Connecticut College

Radiation Use Program, Policy, and Procedures

Revised: 09/2011

EMERGENCY CONTACT INFORMATION

Campus Safety:	Ext. 2222 or 111
RSO:	Dr. Steven Loomis
Office:	Ext. 2135
Home:	Call Campus Safety
Director of EH&S:	Steven Langlois
Office:	Ext. 2252
Home:	Call Campus Safety
Radiation Safety Consultant:	Jim Tocci, Valley Safety Services, Inc.
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The current NRC Materials License is on file in the EH&S Office.

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INTRODUCTION

In order to protect the health and safety of Connecticut College employees and the general public, the use of radioactive material (RAM) and radiation producing equipment must adhere to stringent safety procedures. To ensure that Connecticut College's Radiation Safety Program complies with State and Federal regulations and established safe practices, the College has established a Radiation Use Committee (RUC). This committee is responsible for ensuring adherence to policies and procedures for the conducting research involving the use of radiation and RAM.

The Committee is composed of faculty who are qualified by training and experience in the use of RAM and radiation. The Associate Director of Physical Plant represents the College administration on this Committee. Together, the committee will review all requests to use RAM and radiation producing equipment, to assure the safety of all members of the campus community

It is important and expected that all researchers who wish to use RAM and radiation producing equipment, abide by this policy and its specific procedures. The Radiation Safety Officer (RSO) has been appointed to assist the Radiation Use Committee and researchers in implementing the radiation safety program.

Your full cooperation in participating in this program is essential to safety and health and the College license commitments to the Nuclear Regulatory Commission (NRC).

PURPOSE

To establish policies and procedures for the safe use of radioactive material (RAM) and to minimize the unwarranted exposures to principle investigators and students from radiation during research.

SCOPE

This program applies to all researchers and students and also to any visitors, post-docs, or others who may occasionally work at the College.
This program specifies the requirements and procedures for procuring, using, transporting, transferring, maintaining, securing and disposing of RAM.

POLICY

To keep exposure to personnel who work with RAM as low as reasonably achievable (ALARA) and within the limits established by the Nuclear Regulatory Commission (NRC) and the State of Connecticut. All research involving the use of RAM must be approved by the College Radiation Use Committee (RUC) who will ensure that all proposed experiments are properly planned so that the limits established by the NRC and the State of Connecticut for personnel exposure and RAM effluent releases are not exceeded and are ALARA.

1. RESPONSIBILITIES

President and Board of Directors are responsible for establishing and maintaining a safety program that minimizes the risks associated with the handling of radioactive material (RAM), and which will ensure full compliance with all applicable governmental regulations.

1.1. Radiation Use Committee (RUC)

The RUC is responsible to the President through the Associate Director of Physical Plant for insuring the safe use of radioactive material on campus. All principle investigators engaged in research involving the use of radioactive materials are entitled to membership on the committee. Current committee members are listed below. Responsibilities of the RUC include:

- Establishing policies on the safe use, handling, storage, transport, receipt, shipment, and disposal of radioactive materials.
- Reviewing the radiation safety aspects of proposals for the procurement and use of radioisotopes and for the modification of existing operating procedures involving the use of radioactive materials.
- Reviewing applications renewals, and amendments for Nuclear Regulatory Commission licenses.
- Reviewing and approving the qualifications of requesters to become authorized users of RAM. The RUC will only approve principle investigators who meet the training and experience criteria of 10 CFR 33.15(b)[1]
- Reviewing reports of accidents and incidents involving (radiological occurrences) the use of radioisotopes to determine the cause and taking the necessary corrective action to prevent reoccurrence (**See Appendix (A), Radiological Occurrence Report**).
- Performing an annual audit of the Radiation Safety Program to determine that all activities are being conducted safely and in accordance with all NRC regulations and license conditions.

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[1] Possess a college degree at the bachelor level, or have equivalent training and experience in the physical or biological sciences or in engineering; and

Have at least 40 hours of training and experience in the safe handling of radioactive materials, and in the characteristics of ionizing radiation, units of radiation dose and quantities, radiation detection instrumentation, and biological hazards of exposure to radiation appropriate to the type and forms of byproduct material requested to be used.

Figure 1 - Current Radiation Use Committee Members

Prof. Stephen Loomis (Biology) RSO	Ext. 2135
Steven R. Langlois (Dir, EH&S)	Ext. 2252
Thomas Hobaica (Assoc. Dir, Phys Plant)	Ext. 5429
Prof. Michael Monce (Physics)	Ext. 2348
Prof. Ruth Grahn (Neuroscience)	Ext. 2387
Jim Tocci (Consultant, Valley Safety Services, Inc.)	(413) 323-9571

1.2. Radiation Safety Officer (RSO)

The RSO is responsible to the RUC for implementing the Radiation Safety Program as established by the College. The specific responsibilities of the RSO include:

- Provide individual workers with training, advice, and assistance on all matters pertaining to the safe use of RAM.
- Reviewing work practices to determine compliance with regulations and approved procedures.
- Performing appropriate radiation surveys of RAM use areas.
- Ensuring that radiation survey instruments are properly calibrated at required frequencies.
- Determining the need for, and issuing OF, personnel dosimetry.
- Investigating accidents or incidents involving the use of RAM.
- Ensuring proper disposal of RAM.
- Maintaining RAM inventory, survey, personnel dosimetry, and calibration records.
- Terminating any work involving the use of RAM, which he/she deems unsafe.
- Ensuring that all required signs and labels are applied.

1.3. Authorized Users

Authorized users are responsible to the RUC for assuring the safe use of radioactive materials in his/her laboratory. The authorized user is always the responsible faculty (Principal Investigator, or P.I.).

Faculty members planning to work with RAM must submit a completed copy of **Appendix (B), "Application for Authorization/Renewal to Use Radioisotopes"**, to the RUC for review and approval.

The responsibilities of an authorized user include:

- Complying with and enforcing the radiation safety requirements prescribed in this manual and as authorized by the RUC.
- Wearing appropriate laboratory attire, and Personal Protective Equipment (PPE).
- Properly storing RAM.

- Assuring that all laboratory personnel are properly instructed in safe procedures for working with the radioactive material in use.
- Assuring that proper supervision and oversight of laboratory personnel is implemented. **<u>Note</u>**: Only persons 18 years or older are allowed to work with RAM.
- Assuring that required monitoring devices, protective clothing and equipment, and contamination control methods are used as required.
- Reviewing in advance, all lab procedures to be used in carrying out research work involving radioactive material, for the potential of spills, explosion, implosion, volatility, or fires.
- Assuring the integrity of vacuum systems, cryogenic systems, pressure vessels or equipment to be used in conjunction with radioactive material.
- Assuring that any new and/or complex procedures that involve the use of radioactive material are thoroughly tested in a "dry run" before attempting an actual use.
- Maintain control of visitors to prevent unwarranted radiation exposures.
- Maintaining any record required by the RUC.

1.4. Laboratory Assistants/Students

Laboratory Assistants/Students are responsible for using only P.I./RUC approved safe techniques and procedures in operations involving the use of RAM. Additional responsibilities are:

- Wearing prescribed personnel dosimetry.
- Wearing appropriate laboratory attire and Personal Protective Equipment (PPE).
- Properly storing RAM.
- Properly opening and inspecting packages of RAM.
- Properly packaging RAM for shipment.
- Surveying areas where RAM is used.
- Reporting any accidents or incidents to the RSO and principle investigator.
- Properly labeling RAM containers.
- Complying with all requirements established by the Connecticut College radiation safety program.
- Again, only students 18 or older are authorized to work with RAM.

2. PROCEDURES FOR ORDERING AND RECEIVING RAM

To ensure the proper handling of radioactive material that will be delivered to the campus, the following procedure will be followed.

2.1. Ordering

- When radioactive material (RAM) is ordered, the authorized faculty member will specify that <u>overnight delivery</u> from FedEx, Airborne Express or UPS be used.
- A firm delivery date will be confirmed at the time the order is placed. Once a date of delivery is established, the user will notify the Director of EH&S) at Ext. 2252.
- All RAM Packages should be addressed and delivered to:

    Office of Environmental Health & Safety
    Room 113, Warnshuis Student Health Center

- If the Director of EH&S is not available on the delivery date, the ordering faculty member will have the package shipped directly to his/her lab. In this case, the ordering faculty member will be responsible for being available to take receipt, and for inspecting and checking the package for damage. (See Section 6.2, "Delivery", below.)

2.2. Delivery

- When the FedEx or UPS driver delivers the package containing RAM, the Director of EH&S will sign for and take possession of the material.
- Upon receipt, the Director of EH&S will visually inspect the package for any sign of damage (e.g. crushed, stained, wet, etc.). If opened, torn or damaged it will be refused and the user notified.
- The Director of EH&S will transport the package to the ordering faculty member's laboratory. If the faculty member is not present, the unopened package will be secured (locked) in the lab refrigerator.
- Using a GM survey meter, and running wipe samples through the Liquid Scintillation Counter (LSC), the ordering faculty member will survey the package for external contamination:
    - The exposure rate at 3 feet (or 1m) from package surface will be measured and recorded. If >10 mR/hr., the RSO will be notified.
    - The exposure rate at the surface of the package will be measured and recorded. If >200 mR/hr., the RSO will be notified.
    - Wipe test results should be not higher than twice background. If greater than twice background, the RSO will be notified.
- The ordering faculty member will document the receipt of the RAM, and the radiation survey results on **Appendix (C) - "RAM Receipt/Shipment Record".**
- After opening the package (See 6.3 below), the ordering faculty will staple the packing slip to the "RAM Receipt/Shipment Record", and send it via campus mail to the Director of EH&S for filing.

2.3. Procedures For Opening RAM Packages

- Upon receipt, the ordering faculty member should again inspect the package for any sign of damage. If damage is noted, do not open the package. Stop, and notify the Radiation Safety Officer and/or the Director of EH&S.
- Wearing gloves, open the outer package (following manufacturer's directions, if supplied) and remove the packing slip.
- Open the inner package, and verify that contents agree with those on packing slip. Compare requisition, packing slip, and label on source containers.
- Check the integrity of the final source container. Wipe the external surface of the final source container shield, and check the wipe with the GM survey meter and take precaution against the spread of contamination if necessary. Move to an area of low background radiation to perform this survey. Notify the RSO and/or Director of EH&S if any removable contamination is detected.
- Run the wipe sample through the LSC.
- Using the GM survey meter, monitor the packing material and box for contamination before discarding. If contaminated, treat as radioactive waste. If not contaminated, obliterate radiation labels before discarding in regular trash.
- Staple the packing slip to the "RAM Receipt/Shipment Record", and forward both documents to the Director of EH&S who will maintain them for NRC recordkeeping purposes.

3. INVENTORY/ACCOUNTABILITY OF RAM

The Radiation Safety Officer, or trained designee (Director of EH&S), will review all orders for RAM requested by P.I.'s, to ensure that the requested RAM is authorized by the license, and will not exceed license possession limits.

- The Director of EH&S will log all RAM purchases into the CEMS Inventory system, under the "Radioactive Materials" module. **(Appendix (D)** is a "Screen Grab" of the online CEMS Chemical Inventory system.) CEMS automatically re-calculates the quantity of that specific radioisotope possessed, campus-wide. To ensure that possession limits are not exceeded, the RAM inventory data will be reviewed at the time of each new purchase request.
- A printed copy of the total campus inventory will be generated for the file at the time of each purchase or waste shipment
- The purchase will also be recorded in the "RAM Inventory Log (Appendix (E))
- The Director of EH&S will retain these inventory records indefinitely.

4. STORAGE AND SECURITY OF RAM

All RAM will be properly stored and secured against unauthorized access or removal. Authorized users and laboratory personnel may employ any or all of the following methods to secure RAM:

- Keep RAM labs locked whenever authorized users or staff is not present to maintain control.
- Keep refrigerators, freezers, or other suitable storage cabinets where RAM is stored, locked, except when removing or returning RAM.
- Utilize other lockable containers that are secured inside a larger cabinet or refrigerator or freezer that is not lockable may be used to secure RAM when authorized users are absent and not under control.

5. CALIBRATION OF SURVEY INSTRUMENTS

5.1. Geiger-Müller (GM) Survey Meter

Portable radiation survey instruments must be properly calibrated at least once each year. A GM Survey meter with a "pancake" probe, is used to monitor research lab surfaces for possible contamination of beta emitting RAM such as P-32, P-33, S-35, etc. These units will be calibrated using a two-step procedure as follows:

1. The survey meter will be calibrated using an electronic pulser to ensure proper/accurate pulse counting operation, two points on each scale.

2. The pancake GM probe coupled with the survey meter will then be calibrated together using a low energy beta source, C-14, and a high energy beta source, Sr-90, to determine flux measurement efficiency.

