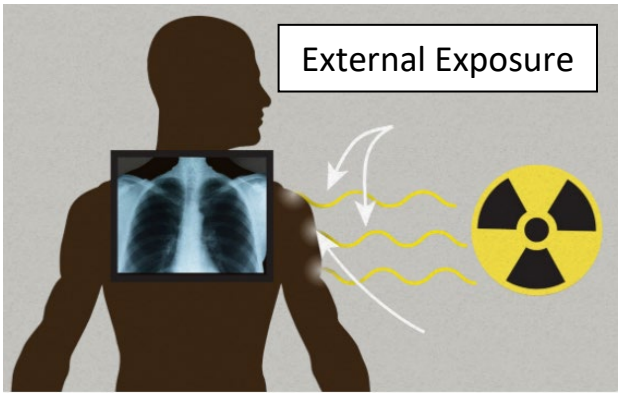
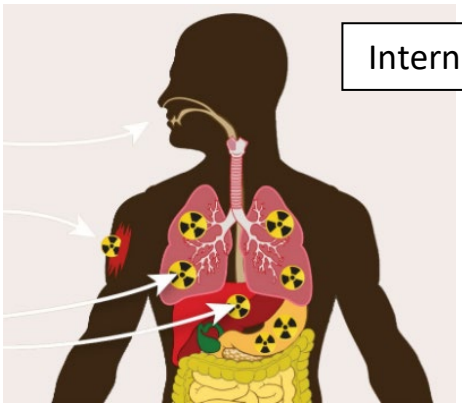
Section B-5
Personnel Monitoring

Individuals working with ionizing radiation can receive radiation dose either externally (e.g., radiation emitted from radioactive material or a device outside the body) or internally (from radioactivity deposited within the body due to ingestion, inhalation, or absorption of radioactive material). To determine the external radiation dose personnel monitoring devices (dosimeters or "**radiation badges**") are used, while **bioassays** are used to determine internal radiation dose.





A. External Monitoring

1. Who Must be Monitored?

Radiation dosimeters (e.g., "badges") monitor radiation exposure from external sources of radiation and radioactive material. State regulations require that the licensee (e.g., UNMC) must monitor exposures to radiation and radioactive material at levels sufficient to demonstrate compliance with the occupational regulatory dose limits. At a minimum, the following individuals must be monitored:

a. Adult workers likely to receive an external radiation dose, in

one year, in excess of 10% of the occupational dose limits, summarized in the table below:

Radiation Dose	Monitoring Required if Annual Dose Exceeds:	Annual Dose Limit
Whole Body Dose (DDE)	500 mrem	5000 mrem
Lens of Eye (LDE)	1500 mrem	15,000 mrem
Extremity (SDE-ME)	5000 mrem	50,000 mrem
Skin (SDE-WB)	5000 mrem	50,000 mrem

b. Declared Pregnant Worker (DPW), a woman who has voluntarily declared in writing of her pregnancy, likely to receive during the entire pregnancy, from radiation doses external to the body, a deep dose equivalent in excess of 100 mrem.

c. Minors (< 18 years old) are required to be monitored if likely to receive in one year from external sources, a DDE in excess of 100 mrem, LDE in excess of 150 mrem, or a SDE (skin or extremity) in excess of 5000 mrem. **NOTE:** Nebraska law does not allow minors to work in “hazardous” jobs which include work with radioactive material.

d. Various users/operators of x-ray producing devices (refer to Section D).

Historical data shows that most UNMC radiation workers never approach values which require personnel monitoring. The majority of the researcher workers receive less than 10 mrem annually and very few exceed 100 mrem. Although not required, it is recommended that all individuals working with radioactive material wear dosimetry. The exception is work solely with very low energy beta emitters (beta

emitters with a maximum energy less than 250 keV, such as H-3, C-14, S-35, cannot penetrate the dead layer of the skin) or the use of very low amounts of radioactivity.

