University of California, Merced

Environmental Health and Safety

Radiation Safety Manual

Revised 8/30/2019

**In case of emergency, dial 911**

**For additional information, call EH&S 209 228-7864**

**http://ehs.ucmerced.edu/research-safety/radiation-safety**

**RADIATION SAFETY MANUAL**

University of California, Merced

**FOREWARD**

Many research and instructional activities use sources of ionizing radiation as a valuable tool to extend fundamental knowledge. These activities are an important part of the University of California’s contribution to the society it serves, and are critical to its mission.

The excellent safety record of the University of California, Merced (UC Merced ) in its use of radiation-producing machines and radioactive materials attests to the success of its radiation safety program.

This manual describes the policies and procedures intended to ensure radiation safety on the Merced campus. All personnel working with ionizing radiation are required to understand and follow these policies and procedures, and must exercise proper care to prevent radiation from becoming a hazard to themselves or to others.

The use of radioactive materials and radiation producing machines is governed by the regulations and requirements issued by the California Department of Public Health (CDPH) and U.S. Nuclear Regulatory Commission (NRC). UC Merced is also committed to implement the requirements expressed in its Radioactive Materials License issued by CDPH, this Radiation Safety Manual (RSM), and any other written commitments made to the CDPH. Radiation users will receive information on changes that affect them.

This manual details how the appropriate state and federal regulations apply at UC Merced. It replaces all previous documents and procedures on this topic.

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Mal Donohue, EHS Director Date

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# **1. ORGANIZATION AND RESPONSIBILITIES**

## 1.1 Policy

The radiation safety and radiation producing machine program was established to assure that

work with radioactive material and radiation producing machines is conducted in a safe

manner, so as to protect health and minimize danger to property and the environment.

Activities involving the use of radioactive material and radiation producing machines at the

University of California, Merced (UC Merced) shall be consistent with this policy.

This Radiation Safety Manual (RSM) sets forth UC Merced policy, organization, operating

procedures and standards of conduct for the use of radioactive material and radiation

producing machines such that compliance with regulations and procedures is ensured. All

personnel using radioactive material and radiation producing machines are required to be

familiar with and comply with the provisions of this document.

## 1.2 Radiation Safety Officer

The UC Merced Radiation Safety Officer (RSO) is responsible for the radiation safety program;

for assuring that the use of radioactive material and radiation producing machines is in

conformity with UC Merced policies and with applicable governmental regulations.

The RSO is responsible for the maintenance of records pertinent to the UC Merced radiation

safety program. These records are necessary to show compliance with government rules and

regulations as well as UC Merced policies and include:

• Training held and attendance

• Radioactive package receipt and package surveys

• Site radioactive material inventory

• Radioactive material use and storage area surveys

• Radioactive waste disposal

• Instrument calibration

• Dosimetry and bioassay results

## 1.3 Alternate Radiation Safety Officer

The Alternate Radiation Safety Officer’s appointment is based on experience in the use of

radioactive material and knowledge of state and federal rules and regulations concerning the

use of radioactive material and radiation producing machines. The Alternate RSO (ARSO)

assumes the responsibilities of the RSO during the RSO’s absence.

## 1.4 Principal Investigators

The Principal Investigators (PIs) and other personnel authorized by the UC Merced Radioactive Material License are responsible for training personnel reporting to them and for ensuring that the UC Merced radiation safety policies and procedures are adhered to.

## 1.5 Radiation Users

Each person using radioactive material or radiation producing machines is responsible for

following established radiation safety procedures, keeping their radiation exposures As Low As

Reasonably Achievable (ALARA), and reporting any spill or suspected internal deposition to the

RSO or the Alternate RSO.

Summary of Responsibilities

|  |  |  |
| --- | --- | --- |
| PI | Lab Worker | RSO |
| Take required training, provide lab specific training. | Take required training | Provide training. |
| Perform Wipe tests monthly |  | Perform wipe tests quarterly. |
| Weekly surveys if using >1mCi |  |  |
| Keep all exposures ALARA. | Keep all exposures ALARA. | Keep all exposures ALARA. |
| Use dosimetry if assigned. | Use dosimetry if assigned. | Provide dosimetry if needed. |
| Keep accurate inventory. | Keep accurate inventory. | Ensure license covers all material and locations on campus. |
| Report exposures, spills, accidents and near misses | Report exposures, spills, accidents and near misses | Investigate exposures, spills, accidents, near misses. |
| Have a current RUA on file. | Follow the current RUA. | Renew the RUA. |
| Follow the radiation safety manual. | Follow the radiation safety manual. | Update the radiation safety manual. |
| Use Geiger counter when using materials or x-ray producing machines. | Use Geiger counter when using materials or x-ray producing machines. | Calibrate Geiger counters and LSC annually. |
| Notify EHS of new machines within 30 days, or desire to purchase new material. |  | Update licenses with state. |
| Use and store radioactive materials and machines only in locations listed on license. | Use and store radioactive materials and machines only in locations listed on license. | Perform package surveys upon receipt of radioactive materials. |
| Collect waste for disposal. | Collect waste for disposal. | Arrange for shipment of waste off campus. |

# **2. LICENCES AND REGULATIONS**

## 2.1 Policy

UC Merced will obtain and maintain all necessary licenses and other required permits needed to fulfill its research goals.

## 2.2 Licenses and Regulations

UC Merced has obtained a radioactive material license from the State of California Department of Public Health. This license describes radioactive material possession limits, use locations, authorized users, and other specifics pertaining to the use of radioactive material. Copies of the license, as well as state and federal regulations, may be obtained from the RSO or the Alternate RSO.

All radiation producing machines are also registered with the state.

## 2.3 License Amendments

Amendments to the license must be obtained prior to the implementation of any of the following changes:

* Use of radioisotopes or locations not specified in the license.
* Need to exceed authorized possession limits.
* Use for purposes other than those authorized.
* Use by new PI.
* Change in the RSO or Alternate RSO

The license amendment must be obtained prior to the anticipated changes.

## 2.4 License Termination

The license will be terminated if all work with radioactive material is stopped or if a site changes ownership. The State of California Department of Public Health must be notified 30 days prior to termination of use together with a plan specifying and describing the termination survey of the site in question.

A report will be submitted to the licensing agency indicating that all radioactive material has been properly disposed of and that the site is free of fixed and/or removable radioactive contamination or decontaminated to the limits specified by the State Radiological Health Branch of the Department of Public Health.

# **3. TRAINING**

## 3.1 Policy

No individual may work with radioactive material, radiation producing machines, or frequent places where they are used or stored, until the individual has received appropriate radiation safety training. Training received must be commensurate with the degree of potential hazards to be encountered. Retraining will be provided bi-annually and is available online at ehs.ucmerced.edu, click the red LMS button.

## 3.2 Training by Radiation Safety Officer

New personnel and personnel starting work with radioactive material at UC Merced must receive basic radiation safety orientation from the RSO or other qualified personnel approved by the RSO. This training must be documented.

The RSO is responsible for scheduling bi-annual refresher training and documenting attendance. The RSO may present other training whenever warranted.

## 3.3 Training by Principal Investigators

The Principal Investigators are responsible for ensuring that each individual whom they

supervise receives adequate initial training as well as additional training needed to safely perform the specific tasks assigned.

## 3.4 Radiation Users

Each individual working with radioactive materials is responsible for working within the limits of the training received.

It is the responsibility of each individual to seek additional information and training as warranted and as job assignments change.

# **4. ACQUISITION AND TRANSFER OF RADIOACTIVE MATERIAL**

## 4.1 Policy

Radioactive material must be acquired, transferred and disposed of in ways which ensure compliance with federal, state and local laws and regulations as well as UC Merced policies, while minimizing impedance of legitimate use.

## 4.2 Acquisition

Acquisition of any radioactive material must be approved by the RSO, the Alternate RSO or the Office of Environmental Health and Safety (EH&S).

Each package must be inspected to ensure that the material received is authorized in form and amount, has been properly contained, and is not contaminated by removable radioactivity. Results of this inspection are summarized on the Radioactive Material Receipt form. A copy of the completed form must be sent to the Office of EH&S.

## 4.3 Inventory

Each acquisition must be added to the radioactive material inventory maintained by each Principal Investigator on the online UC Radiation tool (ehs.ucop.edu/radiation).

The Office of EH&S will review and maintain the inventory for the entire site to

ensure that the license possession limits are not exceeded.

## 4.4 On Site Transfer

Unbreakable secondary containers must be used for transfer of labeled

material within the facility.

## 4.5 Off-Site Transfer

A copy of the consignee’s radioactive material license must be on file with the Office of EH&S prior to any off-site shipment. The Shipper’s Certificate for Radioactive Material form must be completed and signed to ensure compliance with Department of Transportation (DOT) and/or International Air Transport Association (IATA) rules pertaining to packaging, labeling and

contamination limits.

# **5. USE OF RADIOACTIVE MATERIAL**

## 5.1 Policy

Personnel using radioactive materials are responsible for handling them in such manner as to keep radiation exposure ALARA. Handling procedures should minimize the potential for area contamination and environmental release.

## 5.2 Authorization of Use

The RSO or the Alternate RSO must be informed of all new studies involving the use of radioactive material or radiation producing machines. This is achieved by completing the application for Radiation Use Authorization (RUA) and Statement of Training and Experience forms available at ehs.ucop.edu/radiation

The RSO or the Alternate RSO will review the proposed use with respect to safety, and the RSO will notify the Principal Investigator of the completion of the review and specify any additional safety requirements found to be necessary.

The RUA must be amended when there are changes in personnel, isotopes used, procedures, or work locations.

The RUA must be renewed annually.

## 5.3 Posting

Notice to Employees posters issued by the State of California Department of Public Health will be conspicuously posted in all buildings where radioactive materials are used of stored.

Each entryway to locations where radioactive material is used or stored must

be posted with a Caution Radioactive Material sign.

## 5.4 Labeling

Each hood, refrigerator, freezer, container or equipment where radioactive material is used or stored must be labeled with a Caution Radioactive Material sign.

Each transport container holding radioactive material for shipment must be labeled in accordance with DOT and/or IATA regulations.

## 5.5 Security

Radioactive material must be stored in a secure manner minimizing the possibility of unauthorized removal.

## 5.6 Survey Meters

Functional portable survey meters with appropriate detectors must be present whenever more than 10 µCi of any radioisotope, except H-3, is used. Each radiation survey meter must be calibrated at least annually and after undergoing repairs.

## 5.7 Surveys – Monitoring Records

Facilities and equipment where more than 1 mCi is used per week must undergo a routine survey at least once each week. Laboratories using lesser amounts must be surveyed monthly.

A survey includes both swipes to detect removable contamination and direct readings via survey meter, where appropriate.

The RSO, the alternate RSO or the Office of EH&S must be notified if swipe readings exceed 200 DPM/100 cm2.

A copy of the survey results must be forwarded to the Office of EH&S.

Special surveys may be required and/or performed by the RSO or Alternate RSO when conditions so warrant. These surveys must be documented and kept on file in the same

manner as routine surveys.

## 5.8 Handling and Storage

The following general guidelines must be observed for the handling and/or storage of radioactive material in laboratories:

• Eating, drinking, smoking, or application of cosmetics is not permitted.

• Edibles shall not be used or stored in posted refrigerators, freezers or areas where

radioactive material is present.

• Containers or utensils previously used to store food or beverages shall not be used for

storing radioactive materials.

• Protective gloves, lab coats, shoes and appropriate eye protection shall be worn while

working with radioactive material.

• Radioactive material shall be used in areas covered with absorbent paper having an

impervious backing or on trays.

• Liquids, including wastes, shall be stored in screw capped containers, placed in a secondary

container capable of preventing contamination spread should the primary container leak or

break.

• Work and storage areas as well as contaminated items shall be marked with "Caution

Radioactive Material" labels.

• Appropriate portable survey instruments shall be on hand and operable when radioactive

material is being used.

• Prior to leaving an area after the use of radioactive material, personnel shall survey

themselves as well as the use area.

• Transfer of radioactive material between workstations shall be in leak proof unbreakable

containers.

• A legible, accessible and up-to-date inventory shall be maintained by each PI.

• Use and storage areas as well as all containers used to store radioactive material shall be

labeled according to 10 CFR 20, Subpart J.

• All gamma emitters and high energy beta emitters shall be stored in properly shielded

containers.

• Remote handling tools shall be used when appropriate to minimize extremity exposures.

• Appropriate dosimetry shall be worn to monitor exposure to radiation when required by the

guidelines specified in this Manual, see Section 7.3

• Mouth pipetting is prohibited

• Good housekeeping shall be practiced.

• Work with radioactive material shall be in accordance with radiation safety

operating and emergency procedures.

• Spills shall be promptly cleaned according to emergency response procedures

• EH&S shall be notified immediately in case of a spill or personnel contamination exceeding

200 DPM/100 cm2.

# **6. WASTE DISPOSAL**

## 6.1 Policy

Radioactive waste generated by UC Merced shall be disposed of according to license specifications, appropriate regulations and disposal site requirements. Waste minimization shall be practiced by all users of radioactive material.

## 6.2 Storage Locations

All radioactive waste shall be taken to the designated waste storage area for disposal via a licensed radioactive waste vendor.

## 6.3 Waste Categories

## 6.3.1 LSC vials

• LSC vials must be segregated by radioisotope and activity. Two containers are provided

and labeled as follows: [**H-3, C-14, P-32 ONLY]** and [**I-125, S -35 and Ca-45 ONLY]**.

• Only vials are placed in the container. **No plastic bags or cardboard trays are to be**

**placed into the container.**

• Enter date, name, radioisotope and activity **in uCi** on the LSC vial waste log which is

placed on the container.

### 6.3.2 Aqueous Liquids

• No aqueous liquids may be disposed of via the sanitary sewer.

• Aqueous liquids must be placed in unbreakable screw capped containers.

• The containers must be labeled and an appropriate entry must be made in the

aqueous waste log.

### 6.3.3 Mixed Waste

• Mixed waste is liquid waste that contains a radioactive compound plus a non-

radioactive “hazardous” component such as an organic solvent.

• Contact EH&S for the disposal of mixed waste.

### 6.3.4 Short Half-Life Solids

• Short half-life radioisotopes are those having a half-life of less than 90 days.

• **Make sure each radioisotope is placed in a separate box.**

• Make sure there are no radiation warning signs or other hazard signs, such as

“Biohazard”, on or in the waste.

• Make appropriate entry in the short half-life waste log.

### 6.3.5 Long Half-Life Solids

• Long half-life solids are those having a half-life in excess of 90 days

• Long half-life solids do not need to be segregated by isotope

• Make appropriate entry in the long half-life radioactive waste log

### 6.3.6 Contaminated Oil

• Contaminated pump oil must be disposed of as radioactive waste.

• Contact the Office of EH&S for disposal instructions.

### 6.3.7 Biological Waste

• Biological waste consists of animals, tissue, blood, excreta and bedding.

• Contact the Office of EH&S for proper disposal of biological waste.

# **7. DOSIMETRY**

## 7.1 Policy

To maintain its commitment to ALARA, the radiation exposure of personnel working with

radioactive material shall be monitored and appropriate actions initiated to minimize the

potential for occupational exposure.

## 7.2 Previous Dose Assessment

An assessment of radiation exposure received within the last three months will be made for all personnel starting work with radioactive materials.

## 7.3 External Dosimetry

A body badge as well as a finger ring shall be issued to personnel using high energy beta or gamma emitters if quantities in excess of 1 mCi are handled.

Dosimetry shall be exchanged on a quarterly basis.

Dosimeters may not be shared between users!

## 7.4 Bioassay

Routine thyroid counting is required if an individual has handled more than 0.1mCi of I-125 in a

calendar quarter. Thyroid counting is performed every three months.

Special bioassays may be required and shall be prescribed by the RSO on a case-by-case basis.

Any person working with radioactive material may request a bioassay by contacting EH&S.

## 7.5 Action Levels

The RSO will investigate any radiation exposure exceeding 10% of the annual occupation dose

limit. Any positive results shall be transmitted to the individual involved.

EH&S shall maintain records for external as well as internal exposure. These records may be sent to another licensee at the written request of the person to whom the dosimetry was assigned or who was on the bioassay program.

## 7.6 Records

EH&S shall maintain records for external as well as internal exposure. These records may be sent to another licensee at the written request of the person to whom the dosimetry was assigned or who was on the bioassay program.

# **8. RADIATION PRODUCING MACHINES**

The UC Merced campus uses several types of ionizing radiation–producing machines (RPMs). They are classified as follows:

* Class 1- Electron microscopes or other low-hazard machines
* Class 2- Cabinet X-ray machines, X-ray diffraction and fluorescence analysis machines,

portable X-ray machines, and diagnostic X-ray machines.

The Office of Environment Health and Safety will review any unique x-ray equipment that does not clearly fit into these categories and will determine the proper classification for the unit.

## 8.1 Possession, Procurement or Transfer

EH&S must be notified before bringing a RPM onto campus. EH&S must register such machines with the California Department of Public Health (CDPH) within 30 days. However, in the case of machines with an operating potential of greater than 500 kVp or which are capable of producing a significant radiation hazard, UC Merced must notify the CDPH at least 60 days before taking possession of the machine or before starting construction or reconstruction of the room where the machine will be housed (whichever comes first.)

