Wipe Test):** A procedure in which a swab, e.g., a circle of filter paper is rubbed on a surface and its radioactivity measured to determine if the surface is contaminated with loose radioactive material.

**SPECIFIC ACTIVITY:** Total radioactivity of a given nuclide per gram of a compound, element, or radioactive material.

**STANDARD (RADIOACTIVE):** A sample of a radioactive material, usually with a long half-life, in which the number and type of radioactive atoms at a definite reference time is known. Hence, it may be used as a calibration source for radiation-measuring instruments.

**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, measurements or calculations of levels of radiation, concentration or quantities of radioactive material present.

**THERMOLUMINESCENT DOSIMETER (TLD):** A dosimeter made of certain crystalline material which is capable of both storing a fraction of absorbed ionizing radiation and releasing this energy in the form of visible photons when heated. The amount of light released can be used as a measure of radiation exposure to these crystals.

**TOTAL EFFECTIVE DOSE EQUIVALENT (TEDE):** The sum of the deep dose equivalent (external exposures) and committed effective dose equivalent (for internal exposures).

**TRACER, ISOTOPIC:** The isotope or nonnatural mixture of isotopes of an element which may be incorporated into a sample to make possible observation of the course of the 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.

**WASTE, RADIOACTIVE:** Solid, liquid, and gaseous materials from nuclear operations that are radioactive or become radioactive and there is no further use. Wastes are generally as high level (having radioactivity concentrations of hundreds of thousands of curies per gallon or cubic foot), or intermediate (between these extremes).

**WATT:** A unit of power defined as the rate of energy consumption or conversion when 1 joule of energy is consumed or converted per second.

**WEIGHTING FACTOR:** For an organ or tissue 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.

**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.

# **APPENDIX B**

## APPENDIX B

### Radiation Signs & Labels

Because radiation is not detectable by the normal human senses, proper and accurate labeling of all facilities and equipment is of paramount importance. Listed below are the guidelines to follow in determining which labels and postings are required for each type of radiation situation.

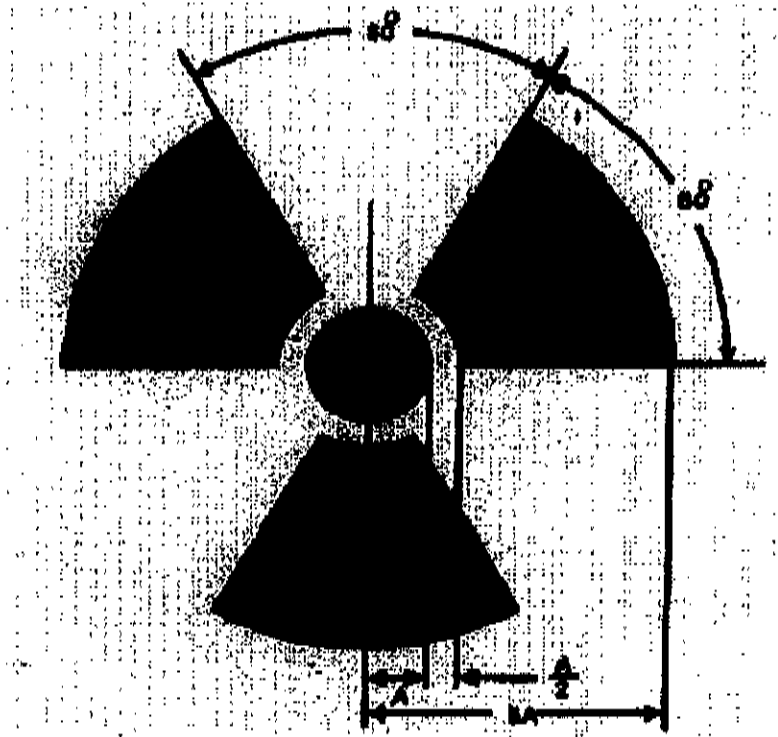
#### NOTICE TO EMPLOYEES

State regulations require that a "Notice to Employees" be posted in a sufficient number of places in the workplace whenever radiation sources are being used. This form details the rights of the individual who works with radiation sources, and provides addresses and phone numbers of the North Carolina Department of Environment and Natural Resources.