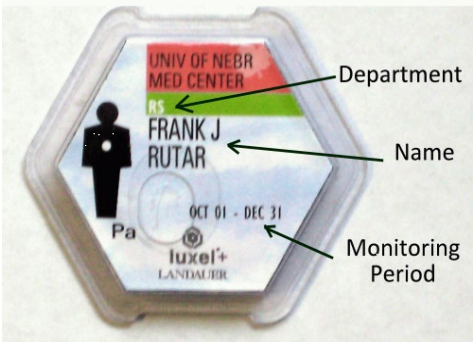
Non-Radiation Workers
Non-radiation workers may also request monitoring if they have a concern regarding radiation exposure

2. Types of Radiation Badges

UNMC utilizes Landauer, Inc., an accredited dosimetry company to provide and process radiation dosimeters. It is important to remember that dosimetry only measures external radiation exposure and offers no protection from radiation.

a. Whole Body Dosimeter (Whole Body Badge)

To monitor exposure at UNMC workers are issued a whole body dosimeter (often referred to as a "radiation badge"). At UNMC, the Luxel OSL (Optically Stimulated Luminescence) Whole Body Dosimeter is used. This dosimeter utilizes a high purity aluminum oxide crystal that has higher sensitivity and environmental stability over other types of radiation badges used. The Luxel dosimeter can measure gamma/x-ray doses down to 1 mrem and beta exposures down to 10 mrem.



The badge utilizes filters to measure the following dose quantities simultaneously:

Deep Dose Equivalent (DDE) is the dose at a tissue depth of 1 cm and is basically the whole body dose the worker is receiving from external radiation. Because most workers do not receive any internal radiation exposure, the DDE is essentially the worker's TEDE (annual limit of 5000 mrem).

Lens Dose Equivalent (LDE), which is the dose at tissue depth of 0.3 cm and is used to estimate the dose to the lens of the eye (annual limit of 50,000 mrem).

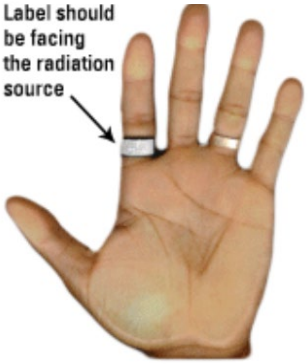
Shallow Dose Equivalent to the Whole Body (SDE-WB) is the dose at a tissue depth of 0.007 cm and is used to estimate the dose to the skin (annual limit of 50,000 mrem).

The whole body radiation badge is worn on the front trunk section of the body and should be worn anytime working with or near radiation sources. It can be worn inside or outside your lab coat. If a lead apron is worn, the badge is worn on the collar area on the outside of the apron. Radiation badges are exchanged semi-annually (Jan. 1st and July 1st) or quarterly (Jan. 1st, April 1st, July 1st, Oct. 1st) depending upon expected radiation exposure.

Because the exposure measured with this badge is your official record of radiation dose, it is important to keep the following in mind:

- Do NOT wear another person's badge.
- Do NOT store your radiation badge near radiation sources.
- If you lose your badge, immediately contact Radiation Safety.
- If your badge becomes damaged, contaminated (e.g., radioactivity is spilled on the badge) or is inadvertently exposed to radiation (e.g., left in an x-ray room), immediately contact Radiation Safety.

b. Extremity Dosimeter ("Ring Badge")



The extremity dosimeter (often referred to as a "ring badge") measures the radiation exposure to the extremities, i.e., the hands. Instead of an OSL, the ring badge uses a TLD (thermoluminescent dosimeter that utilizes a LiF crystal) to measure exposure. It can read doses down to 30 mrem.

It is recommended that a ring badge be used when working with more than 1 millicurie of radioactive higher energy beta, or x/gamma ray emitters (e.g., P-32, P-33, Cr-51, I-131, I-125). The ring badge should be worn on the hand that is likely to receive the highest exposure and comes in a range of sizes (S, M, and L). To avoid contamination, wear the badge inside with the label on the palm side under gloves.

c. Fetal Badge

Any female worker who voluntarily enrolls in the Fetal Monitoring Program will be provided a fetal badge in addition to her regular whole body badge. The badge is identical to the whole body badge except that only the Deep Dose Equivalent (DDE) is measured. The fetal badge is to be worn on the front of the abdomen. If a lead apron is used, the fetal badge should be placed under the apron while the standard whole body badge is worn on the collar outside the apron.