Whenever a portable survey meter will be used to monitor lab areas and surfaces from gamma emitters, such as Cr-51, Rb-86, etc., the unit will be calibrated according to NRC Reg. Guide 10.8, Appendix (D), Sec.1, "Calibration of Instruments".

5.2. Liquid Scintillation Counter (LSC)

The liquid scintillation counter (LSC) used for lab wipe test analysis is calibrated using H-3, C-14, and Cl-36 standards obtained from the manufacturer. These standards are run in the LSC prior to each use of the instrument. Results are logged in an instrument record book and graphed. Whenever background and standard counts are outside 2 standard deviations they will be re-counted. If they then fall within 2 standard deviations, no further action will be taken. If these counts continue to fall outside 2 standard deviations, the manufacturer will service the LSC before resuming use.

These procedures are in agreement with NRC guidance, ref. NRC IN NO.93-30 "NRC Requirements for Evaluation of Wipe Test Results; Calibration of Count Rate Survey Instruments".

6. RADIATION SURVEYS

The Radiation Safety Officer (RSO) is responsible ensuring radiation surveys are performed in accordance with **APPENDIX (L) - METHODS AND FREQUENCY FOR CONDUCTING SURVEYS.**

6.1. Initial Surveys

An initial survey will be made of areas where radioactive material will be used and/or stored before operations are initiated or changes approved, to assure the facilities and equipment are adequate for personnel safety, and contamination control and removal.

6.2. Routine (Monthly) Surveys

On a monthly basis, the RSO (or Director of EH&S) will conduct radiation surveys in all areas where radioactive materials are used and/or stored. This survey should include any equipment (e.g., centrifuges, splash shields, fume hoods, sinks, etc.) that has the potential for contamination.

This survey will be performed using a properly calibrated GM survey meter, and/or wipe samples that are analyzed in the LSC. These surveys will be recorded on room/building specific versions of **Appendix (F) – "Radiation Survey Report**". A detailed description of the monitoring points with results, a statement regarding any hazards noted, and recommendations as to shielding, procedural changes, etc. will be recorded. These survey reports will be filed and maintained indefinitely.

6.3. Researcher Surveys

Utilizing RUC approved equipment and procedures; authorized or individual researchers will evaluate their work areas on a regular basis in concert with their use of RAM, to ensure that radiation and/or contamination levels are kept as low as is reasonably achievable.

6.4. Special Surveys

The RSO is responsible for performing or causing to be performed by other qualified persons the following special surveys:

- Any lab where RAM will no longer be used must receive a comprehensive "Close-Out" survey, before releasing the area for use by others.
- A follow-up survey will be performed in any lab where a spill has occurred after remediation, to ensure that all removable activity has been thoroughly cleaned, and any fixed activity has been located and measured.

7. PERSONNEL DOSIMETRY

Researchers (faculty or students), who in the course of their work might be exposed to 10% or more of the annual limit of 5,000 mRem/year, will be required to wear a personnel dosimeter. It is believed that no individual at Connecticut College will receive as much as 10% of any of the limits in 10 CFR 20. (See 14.6, Figure 1) However, to ensure researcher confidence, and to maintain a database of exposures, Connecticut College will assign appropriate personnel dosimeters to all researchers authorized to work with mCi quantities of high-energy beta emitters or gamma emitter.

Whole body and finger badges will be purchased from a qualified Company, (e.g. Siemans, Landauer, ICN, etc.), on a monthly basis and distributed/collected by the RSO or his designee. The collected dosimeters/film will be sent back to a qualified Company for analysis and recording. The RSO will review all records of dose received by workers to ensure that no unwarranted exposures have been received, i.e., all doses are "As Low As Reasonably Achievable" (ALARA). **Section 14.6, Figure 2, lists the "Maximum Permissible Doses"** for radiation exposures.

Any report of dose from the vendor will be investigated by the RSO, utilizing **Appendix (G) - "Personnel Exposure Investigation Levels".** As required by NRC regulation, a notification letter will be sent to the affected individual(s), informing them of the exposure.

All personnel dosimetry records will be maintained on file indefinitely, and will be made available for inspection by the NRC upon request.

8. PRENATAL RADIATION EXPOSURE

The College, as a licensee of the NRC is required to instruct all employees who work in a restricted area of the health protection problems associated with radiation exposure. In the case of a female employee, this instruction includes information of possible risks to unborn children.

Every attempt is being made to keep exposures to radiation, as low as reasonably achievable. However, experts have recommended that because of the possible increased risk of childhood leukemia and cancer, the radiation dose to an embryo or fetus as a result of occupational exposure should not exceed 0.5 rem. Since this 0.5 rem is lower than the dose generally permitted to adult workers, women may want to take special precautions to avoid receiving higher exposures.

Occupationally exposed women who are, or may become pregnant, are encouraged to read **Appendix (H) -Regulatory Guide 8.13 – "Instruction Concerning Prenatal Radiation Exposure"**, prepared by the NRC. Additionally, they should discuss this matter with their physician and the Radiation Safety Officer.

Pregnant women who become pregnant are required to submit a “Declaration of Pregnancy” letter to the RSO, with a copy to the Manager of Occupational Health & Wellness (In the Human Resources Office). A sample letter is found in Appendix (H).

9. RADIATION SAFETY TRAINING

Laboratory personnel and students, who will be using RAM in their research, will receive training by the Authorized User, with assistance from the RSO and/or the Director of Environmental Health & Safety. Only persons 18 years or older are allowed to work with RAM.

This training will include:

- Instruction on risks from Occupational Radiation Exposure (See **Appendix (I) – Regulatory Guide 8.29 – “Instruction Concerning Risks from Occupational Radiation Exposure”**)
- Instruction in all applicable license conditions, amendments and regulations
- Instruction on the Connecticut College Radiation Protection Program
- General Radiation Safety Practices
- Emergency Procedures
- Specific procedures for safe use of beta emitters used in research

Radiation Safety Training will be documented on **Appendix (J) - “Radiation Safety Training Record”.** Faculty or staff who have previous training and experience may be exempted from this training by the RUC.

The RSO and/or the Director of EH&S, will review radiation safety practices with researchers during routine survey activities. This “on the job” training is the most effective way to ensure continued safe work practices.

Ancillary personnel (e.g., Campus Safety, Custodial, and other Physical Plant personnel) will also receive training in the topics listed above, as well as job specific procedures and precautions. Refresher training will be given annually to these workers.

10. EMERGENCY PROCEDURES

In view of the complicating factors that may arise in an emergency, it is impossible to establish simple rules to cover all situations of a radiation emergency. Key emergency personnel, properly trained and equipped to cope with radiological emergencies will be established, and names posted in all use areas. However most emergencies will probably be of the following types:

- Explosion in or near RAM use area
- Fire in or near RAM use area

- Overexposure of radiation to personnel
- Injury to personnel involving RAM
- Loss of a radioactive material
- Vehicular accident during transport of RAM

In all of the above examples, the primary concern must always be the protection of personnel from radiation hazards. Confinement of any possible contamination or resultant radiation to the immediate environment of the accident should be a secondary concern.

10.1. Emergency Procedures – General

- Notify all persons in the lab of the incident.
- Instruct everyone not involved with the incident to vacate the area, <u>but to only go as far as the hall outside the lab</u> (unless the situation presents an immediate threat to safety or health, e.g., fire or toxic atmosphere.) This is to prevent the spread of any potential radiological contamination.
- Notify Campus Safety at Ext 2222. Calmly describe the situation. Campus Safety will request assistance from the New London Fire Department if necessary.
- Notify the Radiation Safety Officer and the Director of Environmental Health & Safety. **Emergency contact information is found on the cover page of this document.**
- Any incident notification to the NRC and State Department of Health required by regulation will be made by the RSO and the President of the College within the required time following the incident.

10.2. Fire or Explosion

- Attempt extinguishment of fires with readily available type extinguishers if a radiation hazard is not immediately present.
- Efforts should be made to prevent water or fire fighting chemicals from coming in contact with the radiation source.
- Attempt to control runoff, preventing it from entering drainage systems until it has been monitored.

10.3. RAM Spills/Contamination of Laboratory Personnel

- Remove contaminated clothing or Lab Coat.
- Scan the affected area with a GM survey meter.
- Using soap and a <u>gentle</u> scrubbing motion, wash the contaminated skin under tepid running water. DO NOT scrub vigorously, as it may abrade the skin, allowing radioactivity to enter the body.
- Scan the affected area with a GM survey meter.
- Repeat this process until no further radiation is detected.

10.4. Injuries to Personnel Involving RAM Contamination

- Wash minor wounds immediately under running water while spreading the edges of the wound.
- Personnel with minor wounds will be monitored and decontaminated, if necessary, before leaving the laboratory.
- Persons more seriously injured should not be moved until medical help arrives unless other emergencies exist (e.g., fire, toxic atmosphere).

10.5. Loss of a Radioactive Source (or Sources)

- Notify all workers in the area immediately to stop all work/movement.
- Begin a systematic "wall to wall" monitoring using radiation survey instruments.
- Review previous events with workers that lead up to the discovery.
- Ensure that an "inventory error" has not been made.
- If the source still cannot be found or accounted for, notify the RSO immediately so that proper reporting to the Connecticut Department of Health and NRC can be made.

10.6. Radiation Overexposure

- In the event of a suspected or confirmed overexposure, seek prompt medical assistance. The appropriate medical radiation specialists will be consulted.
- Ensure that the RSO is immediately notified, so that proper reporting to the Connecticut Department of Health and NRC can be made.
- Any overexposure will be investigated by the RSO, utilizing guidelines set forth in **Appendix (G) - "Personnel Exposure Investigation Levels".**
- As required by NRC regulation, a notification letter will be sent to the affected individual(s), informing them of the exposure.
- Below is a chart listing the maximum allowable annual human radiation exposure limits.

Figure 2 - Maximum Permissible Doses

Allowable Occupational Dose/Year*	
Total Effective Dose Equivalent	5 Rem (0.05 Sv)
Deep Dose Equivalent + Committed Dose Equivalent to any Individual Organ	50 Rem (0.50 Sv)
Eye Dose Equivalent	15 Rem (0.15 Sv)
Shallow Dose Equivalent to Skin or any Extremities	50 Rem (0.50 Sv)
Dose to Embryo/Fetus	0.5 Rem from Declared Pregnancy to Term

*The above dose limits were established by the NRC in title 10 of the code of Federal Regulations, part 20 (10 CFR 20).

10.7. Motor Vehicle Accident During Transport of RAM

- Stay with vehicle and check all RAM packages for damage.
- Maintain surveillance of all RAM packages until assistance arrives if unable to move the vehicle.
- If a package is damaged, visually inspect inside the package to ensure sources are still properly contained/shielded.
- If necessary, wait for police assistance; send for RSO as soon as possible; use survey meter to check for radiation leakage.
- If necessary repackage the RAM, place it in another vehicle and return to the College.

11. DECONTAMINATION PROCEDURES

Appropriate gloves and protective clothing must be worn during all decontamination procedures. Contact the RSO and/or the Director of EH&S for any decontamination process that is unsuccessful.

11.1. Non-Porous Surfaces

- **Step 1:** Using absorbent towels (cloth or paper), absorb the liquid radioactive material.
- **Step 2:** Rub the contaminated surface for 1 minute with absorbent toweling, moistened with a detergent solution, then wipe dry with toweling.
- **Step 3:** Monitor the surface with the appropriate instrument (GM meter or LSC).
- **Step 4:** Spray the contaminated surface with a complexing agent[2], keeping surface wet for 20 to 30 minutes. Wipe the surface with wet toweling, and then dry toweling.
- **Step 5:** Repeat monitoring.
- Repeat this process until surface contamination is reduced to background level.

11.2. Non-Porous Surfaces Containing Porous Deposits

(Examples of porous deposits include rusted metals, or calcareous growths.)

- **Step 1:** Using absorbent towels (cloth or paper), absorb the liquid radioactive material.
- **Step 2:** Apply an acid solution[3] to the contaminated surfaces for 1 hour. If item is moveable and small enough, immerse the item in the solution.

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[2] Complexing agent - a solution should contain 3%, by weight, of the complexing agent, such as sodium hexamatophosate, sodium ethylene-diamine-tetroacetic acid (NaEDTA), oxalates, carbonates or citrates (may be used on overhead vertical surfaces by adding foam -sodium carbonate or aluminum sulfate). A good commercially available product that has the above contents is **"Dow Bathroom Cleaner"**.

- **Step 3:** Flush the contaminated surface with water, and scrub with detergent solution.
- **Step 4:** Monitor the contaminated area with the appropriate instrument (GM meter or LSC).
- Repeat this process until surface contamination is reduced to background level.