#### POSTINGS USED WITH IONIZING RADIATION

##### *Radiation Caution Symbol*

Each posting involving ionizing radiation shall contain the above symbol and the word "Caution." Authorized signs, tags, tapes and labels are available at the Radiation Safety Laboratory. Cross-hatched area is to be magenta or purple.



The tri-foil area of the symbol shall be magenta or purple printed on a yellow background. No variations to this label are permitted by the Nuclear Regulatory Commission, North Carolina Division of Radiation Protection, or the Radiation Safety Committee. Authorized signs, tags, tapes, and labels are available through the Office of Prospective Health-Radiation Safety Section.

#### *Radiation Areas*

A "**radiation area**" is defined as any area accessible to personnel in which there exists radiation at such levels that a major portion of the body or a critical organ could receive, in any one hour, a dose in excess of 5 mrem, or in any 5 consecutive days a dose in excess of 100 mrem. Each area will be conspicuously posted with a sign or signs bearing the radiation symbol and the words:

#### **CAUTION RADIATION AREA**

A "**high radiation area**" is any area accessible to personnel in which there exists radiation at such levels that a major portion of the body or a critical organ could receive in any one hour a dose in excess of 100 mrem. Each high radiation area will be posted conspicuously with a sign or signs bearing the radiation symbol and the words:

#### **CAUTION HIGH RADIATION AREA**

Each high radiation area must be equipped with a control device which will cause the level of radiation to be reduced below that at which an individual might receive, a dose of 100 mrem in 1 hour, upon entry into the area; or equipped with a control device which will energize a conspicuous visible or audible signal in such a manner that the individual entering the high radiation area and the Approved User of the radiation is made aware of the entry; or maintained locked except during periods when access to the area is required, with positive control over each individual entry. The controls will be established in such a way that no individual will be prevented from leaving a high radiation area.

An "**airborne radioactivity area**" is defined as any room, enclosure, or operating area in which airborne material exists in concentrations in excess of the amounts specified by the **North Carolina Regulations for Protection Against Radiation** or any room, enclosure, or operating area in which airborne radioactive material exists in concentrations, which averaged over the number of hours in any week during which the individuals are in the area exceeds 25% of the amounts specified. Each airborne radioactivity area shall be conspicuously posted with a sign or signs bearing the radiation symbol and the words:



**CAUTION  
AIRBORNE RADIOACTIVITY AREA**

*Radioactive Material*

Each area or room in which radioactive material is used or stored and which contains any radioactive material (other than natural uranium or thorium) in an amount exceeding the quantities listed in the North Carolina Regulations for Protection Against Radiation will be designated as a "restricted area" and shall be conspicuously posted with a sign or signs bearing the radiation caution symbol and the words:

**CAUTION  
RADIOACTIVE MATERIAL(S)**

Each area or room in which natural uranium or thorium is used or stored in an amount exceeding one hundred (100) times the quantity specified in the North Carolina Regulations Against Radiation shall be conspicuously posted with a sign or signs bearing the radiation caution symbol and the words:

**CAUTION  
RADIOACTIVE MATERIAL(S)**

A room or area is not required to be posted with a caution sign because of the presence of a sealed source, providing the radiation level at 30 centimeters from the surface of the source container or housing does not exceed 5 millirem per hour.

Each container which is transported, stored, used, or contaminated with a quantity of licensed material (other than natural uranium or thorium) greater than the quantity of such material specified in the North Carolina Regulations for Protection Against Radiation must have a durable, clearly visible label bearing the radiation caution symbol and the words:

**CAUTION  
RADIOACTIVE MATERIAL(S)**

Laboratory containers, such as beakers, flasks, and test tubes, used transiently in laboratory procedures, do not require labels when the user is present. When such containers are to be left unattended for periods of 8 hours or more, and contain materials in quantities greater than those specified in the North Carolina Regulations For Protection Against Radiation, they will be labeled as described.

Where containers are used for storage, the labels required by this section must state the quantities and kinds of radioactive materials in the containers and the date of the measurement of the quantities.