Because of the lower dose limit for fetal exposure, **both the worker's fetal and regular whole body badges are exchanged on a monthly basis.**

3. How to Enroll in the Radiation Badging Program

Each department has a badge coordinator who has information relevant to enrolling in the badge program (contact the Radiation Safety Office if you do not know the badge coordinator for your department). You must first complete the UNMC Radiation Dosimeter Request Form, which is available electronically on the EH&S Radiation Website. Alternatively, you may contact your department's badge coordinator or Radiation Safety for a paper copy of the form.

All individuals must provide a dose history to the Radiation Safety Office if they are likely to receive in excess of 10% of any applicable annual limit. Additionally, any individual who had been badged (or is badged) at another facility during the current calendar year must provide the Radiation Safety Office with pertinent exposure data. This exposure data will allow adjustments to be made so that none of the annual limits are exceeded.

It is each individual's responsibility to notify the badge coordinator or Radiation Safety Office when they terminate work involving radiation exposure or no longer require a radiation badge. If requested, a

termination report will be forwarded.

How to Enroll in the Fetal Monitoring Program

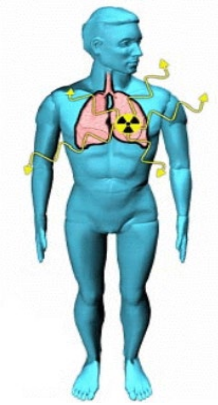
Any pregnant female radiation worker who wishes to voluntarily enroll in the Fetal Monitoring Program needs to complete the Declaration of Pregnancy/Fetal Monitoring form which is available on the EH&S Radiation Safety website. Alternatively, a paper copy of the form can be obtained from the department badge coordinator or Radiation Safety. The form must be signed by both the DPW and her immediate supervisor. The information on this form will allow Radiation Safety Office to calculate the dose received from the date of conception until the date of declaration. Exposure limits for the remaining allowable dose will be set at that time.

A Declared Pregnant Woman (DPW) is limited to **500 mrem for the entire gestation period**. If the dose equivalent to the embryo/fetus is found to be 450 mrem or more when the pregnancy is declared, the DPW is allowed 50 mrem for the remainder of the pregnancy.

The exposure levels for fetal monitoring badges will be evaluated throughout the entire gestation period by the Radiation Safety Office. A fetal ALARA (As Low As Reasonably Achievable) level has been set by the Radiation Safety Office at an exposure of **40 mrem/month**. Should this level be exceeded, the DPW will receive immediate notification.

At the end of the pregnancy, the DPW will contact the Radiation Safety Office to discontinue the fetal monitoring badge. If requested, a Fetal Exposure final report will be generated.

B. Internal Monitoring (Bioassays)



Internal monitoring is conducted to assess the potential intake (ingestion, inhalation, or absorption) of radioactive material into the body. **Bioassays** (direct measurement of radioactive material in the body) is the method of internal monitoring used at UNMC. The bioassay measurements are used to confirm the adequacy of radiological controls and to determine compliance with the occupational dose limits.

There are various types of bioassays that can be used to quantify the amount of activity of a radionuclide internally, including:

a. **Thyroid Bioassay**: Historically, this has been the most commonly performed bioassay at UNMC. Because iodine concentrates in the thyroid, this bioassay is used for individuals working with radioactive forms of Iodine, specifically I-125 and I-131. The gamma radiation emitted by the thyroid is used to estimate the uptake of radioiodine.

b. **Gamma Measurements**: Similar to the thyroid bioassay, a nuclear medicine gamma camera or whole body gamma counter can be used to measure the internal radioactivity in the body if the radionuclide emits gamma radiation in its radioactive decay process.

c. **Excreta Bioassay**: Radioactivity taken up internally will be excreted in the urine or feces. The amount of radioactivity in excreta can be measured using various counters such as a liquid scintillation counter or gamma spectroscopy system.

