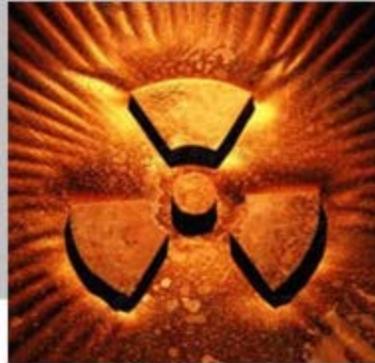




Radiation Safety



RADIATION PROCEDURES MANUAL

Procedure Cover Sheet

Procedure Title: Internal Dosimetry

Procedure Number: RS-11 Rev 0

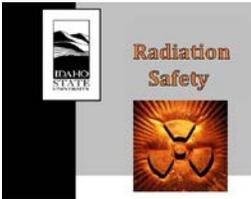
Effective Date: October 12, 2020

Reviewed By: Mason Jaussi
Assistant Radiation Safety Officer

Date: 9-17-2020

Approved By: John Longley
Radiation Safety Officer

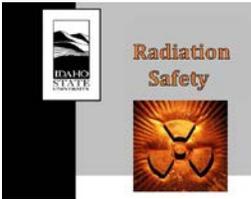
Date: 27-Oct-2020



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1. INTRODUCTION

Idaho State University shall, in accordance with 10 CFR 20.1502 (b), monitor the occupational intake of material by and assess the committed effective dose equivalent to the following three categories of individuals:

- i. Adults likely to receive, in 1 year, an intake in excess of 10 percent of the applicable annual limit on intake (ALI), [500 mrem], in Table 1 of 10 CFR Part 20 - Appendix B;
- ii. Minors likely to receive, in 1 year, a committed effective dose equivalent in excess of 0.1 rem (100 mrem); and
- iii. Declared pregnant women likely to receive, during the entire pregnancy, a committed effective dose equivalent in excess of 0.1 rem (100 mrem).

2. PURPOSE

This procedure specifies the requirements, responsibilities, and methods for performing and reporting internal dosimetry measurements.

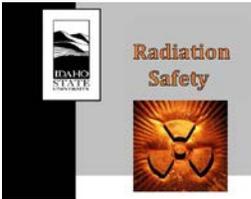
3. SCOPE

Idaho State University demonstrates compliance with the requirements of 10 CFR 20.1502 (b) by performing internal dosimetry measurements, through air sampling or bioassay, for individuals meeting any of the following conditions:

- i. Suspected internal exposure;
- ii. An individual's face has been highly contaminated (>10x removable contamination limits);
- iii. Individual handling dispersible radioactive material greater than 200 times ALI;
- iv. Declared pregnant worker or minor expected to receive at least 100 mrem in a year; and
- v. Individual handling dispersible quantities of radioiodine.

The committed effective dose equivalent will be computed using air sample data in accordance with 10 CFR 20.1204 or through bioassay measurements and the methodology of NUREG-4884. Results will be included in the radiation worker dose record if greater than 10 mrem.

Internal dosimetry measurements for conditions other than those specified above may be required and are at the discretion of the Radiation Safety Officer (RSO).



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4. ROLES AND RESPONSIBILITIES

It is the responsibility of the RSO to include internal monitoring conditions in the Authorized User (AU) permit, if applicable. The RSO and Radiation Safety Department staff have the responsibility to provide bioassay collection materials, technical guidance, and measurement data to the AU and/or researcher.

It is the responsibility of the AU and the researcher to communicate to the RSO if any of the internal monitoring conditions have been met. It is also the responsibility of the AU and/or researcher to provide prompt bioassay samples upon request.

