RADIATION SAFETY MANUAL

for

The University of Wyoming

Revised

January 1979

J.E. Doerges
and
The Radiation Safety Committee

Copies available at the

Radiation Safety Office
Room 212, Biochemistry Building
Telephone 766-3277

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I. ORGANIZATION AND RESPONSIBILITIES

A. Radiation Safety Committee

The Radiation Safety Committee shall consist of at least six voting members appointed by the President of the University, who shall designate the chairperson of the committee. The committee shall consist of at least two representatives from the biological sciences, at least one representative from the physical sciences, at least one representative from engineering, one University administrative officer, one representative from the Department of Energy's Laramie Energy Technology Center, the Safety Officer, the Radiation Safety Officer (RSO)/Health Physicist and the Vice President for Research. A majority of the committee members shall be individually experienced in the safe use of radioactive materials and radiation sources. The cognizant vice president is the Vice President for Research. A quorum shall consist of at least three voting members of the committee.

The Radiation Safety Committee is responsible for establishing and administering the University's policies and procedures for all uses of ionizing radiation (radioactive materials and radiation generating machines) in teaching, research and extension service at University facilities and operating sites, within the restrictions imposed by the U.S. Nuclear Regulatory Commission and/or state agencies. In particular, the committee is responsible for all authorizations for use of radiation sources by individuals, for all programs involving radioactive materials or radiation generating machines and for approval of all facilities in which radiation sources are to be used. The committee may delegate some of its functions to the RSO or to subcommittees, but is responsible for the ultimate performance of these functions.

The Radiation Safety Committee shall select one of its members to serve as secretary and shall assure that accurate records are maintained of all committee actions. The committee shall meet at least once during each calendar quarter. Special meetings of the committee may be called by members of the committee.

B. Radiation Safety Officer

The Radiation Safety Officer, (RSO) shall be a person having specialized training or experience in radiation protection (Health Physics). The primary function of the RSO is to provide guidance and advice to the Radiation Safety Committee and the radiation users on all matters pertaining to the safe use of radiation sources.

The RSO shall coordinate or provide certain centralized services authorized by the Radiation Safety Committee, e.g. personal monitoring, leak testing of sealed sources, calibration of survey instruments, disposal of radioactive wastes, maintenance of inventory records, etc. The RSO serves as an ex-officio member of the Radiation Safety Committee and performs the duties delegated by the committee, e.g. the routine auditing of the activities

of radiation users to assure compliance with license conditions and with state and federal regulations.

The RSO has the authority to halt or terminate the use of any activity involving ionizing radiation which is not in accordance with U.S. Nuclear Regulatory Commission (NRC) or University regulations

C. Radiation Users

Radiation Users are those persons who are authorized by the Radiation Safety Committee to utilize radiation sources at University facilities. Authorizations and responsibilities of users are grouped into three general categories:

1. **Principal Users** are persons with sufficient training, experience and authority to assume full responsibility for programs involving radiation sources. A principal user must ensure that training, work conditions and equipment are all adequate to provide safety and health protection for all workers in the group. Principal users are also responsible for assuring that all uses of radiation sources by subordinates are conducted according to authorized procedures.

2. **Independent Users** are persons with sufficient training and experience to use radiation sources safely without direct supervision, but who lack the authority to assume full responsibility for a radiation program (e.g. technicians and graduate students).

3. **Supervised Users** are persons who must work with radiation sources under the direct supervision of a principal or independent user. Although a user in this category must follow approved procedures, he must not work alone or attempt to supervise others. All supervised and independent users must be responsible to a principal user who in turn, is responsible to the Radiation Safety Committee.

II. EXPOSURE CONTROL

A. Exposure Limits and Personal Monitoring

The following external exposures are to be considered as maximum limits, with every effort to be made to reduce all exposures to the lowest practicable level:

	Maximum Dose Per Calendar Quarter (rem)
to total body, head and trunk, active blood-forming organs, gonads and lenses of eyes	1.25
to thyroid or skin of whole body	7.50
to extremeties (hands and forearms, feet and ankles)	18.75

Personal monitoring devices (e.g. film or TLD badges) will be provided to, and used by, all individuals likely to receive any significant external radiation exposure. Laboratories using unsealed millicurie amounts of ^{3}H, ^{14}C, ^{32}P, or other isotopes in single experiments which film or TLD badges do not adequately monitor will submit urine samples for each individual using the isotope(s) in the laboratory. Laboratories using the isotope(s) routinely shall submit to samples on a regular basis, the schedule determined by the laboratory activity, but at least monthly. Individuals in non-routine laboratories shall submit the urine samples within one week of the usage. Where possible, control urine samples taken before handling the radioisotope(s) should be submitted for comparison. The RSO will supply urine collection bottles, pickup urine samples and process the samples for the isotope(s) of interest.