The type of bioassay and requirements for requiring a bioassay depends upon a number of factors including the radionuclide, chemical form, amount of activity used, and the experimental procedure.

Two separate categories of bioassay measurements determine the frequency and scope of measurements. These are routine measurements

and special monitoring.

1. Routine Bioassays

Routine Measurements include baseline measurements, periodic measurements, and termination measurements. These measurements should be conducted to confirm that appropriate controls exist and to assess dose.

Baseline Measurements

A baseline measurement of radioactive material within the body may be conducted prior to initial work activities that involve work with radioactive material that has the potential of internal contamination or the individual has performed similar type work with that radionuclide.

Periodic Measurements

Depending upon the radionuclide, physical/chemical form (e.g., volatility), and the protocol on how the radioactive material will be used, periodic measurements may be required to demonstrate compliance.

Termination Measurements

When an individual is no longer subject to the bioassay program, because of termination of employment or change in employment status, termination bioassay measurements should be made, when practicable, to ensure that any unknown intakes are quantified.

2. Special Monitoring

Because of uncertainty in the time of intakes and the absence of other data related to the exposure (e.g., physical and chemical forms, exposure duration), correlating positive results to actual intakes for routine measurements can sometimes be difficult. Abnormal and

inadvertent intakes from situations such as inadequate engineering controls, inadvertent ingestion, contamination of a wound, or skin absorption should be evaluated on a case-by-case basis. Circumstances that should be considered when determining whether potential intakes should be evaluated include:

1. The presence of unusually elevated levels of facial and/or nasal contamination.

2. Entry into airborne radioactivity areas without appropriate exposure controls.

3. Operational events with a reasonable likelihood that a worker was exposed to unknown quantities of airborne radioactive material (e.g., loss of system or container integrity).

4. Known or suspected incidents of a worker ingesting radioactive material.

5. Incidents that result in contamination of wounds or other skin absorption.

6. Evidence of damage to or failure of a respiratory protective device.

3. Action Levels for Bioassays

There are two action levels for bioassays: an Evaluation Level and Investigational Level. These action levels are based upon the radionuclide's ALI (Annual Limit of Intake) which is the **intake** (the amount of radioactivity initially taken into the body) that would result in a regulatory dose limit for occupational radiation workers (e.g., Committed Effective Dose Equivalent of 5 rem or Committed Dose Equivalent of 50 rem). The intake is typically calculated by dividing the **uptake** (the amount of radioactivity measured at the

time after initial intake) by the Intake Retention Factor given in NUREG/CR-4884. The intake could also be calculated by determining the effective elimination clearance from several bioassay measurements.

The Evaluation Level is set at an intake of 0.02 ALI and Investigation Level is set at an intake of 0.1 ALI.

If the **Evaluation Level** is exceeded the following actions should be taken:

i. An investigation of the operations involved, including air and other in-facility surveys, should be conducted to determine the causes of exposure and to evaluate the potential for further exposures.

ii. Corrective actions that will eliminate or lower the potential for further exposures should be implemented.

iii. A repeat bioassay should be performed within 24 hours of the last measurement, in order to confirm the presence of intake.

If the **Investigation Level** is exceeded the following actions should be taken;

i. Conduct all the steps for an Evaluation Level.

ii. As soon as possible, refer the case to appropriate medical consultation for recommendations regarding therapeutic procedures that may be conducted to accelerate removal of radioactive material from the body. For radioiodines, this should be done within 2-3 hours after exposure when the time of exposure is known so that any prescribed thyroid-blocking agent may be effective. NCRP Report 161 and the Radiation Emergency Assistance Center/Training Site (REAC/TS) can provide guidance for emergency treatment if a severe intake of radioiodine, or another radionuclide, were to occur.

iii. Conduct repeated measurements as determined by the Radiation Safety Office. The frequency and duration of performing bioassays will be dependent upon the radionuclide's effective half-life in the body. For example, for I-125 or I-131 bioassays should be conducted at approximately 1-week intervals until the thyroid content is less than 1 µCi (37 kBq). If there is a possibility of radioiodine retention in certain parts of the body that requires evaluation, continue bioassay as long as necessary to ensure that appreciable exposures do not go undetected.

iv. If the investigation indicates that further work in the area might result in exposure of a worker to concentrations that would cause the worker to exceed a regulatory dose limit, the worker will be restricted from further work until the source of the exposure is found and corrected.