5. REQUIRED MATERIALS

- Air Monitoring
 - Procedure: RS-11 Appendix A
 - RPR 12A – Air Monitoring Workbook
- Radioiodine Assay
 - Procedure: RS-11 Appendix B
 - RPR 12B – Radioiodine Assay Workbook
- Urinalysis Assay
 - Procedure: RS-11 Appendix C
 - RPR 12C – Urinalysis Assay Workbook

6. PROCEDURE

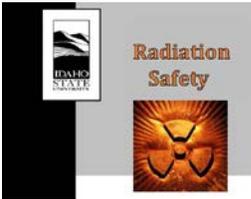
The following sections describe the process for performing internal dosimetry measurements.

6.1. Air Monitoring

Air monitoring will be performed, through Lapel sampling, for any individual handling dispersible radioactive material greater than 200 times ALI. The technical basis for this condition (Condition iii) is provided in Appendix D. The procedure for conducting Lapel sampling is described in Appendix A and measurement data are recorded in the RPR 12A – Air Monitoring Workbook.

6.2. Bioassay

A bioassay is the determination of the type, amount, and possibly location of radioactive material in the human body by direct measurement or by analysis of materials excreted or removed from the body. Bioassays for radioiodine will be performed through direct thyroid measurements. All other bioassays will be performed by methods deemed appropriate by the RSO, but primarily will be through urinalysis.



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6.2.1. Radioiodine Assays

Any person working with radioiodine in quantities greater than or equal to those stated in Regulatory Guide 8.20, Table 2, are required to undergo routine bioassays at intervals deemed appropriate by the RSO. A baseline thyroid measurement will be performed prior to working with these quantities of dispersible radioiodine. The procedure for conducting a thyroid screen is described in Appendix B and the measurement data is recorded in the RPR 12B – Radioiodine Assay Workbook. The results of these assays are maintained by the RSO and are available to the monitored individuals upon request.

If the bioassay result exceeds the evaluation level of 0.02 ALI than the intake will be estimated and a CEDE assigned following the methodology in Reg. Guide 8.9 and NUREG/CR-4884. If the bioassay result exceeds 0.1 ALI, a thorough investigation of the exposure will be made and the RSO will determine appropriate corrective measures.

6.2.2. Urinalysis Assay

A urinalysis screening assay may be performed for radionuclides other than iodine. An initial screening assay is performed to determine whether radioactivity is present in the body, but without precise quantification of activity or dose. If the result of a screening assay indicates the possible presence of radioactive material in the body, at least one additional assay must be performed to verify the result.

If the bioassay result exceeds the evaluation level of 0.02 ALI than the intake will be estimated and a CEDE assigned following the methodology in Reg. Guide 8.9 and NUREG/CR-4884. If the bioassay result exceeds 0.1 ALI, a thorough investigation of the exposure will be made and the RSO will determine appropriate corrective measures.

The procedure for performing a urinalysis assay is provided in Appendix C. Measurement data is recorded in the RPR 12C – Urinalysis Assay Workbook.

7. REFERENCES

10 CFR 20. Standards for Protection Against Radiation. 2019.

USNRC. Acceptable Concepts, Models, Equations and Assumptions for a Bioassay Program. Regulatory Guide 8.9; 1993.

USNRC. Applications of Bioassay for Radioiodine. Regulatory Guide 8.20, Rev. 2; 2014.

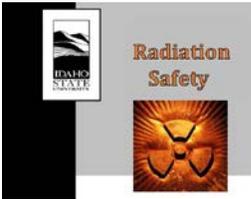
USNRC. Interpretation of Bioassay Measurements. NUREG/CR-4884; 1987.

USNRC. Air Sampling in the Workplace. NUREG-1400; 1993.



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Appendix A – Air Monitoring Procedure



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Air Monitoring Procedure

Air sampling will be performed by lapel sampling for the individuals meeting the conditions specified in RS-11.