The RUA holder must apply for a RUA before acquiring or operating the machine, regardless of the means of acquisition (purchase, lease, gift, loan, “in-house” fabrication) and regardless of ownership.

All individuals must complete the Radiation Producing Machine Safety Training before they are listed on an RUA.

EH&S must be notified before removing a RPM from campus. EH&S must notify the CDPH within 30 days of the transfer.

EH&S must be notified if a RPM is deactivated or rendered incapable of producing radiation. EH&S must notify the CDPH within 30 days of the transfer. Machines that are deactivated must be labeled as follows:

**DEACTIVATED RADIATION-PRODUCING MACHINE**

Do Not Move, Operate or Reactivate Without Notifying EH&S Radiation Safety. CALL **(209) 228-7864**

EH&S renews the registration of all campus RPMs with the CDPH as required.

## 8.2 Use

Operate RPMs in accordance with a valid RUA. Among other items, the RUA lists the RUA holder and other users and describes the machine, operating parameters, procedures, locations, dosimetry, and safety precautions to be used.

Immediately notify EH&S of intended changes in personnel, machine location, machine

repair, operating parameters, or other items specified in the RUA.

Do not bypass safety interlocks except as specified on the approved RUA SOP (usually for

test and/or alignment purposes). Record authorized bypass operations in the “Use Log”.

Notify EH&S immediately if any safety interlocks fail to operate as intended or if an

accidental exposure is suspected.

## 8.3 Personnel Training

Each RPM is controlled by a RUA holder, who is responsible for ensuring compliance with applicable rules and procedures by all operators. The RUA holder and approved operators must have adequate knowledge to ensure safe operation and compliance with the precautions specified by the RUA.

Operators of cabinet x-ray machines and portable units meeting the definition of industrial x-

ray machines must take the UC systemwide Radiation Producing Machines Training and pass written examinations addressing operation, safety and emergency procedures. Machines may only be used by, or under the direct supervision of, an approved operator listed on the RUA.

A qualified authorized repair person may operate a machine during setup, testing, and repair,

and does not need to be on the RUA. If there is any question as to the work to be done or the

qualifications of the repairperson, contact the RSO or alternate RSO.

## 8.4 Radiation Exposures

RPMs must be used in accordance with the manufacturer’s instructions so that the radiation

exposure to operators and others in the vicinity is “as low as reasonably achievable (ALARA),

and use of the machine does not exceed the exposure limits specified in Title 10 CFR 20 and

Title 17, CCR.

## 8.5 Personal Protective Equipment

PPE should be used when it will effectively protect parts of the body that may be exposed

to X-rays. In general, PPE such as leaded aprons, gloves, and/or goggles are useful only for

high-energy (>100 kVp) X-ray sources. PPE does **not** substitute for required engineering

controls.

## 8.6 Location

As a general safety precaution, locate a RPM in a dedicated room or in an area that can be

controlled and secured, away from high-occupancy areas.

Observe the following precautions when installing or relocating a RPM:

* Intercept primary beams by use of a primary barrier (unless the beams are confined or limited by other means).
* Control scatter/secondary radiation to reduce radiation exposure.
* Obtain prior approval from EH&S for any change in location of an RPM

## 8.7 Posting and Labeling

A valid RUA must be posted on or near the radiation producing machine.

Radiation producing machines shall be clearly and visibly labeled to caution individuals that

radiation is produced during operation.

## 8.8 Radiation Surveys

EH&S shall survey each RPM as follows:

* Before the start of use.
* Following any major changes in configuration or repair.
* Annually thereafter.

## 8.9 Dosimetry

Dosimetry is not normally required for personnel working with electron microscopes, X-ray

diffraction or fluorescence units, and other self-contained machines. EH&S shall determine when dosimetry is required.

## 8.10 Safety Devices

Federal, state, and local regulations for radiation-producing machines require that they be equipped with certain safety devices. These typically include a fail-safe warning light, fail-safe interlocks, beam enclosures, and shielding.

In addition, a radiation survey meter may be needed.

## 8.11 Standard Operating Procedure (SOP)

An SOP for each RPM must be established that describes in adequate detail how the machine is used and all safety measures that must be observed.

## 8.12 Use Log

A “Use Log” for each machine shall be maintained. The Use Log shall note the following information:

* Date of use
* Name of the operator(s)
* Description of use
* Beam voltage
* Beam current
* Time beam turned on
* Time beam turned off
* Operational abnormalities, repairs, etc.

## 8.13 Security

The RUA holder is responsible for the ongoing custody and security of any RPM listed on the RUA.

## 8.14 Specific Requirements by Machine Type

The requirements below cover a range of radiation-producing machines commonly used on campus.

Electron Microscopes:

* Valid and current RUA
* Operating log
* Radiation Producing Machines Training

Cabinet X-ray Machines:

* Valid and current RUA All operators must pass the RPM Safety Training and practical examination for that machine
* Operating log
* Dosimetry, as assigned
* Adherence to RUA requirements
* Enclosure. These units must use shielded boxes or be used in shielded rooms such that
  1. no radiation levels outside the shield exceed 2 mrem per hour,
  2. no person is within the shield at any time while the machine is producing X-rays, and
  3. all shield entrances are interlocked in some manner so that any attempt to enter will shut off the machine.
* X-ray indicator(s). Each unit must have a conspicuous fail-safe warning light or device that indicates whether the X-ray tube is energized. The light must be placed near the X-ray tube assembly and labeled “X-ray on”.
* All interlocks, indicators, and other safety devices must be checked and approved by EH&S.
* EH&S Radiation Safety must be notified of any changes to use, machine, personnel, or protocol.
* Interlocks shall be tested annually to ensure they function as designed and the results are documented. Failure of any interlock to function must be documented, reported to EH&S and power to the machine locked out until repairs are made and EH&S inspects the effectiveness of corrective actions.

X-ray Diffraction and Fluorescence Machines*:*

* Valid and current RUA
* Documented training
* Operating log
* Dosimetry, as assigned
* Procedures and records: Normal operating and alignment procedures are to be documented and readily available.
* Beam stop. Each port must have a beam stop that limits the dose rate immediately behind it to less than 2 mrem per hour at maximum settings.
* Locks. Secure unused ports with key-operated power switches so that the key cannot be removed during operation. Do not leave the key in the port lock when the machine is not in operation.
* X-ray indicator(s). Each machine must have a conspicuous fail-safe warning light or device that indicates whether the X-ray tube is energized. The light must be placed near the X-ray tube assembly and labeled “X-ray on”.
* Safety-device approval. All interlocks, indicators, and other safety devices must be checked and approved by the RSO or alternate RSO prior to use.
* Beam enclosure. During routine operation, the primary beam path must be enclosed in a chamber that cannot be entered by any part of the body. The enclosure should be interlocked with the tube high-voltage supply or shutter so that the beam cannot be available unless the enclosure is in place.
* Shutter interlock. If an interlocked beam enclosure is not used, each port’s beam shutter must be interlocked with the accessory apparatus coupling or collimator so that the port can only open if the accessory is in place.
* “Shutter open” indicator. If an interlocked beam enclosure is not used, each port must be provided with a fail-safe “shutter open” indicator.
* Allowable radiation levels. The radiation level outside a beam enclosure typically is limited so that dose rate is 2 mrem per hour or less.
* The RUA holder shall notify EH&S of any changes in machine use, personnel, or protocol. Interlocks shall be tested annually to ensure they function as designed and the results documented. Failure of any interlock to function must be documented, reported to EH&S and power to the machine locked out until repairs are made and EH&S inspects the effectiveness of corrective actions.

# **9. RADIATION INCIDENTS**

## 9.1 Policy

Radiation incidents and other abnormal situations involving radioactive material or radiation

producing machines shall be handled so as to minimize actual, potential or perceived harm to personnel, equipment, facilities, research activities and the environment; to provide proper notification of authorities and to provide proper information to interested parties.

## 9.2 Classification

A reportable radiation incident is any situation requiring the notification of State or Federal

agencies pursuant to Title 17 California Code of Regulations (CCR) paragraph 30295 or Title 10

of Code of Federal Regulations (CFR) 20.2201, 20.2202 and 20.2203.

There are three levels of incident severity requiring different notification schedules

* Immediate notification is required under 10 CFR20.201(i) 20.2021(ii) and 17 CCR 30295.
* Twenty four hour notification is required under 10 CFR 20.2202 (b) and 17 CCR 30295 (b).

• Thirty-day notification is required under 10 CFR 20.2203.

An event not requiring regulatory agency reporting is considered a non-reportable incident.

Classification of an event as a non-reportable radiation incident is at the discretion of the RSO or alternate RSO. In general, non-reportable radiation incidents include:

• Abnormal bioassay or dosimetry results,

• Personnel contamination,

• Area contamination,

• Fires or other similar events in radiation use areas.

**9.3 Incident Management**

9.3.1 Responsibility of Involved Personne**l**

In case ofa spill or high-level contamination, the first individual recognizing the situation

shall:

• Alert persons in the vicinity and keep people out of the affected area.

• Take steps to contain the contamination.

• Notify the PI and EH&S immediately.

• Attempt decontamination as directed by the EH&S.

• Request that others possibly involved remain in the general area until released by

EH&S.

• Resume work in the area after authorization by EH&S

In case of internal or external contamination of an individual the first person recognizing

the situation shall:

• Keep unnecessary personnel out of the affected area.

• Remove the individual from the contaminated location to a nearby clean area.

• If the individual is externally contaminated, remove any contaminated clothing and

wash area with water. Do not use harsh chemical or physical agents.

• Notify the PI and EH&S immediately.

In the event of lost or stolen radioactive material, the first person recognizing the

situation shall notify EH&S immediately.

In case of personnel injury, fire, flood or similar problems, notify EH&S immediately.

### 9.3.2 Responsibility of EHS

Upon being notified of a suspected or verified radiation incident, or similar situation, the RSO or a qualified member of EH&S shall take charge of the radiological aspects of the situation and shall:

• Ensure that medical assistance is obtained without delay, if necessary.

• Arrange for a bioassay and/or send in dosimeters for processing, if necessary.

• Ensure that the PI, RSO, Alternate RSO and the EH&S director are notified.

• Perform necessary release surveys of persons and equipment from the affected area.

• Supervise the decontamination process and provide advice and assistance as

necessary.

• Notify regulatory agencies, if necessary.

• Conduct an investigation, documenting findings and recommendations.

• Assure that required reports are prepared and arrange for their proper and

timely distribution.

• Ensure that corrective and preventive plans are set forth and implemented.

### 9.3.3 Responsibility of Principal Investigators

Arrange for provision of personnel and equipment to decontaminate facilities and equipment under the supervision of a qualified member of EH&S.

Ensure repair, replacement or modification of equipment and facilities to prevent a recurrence of the incident.

Provide personnel training to prevent a recurrence of the incident.

# **Appendix A – Emergency Telephone Numbers**

UC Merced

**Office of Environment Health and Safety 209-228-7864**

**UC Merced Police 24 Hour Dispatch 209-228-2677**

California

**State Radiation Emergency Assistance (24 hour): 1-800-852-7550**

State Radiological Health Branch Richmond: 1-510-620-3416

State Radioactive Material Licensing, Sacramento: 1-916-327-5106

**Appendix B – License**

**For a copy of the current license, please contact EHS at 228-7864**

# **Appendix C – Safety Data Sheets of Common Isotopes**

3H Nuclide Safety Data Sheet Hydrogen-3 [Tritium]

I. PHYSICAL DATA

Radiation: Beta (100% abundance)

Energy: Max.: 18.6 keV; Average: 5.7 keV

Half-Life [T½] : Physical T½: 12.3 years

Biological T½: 10 - 12 days

Effective T½: 10 - 12 days\*

\* Large liquid intake (3-4 liters/day) reduces effective T½ by a factor of 2+; 3H is easily

flushed from the body

Specific Activity: 9650 Ci/g [357 TBq/g] max.

Beta Range: Air: 6 mm [0.6 cm; 0.25 inches]

Water: 0.006 mm [0.0006 cm; 3/10,000 inches]

Solids/Tissue: Insignificant [No 3H betas pass through the dead layer of skin]

II. RADIOLOGICAL DATA

Radiotoxicity: Least radiotoxic of all nuclides; CEDE, ingestion or inhalation:

Tritiated water: 1.73E-11 Sv/Bq (0.064 mrem/uCi) of 3H intake

Organic Compounds: 4.2E-11 Sv/Bq (0.16 mrem/uCi) of 3H intake

Critical Organ: Body water or tissue

Exposure Routes: Ingestion, inhalation, puncture, wound, skin contamination absorption

Radiological Hazard: External Exposure - None from weak 3H beta

Internal Exposure & Contamination - Primary concern

III. SHIELDING

None required - not an external radiation hazard

IV. DOSIMETRY MONITORING

Urine bioassay is the only readily available method to assess intake [for tritium, no intake = no dose]. Be sure to provide a urine sample to Radiation Safety for confirmatory bioassay whenever your annual 3H use exceeds 8 mCi. If negative, no further bioassay is required unless use exceeds 100 mCi at one time or 1000 mCi in one year, or after any accident/incident in which an intake is suspected.

V. DETECTION & MEASUREMENT

Liquid Scintillation Counting is the only readily available method for detecting 3H

NOTE: PORTABLE SURVEY METERS WILL NOT DETECT LABORATORY QUANTITIES OF 3H

VI. SPECIAL PRECAUTIONS

- Avoid skin contamination [absorption], ingestion, inhalation, & injection [all routes of intake]

- Many tritium compounds readily penetrate gloves and skin; handle such compounds remotely and wear double gloves, changing the outer pair at least every 20 minutes.

- While tritiated, DNA precursors are considered more toxic that 3H2O, they are generally less volatile and hence do not normally present a greater hazard.

- The inability of direct-reading instruments to detect tritium and the slight permeability of most material to [tritiated] water & hydrogen [tritium] facilitates undetected spread of contamination. Use extreme care in handling and storage [e.g. sealed double or multiple containment] to avoid contamination, especially with high specific activity compounds.

14C Nuclide Safety Data Sheet Carbon-14

I. PHYSICAL DATA

Radiation: Beta (100% abundance)

Energy: Max.: 156 keV; Average: 49 keV

Half-Life [T½] : Physical T½: 5730 years

Biological T½: 12 days

Effective T½: Bound - 12 days; unbound - 40 days

Specific Activity: 4.46 Ci/g [0.165 TBq/g] max.

Beta Range: Air: 24 cm [10 inches]

Water/Tissue: 0.28 mm [0.012 inches]

[~1% of 14C betas transmitted through dead skin layer, i.e. 0.007 cm depth]

Plastic: 0.25 mm [0.010 inches]

II. RADIOLOGICAL DATA

Radiotoxicity: 0.023 mrem/uCi of 14CO2 inhaled;

2.09 mrem/uCi organic compounds inhaled/ingested

Critical Organ: Fat tissue [most labeled compounds]; bone [some labeled carbonates]

Exposure Routes: Ingestion, inhalation, puncture, wound, skin contamination absorption

Radiological Hazard: External Exposure – None from weak 14C beta

Internal Exposure & Contamination - Primary concern

III. SHIELDING

None required - mCi quantities not an external radiation hazard

IV. DOSIMETRY MONITORING

Urine bioassay is the most readily available method to assess intake [for 14C, no intake = no dose]. Provide a urine sample to Radiation Safety after any accident/incident in which an intake is suspected.

V. DETECTION & MEASUREMENT

Portable Survey Meters: Geiger-Mueller [~10% efficiency];

Beta Scintillator [~5% efficiency]

Wipe Test: Liquid Scintillation Counting is the best readily available method for counting 14C wipe tests

VI. SPECIAL PRECAUTIONS

- Avoid skin contamination [absorption], ingestion, inhalation, & injection [all routes of intake]

- Many 14C compounds readily penetrate gloves and skin; handle such compounds remotely and wear double gloves, changing the outer pair at least every 20 minutes.

32P Nuclide Safety Data Sheet Phosphorous-32

I. PHYSICAL DATA

Radiation: Beta (100% abundance)

Energy: Maximum: 1,710 keV; Average: 695 keV

Half-Life [T½] : Physical T½: 14.29 days

Biological T½: Bone ~ 1155 days; Whole Body ~ 257 days1

Effective T½: 14.29 days

Specific Activity: 286,500 Ci/g [10,600 TBq/g] max.