4. Thyroid Bioassays for I-125 and I-131

Thyroid bioassays are used to assess the intake of I-125 and I-131 compounds that tend to concentrate in the thyroid gland.

Thyroid bioassays are typically performed at the Radiation Safety Office (Shackleford Hall). The procedure involves using a NaI scintillation probe to measure the amount of radioactive iodine in your thyroid (see figure to the right). The procedure normally takes a few minutes to perform. Radiation Safety personnel is available to assist you if needed.

a. Activity at which Thyroid Bioassays are Required

1. A baseline thyroid bioassay should be performed prior

to handling or observing work with volatile radioiodine for the first time.

2. The activity levels at which bioassays are required are given in the table provided on the **Table I** in this section. These quantities apply to both the single quantity handled at any one time or integrated as the total amount of activity introduced into a process over any **three (3) month period**.

3. It should be noted that the table indicates the minimum requirement for performing a thyroid bioassay is recommended that a thyroid bioassay be performed anytime 1 mCi or more of radioiodine is put into process. The bioassay should be performed **6 to 72 hours** after handling to ensure adequate uptake by the thyroid.

4. Individuals may request a bioassay at any time. Bioassays should be performed after spills, contamination events or any abnormal occurrence involving radioioidine.

5. An individual no longer subject to the bioassay program, because of termination of employment or change in employment status should perform a termination bioassay to ensure that any unknown intakes are quantified.

b. Action Levels for Thyroid Bioassays

The limiting ALI's are 60 µCi for I-125 and 50 µCi for I-131. For simplicity, I-131's slightly more conservative ALI will be used for I-125 action levels.

Action Category	Bioassay Action Level for I-125 or I-131
Evaluation Level	Intake = 1 µCi
Investigation Level	Intake = 5 µCi

c. How is the Intake & Thyroid Dose Determined?

The thyroid bioassay is a measurement of the **uptake** in the thyroid, which is the amount of activity measured in the thyroid at some time after the initial intake. The **intake** is calculated by dividing the uptake, by the Intake Retention Factor (NUREG/CR-4884). For I-125 and I-131 the following uptakes correspond to action level intakes:

Uptakes Corresponding to Action Levels		
Time of Bioassay (Hours after Intake)	Evaluation Level (Thyroid Intake = 1 uCi)	Investigation Level (Thyroid Intake = 5 uCi)
6 hrs	**I-125 = 0.0586 uCi I-131= 0.055 uCi**	**I-125 = 0.293 uCi I-131= 0.275 uCi**
12 hrs	**I-125 = 0.0952 uCi I-131= 0.096 uCi**	**I-125 = 0.476 uCi I-131= 0.480 uCi**
24 hrs	**I-125 = 0.141 uCi I-131= 0.133 uCi**	**I-125 = 0.705 uCi I-131= 0.665 uCi**
72 hrs	**I-125 = 0.175 uCi I-131= 0.142 uCi**	**I-125 = 0.875 uCi I-131= 0.710 uCi**
45 days	**I-125 = 0.0823 uCi I-131= 0.0028 uCi**	**I-125 = 0.412 uCi I-131= 0.140 uCi**

The thyroid dose can be calculated by assuming an intake equal to 1 ALI corresponds to a Committed Dose Equivalent to the Thyroid of 50 rem. The non-stochastic ALI for I-125 is 60 uCi and for I-131 the ALI is 50 uCi.