In-vivo bioassay is required for personnel using radioactive I-131 or I-125 as follows:

1. Conditions under which bioassay procedures are required: Routine bioassay will be required for all individuals who handle, at any time, quantities which exceed those shown in TABLE 1. Except as specified in the next paragraph, bioassay is not required when process quantities handled by a worker are less than those listed in TABLE 1.

TABLE 1

Activity Levels Above Which Bioassay for I-125 or I-131 is Necessary

Types of Operation	Activity Handled at Any One Time in Unsealed Form Making Bioassay Necessary: Volatile or Dispersible	Activity Handled at Any One Time in Unsealed Form Making Bioassay Necessary: Bound to Non-volatile agent
Processes in open room or bench, with possible escape of iodine from process vessels.	0.01 mCi	0.1 mCi
Processes with possible escape of iodine carried out within a fume hood of adequate design, face velocity and performance reliability.	0.10 mCi	1.0 mCi
Processes carried out within glove boxes, ordinarily closed, but with possible release of iodine from process and occasional exposure to contaminated box and box leakage.	1.00 mCi	10.0 mCi

2. When respiratory protection devices and special protective clothing, other than laboratory coats and protective gloves, are required bioassay measurements will be performed to verify the effectiveness of the respiratory protection devices and/or other protective clothing. Individuals wearing a respiratory device or protective clothing and subjected to a concentration of I-125 or I-131 (in any form) in air such that his or her intake with no protection would have exceeded the concentrations as listed in TABLE 2. (Data taken from Appendix B 10CFR20.)

TABLE 2

Concentrations in Air Above Natural Background (40 Hours/week for 13 weeks)

Isotope	Form	Concentration: Air (μCi/ml)	Concentration: Water (μCi/ml)
Iodine 131	Soluble	9×10^{-9}	6×10^{-5}
	Insoluble	3×10^{-7}	2×10^{-3}
Iodine 125	Soluble	5×10^{-9}	4×10^{-5}
	Insoluble	2×10^{-7}	6×10^{-3}

Bioassay will also be conducted for personnel working with radioactive I-125 or I-131 and wearing respirators if for any reason the I-125 or I-131 concentration and/or the duration of exposure are unknown.

2. Participation.

All workers handling radioactive iodine in amounts exceeding those in TABLE 1 and others within a few meters and in the same room where the process is carried out shall be monitored.

3. Types of bioassays to be performed.

a. **Baseline.** (Pre-employment or preoperational) Within two weeks prior to beginning work with amounts exceeding those set forth in TABLE 1.

b. **Routine.** At frequencies specified in item 4.

c. **Postoperational and other terminal conditions.** A bioassay is required within the last two weeks of possible exposure to I-125 or I-131 (in amounts exceeding those set forth in TABLE 1) when operations are being discontinued or when the worker is terminating activities with potential exposure to these radionuclides.

d. **Diagnostic.** Followup bioassay is required within two weeks of any measurement exceeding levels given as action points in item 5 in order to confirm the initial result and, in the case of a single intake, to allow an estimate of the effective half-life of radioiodine in the thyroid.

4. Frequency.

a. **Initial Routine.** A bioassay is required between 6 and 72 hours following initial possible exposure to I-125 or I-131 where bioassay is required as set forth in items 1 and 2, and every two weeks thereafter as long as conditions described in items 1 and 2 exist. When work with radioactive iodine is less frequent than every two weeks a bioassay is required between 6 and 72 hours of the end of the work period when radioactive iodine is handled.

b. **After three months.** When a periodic measurement frequency has been selected in accordance with 4.a. the bioassay may be changed to quarterly if, after three months, all of the following conditions are met.

i. The average thyroid burden for each individual assayed in the working area was less than 0.12 μCi of I-125, less than 0.04 μCi of I-131, and less than the corresponding proportionate amount of a mixture of these nuclides during an initial three month period.

ii. The quarterly average radioiodine concentration (μCi/ml) in air breathed by any worker (as obtained when measurements of radioiodine concentrations in air are required) does not exceed 25% of the concentration values for "soluble" iodine given in TABLE 2. When I-131 and I-125 are both present the amounts shall be weighted proportionally.

iii. The working conditions during the three month period, with respect to the potential for exposure, are representative of working conditions during the period in which the quarterly bioassay frequency will be employed, and there is no reasonable expectation that the criteria set forth in 4.b.i. and 4.b.ii. above will be exceeded.

c. **Other.** Between 10 and 48 hours after use of respiratory protective devices or protective clothing to limit exposure as specified in item 1 second paragraph.