All radioactive waste must be clearly labeled with the radioisotope, activity, location, physical form, and date. Special tags with locations for this information are available through the Office of Prospective Health-Radiation Safety Section. These tags should be completed before the waste is picked up.

All radioactive material being shipped from East Carolina University will be labeled in accordance with Department of Transportation Regulations. The Office of Prospective Health-Radiation Safety Section will assist the Approved users with all shipments of radioactive material. Failure to comply with all state and federal regulations could result in severe penalties to East Carolina University.

#### Electronic Products Emitting Ionizing Radiation

Areas in which radiation producing machines are located or are being used shall be posted with the characteristic "Caution Radiation" or "Caution X-rays" sign to warn all unauthorized personnel about entering the radiation area. In addition, the controls of the instrument must have a sign stating: "Caution Radiation, this equipment produces radiation when energized."

# **APPENDIX C**

## APPENDIX C

### Nuclear Medicine Procedures

#### DOSE CALIBRATOR QUALITY CONTROL

##### *Procedure*

##### 1. Check of $^{99m}\text{Tc}$ Setting

- a. Adjust the calibrator for assay of  $^{99m}\text{Tc}$ .
- b. Zero the background reading or record the counts.
- c. Assay the  $^{57}\text{Co}$  source. (NBS traceable)
- d. Record the reading (minus background if needed).
- e. Obtain the expected reading of the source from the source records.
- f. Subtract the reading obtained from the expected value and then divide this number by the expected reading to obtain the percentage difference (x 100).

##### 2. Check of $^{99}\text{Mo}$ Setting

- a. Adjust the calibrator for assay of  $^{99}\text{Mo}$ .
- b. Zero the background reading or record the counts.
- c. Assay the  $^{137}\text{Cs}$  source. (NBS traceable) Do not use the lead shield normally used for  $^{99}\text{Mo}$  breakthrough tests.
- d. Record the reading (minus background if needed).
- e. Obtain from source records the expected reading of the source.
- f. Subtract the reading obtained from the expected reading and then divide this number by the expected reading to obtain the percentage difference (x100).

Within limits of the repeatability of the instrument and accuracy of source calibration, the readings of source(s) for a stable calibrator will then follow the characteristic half-life of the radionuclide. Progressive, or continued, outlying values indicate drift from calibration. Erratic readings indicate drift from calibration, deterioration in electronics, changes in ambient radiation levels, or other problems associated with line voltage or Radio frequency interference. Excessive

background may be due to contamination in the chamber well or inadequate shielding of sources. Any unusual conditions or readings will be documented in the calibration report.

### 3. Reports

A copy of the calibration report will be maintained at East Carolina University.

# **APPENDIX D**

## APPENDIX D

### Safety Information on Common Radionuclides

**ISOTOPE:**  $^3\text{H}$

**COMMON NAME:** Hydrogen-3, Tritium

#### PHYSICAL CHARACTERISTICS

<b>Half Life:</b>	Physical	12.3 years
	Biological	12 days
	Effective	12 days
<b>Radiation Emitted:</b> Beta		
<b>Energy Of Radiation (keV):</b> 18.6 (max), 5.7 (avg)		
<b>Maximum Range Of Beta Particles:</b>	Air	5.0 mm
	Water	0.006 mm

#### RADIATION BIOLOGY

**Critical Organ:** Whole Body

**Toxicity:** Low

**Maximum Body Burden:** 1,000  $\mu\text{Ci}$

**Bioassay:** Urinalysis required within ten working days after working with 25 mCi or more of organically bound tritium or with 100 mCi or more of tritiated water or sodium borohydride.

#### HEALTH PHYSICS

**ALI ( $\mu\text{Ci}$ ):** Oral Ingestion  $8 \times 10^4$

Inhalation  $8 \times 10^4$

**DAC ( $\mu\text{Ci/ml}$ ):** Inhalation  $2 \times 10^{-5}$

**Survey Technique:** Wipes, counted by Liquid Scintillation Counting.

**Shielding Required:** None

**Film Badge Required:** No

**Special Considerations:** Tritium cannot be monitored directly because of the low beta energy. Special care is needed to control contamination. Regular monitoring by wipe testing is advisable. External contamination does not cause a significant radiation exposure itself but can lead to potentially hazardous internal contamination and can interfere with experimental results.