TABLE I Activity Levels Requiring Bioassay for I-125/I-131		
	**Activity Handled in Unsealed Form Making Bioassay Necessary	
Type of Operation	**Volatile Forms (e.g., compounds where radioiodine is normally bound & are known to release radioiodine when the material is in process)** **Example: NaI Liquid**	**Non-volatile Forms (e.g., activity in process is always chemically bound & processed in such a manner that the iodine remains in a non-volatile form)** **Example: Radioimmunoassay (RIA) kits**
Open Room or Bench	**0.1 mCi**	**1.0 mCi**
Fume Hood	**1.0 mCi**	**10.0 mCi**
Glove Box	**10.0 mCi**	**100.0 mCi**

1. **In operations where reagent containers are opened indoors for simple operations such as pouring liquid solutions, the above table does not apply; bioassays should be performed whenever an individual employee handles in open form (e.g., an open bottle or container) more than 50 mCi of I-125 or I-131 at any one time.**

2. **Operations involving the routine use of I-125 or I-131 in an open room or bench should be discouraged. Whenever practicable, sealed bottles or containers holding more than 0.1 mCi of I-125 or I-131 should be opened at least initially within fume hoods recommended fact velocity or 125 lfpm).**

Example: **If a researcher uses a total of 1 mCi of I-125 NaI (assumed to be volatile) over a three-month period and performs all the work in a fume hood, they would be required to perform a thyroid bioassay.**

5. Urine Bioassays for H-3

Urine bioassays are used to assess the intake of radionuclides that do not exhibit uptake within a particular organ. These compounds are typically cleared from the blood via the kidneys and can be measured in the urine for a finite period following the intake. The most likely scenario would involve substantial amounts of tritium (H-3). Urine bioassays have historically not been required at UNMC.

For tritium, analysis of urine for tritium content has proven to be the most reliable method for determining the concentration of tritium in the body. In most cases, after H-3 will enter the body, it will distribute into body water and will not concentrate. It is eliminated with a biological half-life of 10 to 15 days due to normal turnover of body water.

a. When does a Urine Bioassay Need to be Performed?

1. The activity amounts of H-3 requiring a urine bioassay is provided in the Table II. Contact the Radiation Safety Office if you plan to work with a cumulative H-3 activity of 100 mCi (0.1 Ci) or more in a one-month period. It is recommended prior to working with substantial amounts of H-3 that require a urine bioassay.

2. Urine bioassays may be requested at any time and may also be required following spills, personnel contamination, or other abnormal occurrences.

3. To ensure distribution, a urine bioassay is normally performed 24 hours after handling H-3. The frequency for other radionuclides will be determined by the Radiation Safety Office.

b. Bioassay Action Levels

The ALI for Tritium is 80,000 uCi (80 mCi) which is the intake amount that would result in a Committed Effective Dose Equivalent of 5 rem.

Action Category	Action Level	H-3 Intake
Evaluation Level	Intake = 0.02 ALI	1600 uCi
Investigation Level	Intake = 0.10 ALI	8000 uCi

c. How is the Intake & Dose Determined?

The urine bioassay is a measurement of the **uptake** in body, which is the amount of activity remaining in the body sometime after the initial intake. The **intake** is calculated by dividing the uptake by the Intake Retention Factor (NUREG/CR-4884). For H-3, the following uptakes correspond to action level intakes:

Urine Uptakes Corresponding to Action Levels		
Time of Bioassay (Hrs after Intake)	Evaluation Level (0.02 ALI; 1 Rem CEDE)	Investigation Level (0.10 ALI; 5 Rem to CEDE)
1 Day	H-3 = 61.6 uCi	H-3 = 308 uCi
2 Days	H-3 = 60.2 uCi	H-3 = 300 uCi
10 Days	H-3 = 34.6 uCi	H-3 = 172 uCi

5. Bioassays for Other Radionuclides

Bioassay requirements for other radionuclides will be determined by the Radiation Safety Office on a case-by-case basis.

a. A urine bioassay would be necessary when large activity amounts (> 100 mCi) of methionine, cysteine or trans-labeled sulfur-35 are put into process since these compounds have the potential to be slightly volatile.

b. Urine or fecal bioassays are likely to be used when working with alpha emitting radionuclides. The Intake Retention Factor (NUREG/CR-4884) can be used to estimate the intake and subsequent radiation dose.

c. If there is a useful gamma emitting photon in the radionuclide's decay scheme (including daughter products), the use of a gamma camera in Nuclear Medicine or a whole body counter (e.g., used commonly at Nuclear Power facilities) may be helpful in determining the uptake and effective clearance rate in the body. These parameters can then be used to calculate the internal radiation dose to the individual.