Required Materials

- Lapel air sampler with lapel hose attachment
- 37mm filter cassette
- Rotameter – mass flow meter
- Rotameter Calibration Certificate
- RPR-12A – Air Monitoring Workbook

1. Procedure

1.1. Workbook Setup

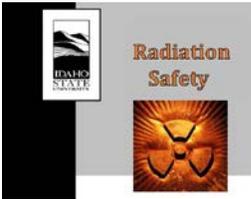
- 1.1.1. Access the RPR12A Workbook
- 1.1.2. Create a copy of the template in a new tab and name it as follows: Facility-Lapel-MONTHDAYYEAR-Initials of worker. Ex. IAC-04032020-MJ
- 1.1.3. Input the Job Description and Sample ID (workers name)
- 1.1.4. Input the Nuclide(s) of interest and associated DAC and ALI from 10 CFR 20 Appendix B.

1.2. Air Sampler Setup

- 1.2.1. Verify the lapel sampler is fully charged and the pump is operating at a flow rate of 2 LPM. Turn of the pump.
- 1.2.2. Place the rotameter in-line between the pump and the filter cassette. Ensure the outlet (not labeled) side of the filter cassette is attached to the hose and the red caps are removed from the filter cassette.
- 1.2.3. Measuring at the center of the ball and record the flow rate on the rotameter. Multiply the recorded flow rate by the calibration factor found on the Calibration Certificate. Record this value in the RPR-12A Workbook.

1.3. Operation

- 1.3.1. Provide the worker with the air sampler and instruct them how to wear the sampler.

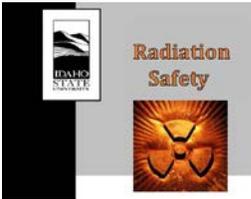


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- 1.3.2. The sampler should be attached to a lab coat pocket or belt with the belt clip attachment. The hose can be run along the workers back and over the shoulder. Tape the hose to the workers shoulder and clip the lapel attachment to the lab coat collar. Verify the filter cassette is in general location of the workers breathing zone.
- 1.3.3. Instruct the worker to turn on the sampler at the beginning of the job, turn off the sampler at the end of the job, and record the sampler start and end times.
- 1.3.4. Upon completion of the sampling. Repeat steps 1.2.2. Record any change in air flow rate and the sampler start and end times in the RPR-12A Workbook.

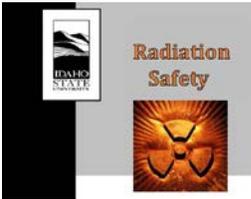
1.4. Air filter counting

- 1.4.1. The air filters are counted on the Radiation Safety's gas-flow proportional counter.
- 1.4.2. Remove the filter from the cassette by twisting the two ends opposite each other.
- 1.4.3. Using tweezers, place the filter in a counting planchet with the fuzzy-side down (shiny side up).
- 1.4.4. Setup the proportional counter with the air filter counting protocol (a 100-minute gross alpha/beta count).
- 1.4.5. After the filter has been counted record the results in the RPR-12C Workbook. For activity below the MDA, enter the MDA values for alpha (dpm) and beta (dpm)
- 1.4.6. If the results yield an activity exceeding the respective MDA, consult the RSO if a recount is needed.



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Appendix B – Radioiodine Assay Procedure



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Iodine-125 Thyroid Screening Procedure

1. INTRODUCTION

This supplement to RS-11, Bioassays describes the steps to perform a thyroid screen of persons working with dispersible radioiodine, specifically Iodine-125 (^{125}I). The thyroid screen is performed with a Ludlum 2200 scaler and Ludlum 44-3 probe. The 44-3 probe is a scintillator specifically designed for detection of ^{125}I and other low energy gamma emitting radionuclides. The 44-3 probe consists of a 2.5 cm x 0.1 cm (1" x 0.4") NaI(Tl) crystal in an aluminum housing. The quality control check of the probe is performed with a ^{129}I source and neck phantom, from which a detection efficiency is derived for ^{125}I . This procedure and derivation are provided in the addendum of this supplement.