**ISOTOPE:** <sup>32</sup>P

**COMMON NAME:** Phosphorous-32

### PHYSICAL CHARACTERISTICS

**Half Life:** Physical 14.3 days  
Biological 257.0 days (whole body)  
1,157.0 days (bone)  
18.0 days (liver)  
257.0 days (brain)  
Effective 13.5 days (whole body)  
14.1 days (bone)  
8.0 days (liver)  
13.5 days (brain)

**Radiation Emitted:** Beta and Bremsstrahlung  
**Energy Of Radiation (keV):** 1,709 (max), 690 (avg)  
**Maximum Range Of Beta Particles:** Air 780.0 mm  
Water 0.8 mm

### RADIATION BIOLOGY

**Critical Organ:** Bone  
**Toxicity:** Medium/Low  
**Maximum Body Burden:** 30 uCi (whole body), 6 uCi (bone)  
**Bioassay:** Not routinely done. Urinalysis is possible.  
**Dose Rate At 1 Meter From 1 mCi Point Source:** 0.091 mR/hr  
**Dose Rate On Contact With 1 mCi:** 78,000 mR/hr

### HEALTH PHYSICS

**ALI (uCi):** Oral Ingestion  $6 \times 10^2$   
Inhalation  $8 \times 10^2$   
**DAC (uCi/ml):** Inhalation  $2 \times 10^{-7}$

**Survey Technique:** Beta survey meter

**Shielding Required:** 1 cm Plexiglas and lead

**Film Badge Required:** Yes-whole body and ring

**Special Considerations:** This is the highest energy radionuclide commonly used in research laboratories. Absorption of high energy beta particles by low density materials gives rise to high intensity Bremsstrahlung which requires lead shielding, particularly when 10 mCi or more are present. Always remember that extremely high radiation exposures, especially to the hands, can occur even from short exposures to small quantities. Laboratory coats and protective glasses should be worn. Double gloving is also strongly recommended. Surveys are required with an appropriate survey instrument immediately at the end of work. The results of these surveys should be recorded. Because it is a bone seeker, special care must be taken to minimize any chance of introducing this isotope into the body.



**ISOTOPE:**  $^{14}\text{C}$

**COMMON NAME:** Carbon-14

**PHYSICAL CHARACTERISTICS**

**Half Life:** Physical 5,730 years  
Biological 10 days (whole body)  
12 days (fat)  
Effective 10 days (whole body)  
12 days (fat)  
**Radiation Emitted:** Beta  
**Energy Of Radiation (keV):** 156 (max), 48 (avg)  
**Maximum Range Of Beta Particles:** Air 24.0 mm  
Water 0.28 mm

**RADIATION BIOLOGY**

**Critical Organ:** Whole Body and Fat  
**Toxicity:** Medium/Low  
**Maximum Body Burden:** 400 uCi (whole body), 300 uCi (fat)  
**Bioassay:** Not routinely done, however urinalysis and breath analysis are possible.

**HEALTH PHYSICS**

**ALI (uCi):** Oral Ingestion  $2 \times 10^3$   
Inhalation  $8 \times 10^3$   
**DAC (uCi/ml):** Inhalation  $2 \times 10^{-6}$

**Survey Technique:** Beta survey meter, thin window G-M survey meter, or wipes, counted by liquid scintillation counting.

**Shielding Required:** 1 cm plexiglass

**Film Badge Required:** No

**Special Considerations:** None

**ISOTOPE:**  $^{35}\text{S}$

**COMMON NAME:** Sulfur-35

**PHYSICAL CHARACTERISTICS**

**Half Life:** Physical 87.4 days  
Biological 90 days (whole body)  
623 days (testis)  
Effective 44.3 (whole body)  
76.4 day (testis)

**Radiation Emitted:** Beta

**Energy of Radiation: (keV):** 167 (max), 49 (mean)

**Maximum Range of Beta Particles:** Air 30.0 mm  
Water 0.28 mm

**RADIATION BIOLOGY**

**Critical Organ:** Whole Body and Testis.

**Toxicity:** Medium/Low

**Maximum Body Burden:** 400 uCi

**Bioassay:** Not routinely done.

**HEALTH PHYSICS**

**ALI (uCi):** Oral Ingestion  $1 \times 10^4$

Inhalation  $6 \times 10^{-6}$

**DAC (uCi/ml):** Inhalation  $2 \times 10^{-8}$

**Survey Techniques:** Beta survey meter; thin window G-M survey meter; or wipes, counted by Liquid Scintillation Counting.