5. Action points and corresponding actions.

a. **Biweekly or more frequent measurements.**

i. Whenever the thyroid burden at the time of measurement exceeds 0.12 μCi of I-125 or 0.04 μCi of I-131, the following actions should be taken.

a) An investigation of the operations involved, including air and other in-plant surveys to determine the causes of exposure and to evaluate the potential for further exposures.

b) If the investigation indicates that further work in the area might result in exposure of a worker to concentrations that would cause the limiting intakes established in 20.103 of 10CFR Part 20 (See TABLE 2) to be exceeded, the worker shall be restricted from further exposure until the source of exposure is discovered and corrected.

c) Corrective actions will be implemented to eliminate or lower the potential for further exposures.

d) A repeat bioassay will be taken within two weeks and the measurement results evaluated within 24 hours after the measurement in order to confirm the presence of internal radioiodine and to obtain an estimate of the effective half-life.

e) Reports or notification as required by paragraphs 20.405, 20.408 and 20.409 of 10CFR Part 20 or as required by conditions of the license pursuant to paragraph 20.108 of 10CFR Part 20 shall be filed.

ii. If the thyroid burden at any time exceeds 0.5 μCi of I-125 or 0.14 μCi of I-131, the following actions shall be taken:

a) Carry out steps described in 5.a

b) Refer the case to the appropriate medical/health physics consultation for recommendations regarding therapeutic procedures that may be carried out to accelerate removal of radioactive iodine from the body.

c) Carry out repeated measurements at approximately 1 week intervals at least until the thyroid burden is less than 0.12 μCi of I-125 or 0.04 μCi of I-131. If there is a possibility of longer term compartments containing I-125 or I-131 that require evaluation, continue measurements as long as necessary to ensure that appreciable exposures to these other compartments do not go undetected.

b. **Quarterly Measurements.** Carry out actions at levels indicated under item 5.a.i. If measurements and surveys indicate an appreciable likelihood that a worker will receive further exposures exceeding criteria set forth in 4.b.i. and 4.b.ii., biweekly or more frequent bioassays will be reinstituted.

6. **Measurement techniques and instrument calibration.**

Radioactive iodine in thyroid burdens will be counted in-vivo using an unshielded NaI(T1) detector touching the skin surface of the neck over the thyroid gland. The pulses from the detector are routed through a photomultiplier tube, a preamplifier, a linear amplifier, a single (or multi-channel) analyzer and then to a scalar. When the single channel analyzer is used the "window" is set for the 0.03548 I-125 gamma or the 0.36447 I-131 gamma as required. The window settings are set to maximize the net count/background ratio in the region of the photoelectric peak.

Calibration of the counting system shall be done by counting a neck phantom with a known amount of I-125 or I-131 (or calibrated simulator) situated in the thyroid geometry. The neck phantom consists of a 6" high, 5" diameter plexiglass tube sealed at one end and a holder for a sealed vial or radioactive iodine at the thyroid position. The phantom is filled with water after the radioactive iodine is in place and the phantom is counted in a geometry similar to a patient. The instrumentation shall have a minimum detectable limit not to exceed 1 nanocurie as a thyroid burden where the minimum detectable limit is defined to be a count rate which exceeds the background by more than three standard deviations of the background count rate.

7. Provision for introducing in-vivo counting for laboratory personnel presently using radioactive iodine and where bioassay has not previously been required.

Laboratory workers in laboratories using I-125 will have preliminary baseline counts performed by May 19, 1978. These baseline counts will be compared with baseline counts for non-users of radioisotopes. Individuals showing elevated count rates significantly above the average baseline for non-users will be counted at least biweekly when not exposed to radioactive iodine to determine the effective half-life and to revise the baseline count rate. If any measurements are obtained indicating action levels specified in item 5 are exceeded, the appropriate corresponding actions will be carried out.