12. OFF-CAMPUS TRANSPORT OF RAM

All RAM to be shipped from the College (For example, sending materials to another institution where a colleague may be engaged in collaborative research) must be properly packaged, labeled, marked, signed, etc., according to applicable U.S. Department of Transportation (DOT) and NRC regulations.

All packaging and shipping will be performed under the supervision of the RSO and the Director of EH&S, who are qualified by training and meet the requirement of 49 CFR 172 Subpart H. This includes obtaining a copy of the receiving institution's NRC license, to verify their authorization to possess the isotope and quantity that will be transferred.

13. MANAGEMENT OF RAM WASTE

Any waste material containing or contaminated by radioactive material is considered a radioactive waste, and must be disposed of appropriately. Procedures for accumulating and preparing radioactive waste for disposal depend on the form of the waste (absorbed liquids, dry solids, etc.), and the isotope group described below.

13.1. Waste Group Descriptions

Radioactive wastes are segregated into four groups based on isotope half-life. When accumulating radioactive wastes, avoid combining isotopes from different groups in the same waste container.

Short-lived radioactive wastes include the following three groups:

> **Group I** radionuclides have a half-life less than or equal to 15 days, such as I-131, In-111, P-32, and Y-90.
>
> **Group II** radionuclides have a half-life equal to or less than 30 days but greater than 15 days, including Cr-51 and P-33.

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[3] A typical acid solution consists of 1/10 gallon (378.54 ml) of hydrochloric acid, and 2/10 lb (90.719 g) of sodium acetate in 1 gallon of water. Corrosive action can be moderated by the addition of corrosion inhibitors to the solution. Good ventilation is a must because of toxicity and explosive gases. PPE (Splash-proof goggles, lab coat and gloves) must be worn when mixing and using corrosive solutions.

Group III radionuclides have a half-life less than 90 days but greater than 30 days. Isotopes include I-125 and S-35.

Long-lived radioactive wastes are in Group IV:

Group IV radionuclides have a half-life equal to or greater than 90 days. Isotopes in this group include H-3, C-14 and Ca-45.

Proper disposal of RAM waste is essential to meeting NRC regulations, and minimizing costs. Following is a list of the types of waste routinely generated at Connecticut College, with procedures for handling them. Contact the RSO or Director of EH&S for guidance for disposal of any other RAM waste your research may generate.

13.2. Solid RAM Waste (Lab Disposables)

- Solid RAM waste should be placed into a labeled laboratory waste pail with opaque plastic bag liners. There must be a separate waste pail for each isotope being used in the lab. When the container/bag is full, lab personnel must label each closed bag with a tag provided by EH&S, containing he following information:

    - Authorized user name
    - Date isotope purchased
    - Isotope(s)
    - Approximate total activity of each isotope in the bag

- The Director of EH&S will pick-up and transport your waste upon request, and bring it to the RAM Waste Storage Facility ("The Morgue") in New London Hall, where it will be stored in double opaque plastic bags in plastic trash containers or drums. Separate drums will be used for isotopes with half-lives of ≤ 90 days. As noted above, long half-life isotopes can be comingled.
- The Director of EH&S will log the waste information from the bag tag on the "Waste Container Inventory Card", taped to each container or drum lid.
- Waste containing isotopes with half-lives of ≤ 90 days will be held for decay at least for 10 half lives. The appropriate future date following 10 half-lives will be calculated by the Director of EH&S and entered on the Waste Container Inventory Card.
- At 10 half-lives the Director of EH&S will monitor the waste with a GM survey meter. If the readings at any location on the waste bag are greater than twice background, the waste will be held for more decay. If readings are less than twice background, the waste will be disposed of as ordinary trash.
- Any needles, pipettes, etc., must be excluded from dry solid waste and packaged in a sharps container.

13.3. Liquid RAM Waste

Aqueous (non-hazardous) liquids containing RAM should be disposed of down the lab sink with the water running slowly (to keep the sink drain flushed clean of residual RAM) for at least 5 minutes after emptying the RAM waste solution. No records of these disposals are required to be kept by lab personnel. Compliance with NRC release limits is monitored on a college-wide level, using RAM inventory and sewer release volume. **Appendix (K) – "Allowable Sanitary Sewer Release Limits of RAM",** is a worksheet for calculating sewer releases

Non-aqueous (hazardous) chemical liquids containing short half-life (≤ 90 days) RAM must be held until the RAM has decayed for 10 half-lives. Because of the extended storage period, the waste container must be of high integrity to ensure that leaking does not occur during the decay period, which could last for 900 days. The Director of EH&S will bring a secondary container to use for transport to the Morgue, and subsequent storage. At the end of the decay period, the waste will be properly monitored to ensure no activity remains before offering it to a chemical waste vendor.

13.4. LSC Vials Containing Liquid Scintillation Cocktail

LSC vials containing (hazardous) scintillation cocktail (e.g., toluene, etc.) Wastes that contain hazardous constituents <u>and</u> radioactive materials are considered "mixed" wastes As discussed in 13.5, below, mixed wastes are difficult and expensive to dispose (unless it is an isotope that can be held for decay). Whenever possible, "non-hazardous" scintillation cocktails should be used.

LSC vials containing (non-hazardous) scintillation cocktail should be placed in plastic bags inside a labeled waste pail in the lab, with no more than 200 vials per bag. Again, all isotopes must be segregated - only one isotope per bag. The only exception is long half-life isotopes (e.g., H-3, C-14 or CL-36), which may be placed in the same bag. Each bag must be labeled with a securely affixed tag with the following information:

- Print the word <u>"Vials"</u> on the tag/label
- Authorized user name
- Date isotope purchased
- Isotope(s)
- Approximate total activity of each isotope in the bag
- LSC cocktail name

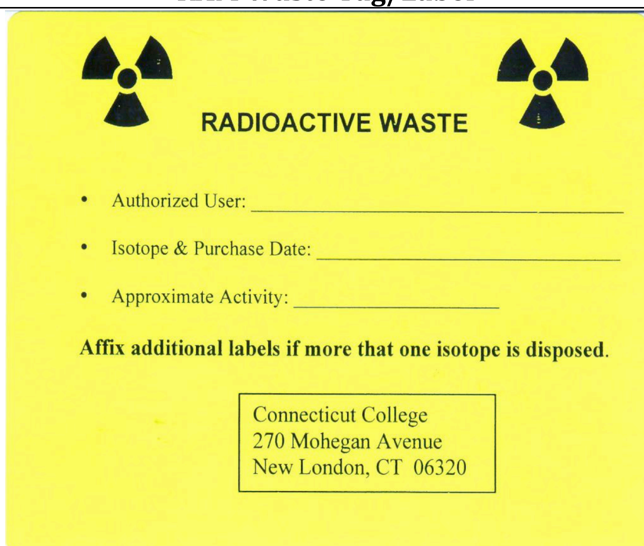
The Director of EH&S will pick-up properly labeled full LSC vial bags upon request, and transport them to the morgue.

13.5. Mixed Waste

Non-aqueous/hazardous chemical liquid wastes, containing long half-life RAM are known as "mixed" wastes. It is extremely expensive and difficult to dispose of mixed wastes**. Any research that will generate mixed waste must be discussed by the RUC beforehand.**

Hazardous liquid waste containers brought to the morgue, either for decay, or for storage pending disposal, must be labeled with ***both*** **radiological and Hazardous Waste labels.** (See Figure 3)

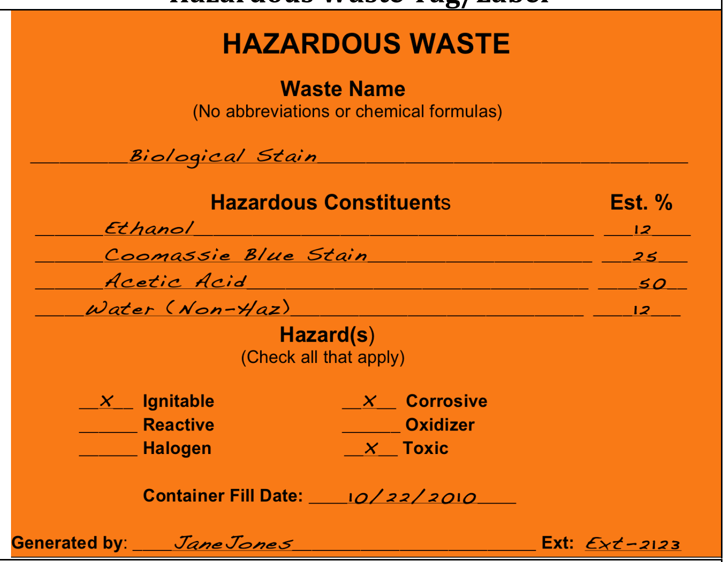
Figure 3 - Radiological and Hazardous Waste Labels

<table>
<tr><th>RAM Waste Tag/Label</th><th>Hazardous Waste Tag/Label</th></tr>
<tr><td>


RADIOACTIVE WASTE

- Authorized User: ____
- Isotope & Purchase Date: ____
- Approximate Activity: ____

Affix additional labels if more that one isotope is disposed.

Connecticut College
270 Mohegan Avenue
New London, CT 06320
</td><td>


HAZARDOUS WASTE

Waste Name
(No abbreviations or chemical formulas)

Biological Stain

Hazardous Constituents	Est. %
Ethanol	12
Coomassie Blue Stain	25
Acetic Acid	50
Water (Non-Haz)	12

Hazard(s)
(Check all that apply)

X **Ignitable**   X **Corrosive**
___ **Reactive**   ___ **Oxidizer**
___ **Halogen**   X **Toxic**

Container Fill Date: 10/22/2010

Generated by: Jane Jones **Ext:** Ext-2123
</td></tr>
<tr><td>

- Authorized user:
- Isotope:
- Isotope purchase date:
- Approx. total activity of each isotope in the waste container or bag:

</td><td>

- Contents: (No chemical formulae or abbreviations)
- Hazard(s):
- Date container closed:
- Generator Info:

</td></tr>
</table>

Appendix (A) – RADIOLOGICAL OCCURRENCE REPORT

☐ **Observation** ☐ **Deficiency** ☐ **Violation**	Report #:
To: (Responsible P.I.):	Date:
From: (Observer):	Bldg./Room:

PART I:
Description of Radiological Occurrence:

Immediate Corrective Action Taken:

Signature: ______________________ Date: ______________
(RSO, Dir, EH&S or Consultant)

Long Term Corrective Action (If required):

PART II:
P.I. Response: *(Complete this section if "Violation" is checked above, and return to the RSO within 3 working days notification. No response necessary for OBSERVATION or DEFICIENCY.)*

Signature: ______________________ Date: ______________
Principal Investigator

PART III:
RUC Disposition:

Appendix (B) – RADIOISOTOPE USE AUTHORIZATION/RENEWAL FORM

PART A

INSTRUCTIONS: Please complete all pertinent items, and forward to the Director of EH&S.

1. ______________________________ ______________________ ______________
   Name of Applicant Department Telephone

2. ____
   Building & laboratory room number(s) where radioactive materials will be used.

3. Are you a previously authorized user? YES _____ NO _____. If NO, complete Item 6 and Part B. If YES, respond to items only as appropriate.

4. Do you plan to use additional isotopes? YES _____ NO _____. If YES, give details in Item 6 and complete Part B.

5. Do you plan to increase your authorized amounts? YES _____ NO _____. If YES, give details in Item 6.

6. Radioisotopes for which authorization is requested. (Attach a supplementary sheet if more space is needed.)

Element/Symbol	Mass Number	Total mCi	Half-life	Chemical/Physical form*

* If a sealed source, state number of manufacturer, model number and amount.

7. If you are a previously authorized user, are there any ***changes*** in your experimental protocols that will affect safety (i.e., larger quantities being used, volatilized RAM generation, increased risk of contamination of personnel, lab and/or equipment, etc.)? YES _____ NO _____. If YES, complete Part B.

8. Certification: "All information contained in this application is correct to the best of my knowledge. I have read and understood "Radioisotope Use Policy and Program" and NRC regulations 10 CFR 19 and 20."

______________________________________ ______________
Signature of Applicant Date

9. APPROVAL of Radiation Use Committee, subject to any conditions listed below.

______________________________________ ______________
Signature of Chairman, RUC Date

RUC Comments:

APPLICATION FOR AUTHORIZATION TO USE RADIOISOTOPES

PART B

10. Describe the purpose for which each radioactive material will be used, in sufficient detail to permit evaluation of potential hazards. If necessary, contact the RSO for assistance in completing this part.

11. Describe laboratory facilities, remote handling equipment, storage containers, shielding, fume hoods, etc., and show how they will contain/control RAM, to protect personnel from exposure. If necessary, contact the RSO for assistance in completing this part.