**Shielding Required:** 1 cm Plexiglas.

**Film Badge Required:** No.

**Special Considerations:** None.

**ISOTOPE:**  $^{51}\text{Cr}$

**COMMON NAME:** Chromium-51

**PHYSICAL CHARACTERISTICS**

**Half Life:** Physical 27.7 days  
Biological 616.0 days  
Effective 26.6 days  
**Radiation Emitted:** Gamma & X-rays  
**Energy Of Radiation (keV):** 320 (9.8%), 5 (22%), 51V K-X-rays  
**Dose Rate At One Meter From A One mCi Source:** 0.023 mR/hr

**RADIATION BIOLOGY**

**Critical Organ:** Whole Body and Lower Large Intestine.  
**Toxicity:** Medium/Low  
**Maximum Body Burden:** 800 uCi  
**Bioassay:** Not routinely done. Urinalysis is possible.

**HEALTH PHYSICS**

**ALI (uCi):** Oral Ingestion  $4 \times 10^4$   
Inhalation  $5 \times 10^4$   
**DAC (uCi/ml):** Inhalation  $2 \times 10^{-5}$   
**Survey Techniques:** Gamma or X-Ray Survey Meter.  
**Shielding Required:** 7.8 mm lead provides 95% attenuation.  
**Film Badge Required:** Yes. If working with large amounts.  
**Special Considerations:** None

**ISOTOPE:**  $^{125}\text{I}$

**COMMON NAME:** Iodine-125

### PHYSICAL CHARACTERISTICS

**Half Life:** Physical 60.1 days  
Biological 138.0 days (Whole Body & Thyroid)  
Effective 41.8 days (Whole Body & Thyroid)  
**Radiation Emitted:** Gamma and X-rays  
**Energy Of Radiation: (keV)** 35 (7% emitted, 93% converted)  
27-32 (138% Tc-X-rays)  
**Dose Rate At One Meter From A One mCi Source:** 0.275 mR/hr

### RADIATION BIOLOGY

**Critical Organ:** Thyroid  
**Toxicity:** Medium/High  
**Maximum Body Burden:** 60  $\mu\text{Ci}$   
**Bioassay:** Routine Thyroid counts required whenever work with unsealed radioiodine in amounts greater than:

**VOLATILE FORM:** Open Bench 1 mCi  
Fume Hood 10 mCi  
Glove Box 100 mCi

**BOUND TO NON-VOLATILE COMPOUND:** Open Bench 10 mCi  
Fume Hood 100 mCi  
Glove Box 1,000 mCi

Bioassay will normally be required whenever work with > 5 mCi in a fume hood or > 1 mCi on an open bench so as to maintain exposures ALARA.

### HEALTH PHYSICS

**ALI ( $\mu\text{Ci}$ ):** Oral Ingestion  $4 \times 10^4$   
Inhalation  $6 \times 10^2$

**DAC ( $\mu\text{Ci/ml}$ ):** Inhalation  $3 \times 10^{-8}$

**Survey Techniques:** Low energy Gamma or X-ray scintillation type survey meter.

**Shielding Required:** 0.8 mm lead provides 95% attenuation.

**Film Badge Required:** Yes, whole body and ring. (See manual)

**Special Considerations:** Volatilization is a most significant problem. Simply opening a vial of Sodium Iodide can cause significant airborne release. Breathing zone and exhaust effluent monitoring may be required. Solutions should not be made acidic or stored frozen. Double gloving strongly recommended. Neutralize all spills with sodium thiosulfate before starting clean-up. All work is normally to be done in an approved hood. Depending on activity used, supplemental "mini hoods", glove boxes, and/or in-line exhaust filters may be required.