Beta Range: Air: 610 cm [240 inches; 20 feet]

Water/Tissue: 0.76 cm [0.33 inches]

Plastic: 0.61 mm [3/8 inches]

II. RADIOLOGICAL DATA

Radiotoxicity2: 94.7 mrem/uCi [Lung] & 15.5 mrem/uCi [CEDE] of 32P inhaled

29.9 mrem/uCi [Bone Marrow] & 8.77 mrem/uCi [CEDE] of 32P ingested

Critical Organ: Bone [soluble 32P]; Lung [Inhalation]; GI Tract [Ingestion - insoluble compounds]

Exposure Routes: Ingestion, inhalation, puncture, wound, skin contamination absorption

Radiological Hazard: External Exposure [unshielded dose rate at 1 mCi 32P vial mouth3: approx. 26rem/hr], Internal Exposure & Contamination

III. SHIELDING

Shield 32P with 3/8 inch Plexiglas and monitor for Bremstrahlung; If Bremstrahlung X-rays detected outside Plexiglas, apply 1/8 to 1/4 inch lead [Pb] shielding outside Plexiglas

The accessible dose rate should be background but must be < 2 mR/hr

IV. DOSIMETRY MONITORING

Wear radiation dosimetry monitoring badges [body & ring] if regularly handling mCi quantities of 32P

V. DETECTION & MEASUREMENT

Portable Survey Meters: Geiger-Mueller

Wipe Test: Liquid Scintillation Counting is an acceptable method for counting 32P wipe tests

VI. SPECIAL PRECAUTIONS

- Avoid skin contamination [absorption], ingestion, inhalation, & injection [all routes of intake].

- Store 32P (including waste) behind Plexiglas shielding [3/8 inch thick]; survey (with GM meter) to

check adequacy of shielding (accessible dose rate < 2 mR/hr; should be background); apply lead

[Pb] shielding outside Plexiglas if needed.

- Use 3/8 inch Plexiglas shielding to minimize exposure while handling 32P.

- Use tools [e.g. Beta Blocks] to handle 32P sources and contaminated objects; avoid direct hand

contact.

- Always have a portable survey meter present and turned on when handling 32P.

- 32P is not volatile, even when heated, and can be ignored as an airborne contaminant4 unless

aerosolized.

1 NCRP Report No. 65, p.88

2 Federal Guidance Report No. 11 [Oak Ridge, TN; Oak Ridge National Laboratory, 1988], p. 122, 156

3 Dupont/NEN, Phosphorous-32 Handling Precautions [Boston, MA; NEN Products, 1985]

4 Bevelacqua, J. Contemporary Health Physics [New York; John Wiley & Sons, 1995], p. 282

35S Nuclide Safety Data Sheet Sulfur-35

I. PHYSICAL DATA

Radiation: Beta (100% abundance)

Energy: Maximum: 167.47 keV; Average: 48.8 keV

Half-Life [T½] : Physical T½: 87.44 days

Biological T½: 623 days [unbound 35S]; 90 days [bound 35S]

Effective T½: 44 - 76 days [unbound 35S]

Specific Activity: 42,707 Ci/g [1,580 TBq/g] max.

Beta Range: Air: 26 cm [10.2 inches]

Water/Tissue: 0.32 mm [0.015 inches]

Plastic: 0.25 mm [0.010 inches]

II. RADIOLOGICAL DATA

Radiotoxicity1: 2.48 mrem/uCi [CEDE] of 35S inhaled

0.733 mrem/uCi of 35S ingested

Critical Organ: Testis

Exposure Routes: Ingestion, inhalation, puncture, wound, skin contamination absorption

Radiological Hazard: External Exposure – None from weak 35S beta

Internal Exposure & Contamination - Primary concern

III. SHIELDING

None required - mCi quantities not an external radiation hazard

IV. DOSIMETRY MONITORING

Urine bioassay is the most readily available method to assess intake [for 35S, no intake = no dose]. Provide a urine sample to Radiation Safety after any accident/incident in which an intake is suspected.

V. DETECTION & MEASUREMENT

Portable Survey Meters: Geiger-Mueller [~10% efficiency]

Beta Scintillator [~5% efficiency]

Wipe Test: Liquid Scintillation Counting is the best readily available method for counting 35S wipe tests.

VI. SPECIAL PRECAUTIONS

- Avoid skin contamination [absorption], ingestion, inhalation, & injection [all routes of intake]

- Many 35S compounds and metabolites are slightly volatile and may create contamination problems if not sealed or otherwise controlled. This occurs particularly when 35S amino acids are thawed, and when they are added to cell culture media and incubated. Therefore vent thawing 35S vials in a hood. Incubators used with 35S will have an activated charcoal trap placed in the incubator. Possibility of volatilization must be taken into account when surveying after use.

1 Federal Guidance Report No. 11 [Oak Ridge, TN; Oak Ridge National Laboratory, 1988], p. 122,156

45Ca Nuclide Safety Data Sheet Calcium-45

I. PHYSICAL DATA

Radiation: Beta (100% abundance)

Energy: Maximum: 257 keV; Average: 77 keV

Half-Life [T½] : Physical T½: 162.61 days

Biological T½: Bone ~ 18,000 days1

Effective T½: 163 Days

Specific Activity: 17,800 Ci/g [659 TBq/g] max.

Beta Range: Air: 52 cm [20 inches]

Water/Tissue: 0.062 cm [0.024 inches]

Plastic (Lucite): 0.053 cm [0.021 inches]

II. RADIOLOGICAL DATA

Radiotoxicity2: 35.8 mrem/uCi [Lung] & 16.2 mrem/uCi [Bone] of 45Ca inhaled

19.4 mrem/uCi [Bone] & 3.2 mrem/uCi [CEDE] of 45Ca ingested

Critical Organ: Bone; Lung [Inhalation]

Exposure Routes: Ingestion, inhalation, puncture, wound, skin contamination absorption

Radiological Hazard: External Exposure - mCi quantities not considered an external hazard

Internal Exposure & Contamination - Primary concern

III. SHIELDING

None required - mCi quantities not an external radiation hazard

IV. DOSIMETRY MONITORING

Urine bioassay is the most readily available method to assess intake. Provide a urine sample to Radiation Safety after any accident/incident in which an intake is suspected. No dosimetry badges needed to work with mCi quantities of 45Ca.

V. DETECTION & MEASUREMENT

Portable Survey Meters: Geiger-Mueller

Wipe Test: Liquid Scintillation Counting works well for counting 45Ca wipe tests

VI. SPECIAL PRECAUTIONS

- Avoid skin contamination [absorption], ingestion, inhalation, & injection [all routes of intake]

1 “Calcium-45 Handling Precautions”, E.I. DuPont de Numours & Co., NEN Products [Boston, MA; 1985]

2 Federal Guidance Report No. 11 [Oak Ridge, TN; Oak Ridge National Laboratory, 1988], p. 122, 156

125I Nuclide Safety Data Sheet Iodine-125

I. PHYSICAL DATA

Radiation: Gamma - 35.5 keV (7% abundance)

X-ray - 27 keV (113% abundance)

Gamma Constant: 0.27 mR/hr per mCi @ 1.0 meter [7.432E-5 mSv/hr per MBq @ 1.0 meter]1

Half-Life [T½] : Physical T½: 60.14 days

Biological T½: 120-138 days (unbound iodine)

Effective T½: 42 days (unbound iodine)

Specific Activity: 1.73E4 Ci/g [642 TBq/g] max.

II. RADIOLOGICAL DATA

Radiotoxicity2: 3.44E-7 Sv/Bq (1273 mrem/uCi) of 125I ingested [Thyroid]

2.16 E-7 Sv/Bq (799 mrem/uCi) of 125I inhaled [Thyroid]

Critical Organ: Thyroid Gland

Intake Routes: Ingestion, inhalation, puncture, wound, skin contamination (absorption);

Radiological Hazard: External & Internal Exposure; Contamination

III. SHIELDING

Lead [Pb]

Half Value Layer [HVL] Tenth Value Layer [TVL]

0.02 mm (0.0008 inches) 0.07 mm (0.003 inches)

- The accessible dose rate should be background but must be < 2 mR/hr

IV. DOSIMETRY MONITORING

- Always wear radiation dosimetry monitoring badges [body & ring] whenever handling > 10 Ci of 125I

- Conduct a baseline thyroid scan prior to first use of 1 mCi or more of radioactive iodine

- Conduct thyroid scan no earlier than 6 hours but within 72 hours of handling 1 mCi or more of 125I or after any suspected intake

V. DETECTION & MEASUREMENT

Portable Survey Meters:

Geiger-Mueller

Low Energy Gamma Detector [~19% eff. for 125I] for contamination surveys

Wipe Test: Liquid Scintillation Counter or Gamma Counter

VI. SPECIAL PRECAUTIONS

- Avoid skin contamination [absorption], ingestion, inhalation, & injection [all routes of intake]

- Use shielding [lead or leaded Plexiglas] to minimize exposure while handling mCi quantities of 125I

- Avoid making low pH [acidic] solutions containing 125I to avoid volatilization

- For Iodinations:

- Use a cannula adapter needle to vent stock vials of 125I used; this prevents puff releases

- Cover test tubes used to count or separate fractions from iodinations with parafilm or other

tight caps to prevent release while counting or moving outside the fume hood.

1 Health Physics & Radiological Health Handbook, 3rd Ed. [Baltimore, MD; Williams & Wilkins, 1998] p. 6-11

2 Federal Guidance Report No. 11 (Oak Ridge TN; Oak Ridge National Laboratory, 1988) P. 136, 166

# **Appendix D - Conversion Factors**

1. **Activity:**

1,000 mCi = 1 Ci = 37 GBq

1,000 uCi = 1 mCi = 37 MBq

250 uCi = 0.25 mCi = 9.25 MBq

100 uCi = 0.1 mCi = 3.7 MBq

50 uCi = 0.05 mCi = 1.85 MBq

1 uCi = 0.001 mCi = 37 KBq

1 Ci = 2.22 x 1012 dpm = 3.7 x 1010 dps = 37 GBq

1 mCi = 2.22 x 109 dpm = 3.7 x 107 dps = 37 MBq

1 uCi = 2.22 x 106 dpm = 3.7 x 104 dps = 37 KBq

= 1 dps = 1 Bq

(dpm = cpm / efficiency)

1. **Prefixes for the International System (IS) of Units:**

***Factor Prefix Symbol***

1018 exa E

1015 peta P

1012 tera T

109 giga G

106 mega M

103 kilo K

10-3 mill m

10-6 micro m

10-9 nano n

10-12 pico p

10-15 femto f

10-18 atto a

1. **Dose and Dose Equivalents:**

***Physical Quantity Non-SI Unit SI Unit Relationship***

Absorbed Dose rad gray (Gy) 1 Gy = 100 rads

1 Gy = 1 J/kg 1 rad = 0.01 Gy

1 rad = 10 mGy

Dose Equivalent rem Sievert (Sv) 1 Sv = 100 rems

1 Sv = 1 J/kg 1 rem = 0.01 Sv

1 rem = 10 mSv

# **Appendix E - Instrument Efficiencies**

Counting efficiency for a radiation detection instrument is defined as the events it detects, counts, divided by the number of disintegrations the source that is being counted emits times 100 to give the counting efficiency in terms of percent:

**CPM/DPM x 100 = Efficiency (in percent)**

**Counting Efficiency for the Liquid Scintillation Counter:**

The LSC counter is calibrated using H-3 and C-14 standards. The activity in the small, 7 mL, vials is as follows:

**H-3 = 54,822 DPM (corrected for decay)**

**C-14 = 42,802 DPM**

Using program#3, which is set up so that Channel A “sees” H-3, Channel B “sees” 125I and S-35 and Channel C “sees” 32P maximum beta energy and gamma emitters.

Counting Efficiency for H-3:

28,028 /54,822 x 100 = **51%**

**Counting Efficiency for C-14 and S-35:**

20,675 /42,802 x 100 = **48 %**

**Counting Efficiency for Higher Energy Beta Emitters and Gamma Emitters:**

Since the half-life for P-32 is ~ 2 weeks, standards are not readily available. The efficiency is quite high **> 90%.**

**Counting Efficiency for Portable Survey Instruments:**

**For H-3:** Portable survey instruments will not detect H-3 (tritium)

**For C-14, S-35, P-33 and other low energy beta emitters (E max. < 0.25 MeV):**

The counting efficiency using a thin window pancake GM detector is **~ 5%**

**For P-32, high energy beta emitters and gamma emitters other than I-125:**

The counting efficiency using a thin window pancake GM detector is **~ 20%**

**For I-125:** The counting efficiency using a **thin crystal scintillation detector is ~ 10%**

# **Appendix F** - **Occupational Dose Limits, Annual Limits of Intake**

PERMISSIBLE EXPOSURE LEVELS

A. Dose Limits

Dose limits are established by the [Nuclear Regulatory Commission (NRC)](http://www.nrc.gov/) and are the legal requirements which must be met for work with radioisotopes. These limits are given in Table 11-1 and are based on the recommendations of nationally and internationally recognized committees such as the [National Council on Radiation Protection (NCRP)](http://www.NCRP.com) and the [International Committee on Radiation Protection (ICRP)](http://www.ICRP.org). The present limits were adopted by the NRC in 1991 and the values given in Table 11-1 are taken from [10CFR Part 20.1201](http://www.nrc.gov/reading-rm/doc-collections/cfr/part020/part020-1201.html). For occupational workers the basic whole body limit requires the Total Effective Dose Equivalent (TEDE) be less than 5 rems per year. The TEDE is the sum of the Deep Dose Equivalent (the dose from external radiation) and the Committed Effective Dose Equivalent (the dose from internally deposited radionuclides). In addition to the TEDE limit there is a limit of 50 rems per year to individual organs, skin and extremities. The eye has a special limit of 15 rem per year. There is also a special limit for declared pregnant workers of 0.5 rem to the fetus for the duration of the pregnancy and of 0.1 rem for members of the general public

The NRC also requires that doses be kept "as low as reasonably achievable" (ALARA). The limits are set as maxima which must not be exceeded but the goal is to keep doses as far below these limits as is practical.

|  |  |
| --- | --- |
| TABLE 11-1 Dose Limits per Year | |
| **Radiation Workers:** | **Dose** |
| Total Effective Dose Equivalent (TEDE) | 5 rem |
| Dose Equivalent to the Eye | 15 rem |
| Shallow Dose Equivalent to skin, extremities | 50 rem |
| TEDE to any other individual organ | 50 rem |
| TEDE to embryo/fetus of declared pregnant woman | 0.5 rem |
| Minors | Ten percent of worker limit |
| Members of the Public | 0.1 rem |

B. Dose Limits for Prenatal Exposure

The fetus is more sensitive to radiation damage than the adult; therefore, the Nuclear Regulatory Commission requires that radiation exposure to the fetus be limited to less than 0.5 rem during the nine months of development for a declared pregnant woman. The [Regulatory Guide 8.13](http://www.nrc.gov/reading-rm/doc-collections/reg-guides/occupational-health/active/8-13/index.html) (Appendix G.3 in this manual)discusses the possible health risks to children of women who are exposed to radiation during pregnancy. This section should be read by all female radiation workers. The Institute is committed to keeping the dose below 0.5 rem for those who declare their pregnancy.

Female radiation workers who become pregnant or who are anticipating pregnancy are encouraged to discuss their radiation exposure situation with the Radiation Safety Officer and supervisor, especially if it is likely that an abdominal exposure of up to 0.5 rem over a nine-month period could be received.

C. Dose Determination

The Total Effective Dose Equivalent (TEDE) is calculated by adding the dose determined from the badge dosimeter (external deep dose equivalent) to that of determined from urine and thyroid bioassay procedures (internal committed effective dose equivalent). If monitoring is required, it is very important that monitoring badges be returned promptly and that urine or thyroid assay schedules be followed. If any badges are lost or if an assay schedule cannot be met, the Radiation Safety Office must be informed and a form completed for an estimate of the dose.

# **Appendix G.1 - New Radioactive Material User Training Sheet**

All lab employees working with radioactive materials should complete this form and indicate which sections they have been trained on. Each PI is responsible for maintaining training records for employees working in his or her laboratory.

Training Documentation

Radiation training topics that apply to lab operations should be indicated by the PI and reviewed annually, or as operations change. **Each lab member** **should sign and date his or her own copy of this page** to indicate that he or she has reviewed and understands the material.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **1. Radioactive Material Use** | | |  | **5. Housekeeping** | |
| \_\_\_ | Radioisotopes and Characteristics | | |  | \_\_\_ | Hoods |
| \_\_\_ | Amount Used | | |  | \_\_\_ | Trays |
|  | Use Areas | | |  | \_\_\_ | Paper |
|  | \_\_\_ | Primary/Secondary Use | |  | **6. Labeling** | |
|  | \_\_\_ | Storage | |  | \_\_\_ | Containers |
|  | \_\_\_ | Waste | |  | \_\_\_ | Waste |
|  | **2. Radiation Detection Instruments** | | |  | \_\_\_ | Equipment/Use Areas |
| \_\_\_ | Portable Meters | | |  | **7. Self-Monitoring** | |
| \_\_\_ | Liquid Scintillation Counter | | |  | \_\_\_ | Instrument Surveys |
| \_\_\_ | Locations | | |  | \_\_\_ | Swipe Surveys |
|  | **3. Incoming/Outgoing Shipments** | | |  | \_\_\_ | Dosimetry |
| \_\_\_ | Radioactive Receipt Form | | |  | \_\_\_ | Bioassay |
| \_\_\_ | Inventory | | |  | **8. Segregation/Waste Disposal** | |
| \_\_\_ | Defacing Warning Signs | | |  | \_\_\_ | Isotope Segregation |
| \_\_\_ | Shipping Certificate | | |  | \_\_\_ | Packaging |
| \_\_\_ | Package Preparation | | |  | \_\_\_ | Minimization |
|  | **4. Personal Protective Equipment** | | |  | \_\_\_ | Records |
|  | \_\_\_ | Safety Glasses | |  | **9. Emergencies** | |
|  | \_\_\_ | | Lab Coats/Gowns |  | \_\_\_ | Minimize Spread |
|  | \_\_\_ | | Gloves |  | \_\_\_ | Notification |
|  | \_\_\_ | | Shielding |  | \_\_\_ | Decontamination |

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# **Appendix G.2 - Safe Use of Radioisotopes**

**INTRODUCTION**

The Office of Environmental Health and Safety (EH&S) presents in this handbook recommendations for the safe use of radioisotopes. These procedures have been developed through laboratory surveys, experiment monitoring, project analysis, and investigations of contamination and exposure incidents. They follow the basic regulations found in the Radiation Safety Manual and precautions specified on individual Radiation Use Authorizations. Recommendations are of a general nature and may not apply to particular protocols. Contact EH&S for advice regarding a specific technique. General radioisotope use recommendations are discussed first, followed by hazards information about specific isotopes. Our experience has shown that there is considerable reduction in area contamination and personnel exposure when these basic precautions are employed.