B. Methods and Frequencies for Conducting Laboratory Surveys

1. Frequency of Survey

Laboratories are classified as low, moderate, or high hazard according to the type and amount of isotope used. The minimum frequency of laboratory surveys is determined by this classification modified by the use patterned after the *Recommendation of the International Commission on Radiological Protection – Report of Committee V:* Pergamon Press, New York, N.Y. (1965)

a. Classification of Laboratory Areas for Survey Frequency Determination

Radionuclide Group**	Low	Medium	High
1	<10 μCi	10 μCi – 1 mCi	>1 mCi
2	<1 mCi	1 mCi – 100 mCi	>100 mCi
3	<100 mCi	100 mCi – 10 Ci	>10 Ci
4	<10 Ci	10 Ci – 1000 Ci	>1000 Ci

**From Table I

b. Frequency of Surveys

1) Low level areas – Not less than once per month.

2) Medium level areas – Not less than once per week.

3) High level areas – Not less than once per day.

c. Modification of Survey Frequency

The amounts of activity in each classification category shall be multiplied by the following factors, based on the type of laboratory activity, to determine the survey of frequency requirements.

Modifying Factor	Multiplication Factor
1. Simple storage.	100
2. Very simple wet operations (e.g. preparation of aliquots of stock solutions).	10
3. Normal chemical operations (e.g. analysis, simple chemical preparation).	1
4. Complex wet operations (e.g. multiple operations, or operations with complex glass apparatus).	.1
5. Simple dry operations (e.g. manipulation of powders) and work with volatile radioactive compounds.	.1
6. Exposure to non-occupational persons.	.1
7. Dry and dusty operations.	0.01

Example: A laboratory in which 10 mCi of a Group 2 radionuclide is used in normal chemical operation should be surveyed on a MEDIUM frequency. If simple storage is done, then a LOW frequency is adequate. (The NEW LOW Range = <1 mCi X 100 = <100 mCi.) If a dry grinding operation is done a HIGH frequency is required. (The NEW HIGH Range = >100 mCi X 0.01 = >1.0 mCi.)

2. Acceptable Limits of Exposure

a. Non-controlled area

Personnel must not receive >2 m in any one hour, or >100 m in 7 consecutive days, or 500 m in any one year. Radiation levels in areas accessible to visitors shall be restricted so that the total visitor exposure during all visits in any twelve consecutive months is <100 m.

b. Controlled area

Exposure rate limits do not apply. A visitor should not exceed 100 mrem per admission and must not exceed 200 mrem per admission. Exposure limits for approved users are set forth in item II.A.

Laboratories approved for the use of unsealed radioisotopes will be independently inspected at least every six months by personnel from the Radiation Safety Office. This inspection includes a survey for radioactive contamination and a check to see that NRC and University regulations are being followed.

C. Personnel Contamination

Contamination external to the body should be detected and removed as rapidly as practicable to prevent its spread to other surface areas, or to the interior of the body. The following procedures are encouraged to reduce the risks of external contamination:

1. Incoming shipments of radioisotopes should be checked for breakage and external contamination when first opened.

2. Protective apparel (aprons, gloves, etc.) should be available to, and used by, radiation workers.

3. Secondary containers lined with absorbent material should be used when radioactive materials are being handled.

4. A radiation worker's hands and clothing should be thoroughly surveyed after handling potentially contaminated materials.

D. Internal Contamination

The following precautions are to be taken when working with unsealed radioactive materials in order to prevent the intake of these materials into the body:

1. Foods and beverages are not to be consumed in areas containing unsealed radioactive materials.

2. Smoking is not permitted in laboratories using radioactive materials.

3. All pipetting of radioactive materials shall be done by mechanical methods, i.e. not by mouth.

4. A fume hood having a face velocity of 75 to 200 feet per minute should be used for handling any radioactive material which may become airborne.

Bioassay procedures other than urine samples may be required when larger than normal quantities of unsealed radioactive material are handled depending on the isotope and the amount of activity. Such situations will be evaluated by the RSO and the Radiation Safety Committee on an individual basis.

III. OPERATING PROCEDURES

A. Program Applications and Approvals

An application for use of radioactive material is required for all new users, new programs, and new facilities. The current form (RS-1) and other directions, etc. required by the Radiation Safety Committee are available through the RSO. The application is reviewed by the RSO, who submits it with comments and/or recommendations to the Radiation Safety Committee for action. The applicant may be asked to attend the meeting. (All Radiation Safety Committee meetings are open to those wishing to attend.)