2. REQUIRED MATERIALS

- Ludlum 2200 scaler with 44-3 probe
- I-129 check source
- Thyroid phantom
- RPR-12B – Radioiodine Assay Workbook

3. PROCEDURE

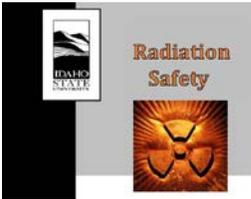
3.1. Quality Control Check

A successful quality control check must be performed on the Ludlum 2200 with the 44-3 probe prior to making any bioassay measurements. The measurement data is recorded in the QC tab of the RPR12B workbook. The procedure is provided in Appendix I of this procedure.

3.2. Thyroid Screening

3.2.1 Perform a background measurement.

- a. The background measurement can be made on the person's lower thigh or the background can be measured using a neck phantom, ideally containing potassium.
- b. Have the person gently hold the 44-3 probe window against their lower thigh and perform a 10-minute count.

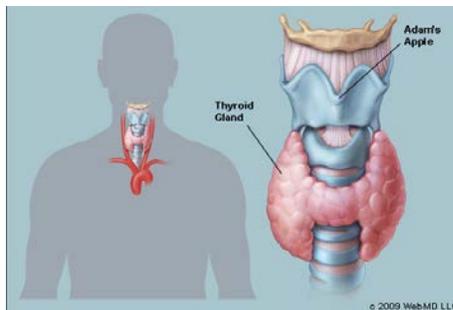


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- c. Record the number of background counts in the RPR 12B workbook, tab RPR12B, under the section titled Screening Assay Data.

3.2.2 Perform the thyroid measurement.

- a. The thyroid is a butterfly shaped endocrine gland located just below the larynx (voice box) as shown below.

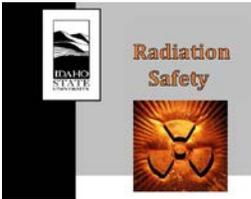


- b. Place the 44-3 probe window in the center of the neck between the Adam's apple and line of the clavicles, as shown in Figure 1, and count for 10-minutes.



Figure 1. Measurement of a subject's thyroid (Youngman 2013).

- c. Record the thyroid counts in the RPR12B workbook under the section titled, Screening Assay Data.
- d. Thank the subject for their compliance and dismiss them. Inform the subject the RSO will discuss the any positive results with them after the data has been evaluated.



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3.3. Data Evaluation

NOTE: If this is a Baseline measurement, prior to the worker handling dispersible radioiodine, follow the steps in Section 3.3.1. If this is a follow-up measurement, proceed to Section 3.3.2.

3.3.1. Baseline Measurement

- a. Fill in the missing information in the RPR12B tab of the workbook and send a copy for the RSO to review and electronically sign.
- b. Once reviewed, place the signed copy of the RPR12B workbook in the radiation workers files under records.
- c. Perform a follow-up measurement within 2 weeks of the worker handling dispersible radioiodine and subsequent measurements every 2 weeks until work with dispersible radioiodine is completed. Add the measurement data to the RPR12B workbook.

3.3.2 Follow-up Measurement

- a. The RPR12B workbook calculates a thyroid activity using the following equation:

$$\text{Activity in thyroid (nCi)} = \frac{(\text{CPM}_{\text{neck}} - \text{CPM}_{\text{thigh}})}{\epsilon}$$

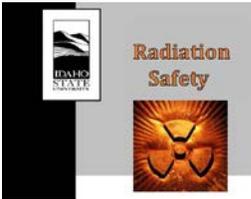
Where,

CPM_{neck} = the count rate of the person's thyroid (cpm)

$\text{CPM}_{\text{thigh}}$ = the background count rate (cpm)

ϵ = the efficiency calculated in the QC check (cpm per nCi of ^{125}I)

- b. The activity in the thyroid is divided by the intake retention fraction (IRF) for the specific day post exposure. The IRF tab shows the IRF table for ^{125}I obtained from IAEA Safety Series No. 37.
- c. Compare the calculated estimated intake (μCi) to the Evaluation level (1 μCi) and Investigation level (5 μCi).
 - i. If the estimated intake is less than the evaluation level than send a copy of the workbook to the RSO to review. Then place the signed copy in the radiation



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- workers files under Records. Proceed with scheduled bioassays as determined by the RSO.
- ii. If the estimated intake exceeds the evaluation level but is less than the investigation level, submit workbook to the RSO for review and further instruction.
 - iii. If the estimated intake exceeds the investigation level contact the RSO immediately to begin an exposure investigation.