**ISOTOPE:** <sup>131</sup>I

**COMMON NAME:** Iodine-131

**PHYSICAL CHARACTERISTICS**

**Half Life:** Physical 8.0 days  
Biological 138.0 days (whole body)  
7.6 days (thyroid)  
Effective 7.6 days (whole body)  
7.6 days (thyroid)  
**Radiation Emitted:** Beta & Gamma  
**Energy Of Radiation (keV):** Beta- 806 (max), 180 (mean)  
Gamma- 80 (2.4%), 284 (5.9%)  
364 (81.8%), 637 (7.2%), 723 (1.8%)  
**Dose Rate At One Meter From 1 uCi Point Source:** 0.283 mR/hr

**RADIATION BIOLOGY**

**Critical Organ:** Thyroid  
**Toxicity:** Medium/High  
**Maximum Body Burden:** 50 uCi (Whole Body), 0.14 uCi (Thyroid)  
**Bioassay:** Routine thyroid counts whenever unsealed radioiodine in amounts greater than:  
**VOLATILE FORM:** Open Bench 1 mCi  
Fume Hood 10 mCi  
Glove Box 100 mCi  
**BOUND TO NON-VOLATILE COMPOUND:** Open Bench 10 mCi  
Fume Hood 100 mCi  
Glove Box 1,000 mCi

Bioassay will normally be required whenever work with > 5 mCi source in a fume hood or > 1 mCi on an open bench so as to maintain exposures ALARA.

**HEALTH PHYSICS**

**ALI (uCi):** Oral Ingestion  $3 \times 10^1$   
Inhalation  $5 \times 10^1$   
**DAC (uCi/ml):** Inhalation  $2 \times 10^{-8}$   
**Survey Technique:** Beta or Gamma survey meter.  
**Shielding Required:** 12.4 mm lead provide 95% attenuation.  
**Film Badge Required:** Yes, whole body and ring (see manual)  
**Special Considerations:** Volatilization is a most significant problem. Simply opening a vile of sodium iodide can cause significant airborne release. Breathing zone and exhaust effluent monitoring may be required. Solutions should not be made acidic or stored frozen. Double gloving is strongly recommended. See Special Considerations for <sup>125</sup>I.

**ISOTOPE:**  $^{99m}\text{Tc}$

**COMMON NAME:** Technetium-99m

**PHYSICAL CHARACTERISTICS**

**Half Life:** Physical 6.0 hours  
Biological 24 hours (whole body)  
Effective 4.8 hours  
**Radiation Emitted:** Gamma and Beta  
**Energy Of Radiation: (keV)** 140 Gamma (90%), .119 Beta  
**Dose Rate At One Foot From A One mCi Source:** 0.6 mR/hr

**RADIATION BIOLOGY**

**Critical Organ:** GI tract (ULI)  
**Toxicity:** Low  
**Maximum Body Burden:** Total Body 200 uCi  
Kidney 800 uCi  
Liver  $1 \times 10^4$  uCi  
Lung  $2 \times 10^4$  uCi  
Bone  $1 \times 10^5$  uCi  
Skin  $1 \times 10^5$  uCi

**Bioassay:** Due to short half life not routinely performed. Urinalysis is possible.

**HEALTH PHYSICS**

**ALI (uCi):** Oral Ingestion  $8 \times 10^4$   
Inhalation  $2 \times 10^5$   
**DAC (uCi/ml):** Inhalation  $6 \times 10^{-5}$

**Survey Technique:** Low energy Gamma or X-ray scintillation type survey meter.

**Shielding Required:** 0.13 cm of lead provides 95% attenuation.

**Film Badge Required:** Yes, whole body. Ring required if handling  $\geq 0.5$  mCi.

**Special Considerations:** Use of syringe shield highly recommended. Work area should be surveyed immediately after use of this material. All surveys should be documented. Personnel contamination surveys should also be conducted after work with this material. Due to the short half life of this isotope, decontamination usually involves securing area for decay.