12. Describe radiation protection procedures, including control measures, and waste disposal procedures. Reference all applicable safety procedures included in the College Radiation Safety Manual throughout this response. The College policy requires all authorized users to read, understand, and adhere to these safety procedures. Use an extra sheet if more space is needed.

RUC Comments:

APPLICATION FOR AUTHORIZATION TO USE RADIOISOTOPES

PART C

Record your experience and training in detail, listing each training period separately. State where training was obtained, its duration, and whether it was formal, or on-the-job; give inclusive dates. If Part B has been completed on a previous application, it may be omitted, unless pertinent new information is available.

13. Type of Training

a. Principles and practices of protection:

b. Radioactivity measurements and monitoring techniques; instrumentation:

c. Mathematics and calculations, basic to measurement of radioactivity:

d. Biological effects of radiation:

e. Pertinent other training, include college and university courses, degrees obtained, with dates and subjects:

14. Types of Experience:

List each type of experience separately. Append a second sheet of more room is needed. List radioactive materials separately or in logical groups, showing maximum amounts used, institution where experience was gained, duration of experience, and type of use:

____ ____________________

Signature of Applicant Date

The RUC will approve applications for authorized use of RAM if the applicant meets qualifications specified by the NRC in 10 CFR 33.15(b):

- Possess a college degree at the bachelor level, or have equivalent training and experience in the physical or biological sciences or in engineering; and
- Have at least 40 hours of training and experience in the safe handling of radioactive materials, and in the characteristics of ionizing radiation, units of radiation dose and quantities, radiation detection instrumentation, and biological hazards of exposure to radiation appropriate to the type and forms of byproduct material requested to be used.

Appendix (C) – RAM RECEIPT/SHIPMENT RECORD

PART I – RECEIPT/SHIPMENT INFORMATION							
☐ **Receipt** ☐ **Transfer** ☐ **Other:** ______________						**Date:**	
Isotope:		**Activity:**		**Form:**		**Cat #:**	
User:				**Bldg./Room:**			
P.O.#:		**P.O. Date:**		**Manufacturer:**			
Container Type:				**DOT Index:**			

PART II – DANGEROUS GOODS IDENTIFICATION

Proper Shipping Name:	Class or Division	UN#	Quantity & Type of Packing	Packing Instructions

"I hereby declare that the contents of this consignment are fully and accurately described above by proper shipping name, and are classified, packed, marked and labeled, and are in all respects in the proper condition for transport by ground or air, according to the applicable international and National Government Regulations."

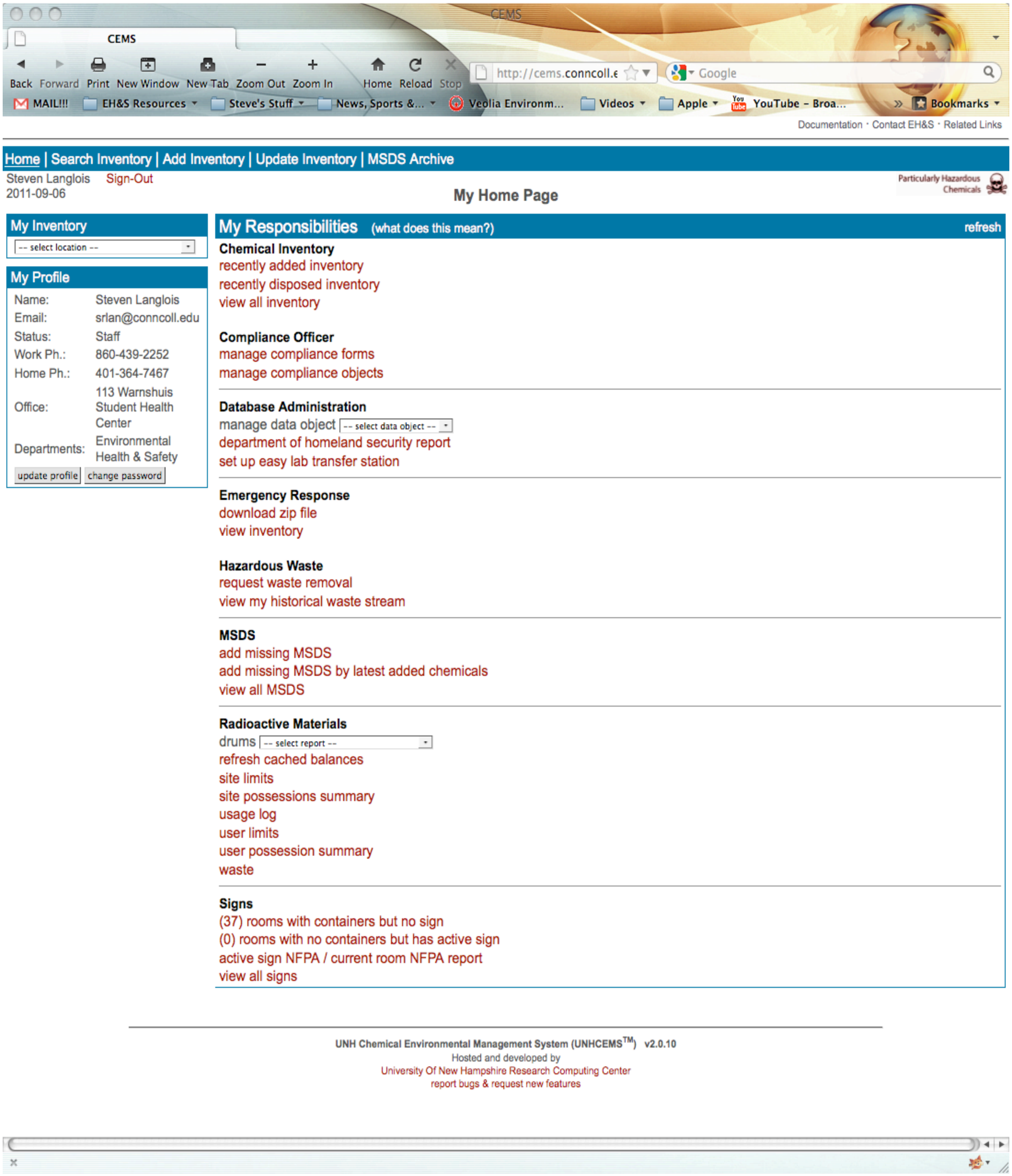
PART III – RADIATION MEASUREMENTS

At 1 Meter from Surface:		**At Surface:**	
Instrument Used:		**Background:**	
Surface Wipe Test:		**Background:**	
Instrument Used:		**Background:**	

Comments:

Signed: ______________________________ Date: ____________________

Appendix (D) – CEMS – RADIOACTIVE MATERIAL INVENTORY SYSTEM



Appendix (E) – RAM INVENTORY LOG

User: ____

P.O. Date	P.P. Number	Isotope	Activity (mCi)	Form	Cat. Number	R/T/D

Appendix (F) – RADIATION SURVEY REPORT

☐ Initial	☐ Monthly	☐ Follow Up	☐ Other ___________________

Surveyor:		Date:	
Responsible P.I.:		Dept:	
Building:		Room #:	
Type of Facility:		Isotopes Present:	
Individuals Present:			

SURVEY DATA

Building/Room: ______________________

Insert Room Drawing

Survey Results

Survey/Wipe Location	GM Meter	LSC Wipes		
		3H	C14	P32
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
LSC Standards				
Blank				

Comments:

Compliance Checklist

Currently using RAM?	YES ____ NO ____	Volatile RAM being used?	YES ____ NO ____
Sink disposal of RAM?	YES ____ NO ____	Drain(s) leaking?	YES ____ NO ____
Floor sealed?	YES ____ NO ____	Good housekeeping?	YES ____ NO ____
Lab occupied or locked?	YES ____ NO ____	RAM secured?	YES ____ NO ____
GM meter present?	YES ____ NO ____	Lab coats being worn?	YES ____ NO ____
10 CFR 20 available?	YES ____ NO ____	NRC Form 3 posted?	YES ____ NO ____
“Caution – RAM” sign?	YES ____ NO ____	RAM work areas taped?	YES ____ NO ____
Other postings?	YES ____ NO ____	Waste container(s) full?	YES ____ NO ____
Film badges worn?	YES ____ NO ____	Eating/drinking in lab?	YES ____ NO ____

Appendix (G) – PERSONNEL EXPOSURE INVESTIGATION LEVELS

Connecticut College has established the following investigational levels, as recommended by the NRC :

		Level I	Level II
1.	Deep Dose Equivalent	125 mrem/qtr	375 mrem/qtr. or 125 mrem/mo.
2.	Eye Dose Equivalent	375 mrem/qtr. or 125 mrem/mo.	1125 mrem/qtr. or 375 mrem/mo.
3.	Shallow Dose Equivalent to Skin or Extremities	1250 mrem/qtr or 417 mrem/qtr	3750 mrem/qtr. or 1250 mrem/mo.

The RSO or Director of EH&S will review all dosimetry reports from commercial vendor immediately upon receipt. The following actions will be taken in those cases where exposure levels at least meet or exceed the investigational levels listed above:

a. Except when deemed appropriate by the RSO, no further action will be taken in those cases where an individual's exposure is less than Level I**.**

b. The RSO will review the exposure of each individual whose monthly exposures equal or exceeds level I. The RSO will consider each such exposure in comparison with those of others performing similar tasks, as an index of ALARA program quality. The RSO will report the results of his reviews at the first Radiation Use Committee (RUC) meeting following the exposure period when the exposure was recorded. If the exposure does not equal or exceed Investigational Level II, no action specifically related to the exposure is required unless deemed appropriate by the Radiation Use Committee. This review will be recorded in the Committee Minutes.

c. The RSO will investigate in a timely manner, the cause(s) of all personnel exposures equaling or exceeding Investigational Level II, and if warranted, take action. A report of the investigation, actions taken (if any), and a copy of the individual's incident report form will be presented to the RUC upon completion of the investigation. The RUC will, at that time, decide on the appropriate corrective action. The details of the incident report and any response will be recorded in the minutes of the RUC meeting.

d. In case were a worker's or a group of workers' exposures need to exceed Investigational Level I, a new higher Investigation Level II may be established on the basis that is consistent with good ALARA practices for that individual or group. Justification for a new investigational Level II will be documented.

e. The RUC will review the justification for, and will approve all revisions of Investigational Level II. In such cases, when the exposure equals or exceeds the newly established Investigational Level II, those actions listed in paragraph c above will be followed. The details of the investigation will be made available to NRC and State inspectors for review at the time of the next inspection.

Appendix (H) – REGULATORY GUIDE 8.13 – INSTRUCTION CONCERNING PRENATAL RADIATION EXPOSURE

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

Regulatory Guide 8.13 - Instruction Concerning Prenatal Radiation Exposure

(Draft was issued as DG-8014)

Revision 3
June 1999

Availability Notice

A. 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 Section 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.

B. 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.

C. REGULATORY POSITION

1. 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.

2. 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.

3. **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).

4. **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.

5. **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.

D. 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

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

2. 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

1. 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.

2. 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.

3. 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.

4. 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.

5. 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.

6. 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.

7. 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.

8. 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.

9. 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.

10. 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.

11. 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.

12. 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.

13. 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.

14. 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.

15. 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.

16. If I have declared my pregnancy in writing, can I revoke my declaration of pregnancy even if I 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.

17. 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.

18. 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

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

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.

USNRC, "Instruction Concerning Risks from Occupational Radiation Exposure," Regulatory Guide 8.29, Revision 1, February 1996.[(1)] (Electronically available at http://www.nrc.gov/reading-rm/doc-collections/reg-guides/)

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

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National Council on Radiation Protection and Measurements, *Considerations Regarding the Unintended Radiation Exposure of the Embryo, Fetus, or Nursing Child*, NCRP Commentary No. 9, Bethesda, MD, 1994.
National Council on Radiation Protection and Measurements, *Risk Estimates for Radiation Protection*, NCRP Report No. 115, Bethesda, MD, 1993.
National Radiological Protection Board, *Advice on Exposure to Ionising Radiation During Pregnancy*, National Radiological Protection Board, Chilton, Didcot, UK, 1998.
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.[2]

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).

1. Single 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.

2. Copies 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.

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Appendix (I) – REGULATORY GUIDE 8.29 – INSTRUCTION CONCERNING RISKS FROM OCCUPATIONAL RADIATION EXPOSURE

U.S. NUCLEAR REGULATORY COMMISSION

Revision 1
February 1996

REGULATORY GUIDE

OFFICE OF NUCLEAR REGULATORY RESEARCH

REGULATORY GUIDE 8.29

(Draft was issued as DG-8012)

INSTRUCTION CONCERNING RISKS FROM OCCUPATIONAL RADIATION EXPOSURE

A. 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 became 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.

B. 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, 4×10^{-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 to 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 rems[1] (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 exposure 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 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.