**GENERAL GUIDELINES FOR THE SAFE USE OF RADIOISOTOPES**

The following are recommendations for the safe use of radioisotopes. These procedures have been developed through laboratory surveys, experiment monitoring, and investigations of contamination and exposure incidents. They are consistent with state regulations and standard radioactive materials license conditions. Recommendations are of a general nature and may not apply to all situations. Specific requirements of your RUA are found in the “Precautions Required” section of your RUA. The Radiation Safety Logbook also contains additional information on issues such as the packaging of radioactive wastes. Contact the EH&S or the Radiation Safety Officer (RSO) if you have questions.

General Bench Work

Locate radioisotope work areas away from heavy traffic and doorways. This reduces the severity of contamination spread should a spill occur. Clear an ample bench area of unnecessary items and cover it with an absorbent material with impervious backing, such as Kimpak. Tape the covering down and label it as a radioactive work area. Keep all equipment associated with the radioactive materials in this defined space. Label all radioisotope containers and contaminated equipment. Keep large volumes of radioactive liquid (that would not be contained by the bench covering) in trays or other secondary containers. If necessary, provide sufficient shielding to reduce radiation fields in the immediate vicinity of the material. Use proper containment for volatile or dispersible materials.

Containment

If volatile or dispersible radioactive materials (especially if high levels) are used there may be a potential for an airborne hazard from dust or vapor. Some containment may be required. Partial containment is offered by the use of chemical fume hoods and biological cabinets. Glove boxes and other specialized devices are available commercially. The EH&S can provide information about applicability and procurement of these devices. All systems to be used for radioisotope work requiring enclosures should be tested and approved before such use, and annually thereafter. The RUA will indicate if a fume hood is required for a certain procedure.

PREPARATION

Equipment

Assemble all items necessary for the procedure, so that delay during the experiment can be avoided. Do not leave hazardous operations unattended while additional equipment is located and prepared. Review the procedure and prepare a list of all materials that might possibly be required. A dry run may be advisable.

Emergency Supplies

Try and foresee what problems might occur, including spills, and store the appropriate materials that may be needed close to the work area. Some examples would be extra gloves and absorbent covering, wipes, paper towels, plastic bags, forceps, and decontamination solution. If a spill can be contained immediately, extensive contamination spread and personnel contamination are less likely.

Protective Clothing

Lab coats, gloves, closed-toe shoes, coverings for the legs, and appropriate eye protection are required for all handling of unsealed radioisotopes. Have enough gloves for frequent changes. Information on more specialized protective equipment is available from EH&S.

Dosimetry

When gamma or high-energy beta emitters are used, radiation dosimetry is usually required. Depending on the isotope and maximum amounts to be handled, TLD finger dosimeters and/or body badges will be assigned. Dosimeters must be worn whenever handling the material for which they are assigned. They must be stored away from radioactive materials and excessive heat and light when not in use. The RUA will indicate what, if any, dosimetry is required

Instrumentation

Use of radioisotopes other than H-3 may require an appropriate radiation survey meter. Survey meter requirements are indicated on the RUA.

RADIOACTIVE WASTE

Place adequate waste receptacles (appropriately labeled) on the work surfaces so waste may be contained immediately after it is produced. For dry waste, a plastic bag in a can or Plexiglas box on the workbench is advised. This avoids transfers of contaminated items to the waste area during the procedure.

Liquid waste containers may also be kept on the bench in secondary containers. As appropriate, shield the waste receptacles for all isotopes except low energy beta emitters. Do not allow wastes to accumulate in the work area.

DRY RUNS

Before performing a new procedure with radioisotopes, it is sometimes helpful to make a dry run without any radioactivity, or at reduced levels. These runs should be identical to the proposed procedure. In some cases colored water may be added to stimulate the radioisotope. This will identify exactly which materials and methods are needed, and space and time requirements. Most likely routes of exposure or contamination may be identified and adjustments made to the procedure to reduce the hazard.

HANDLING PROCEDURES

Shipment Opening

Usually the highest activity is handled when the isotope stock bottle is opened. If the material is such that there is a possible build-up during shipment or storage, the container should be opened in an appropriate containment. A fume hood is a good site for opening packages. Always assume the outside of the primary container is contaminated and handle accordingly.

Direct manipulations

Much of the inadvertent contamination of laboratory surfaces is caused by contact with contaminated work gloves. Nearly all isotope work will involve some direct handling of open isotope containers. Whenever this occurs, assume the gloves are contaminated. Change them immediately if a “clean” item is to be handled. Never wear the gloves away from the immediate work area after direct handling, and check them frequently with a survey meter (except for H-3). A dry run will show when gloves should be changed and preliminary assembly of all equipment will cut down on movement away from the work area to open drawers, refrigerators, etc.

Remote Manipulators

For isotopes presenting an exposure hazard some remote manipulation may be necessary. Use of tongs, forceps, pliers, etc., will lower radiation dose to the hands and reduce contamination spread. Metal implements should be rubber tipped for a more secure grip. Tools are likely to become contaminated and should be checked and cleaned after each use. Any equipment used should be properly labeled.

Transfers

When making liquid transfers do the work in a restricted area of the bench so as to avoid personnel and floor contamination from drips, spills, or splattering. For larger volumes of radioactive solution, a tray or tub should be used so all the liquid can be contained in case of spills. Use aids such as automatic pipettes and funnels. Cap solutions that are not to be used immediately. Do not pipette radioactive material with any mouth-operated procedure.

When moving an isotope solution away from the bench, secondary containment is necessary. Rigid, covered unbreakable carriers are needed if isotopes are to be transferred through public use areas (such as hallways).

SELF MONITORING

When working with isotopes other than H-3, it may be necessary to have a portable survey instrument on hand to monitor exposure levels and check for contamination. A thin-window Geiger-type survey meter is appropriate for work with beta emitters (including C-14 and S-35) and gamma emitters. I-125 monitoring requires use of an I-125 specific scintillation-type detector. The RUA may specify required self-monitoring and documentation requirements.

Monitoring with Survey Meters – With the exception of tritium, virtually all beta and gamma emitters can be “seen” with a GM detector survey instrument. This instrument can be used to determine the rough location and gross nature of contamination. The appropriate method is to position the probe surface 1 to 2 cm above the suspected surface and then slowly “paint” the area, listening to variation in the click rate. In general, to check for equipment of personnel contamination, the meter should be shielded from high background. Bench or floor surfaces should be checked directly and by wiping, then monitoring the wipe.

Wipe monitoring – This method can be used with all radioisotopes, and is the only reliable method for quantitative determination of contamination levels. Contamination levels are normally expressed as cpm/100 sq. cm of surface. The method involves wiping the surface with an absorbent medium (paper wipes) and then counting the wipes by LSC analysis. A background (uncontaminated) wipe is counted as a comparison control.

When using lower-energy beta emitters (H-3, C-14, S-35) surfaces should be checked with dry or damp pieces of filter paper or cotton swabs which are counted by liquid scintillation. Suggested areas to be examined: floor in front of work area, equipment (heaters, stirrers, tubing), and any items handled with work gloves during the experiment (faucet handles, drawer handles, pipetters). If extensive or high-level surface contamination (100 times background) is suspected, call EH&S.

Record Keeping – Documentation is maintained on self-surveys. The count data should be tied to a survey map by means of numbers or letters, so that areas found to be contaminated can be identified.

CLEAN UP

All items involved in the experiment must be surveyed, discarded, or cleaned and properly stored. Rinse reusable contaminated glassware twice (dispose into the liquid radioactive waste) before cleaning. Do not allow potentially contaminated items to accumulate in the work area or the sink.

Low-level surface contamination (bench or floor) may be cleaned in the following manner: rub alternately with a wet paper towel with cleaning solution, then a dry one. Start in least contaminated area and work to most contaminated. Discard the towels into the radioactive waste container after each application.

If possible, one sink should be designated and labeled for radioisotope clean-up purposes and all glassware and liquids that might be slightly contaminated should be placed there.

WASTE DISPOSAL

All contaminated or potentially contaminated material must be disposed of as radioactive waste.

Solid waste is placed in designated labeled containers. Place no liquid in the solid waste containers. Syringes and other sharp objects must be placed in appropriate infectious waste and sharps containers.

Liquid scintillation vials are disposed into designated containers.

Animal and biological tissues are normally segregated from other wastes, labeled, and kept frozen until packaging.

If waste is transported out of the laboratory it must be properly contained. Liquid waste bottles must be labeled, bagged, and carried in secondary containment. Solid wastes must be double bagged. All wastes must be documented as to date, Principal Investigator, and activity present.

Radioactive materials must be disposed CCR in accordance with the requirements of the CHORI radioactive material license and Title 17. Inappropriate disposal (such as to building trash) can result in significant expenditure to recover, regulatory action, potential criminal liability, and undesired publicity.

Once materials such as radioactive shipping containers have been emptied and surveyed to assure that they are not contaminated, deface or remove the radioactive labeling and markings. The containers may then be disposed or recycled as appropriate.

METALLIC LEAD

DO NOT dispose of contaminated lead as dry waste or place it in common trash. Lead must be decontaminated or allowed to decay and disposed of as a hazardous material or recycled.

DISPOSAL OF LIQUID SCINTILLATION COUNTERS

Some liquid scintillation counters contain an internal radioactive source. This radioactive source must be removed prior to disposing of the unit. Contact EH&S for advice on how to handle disposal.

STORAGE AND SECURITY

Radioactive storage containers and enclosures must be properly labeled. This includes cabinets, refrigerators, cold rooms, etc. Verify that all vessels are closed tightly and have secondary containment. Normally, refrigerators or other storage receptacles should be located in the laboratory. Do not store radioactive materials with or near food.

Many types of containers (such as plastic) are permeable to certain compounds, especially H-3 labeled materials. Such leakage has resulted in H-3 contaminated freezer ice. These compounds should be stored in rigid secondary containment such as metal

Storage areas must be shielded so that there is less than 2 millirem per hour at contact with the container.

Laboratories with radioisotopes must be locked when unattended. Fire regulations require that lab doors be closed.

AIRBORNE HAZARDS CONTROL

It is required that proper functioning fume hood or equivalent approved enclosure be used whenever there is a possibility of airborne radioactivity.

To use the safety features of a fume hood effectively, the following procedures should be followed:

Never remove sashes or alter a hood. Always check to see if the hood is operating prior to use.

Remove all unnecessary items from the hood to prevent their contamination. Cover stationary objects not to be used.

Keep the materials in use away from sash openings to ensure containment.

Always wear a lab coat, gloves, and appropriate eye protection (further protection is available for arms and face). Never enter the sash opening without protection; avoid placing your head inside the plane of the hood opening.

Further protection can be achieved by working around a sash or shield and doing certain manipulations inside a plastic bag in the hood. Dry runs are advisable for unfamiliar procedures.

Keep volatile wastes in the hood. Close, mark and bag the container before removal.

EMERGENCIES

If there is any suspected personnel contamination, call EH&S immediately. Wash skin contamination with mild detergent. Do not use solvent or abrasives. If there is a radioisotope spill, contain by spreading absorbent material and limit access to through traffic in the vicinity of the spill. Contact EH&S immediately.

CONTAMINATION CONTROL

Proper use of equipment, techniques, and procedures can prevent personnel, equipment, and facilities from becoming contaminated. The following elements are the basis for a good contamination control program:

PERSONAL PROTECTIVE EQUIPMENT (PPE) – Used to prevent contamination of skin or clothing. PPE is required if there is a possibility of contamination.

Lab Coat – With sleeves long enough to cover the arms to the wrists, and long enough to cover the torso to the thighs. Wear with the closures fastened.

Eye Protection – Worn to protect the eyes from splashes of radioactive and other hazardous materials.

Closed-toe Shoes, Long Pants or Long Dresses – Worn to protect the feet and legs from splashes.

Disposable Gloves – Worn to protect the skin of the hands and wrists from contamination. Most effective if two pairs are worn at a time, with the outer pair changed frequently.

APPROPRIATE BENCH COVERINGS – Used to prevent contamination of bench and hood surfaces.

Plastic Backed Disposable Paper – Taped in place with the plastic side down. These coverings are replaced whenever damaged (worn, soiled or torn) or contaminated.

Containment Trays – These shallow trays are useful for certain work situations. They are available with disposable plastic liners to ensure ease of decontamination.

DOUBLE CONTAINMENT METHODS – The use of secondary containers of sufficient volume to contain all of the liquid should a spill occur.

Liquid Waste Storage Cans – Used to store liquid radwaste bottles.

Transport Containers – Usually a deep plastic tray with a snap fitting lid, these are used to double contain radioactive material being transported between laboratories.

USE OF DISPOSABLES – whenever feasible, it is preferable to use disposable plastic pipette tips, petri dishes, centrifuge tubes, etc. this prevents the need for decontamination of glassware.

APPROPRIATE HANDLING TOOLS – these serve dual purposes, reducing hand contamination while reducing extremity dose (includes tweezers, forceps, tongs and shielded containers).

MARKING AND LABELING – this is the single most important contamination control measure. ALL RADIOACTIVE USE AREAS, EQUIPMENT AND STORAGE CONTAINERS MUST BE MARKED WITH THE RADIATION WARNING SYMBOL.

# **Appendix G.3** **- Prenatal Exposure**

Regulatory Guide 8.13

(Draft was issued as DG-8014)

Revision 3 JUNE 1999

7. INTRODUCTION

The Code of Federal Regulations in 10 CFR Part 19, “Notices, Instructions and Reports to Workers: Inspection and Investigations,” in Section 19.12, “Instructions to Workers,” requires instruction in “the health protection problems associated with exposure to radiation and/or radioactive material, in precautions or procedures to minimize exposure, and in the purposes and functions of protective devices employed.” The instructions must be “commensurate with potential radiological health protection problems present in the work place.”

The Nuclear Regulatory Commission's (NRC's) regulations on radiation protection are specified in

10 CFR Part 20, “Standards for Protection Against Radiation”; and 10 CFR 20.1208, “Dose to an Embryo/Fetus,” requires licensees to “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 (5 mSv).” Section 20.1208 also requires licensees to “make efforts to avoid substantial variation above a uniform monthly exposure rate to a declared pregnant woman.” A declared pregnant woman is defined in 10 CFR 20.1003 as a woman who has voluntarily informed her employer, in writing, of her pregnancy and the estimated date of conception.

This regulatory guide is intended to provide information to pregnant women, and other personnel, to help them make decisions regarding radiation exposure during pregnancy. This Regulatory Guide 8.13 supplements Regulatory Guide 8.29, “Instruction Concerning Risks from Occupational Radiation Exposure” (Ref. 1), which contains a broad discussion of the risks from exposure to ionizing radiation.

Other sections of the NRC's regulations also specify requirements for monitoring external and internal occupational dose to a declared pregnant woman. In 10 CFR 20.1502, “Conditions Requiring Individual Monitoring of External and Internal Occupational Dose,” licensees are required to monitor the occupational dose to a declared pregnant woman, using an individual monitoring device, if it is likely that the declared pregnant woman will receive, from external sources, a deep dose equivalent in excess of 0.1 rem (1 mSv). According to Paragraph (e) of 10 CFR 20.2106, “Records of Individual Monitoring Results,” the licensee must maintain records of dose to an embryo/fetus if monitoring was required, and the records of dose to the embryo/fetus must be kept with the records of dose to the declared pregnant woman. The declaration of pregnancy must be kept on file, but may be maintained separately from the dose records. The licensee must retain the required form or record until the Commission terminates each pertinent license requiring the record.

The information collections in this regulatory guide are covered by the requirements of 10 CFR Parts 19 or 20, which were approved by the Office of Management and Budget, approval numbers 3150-0044 and 3150-0014, respectively. The NRC may not conduct or sponsor, and a person is not required to respond to, a collection of information unless it displays a currently valid OMB control number.

8. DISCUSSION

As discussed in Regulatory Guide 8.29 (Ref. 1), exposure to any level of radiation is assumed to carry with it a certain amount of risk. In the absence of scientific certainty regarding the relationship between low dose exposure and health effects, and as a conservative assumption for radiation protection purposes, the scientific community generally assumes that any exposure to ionizing radiation may cause undesirable biological effects and that the likelihood of these effects increases as the dose increases. At the occupational dose limit for the whole body of 5 rem (50 mSv) per year, the risk is believed to be very low.