**ISOTOPE:**  $^{127}\text{Xe}$

**COMMON NAME:** Xenon-127

**PHYSICAL CHARACTERISTICS**

**Half Life:** Physical 36.41 days  
Biological nil  
Effectiveness nil

**Radiation Emitted:** EC X-rays, Gamma

**Energy of Radiation (keV):** EC 24, 112, 139, 170, 198 Gamma 58 (1.4%), 145 (4.2%), 172 (22%),  
203 (65%), 375 (20%)

**Dose Rate at 1 Meter from a 1 mCi Point Source**

**RADIATION BIOLOGY**

**Critical Organ:** Whole Body

**Toxicity:** Low

**Maximum Body Burden:** N/A Inert Gas

**Bioassay:** Not routinely done. Body burden in lungs can be estimated by nuclear medicine imaging techniques, but these must be conducted essentially at the same time as the exposure due to the essentially instantaneous elimination with respiration

**HEALTH PHYSICS**

**DAC (uCi/ml):** Inhalation  $1 \times 10^{-5}$

**Survey Technique:** Gamma or X-ray survey meter; specially designed Xenon air monitor

**Shielding Required:** 11.4 mm of lead provides 95% attenuation.

**Film Badge Required:** Yes. Whole body and ring

**Special Considerations:** Detailed, written evaluation of air handling characteristics of room where Xe is to be used is mandatory before use can be approved. Exhaled air passed through "Xenon trap" to reduce airborne concentrations in room air and in effluent to environment. Physical place of use and storage may not be changed without prior, written approval of amendment to authorization.

**ISOTOPE:**  $^{133}\text{Xe}$

**COMMON NAME:** Xenon-133

**PHYSICAL CHARACTERISTICS**

**Half Life: Physical**      5.2 days  
   Biological nil  
   Effective nil  
**Radiation Emitted:** EC X-rays, Beta, Gamma  
**Energy of Radiation (keV):** Beta 346 (mean) EC 45 75 Gamma 81 (37%) Cs X-rays  
**Dose Rate at 1 Meter from a 1 mCi Point Source** 0.103 mR/hr

**RADIATION BIOLOGY**

**Critical Organ:** Whole Body  
**Toxicity:** Low  
**Maximum Body Burden:** N/A Inert Gas  
**Bioassay:** Not routinely done. Body burden in lungs can be estimated by nuclear medicine imaging techniques, but these must be conducted essentially at the same time as the exposure due to the essentially instantaneous elimination with respiration

**HEALTH PHYSICS**

**DAC ( $\mu\text{Ci/ml}$ ):** Inhalation  $1 \times 10^{-4}$   
**Survey Technique:** Gamma or X-ray survey meter; specially designed Xenon air monitor  
**Shielding Required:** 7.5 mm of lead provides 95% attenuation.  
**Film Badge Required:** Yes, Whole body and ring  
**Special Considerations:** Detailed, written evaluation of air  
Handling characteristics of room where Xe is to be used is mandatory before use can be approved. Exhaled air passed through "Xenon trap" to reduce airborne concentrations in room air and in effluent to environment. Physical place of use and storage may not be changed without prior, written approval of amendment to authorization.



**ISOTOPE:**  $^{201}\text{Tl}$

**COMMON NAME:** Thallium-201

### PHYSICAL CHARACTERISTICS

**Half Life:** Physical 3.0 days  
Biological 5.0 days  
Effective 1.9 days

**Radiation Emitted:** Gamma and Electron Capture (x-ray)

**Energy Of Radiation: (keV)** 135 Gamma (20%), 167 Gamma (8%) 16, 52, and 84 ec x-rays

**Dose Rate At One Meter From A One mCi Source:** 0.088 mR/hr

### RADIATION BIOLOGY

**Critical Organ:** Not Published

**Toxicity:** Medium/Low

**Maximum Body Burden:** Not Published

**Bioassay:** Not routinely performed. Urinalysis is possible.

### HEALTH PHYSICS

**ALI (uCi):** Oral Ingestion  $2 \times 10^4$   
Inhalation  $2 \times 10^4$

**DAC (uCi/ml):** Inhalation  $9 \times 10^{-6}$

**Survey Technique:** Low energy Gamma or X-ray scintillation type survey meter.

**Shielding required:** 0.114 cm of lead provides 95% attenuation.

**Film Badge Required:** Yes, whole body. Ring required if handling  $\geq 5$  mCi.

**Special Considerations:** Use of syringe shield highly recommended. Work area should be surveyed immediately after use of this material. All surveys should be documented. Personnel contamination surveys should also be conducted after work with this material.