C. 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.

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

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*, Report of the Committee on the Biological Effects of Ionizing Radiation (BEIR V), National Academy Press, Washington, DC, 1990.

2. United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), *Sources and Effects of Ionizing Radiation*, United Nations, New York, 1993.

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.

1. 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.

2. 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 diarrhea,[1] 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 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.

[1]These 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.

3. 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 example, 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.

4. 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.

5. 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 resuspended 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.

6. 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 between 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.

7. 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.

8. 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 1 rem (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 1 rem (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 1 in 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 exposure to radiation as low as is reasonably achievable (ALARA) to avoid unnecessary risk.

9. 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. Because the scientific evidence does not conclusively demonstrate whether 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.

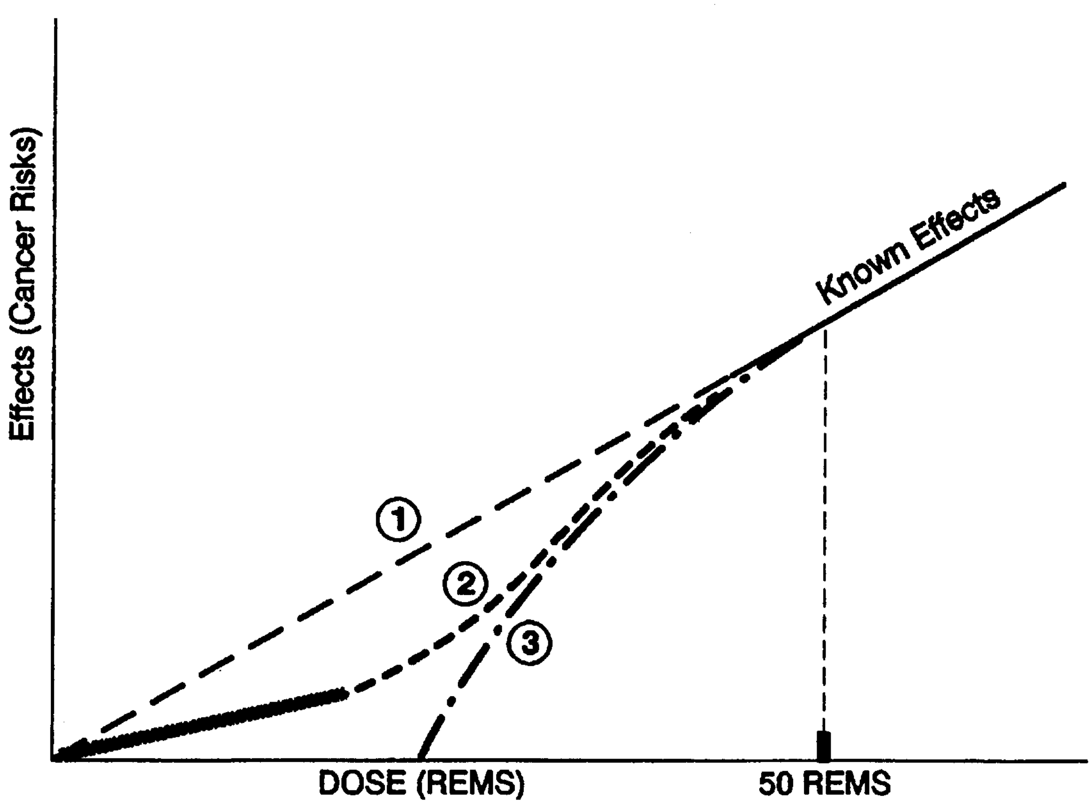

Figure 1. Some Proposed Models for How the Effects of Radiation Vary With Doses at Low Levels

10. How 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 age 18 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.

11. 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

Table 1 Estimated Loss of Life Expectancy from Health Risks[a]

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	

[a]Adapted from Reference 10.

Table 2 Estimated Loss of Life Expectancy from Industrial Accidents[a]

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

[a]Adapted from Reference 10.

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."

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 withdrawn 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.

12. 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.

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 the NRC's occupational limits have any effect on the ability to function sexually.

13. 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 (DDE) from external exposure to the whole body and the committed effective dose equivalent (CEDE) from intakes of radioactive material.
- 50 rems (0.5 Sv) for the total organ dose equivalent (TODE), which is the sum of the DDE from external exposure to the whole body and the committed dose equivalent (CDE) from intakes of radioactive material to any individual organ or tissue, 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 0.5 rem (5 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.

14. 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.

15. 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).

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		0.05
Consumer Products[b]		9
Medical		
Diagnostic X-rays	39	
Nuclear Medicine	14	
Total		53
Total		about 360 mrems/year

[a]Adapted from Table 8.1, NCRP 93 (Ref. 11).

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

16. 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 1 rem (10 mSv); 98.7 percent received less than 2 rems (20 mSv); and the highest reported dose was for two individuals who each received 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 1993[a]

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

[a]From Table 3.1 in NUREG-0713 (Ref. 9).

17. 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 inform 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 radiation 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 to be 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.

19. 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.")

20. 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-benefit 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 provides a safety margin designed to help the licensee avoid doses to workers in excess of the limit.

21. 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 benefits 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.

22. 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).

23. 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.

24. 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. Because of the practice of maintaining radiation exposures ALARA (as low as is reasonably achievable), the average radiation dose to occupationally exposed persons 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.

25. 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 nonradiation 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.

26. 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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REGULATORY ANALYSIS

A separate regulatory analysis was not prepared for this Revision 1 to Regulatory Guide 8.29. A value/impact statement, which evaluated essentially the same subjects as are discussed in a regulatory analysis, accompanied Regulatory Guide 8.29 when it was issued in July 1981.

This Revision 1 to Regulatory Guide 8.29 is needed to conform with the Revised 10 CFR Part 20, "Standards for Protection Against Radiation," as published May 21, 1991 (56 FR 23360). The regulatory analysis prepared for 10 CFR Part 20 provides the regulatory basis for this Revision 1 of Regulatory Guide 8.29, and it 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 in the NRC's Public Document Room at 2120 L Street NW., Washington, DC 20555-0001.

Appendix (J) – RADIATION SAFETY PERSONNEL TRAINING RECORD

Researcher/Student Name: ____ DOB: ____________________
(Must be 18 years or older)

"I have received training in the use of: _________________________________
(Isotope or Radiation Emitting Device)

This training included the following topics:

- Risks from Occupational Radiation Exposure
- Procedures necessary to minimize exposure
- Purpose and function of protective equipment, monitoring equipment, and personnel dosimeters
- The Connecticut College Radiation Protection Program
- License conditions and State regulations governing the use of RAM
- General radiation safety practices
- Emergency response procedures

"I understand the health risks associated with radiation exposure and the precautions necessary to minimize my exposure and/or uptake. I accept the responsibility of performing my assignments in accordance with the procedures of the Connecticut College Radiation Protection Program and those taught to me by authorized faculty members."

Signature of Student: ____ Date: ____________________

Signature of Instructor: ____ Date: ____________________

Appendix (K) – ALLOWABLE SANITARY SEWER RELEASE LIMITS OF RAM
(Soluble form only)

Date: ______________________________

Isotope	**Annual Limit**	**Max. Monthly Avg. Release Concentration (uCi/ml)**	**Calculated Max. Monthly Release* (uCi/mo.)**	**RAM Purchased this Month (uCi/mo.)**	**Release Concentration this Month (uCi/ml)**
P-32	1 Ci total	$9x10^{-5}$	6.89×10^{5}		
S-35		$1x10^{-3}$	7.66×10^{6}		
Ca-45		$2x10^{-4}$	1.53×10^{6}		
I-125		$2x10^{-5}$	1.53×10^{5}		
H-3	5 Ci	1×10^{-2}	7.66×10^{7}		
C-14	1 Ci	3×10^{-4}	2.29×10^{6}		

*If only one isotope is released. If more than one isotope is released, the formula for calculating the allowed monthly release is:

$$R = \frac{\text{Actual conc.}}{9x10^{-5}} + \frac{\text{Actual conc.}}{8x10^{-4}} + \frac{\text{Actual conc.}}{1x10^{-3}} + \frac{\text{Actual conc.}}{2x10^{-4}} + \frac{\text{Actual conc.}}{2x10^{-5}} + \frac{\text{Actual conc.}}{1x10^{-2}} + \frac{\text{Actual conc.}}{3x10^{-4}} \leq 1$$

The above calculations are based on the average monthly release of water to the sanitary sewer by the College of 2.02 x 106 gal./mo., or 7.66 x 109 ml/mo.

Our RAM inventory (which is reviewed upon every purchase) shows that our allowed monthly sewer discharge is far less than the allowable limit, and is in compliance with 10 CFR 20.2003.

Basis: Connecticut College purchased 4.05 x 106 ft3 (30,365,867 gallons) of water in FY 2010. It is assumed that 80% (2.42 x 107 gallons/year) was discharged to the sanitary sewer.

Appendix (L) – METHODS AND FREQUENCY FOR CONDUCTING SURVEYS

METHODS AND FREQUENCY FOR CONDUCTING SURVEYS

A. Classification of Laboratory Areas

Since the premises of licensees vary widely with regard to maximum activity, physical and chemical form of radionuclides, and the various procedures involving byproduct material, it is proper to attempt some classification. The purpose of classification is to determine how frequently the laboratory should be surveyed. The method recommended, which is taken from Report of Committee V, ICRP, 1965, designates three levels **(LOW, MEDIUM, HIGH)** of survey frequency based on radionuclide, activity and use. On the attached Survey Frequency Table, multiply the activity range under LOW, MEDIUM and HIGH survey frequency by the appropriate modifying factor.

Examples:

1. Laboratories or areas using in vitro kits only (I-125, I-131, H-3, C-14, etc.) would probably be classified as LOW level areas.

   Open labelling techniques (modifying factor of 0.1) using more than 100 uCi of I-131 would change the classification to MEDIUM level.

2. Nuclear Medicine imaging areas where Tc-99m is injected and patients imaged would be classified as LOW or MEDIUM level depending on radionuclides and amounts used.

3. The room of an iodine therapy patient would be classified as MEDIUM or HIGH depending on radionuclide and amount used.

4. Areas used for storage of active solutions, preparation of radiopharmaceuticals from reagent kits, elution of Mo-99/Tc-99m generators, preparation of individual doses should generally be considered as MEDIUM level areas on the basis of both activity and handling.

B. **Frequency of Survey**

Low Level Areas............Not less than once per month

Medium Level Areas.........Not less than once per week

High Level Areas...........Not less than once per normal working day

C. **Method of Survey**

Routine surveys should be carried out in two parts to determine both **Radiation Levels** and **Removable Contamination Levels.**

1. Radiation Levels

   Monitoring area with a radiation survey meter sufficiently sensitive to detect 0.1 mR/h. The results of this survey should be recorded on a standard form which should show:

   a. Location, date and type of equipment used
   b. Identification of person conducting the survey
   c. Drawing of area surveyed, identifying relevant features such as active storage areas, active waste areas, etc.
   d. Measured exposure rates, keyed to location on drawing (point out rates that require corrective action).
   e. Corrective action taken in the case of excessive exposure rates, reduced exposure rates after corrective action, and any appropriate comments.

2. Contamination Levels

   A series of wipe tests should be taken in all areas where activity is handled in unsealed form. The location of wipe tests should be indicated on the above mentioned survey form and should be chosen for maximum probability of contamination, e.g. areas where individual doses are drawn up, incoming packages received, frequent pipetting carried out.

   Floors, particularly adjacent to doorways, lead syringe shields, and door and drawer handles should also be wipe tested frequently. Care should be taken that cross contamination does not occur.

   An end window GM or gas flow proportional counter normally may be used for assaying beta emitters at or above C-14 energies; low energy beta emitters will require liquid scintillation counting.

A gamma scintillation counter (example: NaI well counter), should be used for pure gamma emitters. Make sure that the analyzer threshold is set below the lowest gamma energy used in the lab (usually I-125).

Record a background count of 5 to 10 minutes using the same counting conditions used with the wipes.

In the case of wipes contaminated with gamma emitters, the radionuclide can be identified from successive counts with different analyzer settings if the settings have been calibrated with known energy standards.

D. Acceptable Limits

1. Radiation Limits (Whole Body Only)

   a. RAM Use Area:

      Personnel must not receive > 2mR in any one hour, or > 100mR in seven consecutive days, or > 500mR in any one year. Radiation levels in areas accessible to patients or visitors should be restricted so that total patient or visitor exposure during the patient's hospital stay is ≤ 100 mR.

   b. Radiation Controlled Area:

      If an area is controlled for purposes of radiation protection, then exposure rate limits do not apply, but total exposure of patients and associated visitors should not exceed 100mRem per admission and must not exceed 200mRem per admission even under unusual circumstances.