The magnitude of risk of childhood cancer following in utero exposure is uncertain in that both negative and positive studies have been reported. The data from these studies “are consistent with a lifetime cancer risk resulting from exposure during gestation which is two to three times that for the adult” (NCRP Report No. 116, Ref. 2). The NRC has reviewed the available scientific literature and has concluded that the 0.5 rem (5 mSv) limit specified in 10 CFR 20.1208 provides an adequate margin of protection for the embryo/fetus. This dose limit reflects the desire to limit the total lifetime risk of leukemia and other cancers associated with radiation exposure during pregnancy.

In order for a pregnant worker to take advantage of the lower exposure limit and dose monitoring provisions specified in 10 CFR Part 20, the woman must declare her pregnancy in writing to the licensee. A form letter for declaring pregnancy is provided in this guide or the licensee may use its own form letter for declaring pregnancy. A separate written declaration should be submitted for each pregnancy.

9. REGULATORY POSITION

Who Should Receive Instruction

Female workers who require training under 10 CFR 19.12 should be provided with the information contained in this guide. In addition to the information contained in Regulatory Guide 8.29 (Ref. 1), this information may be included as part of the training required under 10 CFR 19.12.

Providing Instruction

The occupational worker may be given a copy of this guide with its Appendix, an explanation of the contents of the guide, and an opportunity to ask questions and request additional information. The information in this guide and Appendix should also be provided to any worker or supervisor who may be affected by a declaration of pregnancy or who may have to take some action in response to such a declaration.

Classroom instruction may supplement the written information. If the licensee provides classroom instruction, the instructor should have some knowledge of the biological effects of radiation to be able to answer questions that may go beyond the information provided in this guide. Videotaped presentations may be used for classroom instruction. Regardless of whether the licensee provides classroom training, the licensee should give workers the opportunity to ask questions about information contained in this Regulatory Guide 8.13. The licensee may take credit for instruction that the worker has received within the past year at other licensed facilities or in other courses or training.

Licensee's Policy on Declared Pregnant Women

The instruction provided should describe the licensee's specific policy on declared pregnant women, including how those policies may affect a woman's work situation. In particular, the instruction should include a description of the licensee's policies, if any, that may affect the declared pregnant woman's work situation after she has filed a written declaration of pregnancy consistent with 10 CFR 20.1208.

The instruction should also identify who to contact for additional information as well as identify who should receive the written declaration of pregnancy. The recipient of the woman's declaration may be identified by name (e.g., John Smith), position (e.g., immediate supervisor, the radiation safety officer), or department (e.g., the personnel department).

Duration of Lower Dose Limits for the Embryo/Fetus

The lower dose limit for the embryo/fetus should remain in effect until the woman withdraws the declaration in writing or the woman is no longer pregnant. If a declaration of pregnancy is withdrawn, the dose limit for the embryo/fetus would apply only to the time from the estimated date of conception until the time the declaration is withdrawn. If the declaration is not withdrawn, the written declaration may be considered expired one year after submission.

Substantial Variations Above a Uniform Monthly Dose Rate

According to 10 CFR 20.1208(b), “The licensee shall make efforts to avoid substantial variation above a uniform monthly exposure rate to a declared pregnant woman so as to satisfy the limit in paragraph (a) of this section,” that is, 0.5 rem (5 mSv) to the embryo/fetus. The National Council on Radiation Protection and Measurements (NCRP) recommends a monthly equivalent dose limit of 0.05 rem (0.5 mSv) to the embryo/fetus once the pregnancy is known (Ref. 2). In view of the NCRP recommendation, any monthly dose of less than 0.1 rem (1 mSv) may be considered as not a substantial variation above a uniform monthly dose rate and as such will not require licensee justification. However, a monthly dose greater than 0.1 rem (1 mSv) should be justified by the licensee.

IMPLEMENTATION

The purpose of this section is to provide information to licensees and applicants regarding the NRC staff's plans for using this regulatory guide.

Unless a licensee or an applicant proposes an acceptable alternative method for complying with the specified portions of the NRC's regulations, the methods described in this guide will be used by the NRC staff in the evaluation of instructions to workers on the radiation exposure of pregnant women.

REFERENCES

USNRC, “Instruction Concerning Risks from Occupational Radiation Exposure,” Regulatory Guide 8.29, Revision 1, February 1996.

National Council on Radiation Protection and Measurements, *Limitation of Exposure to Ionizing Radiation*, NCRP Report No. 116, Bethesda, MD, 1993.

APPENDIX

QUESTIONS AND ANSWERS CONCERNING PRENATAL RADIATION EXPOSURE

Why am I receiving this information?

The NRC's regulations (in 10 CFR 19.12, “Instructions to Workers”) require that licensees instruct individuals working with licensed radioactive materials in radiation protection as appropriate for the situation. The instruction below describes information that occupational workers and their supervisors should know about the radiation exposure of the embryo/fetus of pregnant women.

The regulations allow a pregnant woman to decide whether she wants to formally declare her pregnancy to take advantage of lower dose limits for the embryo/fetus. This instruction provides information to help women make an informed decision whether to declare a pregnancy.

If I become pregnant, am I required to declare my pregnancy?

No. The choice whether to declare your pregnancy is completely voluntary. If you choose to declare your pregnancy, you must do so in writing and a lower radiation dose limit will apply to your embryo/fetus. If you choose not to declare your pregnancy, you and your embryo/fetus will continue to be subject to the same radiation dose limits that apply to other occupational workers.

If I declare my pregnancy in writing, what happens?

If you choose to declare your pregnancy in writing, the licensee must take measures to limit the dose to your embryo/fetus to 0.5 rem (5 millisievert) during the entire pregnancy. This is one-tenth of the dose that an occupational worker may receive in a year. If you have already received a dose exceeding 0.5 rem (5 mSv) in the period between conception and the declaration of your pregnancy, an additional dose of 0.05 rem (0.5 mSv) is allowed during the remainder of the pregnancy. In addition, 10 CFR 20.1208, “Dose to an Embryo/Fetus,” requires licensees to make efforts to avoid substantial variation above a uniform monthly dose rate so that all the 0.5 rem (5 mSv) allowed dose does not occur in a short period during the pregnancy.

This may mean that, if you declare your pregnancy, the licensee may not permit you to do some of your normal job functions if those functions would have allowed you to receive more than 0.5 rem, and you may not be able to have some emergency response responsibilities.

Why do the regulations have a lower dose limit for the embryo/fetus of a declared pregnant woman than for a pregnant worker who has not declared?

A lower dose limit for the embryo/fetus of a declared pregnant woman is based on a consideration of greater sensitivity to radiation of the embryo/fetus and the involuntary nature of the exposure. Several scientific advisory groups have recommended (References 1 and 2) that the dose to the embryo/fetus be limited to a fraction of the occupational dose limit.

What are the potentially harmful effects of radiation exposure to my embryo/fetus?

The occurrence and severity of health effects caused by ionizing radiation are dependent upon the type and total dose of radiation received, as well as the time period over which the exposure was received. See Regulatory Guide 8.29, “Instruction Concerning Risks from Occupational Exposure” (Ref. 3), for more information. The main concern is embryo/fetal susceptibility to the harmful effects of radiation such as cancer.

Are there any risks of genetic defects?

Although radiation injury has been induced experimentally in rodents and insects, and in the experiments was transmitted and became manifest as hereditary disorders in their offspring, radiation has not been identified as a cause of such effect in humans. Therefore, the risk of genetic effects attributable to radiation exposure is speculative. For example, no genetic effects have been documented in any of the Japanese atomic bomb survivors, their children, or their grandchildren.

What if I decide that I do not want any radiation exposure at all during my pregnancy?

You may ask your employer for a job that does not involve any exposure at all to occupational radiation dose, but your employer is not obligated to provide you with a job involving no radiation exposure. Even if you receive no occupational exposure at all, your embryo/fetus will receive some radiation dose (on average 75 mrem (0.75 mSv)) during your pregnancy from natural background radiation.

The NRC has reviewed the available scientific literature and concluded that the 0.5 rem (5 mSv) limit provides an adequate margin of protection for the embryo/fetus. This dose limit reflects the desire to limit the total lifetime risk of leukemia and other cancers. If this dose limit is exceeded, the total lifetime risk of cancer to the embryo/fetus may increase incrementally. However, the decision on what level of risk to accept is yours. More detailed information on potential risk to the embryo/fetus from radiation exposure can be found in References 2-10.

What effect will formally declaring my pregnancy have on my job status?

Only the licensee can tell you what effect a written declaration of pregnancy will have on your job status. As part of your radiation safety training, the licensee should tell you the company's policies with respect to the job status of declared pregnant women. In addition, before you declare your pregnancy, you may want to talk to your supervisor or your radiation safety officer and ask what a declaration of pregnancy would mean specifically for you and your job status.

In many cases you can continue in your present job with no change and still meet the dose limit for the embryo/fetus. For example, most commercial power reactor workers (approximately 93%) receive, in 12 months, occupational radiation doses that are less than 0.5 rem (5 mSv) (Ref. 11). The licensee may also consider the likelihood of increased radiation exposures from accidents and abnormal events before making a decision to allow you to continue in your present job.

If your current work might cause the dose to your embryo/fetus to exceed 0.5 rem (5 mSv), the licensee has various options. It is possible that the licensee can and will make a reasonable accommodation that will allow you to continue performing your current job, for example, by having another qualified employee do a small part of the job that accounts for some of your radiation exposure.

**What information must I provide in my written declaration of pregnancy?**

You should provide, in writing, your name, a declaration that you are pregnant, the estimated date of conception (only the month and year need be given), and the date that you give the letter to the licensee. A form letter that you can use is included at the end of these questions and answers. You may use that letter, use a form letter the licensee has provided to you, or write your own letter.

**To declare my pregnancy, do I have to have documented medical proof that I am pregnant?**

NRC regulations do not require that you provide medical proof of your pregnancy. However, NRC regulations do not preclude the licensee from requesting medical documentation of your pregnancy, especially if a change in your duties is necessary in order to comply with the 0.5 rem (5 mSv) dose limit.

**Can I tell the licensee orally rather than in writing that I am pregnant?**

No. The regulations require that the declaration must be in writing.

**If I have not declared my pregnancy in writing, but the licensee suspects that I am pregnant, do the lower dose limits apply?**

No. The lower dose limits for pregnant women apply only if you have declared your pregnancy in writing. The United States Supreme Court has ruled (in *United Automobile Workers International Union v. Johnson Controls, Inc*., 1991) that “Decisions about the welfare of future children must be left to the parents who conceive, bear, support, and raise them rather than to the employers who hire those parents” (Reference 7). The Supreme Court also ruled that your employer may not restrict you from a specific job “because of concerns about the next generation.” Thus, the lower limits apply only if you choose to declare your pregnancy in writing.

**If I am planning to become pregnant but am not yet pregnant and I inform the licensee of that in writing, do the lower dose limits apply?**

No. The requirement for lower limits applies only if you declare in writing that you are already pregnant.

**What if I have a miscarriage or find out that I am not pregnant?**

If you have declared your pregnancy in writing, you should promptly inform the licensee in writing that you are no longer pregnant. However, if you have not formally declared your pregnancy in writing, you need not inform the licensee of your nonpregnant status.

**How long is the lower dose limit in effect?**

The dose to the embryo/fetus must be limited until you withdraw your declaration in writing or you inform the licensee in writing that you are no longer pregnant. If the declaration is not withdrawn, the written declaration may be considered expired one year after submission.

**If I have declared my pregnancy in writing, can I revoke my declaration of pregnancy even if am still pregnant?**

Yes, you may. The choice is entirely yours. If you revoke your declaration of pregnancy, the lower dose limit for the embryo/fetus no longer applies.

**What if I work under contract at a licensed facility?**

The regulations state that you should formally declare your pregnancy to the licensee in writing. The licensee has the responsibility to limit the dose to the embryo/fetus.

**Where can I get additional information?**

The references to this Appendix contain helpful information, especially Reference 3, NRC's Regulatory Guide 8.29, “Instruction Concerning Risks from Occupational Radiation Exposure,” for general information on radiation risks. The licensee should be able to give this document to you.

For information on legal aspects, see Reference 7, “The Rock and the Hard Place: Employer Liability to Fertile or Pregnant Employees and Their Unborn Children—What Can the Employer Do?” which is an article in the journal *Radiation Protection Management*.

You may telephone the NRC Headquarters at (301) 415-7000. Legal questions should be directed to the Office of the General Counsel, and technical questions should be directed to the Division of Industrial and Medical Nuclear Safety.

You may also telephone the NRC Regional Offices at the following numbers: Region I, (610) 337-5000; Region II, (404) 562-4400; Region III, (630) 829-9500; and Region IV, (817) 860-8100. Legal questions should be directed to the Regional Counsel, and technical questions should be directed to the Division of Nuclear Materials Safety.

REFERENCES FOR APPENDIX

1. National Council on Radiation Protection and Measurements, *Limitation of Exposure to Ionizing Radiation*, NCRP Report No. 116, Bethesda, MD, 1993.
2. International Commission on Radiological Protection, *1990 Recommendations of the International Commission on Radiological Protection*, ICRP Publication 60, Ann. ICRP 21: No. 1-3, Pergamon Press, Oxford, UK, 1991.
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11. M.L. Thomas and D. Hagemeyer, “Occupational Radiation Exposure at Commercial Nuclear Power Reactors and Other Facilities, 1996,” Twenty-Ninth Annual Report, NUREG-0713, Vol. 18, USNRC, 1998.22

1Single copies of regulatory guides, both active and draft, and draft NUREG documents may be obtained free of charge by writing the Reproduction and Distribution Services Section, OCIO, USNRC, Washington, DC 20555-0001, or by fax to (301)415-2289, or by email to <DISTRIBUTION@NRC.GOV>. Active guides may also be purchased from the National Technical Information Service on a standing order basis. Details on this service may be obtained by writing NTIS, 5285 Port Royal Road, Springfield, VA 22161. Copies of active and draft guides are available for inspection or copying for a fee from the NRC Public Document Room at 2120 L Street NW., Washington, DC; the PDR's mailing address is Mail Stop LL-6, Washington, DC 20555;

telephone (202)634-3273; fax (202)634-3343.

2Copies are available at current rates from the U.S. Government Printing Office, P.O. Box 37082, Washington, DC 20402-9328 (telephone (202)512-1800); or from the National Technical Information Service by writing NTIS at 5285 Port Royal Road, Springfield, VA 22161. Copies are available for inspection or copying for a fee from the NRC Public Document Room at 2120 L Street NW., Washington, DC; the PDR's mailing address is Mail Stop LL-6, Washington, DC 20555; telephone (202)634-3273; fax (202)634-3343.

FORM LETTER FOR DECLARING PREGNANCY

This form letter is provided for your convenience. To make your written declaration of pregnancy, you may fill in the blanks in this form letter, you may use a form letter the licensee has provided to you, or you may write your own letter.

DECLARATION OF PREGNANCY

To:

In accordance with the NRC's regulations at 10 CFR 20.1208, “Dose to an Embryo/Fetus,” I am declaring that I am pregnant. I believe I became pregnant in (only the month and year need be provided).

I understand the radiation dose to my embryo/fetus during my entire pregnancy will not be allowed to exceed 0.5 rem (5 millisievert) (unless that dose has already been exceeded between the time of conception and submitting this letter). I also understand that meeting the lower dose limit may require a change in job or job responsibilities during my pregnancy.

(Your signature)

(Your name printed)

(Date)

REGULATORY ANALYSIS

A separate regulatory analysis was not prepared for this regulatory guide. A regulatory analysis prepared for 10 CFR Part 20, “Standards for Protection Against Radiation” (56 FR 23360), provides the regulatory basis for this guide and examines the costs and benefits of the rule as implemented by the guide. A copy of the “Regulatory Analysis for the Revision of 10 CFR Part 20” (PNL-6712, November 1988) is available for inspection and copying for a fee at the NRC Public Document Room, 2120 L Street NW, Washington, DC, as an enclosure to Part 20 (56 FR 23360).

# **Appendix G.4 – NRC Regulatory Guide**

**U.S. NUCLEAR REGULATORY COMMISSION**

REGULATORY GUIDE

**Revision 1** **February 1996**

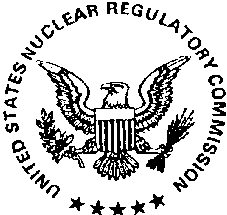
OFFICE OF NUCLEAR REGULATORY RESEARCH

**REGULATORY GUIDE 8.29**

(Draft was issued as DG-8012)

**INSTRUCTION CONCERNING RISKS FROM**

**OCCUPATIONAL RADIATION EXPOSURE**



1. INTRODUCTION

Section 19.12 of 10 CFR Part 19, "Notices, Instructions and Reports to Workers: Inspection and Investigations," requires that all individuals who in the course of their employment are likely to receive in a year an occupational dose in excess of 100 mrem (1 mSv) be instructed in the health protection issues associated with exposure to radioactive materials or radiation. Section 20.1206 of 10 CFR Part 20, "Standards for Protection Against Radiation," requires that before a planned special exposure occurs the individuals involved are, among other things, to be informed of the estimated doses and associated risks.