The RSO may issue temporary approval pending a Radiation Safety Committee meeting.

Applications are approved for specific isotopes, types of experiments, and periods of time. Major revisions in a user program requires an amended or new application.

Applications must contain all of the information that may be needed by the committee to evaluate both the legal and safety aspects of the application; in particular, the following items should be included:

1. Pertinent training and experience of a new user applicant. Minimum requirements for principal and independent users are:

   a. A college degree at the bachelors level, or the equivalent training and experience, in the physical or biological sciences, or in engineering.

   b. At least 40 hours of training and experience in the safe handling of radioactive materials, and in the characterisitcs 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 by-product material used.

2. Names and qualification of all persons to be involved in the proposed program.

3. Types and quantities of radioactive materials to be used (or description of a radiation generating machine and its output, if appropriate).

4. Purpose of the proposed program with regard to teaching research, etc.

5. Specific locations and facilities to be utilized (e.g. buildings, rooms, storage facilities, hoods available, etc.).

6. Instruments and techniques to be used to evaluate exposures or contamination.

7. Types and quantities of wastes expected, and proposed methods of waste packaging and disposal.

8. Administrative controls and provisions for record keeping, material control and accounting, and management review to assure safe operation.

B. Acquisition of Radiation Sources

All orders for radioactive materials or radiation sources must be approved in advance by the RSO. This requirement also applies to *no-charge* and *generally* licensed acquisitions. All orders will be checked by the RSO to verify that they are in accord with authorizations of the Radiation Safety Committee and the conditions of the University's NRC by-products materials license. All radioactive shipments are required to be delivered to the Radiation Safety Office where they are leak tested, checked against the original order, etc. and if everything is in order delivered to the user.

All transactions of radioactive material from one principal user to another must be processed through the Radiation Safety Office to ensure that NRC and University regulations are satisfied. Radioactive shipments off campus must also be processed through the Radiation Safety Office.

C. Handling, Labeling and Storage of Radiation Sources

For convenience, the term "Control Unit" is used in this manual to refer to the activity, in microcuries, that determines the labeling and waste disposal requirements for any radionuclide. The values of the Control Unit for various radionuclides are listed in Table II.

The following signs or labels, carrying the approved radiation symbol, are to be placed on rooms, containers, etc. as indicated:

CAUTION – RADIOACTIVE MATERIAL – for each room or container in which is used, transported or stored a combined quantity of radioactive material greater than one control unit (see Table II).

CAUTION – RADIATION AREA – for areas in which the exposure rate is, or could be, from 2 to 100 mrem/hour.

CAUTION – HIGH RADIATION AREA – for areas having actual or potential exposure rates greater than 100 mrem/hour.

All labels or individual containers of radioisotopes shall also include the type and quantity of nuclide, date of assay and should include the name of the responsible user. (Containers used transiently while the user is present are exempt from these labeling requirements.)

General guidelines for work with radioactive materials are shown in Table III.

D. Training and Experience of Students Before Allowing Use of Radioactive Materials.

Students under 18 are not permitted to work with radioisotopes in amounts exceeding that generally licensed by the NRC without specific approval of the Radiation Safety Committee.

No previous training or experience is necessary in laboratory classes designed and used to teach radiation safety, radioactive principles, or radioactive techniques. Students may be permitted to work with unsealed radioactive material as a supervised user if:

1. Students can be classified as independent users if they can demonstrate the equivalent of 40 hours of training and experience in the safe handling of radioactive materials, 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 form of by-product material used. Independent users must also be familiar with established administrative controls and provisions related to procurement of by-product material, procedures, record keeping, material control and accounting, and management review to assure safe operation as set forth by the principal user.

2. The student is under the direct supervision of a principal user, (i.e.) a supervised user.

Students may be permitted to work with sealed radioactive sources incorporated into measurement instruments without direct supervision of an independent or principle user provided:

1. The student has at least four hours of training on safe handling of radioactive materials, characterization of ionizing radiation, units of radiation dose and quantities, radiation detection instrumentation, and biological hazard of exposure to radiation appropriate to the type and forms of by-product material used.

2. The student has had "hands on training" in the proper use of the instrument equivalent to at least one-half day of field or laboratory use.