# **APPENDIX E**

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### **REFERENCES AND STANDARDS**

#### **FEDERAL**

The federal government is heavily involved in the control of radiation sources by the issuance of regulations and standards. This control however, does not come from a single agency or group of coordinated agencies. Because of this it is sometimes difficult for biomedical institutions to be in full compliance with all of the existing regulations.

All of the federal agencies that control radiation have their headquarters located in Washington, D.C. and can be contacted directly for assistance. listed below are those agencies, their primary regulations (known as the Code of Federal Regulations), and their principle function in radiation protection.

**Agency: Nuclear Regulatory Commission**

**Primary Regulation: NRC 10 CFR 20**

**Function: All radioactive material licensing, nuclear power plant operation standards and control**

**Agency: Center for Devices and Radiological Health/Food and Drug Administration**

**Primary Regulation: CDRH 21 CFR 1000-1050**

**Function: Standards on electronic products emitting radiation**

**Agency: Department of Transportation**

**Primary Regulation: DOT 49 CFR 171-179**

**Function: Regulations on transportation of all hazardous materials including radioactive material.**

**Agency: Environmental Protection Agency**

**Primary Regulation: EPA 40 CFR**

**Function: Standards on exposure limits and releases of radioactive material to air, land and water.**

**Agency: Occupational Safety and Health Administration**

**Primary Regulation: OSHA 29 CFR 1910**

**Function: Standards on the exposure of workers to radiation sources.**

#### **STATE**

Where state agencies parallel federal regulations, it is possible for the state to take over the role of the federal agency within its borders. Such is the case for the State of North Carolina and its agreement status with the Nuclear Regulatory Commission. The State of North Carolina "agrees" to take over the regulatory role, except for nuclear power plants, within the borders of the state. The principle agency and regulations involved in controlling radiation in North Carolina are:

North Carolina Radiation Protection Section  
Department of Environment and Natural Resources  
1645 Mail Service Center  
Raleigh, NC 27699-1645  
(919) 571-4141

**North Carolina Regulations for Protection Against Radiation**  
Title 10, Chapter 3, Subchapter 3G, Radiation

The State of North Carolina Division of Radiation Protection issues licenses for radioactive material, registrations for radiation producing machines and standards for the control of radiation. In addition, state agencies controlling hazardous waste, air pollution and occupational exposures (Department of Labor) are also involved in radiological health.

**LOCAL**

Almost no added regulations or restrictions are placed on working with radiation by local agencies and health departments. Most local health departments are ill equipped to regulate radiation sources. However, some local governments have begun attempts to restrict shipments of hazardous material including radioactive material through their locality. Eventually jurisdiction will have to be settled between Federal, State and Local regulations.

**VOLUNTARY STANDARDS AND ORGANIZATIONS**

There are a number of major organizations which publish voluntary reports, standards and information concerning radiation protection. Some of them are:

- National Council on Radiation Protection (NCRP)**
- American National Standards Institute (ANSI)**
- International Commission on Radiation Protection (ICRP)**
- International Commission on Radiation Units and Measurements (ICRU)**
- International Atomic Agency (IAEA)**

In addition, the **Health Physics Society** is the primary professional organization concerned with radiation protection. The primary objective of the Society is the development of scientific knowledge and practical means for the protection of man and his environment from the harmful effects of radiation. The Society publishes a journal, sponsors scientific meetings and establishes local chapters. The national organization and the local North Carolina chapter can be contacted for further information at the following addresses:

**Health Physics Society**  
1313 Dolley Madison Blvd.  
Suite 402  
McLean, VA 22101  
(703) 790-2672

**North Carolina Chapter**  
Health Physics Society  
Box 13183  
Research Triangle Park, NC 27709