      An employee's total exposure must be ≤ 1.25Rem/13 weeks (there are certain conditions where up to 3Rem/13 weeks is allowed, but this exposure level cannot be continued routinely). On a basis of **40 hour/week of exposure, the maximum exposure rate would have to be ≤ 2.5mR/h.** In practice, the radiation levels should be kept as low as is practicable and always below applicable limits.

2. Contamination Limits

   An individual wipe test should routinely cover approximately 100 - 150 cm^2. Ideally, any contamination more than a few DPM above background should be cleaned up; however, a more usual level for ß-γ at which cleanup is initiated is about 200 DPM. **At approximately 1000 DPM a Contamination Zone should be established until the contamination is removed.**

Contamination levels may also be estimated with a survey meter. As a rough rule of thumb, establish a Contamination Zone if readings are > 1000 CPM for Groups III and IV radionuclides when measured with a thin window GM meter. Of course, this particular instrument will not detect low energy beta emitters such as tritium.

Note:

a. Patients administered radioactive material for diagnostic or therapeutic procedures are excluded from these limits.

b. Refer to 10 CFR 20 for additional details on acceptable limits.

INFORMATION FOR CLASSIFYING LABORATORIES*
Classification of Laboratories

Radionuclide Group**	Low (monthly)	Medium (weekly)	High (daily)
1	< 10 uCi	10 uCi to 1 mCi	> 1 mCi
2	< 1 mCi	1 mCi to 100 mCi	> 100 mCi
3	< 100 mCi	100 mCi to 10 Ci	> 10 Ci
4	< 10 Ci	10 Ci to 1000 Ci	> 1000 Ci

Survey Frequency Category

Proportional fractions are to be used for more than one isotope.

Modifying Factors	Factors
Simple storage	x 100
Very simple wet operations (e.g. preparation of all liquids of stock solutions)	x 10
Normal chemical operations (e.g. analysis, simple chemical preparations)	x 1
Complex wet operations (e.g. multiple operations, or operations with complex glass apparatus)	x 0.1
Simple dry operations (e.g. manipulation of powders) and work with volatile radioactive compounds	x 0.1
Exposure of non-occupational persons	x 0.1
Dry and dusty operation (e.g. grinding)	x 0.01

The object is to determine how often to survey the laboratory. To do this, **multiply** the activity range under LOW, MEDIUM, and HIGH survey frequency by the appropriate Modifying Factor to construct a new set of mCi ranges for LOW, MEDIUM, and HIGH survey frequency.

EXAMPLE: A lab in which 10 mCi of Group II radionuclide is used in normal chemical operations should be surveyed on a MEDIUM frequency. However, if only simple storage is done, then a LOW frequency is adequate (<1 mCi x 100 = < 100 mCi new LOW range). But if a dry grinding operation is done, a HIGH frequency is required (>100 mCi x 0.01 = > 1 mCi new HIGH range).

* Patterned after the Recommendation of theInternational Commission on Radiological Protection-Report of Committee V; Pergamon Press, New York, N.Y. (1965).

** See Table 1

TABLE 1

CLASSIFICATION OF ISOTOPES ACCORDING TO RELATIVE RADIOTOXICITY PER UNIT ACTIVITY

Group 1++

Pb-210	Po-210	Ra-223	Ra-226	Ra-228	Ac-227	Th-227	Th-228	Th-230
Pa-231	U-230	U-232	U-233	U-234	Np-237	Pu-238	Pu-239	Pu-240
Pu-241	Pu-242	Am-241	Am-243	Cm-242	Cm-234	Cm-244	Cm-245	Cm-246
Cf-249	Cf-250	Cf-252						

Group 2++

Na-22	Cl-36	Ca-45	Sc-46	Mn-54	Co-56	Co-60	Sr-89	Sr-90
Y-91	Zr-95	Ru-105	Ag-110m	Cd-115m	In-114m	Sb-124	Sb-125	Te-127m
Tc-129m	I-124	I-126	I-131	I-133	Cs-134	Cs-137	Ba-140	Ce-144
Eu-152(13y)		Eu-154	Tb-160	Tm-170	Hf-181	Ta-182	Ir-192	Tl-204
Bi-207	Bi-210	At-211	Pb-212	Ra-224	Ac-228	Pa-230	Th-234	U-236
Bk-249								

Group 3++

Be-7	C-14	F-18	Na-24	Cl-38	Si-31	P-32	S-35	A-41
K-42	K-43	Ca-47	Sc-47	Sc-48	V-48	Cr-51	Mn-52	Mn-56
Fe-52	Fe-55	Fe-59	Co-57	Co-58	Ni-63	Ni-65	Cu-64	Zn-65
Zn-69m	Ga-72	As-73	As-74	As-76	As-77	Sc-75	Br-82	Kr-85m
Kr-87	Rb-86	Sr-85	Sr-91	Y-90	Y-92	Y-93	Zr-97	Nb-93m
Nb-95	Mo-99	Tc-96	Tc-97m	Tc-97	Tc-99	Ru-97	Ru-103	Ru-105
Rh-105	Pd-103	Pd-109	Ag-105	Ag-111	Cd-109	Cd-115	In-115m	Sn-113
Sn-125	Sb-122	Te-125m	Te-127	Te-129	Te-131m	Te-132	I-130	I-132
I-134	I-135	Xe-135	Cs-131	Cs-136	Ba-131	La-140	Ce-141	Ce-143
Pr-142	Pr-143	Nd-147	Nd-149	Pm-147	Pm-149	Sm-151	Sm-153	Eu-152
Eu-155	Gd-153	Gd-159	Dy-165	Dy-166	Ho-166	Er-169	Er-171	(9.2 hr)
Tm-171	Yb-175	La-177	W-181	W-185	W-187	Re-183	Re-186	Re-188
Os-185	Os-191	Os-193	Ir-190	Ir-194	Pt-191	Pu-193	Pt-197	Au-196
Au-198	Au-199	Hg-197	Hg-197m	Hg-203	Tl-200	Tl-201	Tl-202	Pb-203
Bi-206	Bi-212	Rn-220	Rn-222	Th-231	Pa-233	Np-239		

Group 4++

H-3	0-15	A-37	Co-58m	Ni-59	Zn-69	Gc-71	Kr-85	Sr-85m
Rb-87	Y-91m	Zr-93	Nb-97	Tc-96m	Tc-99m	Rh-103m	In-113	I-129
Xe-131m	Xe-133	Cs-134m	Cs-135	Sm-147	Re-187	Os-191m	Pt-193m	Pt-197m
Th-232	Th-Nat	U-235	U-238	U-Nat				

GLOSSARY

Absorbed Dose:

The energy imparted by ionizing radiation per unit mass of irradiated material. The units of absorbed dose are, the rad and the gray (Gy).

Absorption:

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

Activity

The rate of disintegration (transformation) or decay of radioactive material per unit time. The units of activity (also known as radioactivity) are the curie (Ci) and the becquerel (Bq). For related information, see Measuring Radiation.

ALARA

As defined in Title 10, Section 20.1003, of the *Code of Federal Regulations* (http://www.nrc.gov/reading-rm/doc-collections/cfr/part020/part020-1003.html10 CFR 20.1003), ALARA is an acronym for "as low as (is) reasonably achievable," which means making every reasonable effort to maintain exposures to ionizing radiation as far below the dose limits as practical, consistent with the purpose for which the licensed activity is undertaken, taking into account the state of technology, the economics of improvements in relation to state of technology, the economics of improvements in relation to benefits to the public health and safety, and other societal and socioeconomic considerations, and in relation to utilization of nuclear energy and licensed materials in the public interest. For additional detail, see Dose Limits for Radiation Workers and Dose Limits for Radiation Workers.

Alpha particle

A positively charged particle ejected spontaneously from the nuclei of some radioactive elements. It is identical to a helium nucleus that has a mass number of 4 and an electrostatic charge of +2. It has low penetrating power and a short range (a few centimeters in air). The most energetic alpha particle will generally fail to penetrate the dead layers of cells covering the skin, and can be easily stopped by a sheet of paper. Alpha particles are hazardous when an alpha-emitting isotope is inside the body. For additional detail, see Radiation Basics.

Annual limit on intake (ALI)

As defined in Title 10, Section 20.1003, of the *Code of Federal Regulations* (http://www.nrc.gov/reading-rm/doc-collections/cfr/part020/part020-1003.html10 CFR 20.1003), ALI is the derived limit for the amount of radioactive material taken into the body of an adult worker by inhalation or ingestion in a year. ALI is the smaller value of intake of a given radionuclide in a year by the "reference man" that would result in a committed effective dose equivalent (CEDE) of 5 rems (0.05 sievert) or a committed dose equivalent (CDE) of 50 rems (0.5 sievert) to any individual organ or tissue. ALI values for intake by ingestion and inhalation of selected radionuclides are given in Table 1, Columns 1 and 2, of Appendix B to 10 CFR Part 20, "Standards for Protection Against Radiation." For additional detail, see Information for Radiation Workers.

Background radiation

The natural radiation that is always present in the environment. It includes cosmic radiation which comes from the sun and stars, terrestrial radiation which comes from the Earth, and internal radiation which exists in all living things. The typical average individual exposure in the United States from natural background sources is about 300 millirems per year. For additional information, see Natural Background Sources and Doses in Our Daily Lives.

Becquerel (Bq)

One of three units used to measure radioactivity, which refers to the amount of ionizing radiation released when an element (such as uranium) spontaneously emits energy as a result of the radioactive decay (or disintegration) of an unstable atom. Radioactivity is also the term used to describe the rate at which radioactive material emits radiation, or how many atoms in the material decay (or disintegrate) in a given time period. As such, 1 Bq represents a rate of radioactive decay equal to 1 disintegration per second, and 37 billion (3.7 x 1010) Bq equals 1 curie (Ci).

Beta particle

A charged particle (with a mass equal to 1/1837 that of a proton) that is emitted from the nucleus of a radioactive element during radioactive decay (or disintegration) of an unstable atom. A negatively charged beta particle is identical to an electron, while a positively charged beta particle is called a positron. Large amounts of beta radiation may cause skin burns, and beta emitters are harmful if they enter the body. Beta particles may be stopped by thin sheets of metal or plastic. For additional detail, see Radiation Basics.

Bioassay

The determination of kinds, quantities, or concentrations and, in some cases, locations of radioactive material in the human body, whether by direct measurement (in vivo counting) or by analysis and evaluation of materials excreted or removed (in vitro) from the human body.

Biological half-life

The time required for a biological system, such as that of a human, to eliminate, by natural processes, half of the amount of a substance (such as a radioactive material) that has entered it.

prostate, ovaries, or uterus). The radioactive implant may be temporary or permanent, and the radiation attacks the tumor as long as the device remains in place. Brachytherapy uses radioisotopes, such as iridium-192 or iodine-125, which are regulated by the NRC and its Agreement States. For additional information, see Brachytherapy.

Bremsstrahlung:

Electromatic (x-ray) radiation associated with the deceleration of charged particles passing through matter. Usually associated with energetic beta emitters, such as phosphorus-32.

Calibration

The adjustment, as necessary, of a measuring device such that it responds within the required range and accuracy to known values of input.

Carrier free:

An adjective applied to one or more radioactive isotopes of an element in minute quantity, essentially undiluted with a stable isotope carrier.

Committed dose equivalent (CDE)

As defined in Title 10, Section 20.1003, of the *Code of Federal Regulations* (http://www.nrc.gov/reading-rm/doc-collections/cfr/part020/part020-1003.html10 CFR 20.1003), the CDE (HT,50) is the dose to some specific organ or tissue of reference (T) that will be received from an intake of radioactive material by an individual during the 50-year period following the intake.

Committed effective dose equivalent (CEDE)

As defined in Title 10, Section 20.1003, of the *Code of Federal Regulations* (http://www.nrc.gov/reading-rm/doc-collections/cfr/part020/part020-1003.html10 CFR 20.1003), the CEDE ($H_{E,50}$) is the sum of the products of the committed dose equivalents for each of the body organs or tissues that are irradiated multiplied by the weighting factors (W_T) applicable to each of those organs or tissues ($H_{E,50} = \Sigma W_T H_{T.50}$).

Contamination

Undesirable radiological, chemical, or biological material (with a potentially harmful effect) that is either airborne, or deposited in (or on the surface of) structures, objects, soil, water, or living organisms in a concentration that makes the medium unfit for its next intended use.

Count (Radiation Measurements):

The external indication of a device designed to numerate ionizing events. It may refer to a single detected event or to the total registered in a given period of time. The term is often erroneously used to designate a disintegration, ionizing event, or voltage pulse.

Cumulative dose

The total dose that an occupationally exposed worker receives as a result of repeated exposures to ionizing radiation to to the same portion of the body, or to the whole body, over time. For additional detail, see Information for Radiation Workers.