C. Results of Monitoring

All personnel who are provided monitoring (external and/or internal) may contact the Radiation Safety Office at any time to get their radiation exposure history or most current badge readings. In addition, UNMC provides the following exposure history reports:

1. Annual Reports

Each worker who is required to be monitored for radiation dose by regulation is furnished annually a written report of the worker's dose. This written report must include:

a) The deep dose equivalent to the whole body, lens dose equivalent, and shallow dose equivalent to the skin. These doses are typically measured with the worker's whole body badge (e.g., DDE, LDE, SDE).

b) The shallow dose equivalent to the extremities which is typically measured with an extremity ("ring") badge.
c) Any intake of radioactive material and the corresponding radiation dose (committed effective dose equivalent) from this intake. This is determined by performing a bioassay (e.g., thyroid bioassay).
d) The TEDE (Total Effective Dose Equivalent) which is the sum of the effective dose equivalent from external and internal exposures. Typically, this is the DDE from the worker's radiation badge plus the dose from any intake of radioactive material.

Exposure histories at UNMC indicate that UNMC radiation workers are well below the values requiring monitoring and therefore, these annual reports are not required by regulation. However, UNMC currently provides this annual report to each worker who provided a radiation badge. Workers who terminate employment with UNMC will be mailed this annual report if a forwarding address is provided to the Radiation Safety Office or Human Resources.

2. Termination Reports

At the request of a worker who is required by regulation to be monitored and is terminating employment (or has terminated employment), UNMC will provide a termination report regarding the radiation dose received by that worker for the current year. If the most recent results are not available at the time, a written estimate will be provided with a clear indication that this is an estimate. If a worker requests a written report of their doses, it will be provided within 30 days after it is received from the company providing the dosimetry services.

TABLE II
Activity Levels Requiring Bioassay for Tritium (H-3)

Type of Operation[a]	Activity Handled in Unsealed Form Making Bioassay Necessary		
	HTO[b] and Other Tritiated Compounds (Including Nucleotide Precursors)	Tritium (HT or T_2)[c] Gas in Sealed Process Vessels[d]	HTO Mixed with More Than 10 kg of Inert H_20 (e.g., in Reactor Coolant)[e]
Processes in open room or bench with possible escape of tritium from process vessels	0.1 Ci	100 Ci	0.01 Ci/kg
Processes with possible escape of tritium conducted within a fume hood of adequate design, face velocity, and performance reliability	1 Ci	1,000 Ci	0.1 Ci/kg
Processes conducted within glove boxes that are ordinarily closed but with possible release of tritium from process vessels and occasional exposure to contaminated box and leakage	10 Ci	10,000 Ci	1 Ci/kg

a Quantities (<10 kg) of substances containing tritium that are present during operations may be considered to be either the amount processed by an individual at any one time (when accidental intake is more likely) or the amount of activity that entered into the process (throughout) during any one month (when routine handling of repeated batches is the more likely source of exposure).

b HTO is a symbol for a water molecule in which a tritium atom (T) is present in place of a normal hydrogen atom (H).

c A molecule of hydrogen gas contains two hydrogen atoms. Either one of these atoms may be replaced with T to form HT, or two T atoms may combine to form T_2 gas.

d This assumes that adequate air monitoring has established that there is no tritium leakage or that no significant amount of tritium gas can be converted to HTO before intake.

e This column is applicable in place of the previous two columns in cases where tritium can be identified at measurable concentrations in substantial amounts of water or other substances, such as a nuclear power plant. A baseline urine bioassay is required prior to participation in most radiation safety protocol activities. If a urine bioassay is required by the protocol, a second urine bioassay will be requested after the initial experiment.