This regulatory guide describes the information that should be provided to workers by licensees about health risks from occupational exposure. This revision conforms to the revision of 10 CFR Part 20 that be­ came effective on June 20, 1991, to be implemented by licensees no later than January 1, 1994. The revision of 10 CFR Part 20 establishes new dose limits based on the effective dose equivalent (EDE), requires the summing of internal and external dose, establishes a requirement that licensees use procedures and engineering controls to the extent practicable to achieve occupational doses and doses to members of the public that are as low as is reasonably achievable (ALARA), provides for planned special exposures, establishes a dose limit for the embryo/fetus of an occupationally exposed declared pregnant woman, and explicitly states that Part 20 is not to be construed as limiting action that may be necessary to protect health and safety during emergencies.

Any information collection activities mentioned in this regulatory guide are contained as requirements in 10 CFR Part 19 or 10 CFR Part 20. These regulations provide the regulatory bases for this guide. The information collection requirements in 10 CFR Parts 19 and 20 have been cleared under OMB Clearance Nos. 3150-0044 and 3150-0014, respectively.

DISCUSSION

It is important to qualify the material presented in this guide with the following considerations.

The coefficient used in this guide for occupational radiation risk estimates, 4 x l0-4 health effects per rem, is based on data obtained at much higher doses and dose rates than those encountered by workers. The risk coefficient obtained at high doses and dose rates was reduced to account for the reduced effectiveness of lower doses and dose rates in producing the stochastic effects observed in studies of exposed humans.

The assumption of a linear extrapolation from the lowest doses at which effects are observable down the occupational range has considerable uncertainty. The report of the Committee on the Biological Effects of Ionizing Radiation (Ref. 1) states that

" ... departure from linearity cannot be excluded at low doses below the range of observation. Such departures could be in the direction of either an increased or decreased risk. Moreover, epidemiologic data cannot rigorously exclude the existence of a threshold in the 100 mrem dose range. Thus, the possibility that there may be no risk from exposures comparable to external natural background radiation cannot be ruled out. At such low doses and dose rates, it must be acknowledged that the lower limit of the range of uncertainty in the risk estimates extends to zero."

The issue of beneficial effects from low doses, or hormesis, in cellular systems is addressed by the United Nations Scientific Committee on the Effects of Atomic Radiation (Ref. 2). UNSCEAR states that "... it would be premature to conclude that cellular adaptive responses could convey possible beneficial effects to the organism that would outweigh the detrimental effects of exposures to low doses of low-LET radiation."

In the absence of scientific certainty regarding the relationship between low doses and health effects, and as a conservative assumption for radiation protection purposes, the scientific community generally assumes that any exposure to ionizing radiation can cause biological effects that may be harmful to the exposed person and that the magnitude or probability of these effects is directly proportional to the dose. These effects may be classified into three categories:

*Somatic Effects:* Physical effects occurring in the exposed person. These effects may be observable after a large or acute dose (e.g., 100 rems1 (1 Sv) or more to the whole body in a few hours); or they may be effects such as cancer that may occur years after exposure to radiation.

*Genetic Effects:* Abnormalities that may occur in the future children of exposed individuals and in subsequent generations (genetic effects exceeding normal incidence have not been observed in any of the studies of human populations).

*Teratogenic Effects:* Effects such as cancer or congenital malformation that may be observed in children who were exposed during the fetal and embryonic stages of development (these effects have been observed from high, i.e., above 20 rems (0.2 Sv), acute exposures).

The normal incidence of effects from natural and manmade causes is significant. For example, approximately 20% of people die from various forms of cancer whether or not they ever receive occupational expo­ sure to radiation. To avoid increasing the incidence of such biological effects, regulatory controls are imposed on occupational doses to adults and minors and on doses to the embryo/fetus from occupational exposures of declared pregnant women. Radiation protection training for workers who are occupationally exposed to ionizing radiation is an essential component of any program designed to ensure compliance with NRC regulations. A clear understanding of what is

1In the International System of Units (SI), the rem is replaced by the sievert; 100 rems is equal to 1 sievert (Sv).

presently known about the biological risks associated with exposure to radiation will result in more effective radiation protection training and should generate more interest on the part of the workers in complying with radiation protection standards. In addition, pregnant women and other occupationally exposed workers should have available to them relevant information on radiation risks to enable them to make informed decisions regarding the acceptance of these risks. It is intended that workers who receive this instruction will develop respect for the risks involved, rather than excessive fear or indifference

REGULATORY POSITION

Instruction to workers performed in compliance with 10 CFR 19.12 should be given prior to occupational exposure and periodically thereafter. The frequency of retraining might range from annually for licensees with complex operations such as nuclear power plants, to every three years for licensees who possess, for example, only low-activity sealed sources. If a worker is to participate in a planned special exposure, the worker should be informed of the associated risks in compliance with 10 CFR 20.1206.

In providing instruction concerning health protection problems associated with exposure to radiation, all occupationally exposed workers and their supervisors should be given specific instruction on the risk of biological effects resulting from exposure to radiation. The extent of these instructions should be commensurate with the radiological risks present in the workplace.

The instruction should be presented orally, in printed form, or in any other effective communication media to workers and supervisors. The appendix to this guide provides useful information for demonstrating compliance with the training requirements in 10 CFR Parts 19 and 20. Individuals should be given an opportunity to discuss the information and to ask questions. Testing is recommended, and each trainee should be asked to acknowledge in writing that the instruction has been received and understood.

**D. IMPLEMENTATION**

The purpose of this section is to provide information to applicants and licensees regarding the NRC staff's plans for using this regulatory guide.

Except in those cases in which an applicant or licensee proposes acceptable alternative methods for complying with specified portions of the Commission's regulations, the guidance and instructional materials in this guide will be used in the evaluation of applications for new licenses, license renewals, and license amendments and for evaluating compliance with 10 CFR 19.12 and 10 CFR Part 20.

**REFERENCES**

1. National Research Council, *Health Effects of Exposure to Low Levels of Ionizing Radiation,* Re­ port of the Committee on the Biological Effects of Ionizing Radiation (BEIR V), National Academy Press, Washington, DC, 1990.

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APPENDIX

INSTRUCTION CONCERNING RISKS FROM OCCUPATIONAL RADIATION EXPOSURE

This instructional material is intended to provide the user with the best available information about the health risks from occupational exposure to ionizing radiation. Ionizing radiation consists of energy or small particles, such as gamma rays and beta and alpha particles, emitted from radioactive materials, which can cause chemical or physical damage when they deposit energy in living tissue. A question and answer format is used. Many of the questions or subjects were developed by the NRC staff in consultation with workers, union representatives, and licensee representatives experienced in radiation protection training.

This Revision 1 to Regulatory Guide 8.29 updates the material in the original guide on biological effects and risks and on typical occupational exposure. Additionally, it conforms to the revised 10 CFR Part 20, "Standards for Protection Against Radiation," which was required to be implemented by licensees no later than January 1, 1994. The information in this appendix is intended to help develop respect by workers for the risks associated with radiation, rather than unjustified fear or lack of concern. Additional guidance concerning other topics in radiation protection training is provided in other NRC regulatory guides.

**What is meant by health risk?**

A health risk is generally thought of as something that may endanger health. Scientists consider health risk to be the statistical probability or mathematical chance that personal injury, illness, or death may result from some action. Most people do not think about health risks in terms of mathematics. Instead, most of us consider the health risk of a particular action in terms of whether we believe that particular action will, or will not, cause us some harm. The intent of this appendix is to provide estimates of, and explain the bases for, the risk of injury, illness, or death from occupational radiation exposure. Risk can be quantified in terms of the probability of a health effect per unit of dose received.

When x-rays, gamma rays, and ionizing particles interact with living materials such as our bodies, they may deposit enough energy to cause biological damage. Radiation can cause several different types of events such as the very small physical displacement of molecules, changing a molecule to a different form, or ionization, which is the removal of electrons from atoms and molecules. When the quantity of radiation energy deposited in living tissue is high enough, biological damage can occur as a result of chemical bonds being broken and cells being damaged or killed. These effects can result in observable clinical symptoms.

The basic unit for measuring absorbed radiation is the rad. One rad (0.01 gray in the International System of units) equals the absorption of 100 ergs (a small but measurable amount of energy) in a gram of material such as tissue exposed to radiation. To reflect biological risk, rads must be converted to rems. The new international unit is the Sievert (100 rems = 1 Sv). This conversion accounts for the differences in the effectiveness of different types of radiation in causing damage. The rem is used to estimate biological risk. For beta and gamma radiation, a rem is considered equal to a rad.

**What are the possible health effects of exposure to radiation?**

Health effects from exposure to radiation range from no effect at all to death, including diseases such as leukemia or bone, breast, and lung cancer. Very high (100s of rads), short-term doses of radiation have been known to cause prompt (or early) effects, such as vomiting and diarrhea1, skin burns, cataracts, and even death. It is suspected that radiation exposure may be linked to the potential for genetic effects in the children of exposed parents. Also, children

1These symptoms are early indicators of what is referred to as the acute radiation syndrome, caused by high doses delivered over a short time period, which includes damage to the blood­ forming organs such as bone marrow, damage to the gastrointestinal system, and, at very high doses, can include damage to the central nervous system.

who were exposed to high doses (20 or more rads) of radiation prior to birth (as an embryo/fetus) have shown an increased risk of mental retardation and other congenital malformations. These effects (with the exception of genetic effects) have been observed in various studies of medical radiologists, uranium miners, radium workers, radiotherapy patients, and the people exposed to radiation from atomic bombs dropped on Japan. In addition, radiation effects studies with laboratory animals, in which the animals were given relatively high doses, have provided extensive data on radiation-induced health effects, including genetic effects.

It is important to note that these kinds of health effects result from high doses, compared to occupational levels, delivered over a relatively short period of time.

Although studies have not shown a consistent cause-and-effect relationship between current levels of occupational radiation exposure and biological effects, it is prudent from a worker protection perspective to assume that some effects may occur.

**What is meant by early effects and delayed or late effects?**

EARLY EFFECTS

Early effects, which are also called immediate or prompt effects, are those that occur shortly after a large exposure that is delivered within hours to a few days. They are observable after receiving a very large dose in a short period of time, for example, 300 rads (3 Gy) received within a few minutes to a few days. Early effects are not caused at the levels of radiation exposure allowed under the NRC's occupational limits.

Early effects occur when the radiation dose is large enough to cause extensive biological damage to cells so that large numbers of cells are killed. For early effects to occur, this radiation dose must be received within a short time period. This type of dose is called an acute dose or acute exposure. The same dose received over a long time period would not cause the same effect. Our body's natural biological processes are constantly repairing damaged cells and replacing dead cells; if the cell damage is spread over time, our body is capable of repairing or replacing some of the damaged cells, reducing the observable adverse conditions.

For example, a dose to the whole body of about 300-500 rads (3-5 Gy), more than 60 times the annual occupational dose limit, if received within a short time period (e.g., a few hours) will cause vomiting and diarrhea within a few hours; loss of hair, fever, and weight loss within a few weeks; and about a *50* percent chance of death if medical treatment is not provided. These effects would not occur if the same dose were accumulated gradually over many weeks or months (Refs. 1 and 2). Thus, one of the justifications for establishing annual dose limits is to ensure that occupational dose is spread out in time.

It is important to distinguish between whole body and partial body exposure. A localized dose to a small volume of the body would not produce the same effect as a whole body dose of the same magnitude. For ex­ ample, if only the hand were exposed, the effect would mainly be limited to the skin and underlying tissue of the hand. An acute dose of 400 to 600 rads (4-6 Gy) to the hand would cause skin reddening; recovery would occur over the following months and no long­ term damage would be expected. An acute dose of this magnitude to the whole body could cause death within a short time without medical treatment. Medical treatment would lessen the magnitude of the effects and the chance of death; however, it would not totally eliminate the effects or the chance of death.

DELAYED EFFECTS

Delayed effects may occur years after exposure. These effects are caused indirectly when the radiation changes parts of the cells in the body, which causes the normal function of the cell to change, for example, normal healthy cells turn into cancer cells. The potential for these delayed health effects is one of the main concerns addressed when setting limits on occupational doses.

A delayed effect of special interest is genetic effects. Genetic effects may occur if there is radiation damage to the cells of the gonads (sperm or eggs). These effects may show up as genetic defects in the children of the exposed individual and succeeding generations. However, if any genetic effects (i.e., effects in addition to the normal expected number) have been caused by radiation, the numbers are too small to have been observed in human populations exposed to radiation. For example, the atomic bomb survivors (from Hiroshima and Nagasaki) have not shown any significant radiation-related increases in genetic defects (Ref. 3). Effects have been observed in animal studies conducted at very high levels of exposure and it is known that radiation can cause changes in the genes in cells of the human body. However, it is believed that by maintaining worker exposures below the NRC limits and consistent with ALARA, a margin of safety is provided such that the risk of genetic effects is almost eliminated.

**What is the difference between acute and chronic radiation dose?**

Acute radiation dose usually refers to a large dose of radiation received in a short period of time. Chronic dose refers to the sum of small doses received repeatedly over long time periods, for example, 20 mrem (or millirem, which is 1-thousandth of a rem) (0.2 mSv) per week every week for several years. It is assumed for radiation protection purposes that any radiation dose, either acute or chronic, may cause delayed effects. However, only large acute doses cause early effects; chronic doses within the occupational dose limits do not cause early effects. Since the NRC limits do not permit large acute doses, concern with occupational radiation risk is primarily focused on controlling chronic exposure for which possible delayed effects, such as cancer, are of concern.

The difference between acute and chronic radiation exposure can be shown by using exposure to the sun's rays as an example. An intense exposure to the sun can result in painful burning, peeling, and growing of new skin. However, repeated short exposures provide time for the skin to be repaired between exposures. Whether exposure to the sun's rays is long term or spread over short periods, some of the injury may not be repaired and may eventually result in skin cancer.

Cataracts are an interesting case because they can be caused by both acute and chronic radiation. A certain threshold level of dose to the lens of the eye is required before there is any observable visual impairment, and the impairment remains after the exposure is stopped. The threshold for cataract development from acute exposure is an acute dose on the order of 100 rads (1 Gy). Further, a cumulative dose of 800 rads (8 Gy) from protracted exposures over many years to the lens of the eye has been linked to some level of visual impairment (Refs. 1 and 4). These doses exceed the amount that may be accumulated by the lens from normal occupational exposure under the current regulations.

**What is meant by external and internal exposure?**

A worker's occupational dose may be caused by exposure to radiation that originates outside the body, called "external exposure," or by exposure to radiation from radioactive material that has been taken into the body, called "internal exposure." Most NRC­ licensed activities involve little, if any, internal exposure. It is the current scientific consensus that a rem of radiation dose has the same biological risk regardless of whether it is from an external or an internal source. The NRC requires that dose from external exposure and dose from internal exposure be added together, if each exceeds 10% of the annual limit, and that the total be within occupational limits. The sum of external and internal dose is called the total effective dose equivalent (TEDE) and is expressed in units of rems (Sv).

Although unlikely, radioactive materials may enter the body through breathing, eating, drinking, or open wounds, or they may be absorbed through the skin. The intake of radioactive materials by workers is generally due to breathing contaminated air. Radioactive materials may be present as fine dust or gases in the workplace atmosphere. The surfaces of equipment and workbenches may be contaminated, and these materials can be re-suspended in air during work activities.

If any radioactive material enters the body, the material goes to various organs or is excreted, depending on the biochemistry of the material. Most radioisotopes are excreted from the body in a few days. For example, a fraction of any uranium taken into the body will deposit in the bones, where it remains for a longer time. Uranium is slowly eliminated from the body, mostly by way of the kidneys. Most workers are not exposed to uranium. Radioactive iodine is preferentially deposited in the thyroid gland, which is located in the neck.

To limit risk to specific organs and the total body, an annual limit on intake (ALI) has been established for each radionuclide. When more than one radionuclide is involved, the intake amount of each radionuclide is reduced proportionally. NRC regulations specify the concentrations of radioactive material in the air to which a worker may be exposed for 2,000 working hours in a year. These concentrations are termed the derived air concentrations (DACs). These limits are the total amounts allowed if no external radiation is received. The resulting dose from the internal radiation sources (from breathing air at 1 DAC) is the maximum allowed to an organ or to the worker's whole body.

**How does radiation cause cancer?**

The mechanisms of radiation-induced cancer are not completely understood. When radiation interacts with the cells of our bodies, a number of events can occur. The damaged cells can repair themselves and permanent damage is not caused. The cells can die, much like the large numbers of cells that die every day in our bodies, and be replaced through the normal biological processes. Or a change can occur in the cell's reproductive structure, the cells can mutate and subsequently be repaired without effect, or they can form precancerous cells, which may become cancerous. Radiation is only one of many agents with the potential for causing cancer, and cancer caused by radiation cannot be distinguished from cancer attributable to any other cause.