3. Written instructions on operating and emergency procedures are immediately available.

4. The student does not work without another person in the vicinity available for assistance.

E. **Disposal of Radioactive Wastes**

Small quantities of radioactive wastes may be disposed of to the sanitary sewer system provided that they are soluble or readily dispersible in Water. The University, as the licensee, is limited to a total of 10 control (see Table II) units per day. Written plans for the disposal of radioactive materials to the sewer system must be submitted to the RSO prior to any release of such materials to the sewer and upon approval no more than *one* control unit may be released by an individual user per day.

Most radioactive wastes are to be collected for burial. The University is authorized to bury up to 1000 control units at one time, with 27 burials per year authorized. Collection methods and containers should be approved by the RSO prior to use.

The maximum quantities of radioactivity that can be disposed of directly by the University are one curie per year to the sewer and one cuire per year by burial. Materials that exceed any of the preceding limits may be appropriately packaged and transferred to a commercial waste handler licensed by the USNRC. Arrangements for this service are to be made with the RSO.

For purposes of establishing the disposal limits for known mixtures or radioisotopes, the fractional contribution of each isotope must be determined. The calculation is performed as follows:

$$\text{Number of control units} = \frac{a}{A} + \frac{b}{B} + \frac{c}{C} + \cdots$$

where: A, B, C, etc. represent the activity in microcuries of one control unit for each isotope of interest as listed in Table II, and: a, b, c, etc. represent the activity in microcuries of each isotope for which disposal is planned.

F. **Closing Radioactive Accounts**

One time projects, principal users who discontinue the use of radioactivity, and principal users who leave the University are required to close out the radioactive account with the RSO. All radioactivity left in the account must be processed through the Radiation Safety Office. A laboratory survey for radioactive contamination will be performed by the RSO.

G. **Accidents Involving Ionizing Radiation**

Proper planning of the use of ionizing radiation should prevent accidents. When accidents do happen the following procedures should be followed.

1. Check for contamination of individuals. If contamination is found or suspected decontaminate as quickly as possible taking into account the amount of contamination, type of radiation and the possibility of internal contamination.

2. Take steps to prevent the spread of contamination including:

   a. Shut off ventilation system if there is a possibility of airborne contamination.

   b. Prevent ingress into the contaminated area by any unnecessary personnel.

   c. Keep any contamination localized.

3. Notify the Radiation Safety Office and the principal user responsible for the laboratory as soon as possible. Telephone numbers are listed on the radiation sign for the laboratory.

IV. RECORD REQUIREMENTS

A. Authorizations and Qualifications

All actions of the Radiation Safety Committee pertaining to applications, qualifications and authorizations of users for work with radiation sources are to be recorded in the minutes of committee meetings and maintained as permanent records. In addition, the actual applications and statements of qualifications are to be maintained, together with descriptions of authorized programs in a central file under the supervision of the RSO.

B. Inventories and Disposals

Each principal user must ensure that complete records are maintained of all radioactive materials used under his jurisdiction. The inventory records must identify the materials accurately and account for all receipts, disposals and actual amount on hand at any time. A central inventory of all materials acquired under the University's license is to be maintained by the RSO.

C. Surveys and Assays

A permanent record is to be maintained by each principal user of all surveys and assays conducted of facilities, materials and personnel under his jurisdiction. Copies of these items are also to be provided to the RSO for inclusion in the central files.

D. Exposures

Exposure data obtained from external personal monitoring devises and from bioassay procedures are to be maintained for all radiation users and any other persons exposed to radiation sources (except for medical exposures). These records are to be kept in a central file by the RSO. Any individual may obtain a summary of his own exposure record annually upon written request of the RSO.

V. MISCELLANEOUS

TABLE I – Hazard From Absorption Into the Body
(adapted from NBS handbook 92)

	Low Level		Medium Level		High Level	
Group 1. Very High Hazard.	10μc	100μc	1mc	10mc	100mc	1c	10c
Group 2. High Hazard.	10μc	100μc	1mc	10mc	100mc	1c	10c
Group 3. Medium Hazard.	10μc	100μc	1mc	10mc	100mc	1c	10c
Group 4. Low Hazard.	10μc	100μc	1mc	10mc	100mc	1c	10c