Informative References

American National Standards Institute, Inc. Thyroid phantom used in occupational monitoring. McLean, VA: Health Physics Society; ANSI/HPS N13.44-2014; 1984.

Carson D. Differences in efficiencies for I-125 and I-129. Ludlum Measurements, Inc.; 2010.

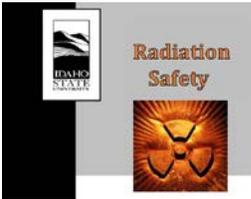
International Commission on Radiological Protection. Individual monitoring for internal exposure of workers. Oxford: Pergamon Press; ICRP Publication 78; Ann ICRP 27(3/4): 1997.

International Commission on Radiological Protection. Nuclear decay data for dosimetric calculations. Orlando, FL: Elsevier; ICRP Publication 107; Ann ICRP 38(3): 2008.

Regulatory Guide 8.20, Applications of bioassay for radioiodine. U.S. Nuclear Regulatory Commission, Washington, DC; 2011.

NUREG/CR-4884, Interpretation of bioassay measurements. U.S. Nuclear Regulatory Commission, Washington, DC; 1988.

Youngman MJ. Practical guidance on thyroid monitoring for radioiodine using hand-held instruments. Health Protection Agency, Centre for Radiation, Chemical and Environmental Hazards. Oxfordshire, UK: HPA-CRCE-044; 2013.



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Appendix I – Quality Control Check of Ludlum 2200 Scaler with 44-3 probe

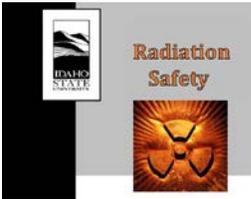
The QC check of the Ludlum 2200 scaler and 44-3 probe is performed with the ^{129}I source and neck phantom. The data is entered into the RPR12B – Radioiodine Assay Workbook under the QC Check tab.

Required Materials

- Ludlum 2200 scaler with 44-3 probe
- Neck phantom
- ^{129}I source
- RPR12B – Radioiodine Assay workbook

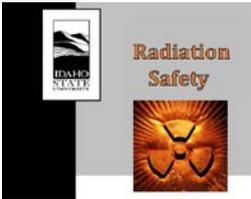
Procedure

- 1) Adjust the settings on the Ludlum 2200 to the following control settings:
 - HV: 195 on potentiometer
 - THR: 100 on potentiometer
 - WIN: 240 on potentiometer
 - Minutes: 10
 - 0.1/1 toggle: 1
 - IN/OUT toggle: IN
- 2) Perform a background measurement
 - a. Place the neck phantom (without the ^{129}I source) in direct contact with the 44-3 probe and count for 10 minutes.
 - b. Record the background counts in the column labeled Phantom Background in the QC tab in the RPR12B workbook.
- 3) Perform a quality control measurement
 - a. Place the ^{129}I source in the phantom
 - b. Align the probe with the (+) on the phantom and count for 10 minutes.
 - c. Record the measured counts in the column labeled Phantom I-129 Source
- 4) Review the results
 - a. Ensure the result in the column Phantom I-129 Net is within the 3-sigma UCL and LCL.
 - b. Ensure the Calculated Efficiency is correct. The efficiency should be roughly 20 cpm per nCi. See Appendix II.



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- 5) Copy the date into the RPR12B tab under, Date QC check performed. All QC data will be automatically populated. Verify the data is correct.
- 6) The instrument is now ready for use.