Radiobiologists have studied the relationship be­ tween large doses of radiation and cancer (Refs. *5* and 6). These studies indicate that damage or change to genes in the cell nucleus is the main cause of radiation­ induced cancer. This damage may occur directly through the interaction of the ionizing radiation in the cell or indirectly through the actions of chemical products produced by radiation interactions within cells. Cells are able to repair most damage within hours; however, some cells may not be repaired properly. Such misrepaired damage is thought to be the origin of cancer, but misrepair does not always cause cancer. Some cell changes are benign or the cell may die; these changes do not lead to cancer. Many factors such as age, general health, inherited traits, sex, as well as exposure to other cancer­ causing agents such as cigarette smoke can affect susceptibility to the cancer-causing effects of radiation. Many diseases are caused by the interaction of several factors, and these interactions appear to increase the susceptibility to cancer.

**Who developed radiation risk estimates?**

Radiation risk estimates were developed by several national and international scientific organizations over the last 40 years. These organizations include the National Academy of Sciences (which has issued several reports from the Committee on the Biological Effects of Ionizing Radiations, BEIR), the National Council on Radiation Protection and Measurements (NCRP), the International Commission on Radiological Protection (ICRP), and the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). Each of these organizations continues to review new research findings on radiation health risks.

Several reports from these organizations present new findings on radiation risks based upon revised estimates of radiation dose to survivors of the atomic bombing at Hiroshima and Nagasaki. For example, UNSCEAR published risk estimates in 1988 and 1993 (Refs. *5* and 6). The NCRP also published a report in 1988, "New Dosimetry at Hiroshima and Nagasaki and Its Implications for Risk Estimates" (Ref. 7). In January 1990, the National Academy of Sciences released the fifth report of the BEIR Committee, "Health Effects of Exposure to Low Levels of Ionizing Radiation" (Ref. 4). Each of these publications also provides extensive bibliographies on other published studies concerning radiation health effects for those who may wish to read further on this subject.

**What are the estimates of the risk of fatal cancer from radiation exposure?**

We don't know exactly what the chances are of getting cancer from a low-level radiation dose, primarily because the few effects that may occur cannot be distinguished from normally occurring cancers. However, we can make estimates based on extrapolation from extensive knowledge from scientific research on high dose effects. The estimates of radiation effects at high doses are better known than are those of most chemical carcinogens (Ref. 8).

From currently available data, the NRC has adopted a risk value for an occupational dose of 1rem (0.01 Sv) Total Effective Dose Equivalent (TEDE) of 4 in 10,000 of developing a fatal cancer, or approximately 1 chance in 2,500 of fatal cancer per rem of TEDE received. The uncertainty associated with this risk estimate does not rule out the possibility of higher risk, or the possibility that the risk may even be zero at low occupational doses and dose rates.

The radiation risk incurred by a worker depends on the amount of dose received. Under the linear model explained above, a worker who receives *5* rems (0.05 Sv) in a year incurs 10 times as much risk as another worker who receives only 0.5 rem (0.005 Sv). Only a very few workers receive doses near *5* rems(0.05 Sv) per year (Ref. 9).

According to the BEIR V report (Ref. 4), approximately one in five adults normally will die from cancer from all possible causes such as smoking, food, alcohol, drugs, air pollutants, natural background radiation, and inherited traits. Thus, in any group of 10,000 workers, we can estimate that about 2,000 (20%) will die from cancer without any occupational radiation exposure.

To explain the significance of these estimates, we will use as an example a group of 10,000 people, each exposed to 1rem (0.01 Sv) of ionizing radiation. Using the risk factor of 4 effects per 10,000 rem of dose, we estimate that 4 of the 10,000 people might die from delayed cancer because of that 1-rem dose (although the actual number could be more or less than 4) in addition to the 2,000 normal cancer fatalities expected to occur in that group from all other causes. This means that a 1-rem (0.01 Sv) dose may increase an individual worker's chances of dying from cancer from 20 percent to 20.04 percent. If one's lifetime occupational dose is 10 rems, we could raise the estimate to 20.4 percent. A lifetime dose of 100 rems may increase chances of dying from cancer from 20 to 24 percent. The average measurable dose for radiation workers reported to the NRC was 0.31 rem (0.0031 Sv) for 1993 (Ref. 9). Today, very few workers ever accumulate 100 rems (1 Sv) in a working lifetime, and the average career dose of workers at NRC-licensed facilities is 1.5 rems (0.015 Sv), which represents an estimated increase from 20 to about 20.06 percent in the risk of dying from cancer.

It is important to understand the probability factors here. A similar question would be, "If you select one card from a full deck of cards, will you get the ace of spades?" This question cannot be answered with a simple yes or no. The best answer is that your chance is 1in 52. However, if 1000 people each select one card from full decks, we can predict that about 20 of them will get an ace of spades. Each person will have 1 chance in 52 of drawing the ace of spades, but there is no way we can predict which persons will get that card. The issue is further complicated by the fact that in a drawing by 1000 people, we might get only 15 successes, and in another, perhaps 25 correct cards in 1000 draws. We can say that if you receive a radiation dose, you will have increased your chances of eventually developing cancer. It is assumed that the more radiation exposure you get, the more you increase your chances of cancer.

The normal chance of dying from cancer is about one in five for persons who have not received any occupational radiation dose. The additional chance of developing fatal cancer from an occupational exposure of 1 rem (0.01 Sv) is about the same as the chance of drawing any ace from a full deck of cards three times in a row. The additional chance of dying from cancer from an occupational exposure of 10 rem (0.1 Sv) is about equal to your chance of drawing two aces successively on the first two draws from a full deck of cards.

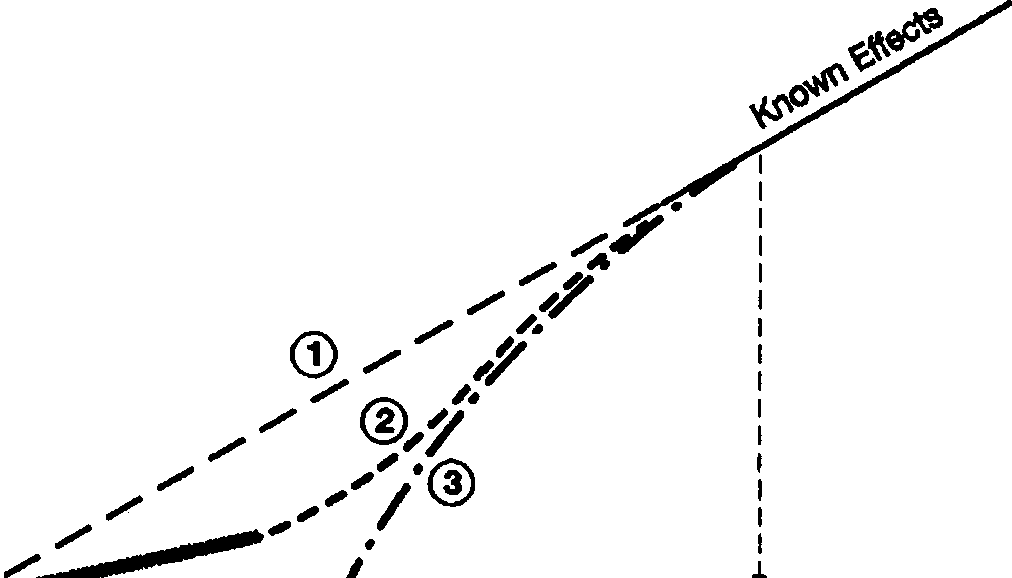
It is important to realize that these risk numbers are only estimates based on data for people and research animals exposed to high levels of radiation in short periods of time. There is still uncertainty with regard to estimates of radiation risk from low levels of exposure. Many difficulties are involved in designing research studies that can accurately measure the projected small increases in cancer cases that might be caused by low exposures to radiation as compared to the normal rate of cancer.

These estimates are considered by the NRC staff to be the best available for the worker to use to make an informed decision concerning acceptance of the risks associated with exposure to radiation. A worker who decides to accept this risk should try to keep expo­ sure to radiation as low as is reasonably achievable (ALARA) to avoid unnecessary risk.

**If I receive a radiation dose that is within occupational limits, will it cause me to get cancer?**

Probably not. Based on the risk estimates previously discussed, the risk of cancer from doses below the occupational limits is believed to be small. Assessment of the cancer risks that may be associated with low doses of radiation are projected from data available at doses larger than 10 rems (0.1 Sv) (Ref. 3). For radiation protection purposes, these estimates are made using the straight line portion of the linear quadratic model (Curve 2 in Figure 1). We have data on cancer probabilities only for high doses, as shown by the solid line in Figure 1. Only in studies involving radiation doses above occupational limits are there dependable determinations of the risk of cancer, primarily because below the limits the effect is small compared to differences in the normal cancer incidence from year to year and place to place. The ICRP, NCRP, and other standards-setting organizations assume for radiation protection purposes that there is some risk, no matter how small the dose (Curves 1 and 2). Some scientists believe that the risk drops off to zero at some low dose (Curve 3), the threshold effect. The ICRP and NCRP endorse the linear quadratic model as a conservative means of assuring safety (Curve 2).

For regulatory purposes, the NRC uses the straight line portion of Curve 2, which shows the number of effects decreasing linearly as the dose decreases. Be­ cause the scientific evidence does not conclusively demonstrate whether



**DOSE (REMS) 50REMS**

Figure 1. Some Proposed Models for How the Effects of Radiation Vary With Doses at Low Levels

there is or is not an effect at low doses, the NRC assumes for radiation protection purposes, that even small doses have some chance of causing cancer. Thus, a principle of radiation protection is to do more than merely meet the allowed regulatory limits; doses should be kept as low as is reasonably achievable (ALARA). This is as true for natural carcinogens such as sunlight and natural radiation as it is for those that are manmade, such as cigarette smoke, smog, and x-rays.



H**ow can we compare the risk of cancer from radiation to other kinds of health risks?**

One way to make these comparisons is to compare the average number of days of life expectancy lost because of the effects associated with each particular health risk. Estimates are calculated by looking at a large number of persons, recording the age when death occurs from specific causes, and estimating the average number of days of life lost as a result of these early deaths. The total number of days of life lost is then averaged over the total observed group.

Several studies have compared the average days of life lost from exposure to radiation with the number of days lost as a result of being exposed to other health risks. The word "average" is important because an individual who gets cancer loses about 15 years of life expectancy, while his or her coworkers do not suffer any loss.

Some representative numbers are presented in Table 1. For categories of NRC-regulated industries with larger doses, the average measurable occupational dose in 1993 was 0.31 rem (0.0031 Sv). A simple calculation based on the article by Cohen and Lee (Ref.10) shows that 0.3 rem (0.003 Sv) per year from age18 to 65 results in an average loss of 15 days. These estimates indicate that the health risks from occupational radiation exposure are smaller than the risks associated with many other events or activities we encounter and accept in normal day-to-day activities.

It is also useful to compare the estimated average number of days of life lost from occupational exposure to radiation with the number of days lost as a result of working in several types of industries. Table 2 shows average days of life expectancy lost as a result of fatal work-related accidents. Table 2 does not include non accident types of occupational risks such as occupational disease and stress because the data are not available.

These comparisons are not ideal because we are comparing the possible effects of chronic exposure to radiation to different kinds of risk such as accidental death, in which death is inevitable if the event occurs. This is the best we can do because good data are not available on chronic exposure to other workplace carcinogens. Also, the estimates of loss of life expectancy for workers from radiation-induced cancer do not take into consideration the competing effect on the life expectancy of the workers from industrial accidents.

**Table 1 Estimated Loss of Life Expectancy from Health Risks8**

*Health Risk* *Estimate* *of Life Expectancy Lost* *(average)*

Smoking 20 cigarettes a day 6 years

Overweight (by 15%) 2 years

Alcohol consumption (U.S. average) 1 year

All accidents combined 1 year

Motor vehicle accidents 207 days

Home accidents 74 days

Drowning 24 days

All natural hazards (earthquake, lightning, flood, etc.) 7 days

Medical radiation 6 days

Occupational Exposure

0.3 rem/y from age 18 to 65 15 days

1 rem/y from age 18 to 65 51 days

**Table 2 Estimated Loss of Life Expectancy from Industrial Accidentsa**

*Industry Type* *Estimated Days of Life Expectancy Lost (Average)*

All industries 60

Agriculture 320

Construction 227

Mining and Quarrying 167

Transportation and

Public Utilities 160

Government 60

Manufacturing 40

Trade 27

Services 27

aAdapted from Reference 10.

**What are the health risks from radiation exposure to the embryo/fetus**?

During certain stages of development, the embryo/ fetus is believed to be more sensitive to radiation damage than adults. Studies of atomic bomb survivors exposed to acute radiation doses exceeding 20 rads (0.2 Gy) during pregnancy show that children born after receiving these doses have a higher risk of mental retardation. Other studies suggest that an association exists between exposure to diagnostic x-rays before birth and carcinogenic effects in childhood and in adult life. Scientists are uncertain about the magnitude of the risk. Some studies show the embryo/fetus to be more sensitive to radiation-induced cancer than adults, but other studies do not. In recognition of the possibility of increased radiation sensitivity, and because dose to the embryo/fetus is involuntary on the part of the embryo/ fetus, a more restrictive dose limit has been established for the embryo/fetus of a declared pregnant radiation worker. See Regulatory Guide 8.13, "Instruction Concerning Prenatal Radiation Exposure" for women (Refs. 1 and 4). These doses are far greater than the NRCs occupational dose limits for workers.

Although acute doses can affect fertility by reducing sperm count or suppressing ovulation, they do not have any direct effect on one's ability to function sexually. No evidence exists to suggest that exposures within in the NRC's occupational limits have any effect on the ability to function sexually.

If an occupationally exposed woman declares her pregnancy in writing, she is subject to the more restrictive dose limits for the embryo/fetus during the remainder of the pregnancy. The dose limit of *500* mrems *(5* mSv) for the total gestation period applies to the embryo/fetus and is controlled by restricting the exposure to the declared pregnant woman. Restricting the woman's occupational exposure, if she declares her pregnancy, raises questions about individual privacy rights, equal employment opportunities, and the possible loss of income. Because of these concerns, the declaration of pregnancy by a female radiation worker is voluntary. Also, the declaration of pregnancy can be with­ drawn for any reason, for example, if the woman believes that her benefits from receiving the occupational exposure would outweigh the risk to her embryo/fetus from the radiation exposure.

**Can a worker become sterile or impotent from normal occupational radiation exposure?**

No. Temporary or permanent sterility cannot be caused by radiation at the levels allowed under NRC's occupational limits. There is a threshold below which these effects do not occur. Acute doses on the order of 10 rems (0.1 Sv) to the testes can result in a measurable but temporary reduction in sperm count. Temporary sterility (suppression of ovulation) has been observed in women who have received acute doses of 150 rads (1.5 Gy). The estimated threshold (acute) radiation dose for induction of permanent sterility is about 200 rads (2 Gy) for men and about 350 rads (3.5 Gy) for women (Refs. 1 and 4). These doses are far greater than the NRC’s occupational dose limits for workers.

**What are the NRC occupational dose limits?**

*For adults,* an annual limit that does not exceed:

* *5* rems (0.05 Sv) for the total effective dose equivalent (TEDE), which is the sum of the deep dose equivalent (DOE) from external exposure to the whole body and the committed effective dose equivalent (CEDE) from intakes of radioactive material.
* *550* rems (0.5 Sv) for the total organ dose equivalent (TODE), which is the sum of the DOE from external exposure to the whole body and the com­ mitted dose equivalent (CDE) from intakes of radioactive material to any individual organ or tis­ sue, other than the lens of the eye.
* 15 rems (0.15 Sv) for the lens dose equivalent (LDE), which is the external dose to the lens of the eye.
* *50* rems (0.5 Sv) for the shallow dose equivalent (SDE), which is the external dose to the skin or to any extremity.

*For minor workers,* the annual occupational dose limits are 10 percent of the dose limits for adult workers.

*For protection of the embryo/fetus* of a declared pregnant woman, the dose limit is *O.S* rem *(S* mSv) during the entire pregnancy.

The occupational dose limit for adult workers of *5* rems (0.05 Sv) TEDE is based on consideration of the potential for delayed biological effects. The 5-rem (0.05 Sv) limit, together with application of the concept of keeping occupational doses ALARA, provides a level of risk of delayed effects considered acceptable by the NRC. The limits for individual organs are below the dose levels at which early biological effects are observed in the individual organs.

The dose limit for the embryo/fetus of a declared pregnant woman is based on a consideration of the possibility of greater sensitivity to radiation of the embryo/fetus and the involuntary nature of the exposure.

**What is meant by ALARA?**

ALARA means "as low as is reasonably achievable." In addition to providing an upper limit on an individual's permissible radiation dose, the NRC requires that its licensees establish radiation protection programs and use procedures and engineering controls to achieve occupational doses, and doses to the public, as far below the limits as is reasonably achievable. "Reasonably achievable" also means "to the extent practicable." What is practicable depends on the purpose of the job, the state of technology, the costs for averting doses, and the benefits. Although implementation of the ALARA principle is a required integral part of each licensee's radiation protection program, it does not mean that each radiation exposure must be kept to an absolute minimum, but rather that "reasonable" efforts must be made to avert dose. In practice, ALARA includes planning tasks involving radiation exposure so as to reduce dose to individual workers and the work group.