	Low Level	Medium Level	High Level
Group 1. Very High Hazard.	*Pb^{210}, Po^{210}, *Ra^{226}, *Ra^{228}, Ac^{227}, Th^{228}, Th^{230}, Np^{237}, Pu^{238}, Pu^{239}, Pu^{240}, Pu^{241}, Pu^{242}, *Am^{241}, Cm^{242}		
Group 2. High Hazard.	*Na^{22}, Ca^{45}, *Sc^{46}, *Co^{60}, Sr^{89}, *Ru^{106}, $^{95}Tb^{124}$, $^{95}Tb^{131}$, *Cs^{137}, *Ce^{144}, *Eu^{154}, *Tm^{170}, Bi^{210}, At^{211}, Ra^{224}, U^{233}		
Group 3. Medium Hazard.	C^{14}, *Na^{24}, Si^{31}, P^{32}, S^{35}, Cl^{36}, *K^{42}, Sc^{47}, *V^{48}, *Cr^{51}, *Mn^{54}, *Mn^{56}, Fe^{55}, *Fe^{59}, *Co^{58}, *Zn^{65}, *Ga^{72}, *As^{76}, *Rb^{86}, Sr^{89}, Y^{90}, Y^{91}, *Zr^{95}, *Nb^{95}, *Mo^{99}, *Ru^{103}, *Rh^{105}, Pd^{109}, Ag^{108}, Ag^{111}, *Cd^{109}, *Sn^{113}, *Te^{127}, *Te^{129M}, *Ba^{140}, *La^{140}, Pr^{143}, Pm^{147}, Sm^{151}, *Ho^{166}, *Tm^{170}, *Lu^{177}, *Re^{186}, *Ir^{190}, Ir^{192}, *Pt^{191}, *Pt^{193}, *Au^{196}, *Au^{198}, *Au^{199}, *Tl^{200}, *Tl^{201}, Tl^{202}, Tl^{204}, *Pb^{203}, Rn^{220}, *Rn^{222}, U^{238}		
Group 4. Low Hazard.	H^3, *Be^7, C^{14}, F^{18}, Ni^{59}, Zn^{69}, Ge^{71}, U^{238}, Natural Thorium, Natural Uranium, Noble Gases.		

*Emits gamma radiation in significant amounts.

TABLE II

Control Units for Radionuclides

The number of microcuries listed for each nuclide constitutes one (1) control unit for that nuclide for determination of labeling requirements and for waste disposal calculations.

Material	Microcuries
Americium-241	0.01
Antimony-122	100
Antimony-124	10
Antimony-125	10
Arsenic-73	100
Arsenic-74	10
Arsenic-76	10
Arsenic-77	100
Barium-131	10
Barium-140	10
Bismuth-210	1
Bromine-82	10
Cadmium-109	10
Cadmium-115m	10
Cadmium-115	100
Calcium-45	10
Calcium-47	10
Carbon-14	100
Cerium-141	100
Cerium-143	100
Cerium-144	1
Cesium-131	1,000
Cesium-134m	100
Cesium-134	1
Cesium-135	10
Cesium-136	10
Cesium-137	10
Chlorine-36	10
Chlorine-38	10
Chromium-51	1,000
Cobalt-58m	10
Cobalt-58	10
Cobalt-60	1
Copper-64	100
Dysprosium-165	10
Dysprosium-166	100
Erbium-169	100
Erbium-171	100
Europium-152 9.2h	100
Europium-152 13yr	1
Europium-154	1
Europium-155	10
Fluorine-18	1,000
Gadolinium-153	10
Gadolinium-159	100
Gallium-72	10
Germanium-71	100
Gold-198	100
Gold-199	100
Hafnium-181	10
Holmium-166	100
Hydrogen-3	1,000
Indium-113m	100
Indium-114m	10
Indium-115m	100
Indium-115	10
Iodine-125	1
Iodine-126	1
Iodine-129	0.1
Iodine-131	1
Iodine-132	10
Iodine-133	1
Iodine-134	10
Iodine-135	10
Iridium-192	10
Iridium-194	100
Iron-55	100
Iron-59	10
Krypton-85	100
Krypton-87	10
Lanthanum-140	10
Lutetium-177	100
Manganese-52	10
Manganese-54	10