Curie (Ci)

One of three units used to measure the intensity of radioactivity in a sample of material. This value refers to the amount of ionizing radiation released when an element (such as uranium) spontaneously emits energy as a result of the radioactive decay (or disintegration) of an unstable atom. Radioactivity is also the term used to describe the rate at which radioactive material emits radiation, or how many atoms in the material decay (or disintegrate) in a given time period. As such, 1 Ci is equal to 37 billion (3.7×10^{10}) disintegrations per second, so 1 Ci also equals 37 billion (3.7×10^{10}) Bequerels (Bq). A curie is also a quantity of any radionuclide that decays at a rate of 37 billion disintegrations per second (1 gram of radium, for example). The curie is named for Marie and Pierre Curie, who discovered radium in 1898.

Daughter products

Isotopes that are formed by the radioactive decay of some other isotope. In the case of radium-226, for example, there are 10 successive daughter products, ending in the stable isotope lead-206.

Decay, radioactive

The spontaneous transformation of one radioisotope into one or more different isotopes (known as "decay products" or "daughter products"), accompanied by a decrease in radioactivity (compared to the parent material). This transformation takes place over a defined period of time (known as a "half-life"), as a result of electron capture; fission; or the emission of alpha particles, beta particles, or photons (gamma radiation or x-rays) from the nucleus of an unstable atom. Each isotope in the sequence (known as a "decay chain") decays to the next until it forms a stable, less energetic end product. In addition, radioactive decay may refer to gamma-ray and conversion electron emission, which only reduces the excitation energy of the nucleus.

Declared pregnant woman

A woman who is an occupational radiation worker and has voluntarily informed her employer, in writing, of her pregnancy and the estimated date of conception (see 10 CFR 20.1003 and 20.1208).

Decontamination

A process used to reduce, remove, or neutralize radiological, chemical, or biological contamination to reduce the risk of exposure. Decontamination may be accomplished by cleaning or treating surfaces to reduce or remove the contamination; filtering contaminated air or water; subjecting contamination to evaporation and precipitation; or covering the contamination to shield or absorb the radiation. The process can also simply allow adequate time for natural radioactive decay to decrease the radioactivity.

Dose

A general term, which may be used to refer to the amount of energy absorbed by an object or person per unit mass. Known as the "absorbed dose," this reflects the amount of energy that ionizing radiation sources deposit in materials through which they pass, and is measured in units of radiation-absorbed dose (rad). The related international system unit is the gray (Gy), where 1 Gy is equivalent to 100 rad. By contrast, the biological dose or dose equivalent, given in rems or sieverts (Sv), is a measure of the biological damage to living tissue as a result of radiation exposure. For additional information, see Doses in Our Daily Lives and Measuring Radiation.

Dose equivalent

A measure of the biological damage to living tissue as a result of radiation exposure. Also known as the " biological dose," the dose equivalent is calculated as the product of absorbed dose in tissue multiplied by a quality factor and then sometimes multiplied by other necessary modifying factors at the location of interest. The dose equivalent is expressed numerically in rems or sieverts (Sv) (see http://www.nrc.gov/reading-rm/doc-collections/cfr/part020/part020-1003.html10 CFR 20.1003). For additional information, see Doses in Our Daily Lives and Measuring Radiation.

Dose rate

The dose of ionizing radiation delivered per unit time. For example, rems or sieverts (Sv) per hour.

Dose, absorbed

The amount of energy absorbed by an object or person per unit mass. Known as the "absorbed dose," this reflects the amount of energy that ionizing radiation sources deposit in materials through which they pass, and is measured in units of radiation-absorbed dose (rad). The related international system unit is the gray (Gy), where 1 Gy is equivalent to 100 rad. For additional information, see Doses in Our Daily Lives and Measuring Radiation.

Dosimeter

A small portable instrument (such as a film badge, thermoluminescent dosimeter, or pocket dosimeter) used to measure and record the total accumulated personal dose of ionizing radiation. For additional information, see Detecting Radiation.

Dosimetry

The theory and application of the principles and techniques involved in measuring and recording doses of ionizing radiation.

Effective Dose Equivalent

The sum of the products of the dose equivalent to the organ or tissue (H_T) and the weighting factors (W_T) applicable to each of the body organs or tissues that are irradiated ($H_E = \Sigma W_T H_T$).

Effective half-life

The time required for the activity of a particular radioisotope deposited in a living organism, such as a human or an animal, to be reduced by 50 percent as a result of the combined action of radioactive decay and biological elimination. Effective half-life is related to, but different from, the radiological half-life and the biological half-life.

Electron

An elementary particle with a negative charge and a mass 1/1837 that of a proton. Electrons surround the positively charged nucleus of an atom, and determine its chemical properties.

Element

One of the 103 known chemical substances that cannot be broken down further without changing its chemical properties. Some examples include hydrogen, nitrogen, gold, lead, and uranium. See the periodic table of elements.

The area surrounding the reactor where the reactor licensee has the authority to determine all activities, including exclusion or removal of personnel and property.

Exposure

Absorption of ionizing radiation or ingestion of a radioisotope. Acute exposure is a large exposure received over a short period of time. Chronic exposure is exposure received over a long period of time, such as during a lifetime. The National Council on Radiation Protection and Measurements (NCRP) estimates that an average person in the United States receives a total annual dose of about 0.62 rem (620 millirem) from all radiations sources, a level that has not been shown to cause humans any harm. Of this total, natural background sources of radiation—including radon and thoron gas, natural radiation from soil and rocks, radiation from space and radiation sources that are found naturally within the human body—account for approximately 50 percent. Medical procedures such as computed tomography (CT scans) and nuclear medicine account approximately for another 48 percent. Other small contributors of exposure to the U.S. population includes consumer products and activities, industrial and research uses, and occupational tasks. The maximum permissible yearly dose for a person working with or around nuclear material is 5 rem. For additional detail, see Doses in Our Daily Lives and Measuring Radiation.

External radiation

Exposure to ionizing radiation when the radiation source is located outside the body.

Extremities

The hands, forearms, elbows, feet, knees, leg below the knees, and ankles. Permissible radiation exposures in these regions are generally greater than those for whole body exposure because the extremities contain fewer blood-forming organs and have smaller volumes for energy absorption. (See http://www.nrc.gov/reading-rm/doc-collections/cfr/part020/part020-1003.html10 CFR 20.1003.)

Film badge

Photographic film used to measure exposure to ionizing radiation for purposes of personnel monitoring. The film badge may contain two or three films of differing sensitivities, and it may also contain a filter that shields part of the film from certain types of radiation.

Gamma radiation

High-energy, short-wavelength, electromagnetic radiation emitted from the nucleus of an atom. Gamma radiation frequently accompanies emissions of alpha particles and beta particles, and always accompanies fission. Gamma rays are similar to x-rays, but are very penetrating and are best stopped or shielded by dense materials, such as lead or depleted uranium.

Geiger-Mueller counter

A radiation detection and measuring instrument. It consists of a gas-filled tube containing electrodes, between which there is an electrical voltage, but no current, flowing. When ionizing radiation passes through the tube, a short, intense pulse of current passes from the negative electrode to the positive electrode and is measured or counted. The number of pulses per second measures the intensity of the radiation field. It was named for Hans Geiger and W. Mueller, who invented it in the 1920s. It is sometimes called simply a Geiger counter or a G-M counter and is the most commonly used portable radiation instrument. For related information, see Detecting Radiation.

Gray (Gy)

One of the two units used to measure the amount of radiation absorbed by an object or person, known as the "absorbed dose," which reflects the amount of energy that radioactive sources (with any type of ionizing radiation) deposit in materials (e.g., water, tissue, air) through which they pass. One gray (Gy) is the international system of units (SI) equivalent of 100 rads, which is equal to an absorbed dose of 1 Joule/kilogram. An absorbed dose of 0.01 Gy means that 1 gram of material absorbed 100 ergs of energy (a small but measurable amount) as a result of exposure to radiation. For additional information, see Doses in Our Daily Lives and Measuring Radiation.

Half-life

The time in which one half of the atoms of a particular radioactive substance disintegrate into another nuclear form. Measured half-lives vary from millionths of a second to billions of years. Also called physical or radiological half-life.

Half-life (radiological)

The time required for half the atoms of a particular radioisotope to decay into another isotope. A specific half-life is a characteristic property of each radioisotope. Measured half-lives range from millionths of a second to billions of years, depending on the stability of the nucleus. Radiological half-life is related to, but different from, the biological half-life and the effective half-life.

Half-life, biological

The time required for the body to eliminate one half of the material taken in by natural biological means.

Half-life, effective

The time required for the activity of a particular radioisotope deposited in a living organism, such as a human or an animal, to be reduced by 50 percent as a result of the combined action of radioactive decay and biological elimination. Effective half-life is related to, but different from, the radiological half-life and the biological half-life.

Half-thickness

Any given absorber that will reduce the intensity of an original beam of ionizing radiation to one-half of its initial value.

countries and multiple international partners work together to promote the safe, secure, and peaceful use of nuclear technologies. The United Nations established the IAEA in 1957 as "Atoms for Peace."

Ion

(1) An atom that has too many or too few electrons, causing it to have an electrical charge, and therefore, be chemically active. (2) An electron that is not associated (in orbit) with a nucleus.

Ionization

The process of adding one or more electrons to, or removing one or more electrons from, atoms or molecules, thereby creating ions. High temperatures, electrical discharges, or nuclear radiations can cause ionization.

Ionization chamber

An instrument that detects and measures ionizing radiation by measuring the electrical current that flows when radiation ionizes gas in a chamber, making the gas a conductor of electricity.

Ionizing radiation

A form of radiation, which includes alpha particles, beta particles, gamma rays, x-rays, neutrons, high-speed electrons, high-speed protons, and other particles capable of producing ions. Compared to non-ionizing radiation, such as radio- or microwaves, or visible, infrared, or ultraviolet light, ionizing radiation is considerably more energetic. When ionizing radiation passes through material such as air, water, or living tissue, it deposits enough energy to produce ions by breaking molecular bonds and displace (or remove) electrons from atoms or molecules. This electron displacement may lead to changes in living cells. Given this ability, ionizing radiation has a number of beneficial uses, including treating cancer or sterilizing medical equipment. However, ionizing radiation is potentially harmful if not used correctly, and high doses may result in severe skin or tissue damage. It is for this reason that the NRC strictly regulates commercial and institutional uses of the various types of ionizing radiation. Radiation, as used in http://www.nrc.gov/reading-rm/doc-collections/cfr/part020/10 CFR Part 20, does not include non-ionizing radiation (see also http://www.nrc.gov/reading-rm/doc-collections/cfr/part020/part020-1003.html10 CFR 20.1003).

Irradiation

Exposure to ionizing radiation. Irradiation may be intentional, such as in cancer treatments or in sterilizing medical instruments. Irradiation may also be accidental, such as being exposed to an unshielded source. Irradiation does not usually result in radioactive contamination, but damage can occur, depending on the dose received.

Isotope

Two or more forms (or atomic configurations) of a given element that have identical atomic numbers (the same number of protons in their nuclei) and the same or very similar chemical properties but different atomic masses (different numbers of neutrons in their nuclei) and distinct physical properties. Thus, carbon-12, carbon-13, and carbon-14 are isotopes of the element carbon, and the numbers denote the approximate atomic masses. Among their distinct physical properties, some isotopes (known as radioisotopes) are radioactive because their nuclei emit radiation as they strive toward a more stable nuclear configuration. For example, carbon-12 and carbon-13 are stable, but carbon-14 is unstable and radioactive.

Licensed material

Source material, byproduct material, or special nuclear material that is received, possessed, used, transferred, or disposed of under a general license or specific license issued by the NRC or Agreement States.

Licensee

A company, organization, institution, or other entity to which the NRC or an Agreement State has granted a general license or specific license to construct or operate a nuclear facility, or to receive, possess, use, transfer, or dispose of source material, byproduct material, or special nuclear material.

Low-level radioactive waste (LLW)

A general term for a wide range of items that have become contaminated with radioactive material or have become radioactive through exposure to neutron radiation. A variety of industries, hospitals and medical institutions, educational and research institutions, private or government laboratories, and nuclear fuel cycle facilities generate LLW as part of their day-to-day use of radioactive materials. Some examples include radioactively contaminated protective shoe covers and clothing; cleaning rags, mops, filters, medical tubes, swabs, and hypodermic syringes; carcasses and tissues from laboratory animals. The radioactivity in these wastes can range from just above natural background levels to much higher levels.

Microcurie

One millionth of a curie. That amount of radioactive material that disintegrates (decays) at the rate of 37 thousand atoms per second.

Millirem

One thousandth of a rem (0.001 rem).