There are several ways to control radiation doses, e.g., limiting the time in radiation areas, maintaining distance from sources of radiation, and providing shielding of radiation sources to reduce dose. The use of engineering controls, from the design of facilities and equipment to the actual set-up and conduct of work activities, is also an important element of the ALARA concept.

An ALARA analysis should be used in determining whether the use of respiratory protection is advisable. In evaluating whether or not to use respirators, the goal should be to achieve the optimal sum of external and internal doses. For example, the use of respirators can lead to increased work time within radiation areas, which increases external dose. The advantage of using respirators to reduce internal exposure must be evaluated against the increased external exposure and related stresses caused by the use of respirators. Heat stress, reduced visibility, and reduced communication associated with the use of respirators could expose a worker to far greater risks than are associated with the internal dose avoided by use of the respirator. To the extent practical, engineering controls, such as containments and ventilation systems, should be used to reduce workplace airborne radioactive materials.

**Table 3 Average Annual Effective Dose Equivalent to Individuals in the U.S**. a

*Source* *Effective Dose Equivalent (mrems)*

Natural

Radon 200

Other than Radon 100

Total 300

Nuclear Fuel Cycle 00.5

Consumer Productsb 9

Medical

Diagnostic X-rays 39

Nuclear Medicine 14

Total 53

Total about 360 mrems/year

aAdapted from Table 8.1, NCRP 93 (Ref. 11).

bincludes building material, television receivers, luminous watches, smoke detectors, etc. (from Table 5.1, NCRP 93, Ref. 11).

**What are background radiation exposures?**

The average person is constantly exposed to ionizing radiation from several sources. Our environment and even the human body contain naturally occurring radioactive materials (e.g., potassium-40) that contribute to the radiation dose that we receive. The largest source of natural background radiation exposure is terrestrial radon, a colorless, odorless, chemically inert gas, which causes about *55* percent of our average, nonoccupational exposure. Cosmic radiation originating in space contributes additional exposure. The use of x-rays and radioactive materials in medicine and dentistry adds to our population exposure. As shown below in Table 3, the average person receives an annual radiation dose of about 0.36 rem (3.6 mSv). By age 20, the average person will accumulate over 7 rems (70 mSv) of dose. By age 50, the total dose is up to 18 rems (180 mSv). After 70 years of exposure this dose is up to 25 rems (250 mSv).

**What are the typical radiation doses received by workers?**

For 1993, the NRC received reports on about a quarter of a million people who were monitored for occupational exposure to radiation. Almost half of those monitored had no measurable doses. The other half had an average dose of about 310 mrem (3.1 mSv) for the year. Of these, 93 percent received an annual dose of less than 1rem ( 10 mSv); 98.7 percent received less than 2 rems (20 mSv); and the highest reported dose was for two individuals who each re­ ceived between *5* and 6 rems (50 and 60 mSv).

Table 4 lists average occupational doses for workers (persons who had measurable doses) in various occupations based on 1993 data. It is important to note that beginning in 1994, licensees have been required to sum external and internal doses and certain licensees are required to submit annual reports. Certain types of licensees such as nuclear fuel fabricators may report a significant increase in worker doses because of the exposure to long-lived airborne radionuclides and the requirement to add the resultant internal dose to the calculation of occupational doses.

**Table 4 Reported Occupational Doses for 1993a**

Occupational Subgroup Average Measurable Dose per Worker (millirems)

Industrial Radiography 540

Commercial Nuclear Power Reactors 310

Manufacturing and Distribution

of Radioactive Materials 300

Low-Level Radioactive Waste

Disposal 270

Independent Spent Nuclear Fuel

Storage 260

Nuclear Fuel Fabrication 130

aFrom Table 3.1 in NUREG-0713 (Ref. 9).

**How do I know how much my occupational dose (exposure) is?**

If you are likely to receive more than 10 percent of the annual dose limits, the NRC requires your employer, the NRC licensee, to monitor your dose, to maintain records of your dose, and, at least on an annual basis for the types of licensees listed in 10 CFR 20.2206, "Reports of Individual Monitoring," to in­ form both you and the NRC of your dose. The purpose of this monitoring and reporting is so that the NRC can be sure that licensees are complying with the occupational dose limits and the ALARA principle.

External exposures are monitored by using individual monitoring devices. These devices are required to be used if it appears likely that external exposure will exceed 10 percent of the allowed annual dose, i.e., 0.5 rem (5 mSv). The most commonly used monitoring devices are film badges, thermoluminescence dosimeters (TLDs), electronic dosimeters, and direct reading pocket dosimeters.

With respect to internal exposure, your employer is required to monitor your occupational intake of radioactive material and assess the resulting dose if it appears likely that you will receive greater than 10 percent of the annual limit on intake (ALI) from intakes in 1 year. Internal exposure can be estimated by measuring the radiation emitted from the body (for example, with a "whole body counter") or by measuring the radioactive materials contained in biological samples such as urine or feces. Dose estimates can also be made if one knows how much radioactive material was in the air and the length of time during which the air was breathed.

**18. What happens if a worker exceeds the annual dose limit?**

If a worker receives a dose in excess of any of the annual dose limits, the regulations prohibit any occupational exposure during the remainder of the year in which the limit is exceeded. The licensee is also required to file an overexposure report with the NRC and provide a copy to the individual who received the dose. The licensee may be subject to NRC enforcement action such as a fine (civil penalty), just as individuals are subject to a traffic fine for exceeding a speed limit. The fines and, in some serious or repetitive cases, suspension of a license are intended to encourage licensees to comply with the regulations.

Radiation protection limits do not define safe or unsafe levels of exposure. Exceeding a limit does not mean that you will get cancer. For radiation protection purposes, it is assumed that risks are related to the size of the radiation dose. Therefore, when your dose is higher your risk is also considered higher. These limits are similar to highway speed limits. If you drive at 70 mph, your risk is higher than at 55 mph, even though you may not actually have an accident. Those who set speed limits have determined that the risks of driving in excess of the speed limit are not acceptable. In the same way, the revised 10 CFR Part 20 establishes a limit for normal occupational exposure of 5 rems (0.05 Sv) a year. Although you will not necessarily get cancer or some other radiation effect at doses above the limit, it does mean that the licensee’s safety program has failed in some way. Investigation is warranted to determine the cause and correct the conditions leading to the dose in excess of the limit.

**What is meant by a "planned special exposure"?**

A "planned special exposure" (PSE) is an infrequent exposure to radiation, separate from and in addition to the radiation received under the annual occupational limits. The licensee can authorize additional dose in any one year that is equal to the annual occupational dose limit as long as the individual's total dose from PSEs does not exceed five times the annual dose limit during the individual's lifetime. For example, licensees may authorize PSEs for an adult radiation worker to receive doses up to an additional *5* rems (0.05 Sv) in a year above the 5-rem (0.05-Sv) annual TEDE occupational dose limit. Each worker is limited to no more than 25 rems (0.25 Sv) from planned special exposures in his or her lifetime. Such exposures are only allowed in exceptional situations when alternatives for avoiding the additional exposure are not available or are impractical.

Before the licensee authorizes a PSE, the licensee must ensure that the worker is informed of the purpose and circumstances of the planned operation, the estimated doses expected, and the procedures to keep the doses ALARA while considering other risks that may be present. (See Regulatory Guide 8.35, "Planned Special Exposures.)

**Why do some facilities establish administrative control levels that are below the NRC limits?**

There are two reasons. First, the NRC regulations state that licensees must take steps to keep exposures to radiation ALARA. Specific approval from the licensee for workers to receive doses in excess of administrative limits usually results in more critical risk-bene­ fit analyses as each additional increment of dose is approved for a worker. Secondly, an administrative control level that is set lower than the NRC limit pro­ vides a safety margin designed to help the licensee avoid doses to workers in excess of the limit.

**Why aren't medical exposures considered as part of a worker's allowed dose?**

NRC rules exempt medical exposure, but equal doses of medical and occupational radiation have equal risks. Medical exposure to radiation is justified for reasons that are quite different from the reasons for occupational exposure. A physician prescribing an x­ ray, for example, makes a medical judgment that the benefit to the patient from the resulting medical information justifies the risk associated with the radiation. This judgment may or may not be accepted by the patient. Similarly, each worker must decide on the bene­ fits and acceptability of occupational radiation risk, just as each worker must decide on the acceptability of any other occupational hazard.

Consider a worker who receives a dose of 3 rems (0.03 Sv) from a series of x-rays in connection with an injury or illness. This dose and any associated risk must be justified on medical grounds. If the worker had also received 2 rems (0.02 Sv) on the job, the combined dose of 5 rems (0.05 Sv) would in no way incapacitate the worker. Restricting the worker from additional job exposure during the remainder of the year would not have any effect on the risk from the 3 rems (0.03 Sv) already received from the medical exposure. If the individual worker accepts the risks associated with the x-rays on the basis of the medical benefits and accepts the risks associated with job-related exposure on the basis of employment benefits, it would be unreasonable to restrict the worker from employment involving exposure to radiation for the remainder of the year.

**How should radiation risks be considered in an emergency?**

Emergencies are "unplanned" events in which actions to save lives or property may warrant additional doses for which no particular limit applies. The revised 10 CFR Part 20 does not set any dose limits for emergency or lifesaving activities and states that nothing in Part 20 "shall be construed as limiting actions that may be necessary to protect health and safety."

Rare situations may occur in which a dose in excess of occupational limits would be unavoidable in order to carry out a lifesaving operation or to avoid a large dose to large populations. However, persons called upon to undertake any emergency operation should do so only on a voluntary basis and with full awareness of the risks involved.

For perspective, the Environmental Protection Agency (EPA) has published emergency dose guidelines (Ref. 2). These guidelines state that doses to all workers during emergencies should, to the extent practicable, be limited to 5 rems (0.05 Sv). The EPA further states that there are some emergency situations for which higher limits may be justified. The dose resulting from such emergency exposures should be limited to 10 rems (0.1 Sv) for protecting valuable property, and to 25 rems (0.25 Sv) for lifesaving activities and the protection of large populations. In the context of this guidance, the dose to workers that is incurred for the protection of large populations might be considered justified for situations in which the collective dose to others that is avoided as a result of the emergency operation is significantly larger than that incurred by the workers involved.

Table 5 presents the estimates of the fatal cancer risk for a group of 1,000 workers of various ages, assuming that each worker received an acute dose of 25 rems (0.25 Sv) in the course of assisting in an emergency. The estimates show that a 25-rem emergency dose might increase an individual's chances of developing fatal cancer from about 20% to about 21%.

**Table 5 - Risk of Premature Death from Exposure to 25-Rems (0.25-Sv) Acute Dose**

*Age at Exposure (years)* *Estimated Risk of Premature Death (Deaths per 1,000 Persons Exposed)*

20-30 9.1

30-40 7.2

40-50 5.3

50-60 3.5

Source: EPA-400-R-92-001 (Ref. 2).

**How were radiation dose limits established?**

The NRC radiation dose limits in 10 CFR Part 20 were established by the NRC based on the recommendations of the ICRP and NCRP as endorsed in Federal radiation protection guidance developed by the EPA (Ref. 12). The limits were recommended by the ICRP and NCRP with the objective of ensuring that working in a radiation-related industry was as safe as working in other comparable industries. The dose limits and the principle of ALARA should ensure that risks to workers are maintained indistinguishable from risks from background radiation.

**Several scientific reports have recommended that the NRC establish lower dose limits. Does the NRC plan to reduce the regulatory limits?**

Since publication of the NRC's proposed rule in 1986, the ICRP in 1990 revised its recommendations for radiation protection based on newer studies of radiation risks (Ref. 13), and the NCRP followed with a revision to its recommendations in 1993. The ICRP recommended a limit of 10 rems (0.1 Sv) effective dose equivalent (from internal and external sources), over a 5-year period with no more than *5* rems (0.05 Sv) in 1 year (Ref. 13). The NCRP recommended a cumulative limit in rems, not to exceed the individual's age in years, with no more than *5* rems (0.05 Sv) in any year (Ref. 14).

The NRC does not believe that additional reductions in the dose limits are required at this time. Be­ cause of the practice of maintaining radiation exposures ALARA (as low as is reasonably achievable), the average radiation dose to occupationally exposed per­ sons is well below the limits in the current Part 20 that became mandatory January 1, 1994, and the average doses to radiation workers are below the new limits recommended by the ICRP and the NCRP.

**What are the options if a worker decides that the risks associated with occupational radiation exposure are too high?**

If the risks from exposure to occupational radiation are unacceptable to a worker, he or she can request a transfer to a job that does not involve exposure to radiation. However, the risks associated with the exposure to radiation that workers, on the average, actually receive are comparable to risks in other industries and are considered acceptable by the scientific groups that have studied them. An employer is not obligated to guarantee a transfer if a worker decides not to accept an assignment that requires exposure to radiation.

Any worker has the option of seeking other employment in a non-radiation occupation. However, the studies that have compared occupational risks in the nuclear industry to those in other job areas indicate that nuclear work is relatively safe. Thus, a worker may find different kinds of risk but will not necessarily find significantly lower risks in another job.

**Where can one get additional information on radiation risk?**

The following list suggests sources of useful information on radiation risk:

The employer-the radiation protection or health physics office where a worker is employed.

Nuclear Regulatory Commission Regional Offices:

|  |  |  |
| --- | --- | --- |
| King of Prussia, Pennsylvania | (610) | 337-5000 |
| Atlanta, Georgia | (404) | 331-4503 |
| Lisle, Illinois | (708) | 829-9500 |
| Arlington, Texas | (817) | 860-8100 |

U.S. Nuclear Regulatory Commission Headquarters

Radiation Protection & Health Effects Branch

Office of Nuclear Regulatory Research Washington, DC 20555

Telephone: (301) 415-6187

Department of Health and Human Services Center for Devices and Radiological Health 1390 Piccard Drive, MS HFZ-1

Rockville, MD 20850

Telephone: (301) 443-4690

U.S. Environmental Protection Agency Office of Radiation and Indoor Air Criteria and Standards Division

401 M Street NW.

Washington, DC 20460

Telephone: (202) 233-9290

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\*Copies are available for inspection or copying for a fee from the NRC Public Document Room at 2120 L Street NW., Washington, DC; the PDR's mailing address is Mail Stop LL-6, Washington, DC *20555;* telephone (202) 634-3273; fax (202) 634-3343. Copies may be purchased at current rates from the U.S. Government Printing Office, P.O. Box 37082, Washington, DC 20402-9328 (tele­ phone (202) 512-2249); or from the National Technical Information Service by writing NTIS at *5285* Port Royal Road, Springfield, VA 22161.

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# **Appendix H.1 - Radioactive Material Receipt**

UC Merced Office of Environmental Health and Safety

**(Alternatively this can be tracked in** [**UC Radiation**](file:///C:\Users\ksmith23\AppData\Roaming\Microsoft\Word\ehs.ucop.edu\radiation)**)**

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Principal Investigator: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Surveyed by: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Meter Serial No.\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_Meter Efficiency:\_\_\_\_\_\_\_\_\_\_\_\_\_\_Last Calibrated:\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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| Surveyed with Geiger Counter/ LSC | Results |
| Shipping documents:  Present?  Compound and amount conform to order? | Yes/No  Yes/No |
| Swipe: Outside container | Background or \_\_\_cpm |
| Meter: Outside container (contact) | Background or\_\_\_\_\_cpm \_\_\_\_\_dpm  Report results over 100dpm/100cm2 |
| Meter: Outside container (1 meter) | Background or \_\_\_mrem/hr |
| Swipe on LSC of primary container | Background or \_\_\_cpm |
| Packing materials | Background or \_\_\_cpm |
| Radiation Labels defaced on shipping container | Yes/No |
| Isotope added to inventory | Yes/No |

Comments:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Conversion factor for I=125 may use 1mr/hr = 30,000 cpm.

DPM = cpm/efficiency

LSC = Liquid scintillation counter V 8/2017

# **Appendix H.2 – Radioisotope Inventory**

**UC Merced**

**OFFICE OF ENVIRONMENTAL HEALTH AND SAFETY**

**Radioisotope Material Inventory (Alternatively this can be tracked in** [**UC Radiation**](file:///C:\Users\ksmith23\AppData\Roaming\Microsoft\Word\ehs.ucop.edu\radiation)**)**

Location: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Received by: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Date Received: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

|  |  |  |  |
| --- | --- | --- | --- |
| Company |  | Compound |  |
| Isotope |  | Lot Number |  |
| Activity Units (µCi) |  | Reference Date |  |
|  |  |  |  |

|  |  |  |  |
| --- | --- | --- | --- |
| User | Date Removed | Activity Removed | Activity Remaining |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
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|  |  |  |  |

V 8/2005

# **Appendix H.3 – Radioactive Contamination Survey Record**

Perform a survey at the end of EACH DAY of use.

University of California, Merced

Environmental Health and Safety

209 228-7864

Authorized User:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Building:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Room:\_\_\_\_\_\_\_\_\_\_\_\_

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Date | User Initials | Isotope Used | Survey location | Meter Survey\* | Wipe Survey\* dpm  (report any results over 100dpm/100cm2 to EHS immediately) | Results | Cleanup efforts (comments) |
|  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |
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|  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |

\*State “background” or “see LSC results”