TABLE II continued

Material	Microcuries
Manganese-56	10
Mercury-197m	100
Mercury-197	100
Mercury-203	10
Molybdenum-99	100
Neodymium-147	100
Neodymium-149	100
Nickel-59	100
Nickel-63	10
Nickel-65	100
Niobium-93m	10
Niobium-95	10
Niobium-97	10
Osmium-185	10
Osmium-191m	100
Osmium-191	100
Osmium-193	100
Palladium-103	100
Palladium-109	100
Phosphorus-32	10
Platinum-191	100
Platinum-193m	100
Platinum-193	100
Platinum-197m	100
Platinum-197	100
Plutonium-239	0.01
Polonium-210	0.01
Potassium-42	10
Praseodymium-142	100
Praseodymium-143	100
Promethium-147	10
Promethium-149	10
Radium-226	0.01
Rhenium-186	100
Rhenium-188	100
Rhodium-103m	100
Rhodium-105	100
Rubidium-86	10
Rubidium-87	10
Ruthenium-97	100
Ruthenium-103	10
Ruthenium-105	10
Ruthenium-106	1
Samarium-151	10
Samarium-153	100
Scandium-46	10
Scandium-47	100
Scandium-48	10
Selenium-75	10
Silicon-31	100
Silver-105	10
Silver-110m	1
Silver-111	100
Sodium-24	10
Strontium-85	10
Strontium-89	1
Strontium-90	00.1
Strontium-91	10
Strontium-92	10
Sulphur-35	100
Tantalum-182	10
Technetium-96	10
Technetium-97m	100
Technetium-97	100
Technetium-99m	100
Technetium-99	10
Tellurium-125m	10
Tellurium-127m	10
Tellurium-127	100
Tellurium-129m	10
Tellurium-129	100
Tellurium-131m	10
Tellurium-132	10
Terbium-160	10
Thallium-200	100
Thallium-201	100
Thallium-202	100
Thallium-204	10
Thorium (natural)	50
Thulium-170	10
Thulium-171	10
Tin-113	10

TABLE II continued

Material	Microcuries	Material	Microcuries
Tin-125	10	Yttrium-91	10
Tungsten-181	10	Yttrium-92	100
Tungsten-185	10	Yttrium-93	100
Tungsten-187	100	Zinc-95	10
Uranium (natural)	50	Zinc-69m	100
Uranium-233	0.01	Zinc-69	1,000
Uranium-234		Zirconium-93	10
Uranium-235	0.01	Zirconium-95	10
Vanadium-48	10	Zirconium-97	10
Xenon-131m	1,000		
Xenon-133	100	Unidentified radioactive materials or any of the above in unknown mixture	0.1
Xenon-135	100		
Ytterbium-175	100		
Yttrium-90	10		

TABLE III – Radioactive Materials Handling Guide

Activity levels	LOW (Up to 10 Control units)	MEDIUM (10-1000 Control Units)	HIGH (Over 1000 Control Units)
Application	General precautions applicable to all work with radioactive materials.	Precautions required in addition to those of low level work.	Protection requirements in addition to those for medium level work.
Work Area Control	Confine work to a reasonable small area. Use traps with absorbent liners. Keep foods away.	Work in fume hood. Restrict personnel access. Make frequent contamination surveys.	Area must be restricted. Work only in approved enclosures.*
Personal Contamination Control	Wear lab coat or apron and gloves. Use mechanical pipettes. Check hands and clothes for contamination before leaving.	Use disposable gloves and remove them carefully. Sampling for airborne contamination may be necessary.*	Special protective clothing, shoe covers, respirators, etc. may be required.* Check hands and clothes frequently for contamination.
Personal Exposure Monitoring	Film badges may be required* except for low energy β emitters (e.g. ^{3}H, ^{14}C, and ^{35}S).	Measure exposure rates periodically. Bioassay procedures may be required.*	Measure exposure rates frequently. Special monitoring devices, e.g. pocket chamber dosimeters, may be required.*
Storage and Labeling	Keep containers sealed and in secondary containers. Mark containers with radiation symbol,* isotope, activity, date and preferably responsible user.	Ventilated and shielded storage may be necessary. Work and storage locations require radiation labels.* Exposure rates required on some labels.	Return unused materials to specially designated storage location immediately after use. Special radiation hazard signs may be required.*
Waste Disposal	Use separate containers for radioactive waste.* Use only approved methods for disposal. Maintain accurate records of all disposals.	Obtain advance authorization for disposal methods.* Special waste containers and waste storage areas may be required.*	Commercial disposal service may be required.* Determine waste activity levels by specific assay.

*Advice and/or services available from the Radiation Safety Office.