Milliroentgen (mR)

One thousandth of a roentgen (R). 1mR = 10^{-3} R = 0.001 R.

Monitoring of radiation

Periodic or continuous determination of the amount of ionizing radiation or radioactive contamination in a region. Radiation monitoring is a safety measure to protect the health and safety of the public and the environment through the use of bioassay, alpha scans, and other radiological survey methods to monitor air, surface water and ground water, soil and sediment, equipment surfaces, and personnel. For related information, see Radiation Monitoring at Nuclear Power Plants and the related fact sheets listed on that page.

Neutron

An uncharged elementary particle, with a mass slightly greater than that of the proton, found in the nucleus of every atom heavier than hydrogen.

Nuclide

A general term referring to all known isotopes, both stable (279) and unstable (about 2,700), of the chemical elements.

Occupational Dose

The internal and external dose of ionizing radiation received by workers in the course of employment in such areas as fuel cycle facilities, industrial radiography, nuclear medicine, and nuclear power plants. These workers are exposed to varying amounts of radiation, depending on their jobs and the sources with which they work. The NRC requires its licensees to limit occupational exposure to 5,000 mrem (50 mSv) per year. Occupational dose does not include the dose received from natural background sources, doses received as a medical patient or participant in medical research programs, or "second-hand doses" received through exposure to individuals treated with radioactive materials. For additional detail, see Information for Radiation Workers and Measuring Radation.

Periodic table

An arrangement of chemical elements in order of increasing atomic number. Elements of similar properties are placed one under the other, yielding groups or families of elements.

Within each group, there is a variation of chemical and physical properties, but in general, there is a similarity of chemical behavior within each group. (See an online periodic table.)

Personnel monitoring

The use of portable survey meters to determine the amount of radioactive contamination on individuals, or the use of dosimetry to determine an individual's occupational radiation dose.

Photon

A quantum (or packet) of energy emitted in the form of electromagnetic radiation. Gamma rays and x-rays are examples of photons.

Pig

A colloquial term describing a container (usually lead or depleted uranium) used to ship or store radioactive materials. The thick walls of this shielding device protect the person handling the container from radiation.

Proton

An elementary nuclear particle with a positive electric charge located in the nucleus of an atom.

Rad (radiation absorbed dose)

One of the two units used to measure the amount of radiation absorbed by an object or person, known as the "absorbed dose," which reflects the amount of energy that radioactive sources deposit in materials through which they pass. The radiation-absorbed dose (rad) is the amount of energy (from any type of ionizing radiation) deposited in any medium (e.g., water, tissue, air). An absorbed dose of 1 rad means that 1 gram of material absorbed 100 ergs of energy (a small but measurable amount) as a result of exposure to radiation. The related international system unit is the gray (Gy), where 1 Gy is equivalent to 100 rad. For additional information, see Doses in Our Daily Lives and Measuring Radiation.

Radiation (ionizing radiation)

Alpha particles, beta particles, gamma rays, x-rays, neutrons, high-speed electrons, high-speed protons, and other particles capable of producing ions. Radiation, as used in http://www.nrc.gov/reading-rm/doc-collections/cfr/part020/10 CFR Part 20, does not include non-ionizing radiation, such as radio- or microwaves, or visible, infrared, or ultraviolet light (see also http://www.nrc.gov/reading-rm/doc-collections/cfr/part020/part020-1003.html10 CFR 20.1003). For additional detail, see Radiation, ionizing.

Radiation area

Any area with radiation levels greater than 5 millirems (0.05 millisievert) in one hour at 30 centimeters from the source or from any surface through which the radiation penetrates.

Radiation detection instrument

A device that detects and displays the characteristics of ionizing radiation.

Radiation shielding

Reduction of radiation by interposing a shield of absorbing material between any radioactive source and a person, work area, or radiation-sensitive device.

Radiation source

A radioactive material or byproduct that is specifically manufactured or obtained for the purpose of using the emitted radiation. Such sources are commonly used in teletherapy or industrial radiography; in various types of industrial gauges, irradiators, and gamma knives; and as power sources for batteries (such as those used in spacecraft). These sources usually consist of a known quantity of radioactive material, which is encased in a manmade capsule, sealed between layers of nonradioactive material, or firmly bonded to a nonradioactive substrate to prevent radiation leakage. Other radiation sources include devices such as accelerators and x-ray generators.

Radiation standards

Exposure limits; permissible concentrations; rules for safe handling; and regulations regarding receipt, possession, use, transportation, storage, disposal, and industrial control of radioactive material. For detail, see Title 10, Part 20, of the Code of Federal Regulations (10 CFR Part 20), "Standards for Protection Against Radiation."

Radiation warning symbol

An officially prescribed magenta or black trefoil on a yellow background, which must be displayed where certain quantities of radioactive materials are present or where certain doses of radiation could be received. For detail, see the Fact Sheet on the New International Radiation Warning Symbol.

Radiation, ionizing

A form of radiation, which includes alpha particles, beta particles, gamma rays, x-rays, neutrons, high-speed electrons, high-speed protons, and other particles capable of producing ions. Compared to non-ionizing radiation, such as radio- or microwaves, or visible, infrared, or ultraviolet light, ionizing radiation is considerably more energetic. When ionizing radiation passes through material such as air, water, or living tissue, it deposits enough energy to produce ions by breaking molecular bonds and displace (or remove) electrons from atoms or molecules. This electron displacement may lead to changes in living cells. Given this ability, ionizing radiation has a number of beneficial uses, including treating cancer or sterilizing medical equipment. However, ionizing radiation is potentially harmful if not used correctly, and high doses may result in severe skin or tissue damage. It is for this reason that the NRC strictly regulates commercial and institutional uses of the various types of ionizing radiation. Radiation, as used in http://www.nrc.gov/reading-rm/doc-collections/cfr/part020/10 CFR Part 20, does not include non-ionizing radiation (see also http://www.nrc.gov/reading-rm/doc-collections/cfr/part020/part020-1003.html10 CFR 20.1003).

Radiation, nuclear

Energy given off by matter in the form of tiny fast-moving particles (alpha particles, beta particles, and neutrons) or pulsating electromagnetic rays or waves (gamma rays) emitted from the nuclei of unstable radioactive atoms. All matter is composed of atoms, which are made up of various parts; the nucleus contains minute particles called protons and neutrons, and the atom's outer shell contains other particles called electrons. The nucleus carries a positive electrical charge, while the electrons carry a negative electrical charge. These forces work toward a strong, stable balance by getting rid of excess atomic energy (radioactivity). In that process, unstable radioactive nuclei may emit energy, and this spontaneous emission is called nuclear radiation. All types of nuclear radiation are also ionizing radiation, but the reverse is not necessarily true; for example, x-rays are a type of ionizing radiation, but they are not nuclear radiation because they do not originate from atomic nuclei. In addition, some elements are naturally radioactive, as their nuclei emit nuclear radiation as a result of radioactive decay, but others are induced to become radioactive by being irradiated in a reactor. Naturally occurring nuclear radiation is indistinguishable from induced radiation.

Radioactive contamination

Undesirable radioactive material (with a potentially harmful effect) that is either airborne or deposited in (or on the surface of) structures, objects, soil, water, or living organisms (people, animals, or plants) in a concentration that may harm people, equipment, or the environment.

Radioactive decay

The spontaneous transformation of one radioisotope into one or more different isotopes (known as "decay products" or "daughter products"), accompanied by a decrease in radioactivity (compared to the parent material). This transformation takes place over a defined period of time (known as a "half-life"), as a result of electron capture; fission; or the emission of alpha particles, beta particles, or photons (gamma radiation or x-rays) from the nucleus of an unstable atom. Each isotope in the sequence (known as a "decay chain") decays to the next until it forms a stable, less energetic end product. In addition, radioactive decay may refer to gamma-ray and conversion electron emission, which only reduces the excitation energy of the nucleus.

Radioactivity

The property possessed by some elements (such as uranium) of spontaneously emitting energy in the form of radiation as a result of the decay (or disintegration) of an unstable atom. Radioactivity is also the term used to describe the rate at which radioactive material emits radiation. Radioactivity is measured in curies (Ci), becquerels (Bq), or disintegrations per second.. For related information, see Measuring Radiation.

Radioisotope (Radionuclide)

An unstable isotope of an element that decays or disintegrates spontaneously, thereby emitting radiation. Approximately 5,000 natural and artificial radioisotopes have been identified.

Radiological survey

The evaluation of the radiation hazards accompanying the production, use, or existence of radioactive materials under a specific set of conditions. Such evaluation customarily includes a physical survey of the disposition of materials and equipment, measurements or estimates of the levels of radiation that may be involved, and a sufficient knowledge of processes affecting these materials to predict hazards resulting from expected or possible changes in materials or equipment.

Radionuclide

An unstable isotope of an element that decays or disintegrates spontaneously, thereby emitting radiation. Approximately 5,000 natural and artificial radioisotopes have been identified.

Radiosensitivity

The relative susceptibility of cells, tissues, organs, organisms, or other substances to the injurious action of radiation.

REM (Roentgen equivalent man)

One of the two standard units used to measure the dose equivalent (or effective dose), which combines the amount of energy (from any type of ionizing radiation that is deposited in human tissue), along with the medical effects of the given type of radiation. For beta and gamma radiation, the dose equivalent is the same as the absorbed dose. By contrast, the dose equivalent is larger than the absorbed dose for alpha and neutron radiation, because these types of radiation are more damaging to the human body. Thus, the dose equivalent (in rems) is equal to the absorbed dose (in rads) multiplied by the quality factor of the type of radiation [see Title 10, Section 20.1004, of the *Code of Federal Regulations* (10 CFR 20.1004), "Units of Radiation Dose"]. The related international system unit is the sievert (Sv), where 100 rem is equivalent to 1 Sv. For additional information, see Doses in Our Daily Lives and Measuring Radiation. **Roentgen (R)**

A unit of exposure to ionizing radiation. It is the amount of gamma or x-rays required to produce ions resulting in a charge of 0.000258 coulombs/kilogram of air under standard conditions. Named after Wilhelm Roentgen, the German scientist who discovered x-rays in 1895.

Scintillation detector

The combination of phosphor, photomultiplier tube, and associated electronic circuits for counting light emissions produced in the phosphor by ionizing radiation.

Sealed source

Any radioactive material or byproduct encased in a capsule designed to prevent leakage or escape of the material.

Shallow-Dose Equivalent (SDE)

The external exposure dose equivalent to the skin or an extremity at a tissue depth of 0.007 centimeters (7 mg/cm^2) averaged over an area of 1 square centimeter.

Shielding

Any material or obstruction that absorbs radiation and thus tends to protect personnel or materials from the effects of ionizing radiation.

Sievert (Sv)

The international system (SI) unit for dose equivalent equal to 1 Joule/kilogram. 1 sievert = 100 rem. Named for physicist Rolf Sievert.

ongoing series of reactions, possibly as a result of increased neutron leakage or poisons.

Survey meter

Any portable radiation detection instrument especially adapted for inspecting an area or individual to establish the existence and amount of radioactive material present.

Terrestrial radiation

The portion of the natural background radiation that is emitted by naturally occurring radioactive materials, such as uranium, thorium, and radon in the earth.

Total Effective Dose Equivalent (TEDE)

The sum of the deep-dose equivalent (for external exposures) and the committed effective dose equivalent (for internal exposures).

Tritium

A radioactive isotope of hydrogen. Because it is chemically identical to natural hydrogen, tritium can easily be taken into the body by any ingestion path. It decays by emitting beta particles and has a half-life of about 12.5 years. For related information, see the Fact Sheet on Tritium, Radiation Protection Limits, and Drinking Water Standards.

responsible for preparing for and responding to all hazards and disasters and includes the formerly separate Federal Emergency Management Agency, the Coast Guard, and the Secret Service.

induction of stochastic effects of radiation (see 10 CFR 20.1003 for complete information).

Whole-body exposure

Whole body exposure includes at least the external exposure, head, trunk, arms above the elbow, or legs above the knee. Where a radioisotope is uniformly distributed throughout the body tissues, rather than being concentrated in certain parts, the irradiation can be considered as whole-body exposure (see also http://www.nrc.gov/reading-rm/doc-collections/cfr/part020/part020-1003.html10 CFR 20.1003).

Wipe sample

A sample made for the purpose of determining the presence of removable radioactive contamination on a surface. It is done by wiping, with slight pressure, a piece of soft filter paper over a representative type of surface area. It is also known as a "swipe" or "smear" sample.

X-rays

Penetrating electromagnetic radiation (photon) having a wavelength that is much shorter than that of visible light. These rays are usually produced by excitation of the electron field around certain nuclei. In nuclear reactions, it is customary to refer to photons originating in the nucleus as x-rays.