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Appendix II – ¹²⁹I to ¹²⁵I Efficiency Derivation

For this derivation, we make the following assumptions:

- ¹²⁹I source has an activity (A_S) of 80 nCi;
- The expected CPM with ¹²⁹I source in neck phantom is 900 cpm
- The expected CPM with no source in neck phantom (background) is 31 cpm
- The background measurement is taken on the neck phantom (without the source) or on the thigh of the subject (CPM_{thigh}).

The detection efficiency of ¹²⁵I is calculated from the detection of ¹²⁹I as it emits similar energy gamma-ray and has a much longer half-life. The detection efficiency in units of CPM per nCi of ¹²⁵I is calculated as follows:

$$\text{efficiency (CPM per nCi of } ^{125}\text{I)} = \epsilon = \frac{CPM_{source} - CPM_{background}}{A_S * 0.539}$$

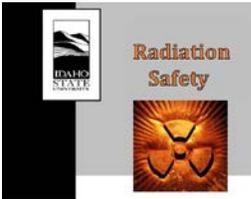
The ratio of photon yields from ¹²⁵I and ¹²⁹I (0.539) is used to derive the detection efficiency for ¹²⁵I. The following section will show the derivation of this value.

	¹²⁵ I	¹²⁹ I
Radioactive Half-Life	59.4 days	1.57x10 ⁷ years
Mean Gamma-ray Energy	35.5 keV	39.6 keV

The photon yield factor is verified as follows:

Photon Emission Products: ¹²⁵ I		Photon Emission Products: ¹²⁹ I	
Energy (keV)	Yield Fraction	Energy (keV)	Yield Fraction
3.770	15.4%	4.110	8.2%
27.202	39.2%	9.458	20.0%
27.472	73.2%	29.779	37.0%
31.000	25.4%	33.600	13.2%
35.492	6.4%	39.581	7.5%
Sum	144.2%	Sum	77.7%

Note: the sum of the photon yield fraction is ignoring the 3.770 and 4.110 keV photon emissions as they are essentially undetectable (Carson 2010).



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The ratio of ^{129}I photon yield to that of ^{125}I is:

$$\frac{77.7\%}{144.2\%} = 53.9\% \text{ or } 0.539$$

$$\text{efficiency (CPM per nCi of } ^{125}\text{I)} = \epsilon = \frac{CPM_{\text{source}} - CPM_{\text{thigh}}}{\text{Source Activity} * 0.539}$$

Conversely, Ludlum instruments (Carson 2010) calculates the photon yield ratio of ^{125}I to that of ^{129}I , yielding a factor 1.86, which is then multiplied by the efficiency for ^{129}I to approximate the efficiency of ^{125}I .

$$\frac{144.2\%}{77.7\%} = 185.6\% \text{ or } 1.86$$

$$\text{efficiency (CPM per nCi of } ^{125}\text{I)} = \epsilon = \frac{CPM_{\text{source}} - CPM_{\text{thigh}}}{\text{Source Activity}} * 1.86$$

A simple test shows that either method is correct as they yield the approximately the same answer

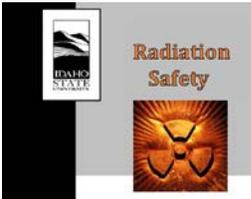
Test 1:

$$\text{efficiency (CPM per nCi of } ^{125}\text{I)} = \epsilon = \frac{896 \text{ cpm} - 31 \text{ cpm}}{80 \text{ nCi} * 0.539} = 20.06 \text{ cpm/nCi}$$

Test 2:

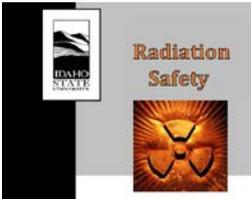
$$\text{efficiency (CPM per nCi of } ^{125}\text{I)} = \epsilon = \frac{896 \text{ cpm} - 31 \text{ cpm}}{80 \text{ nCi}} * 1.86 = 20.11 \text{ cpm/nCi}$$

Ludlum Measurements, Inc. (Carson 2010) published the following expected efficiencies when using the Model 44-3 probe: **^{125}I efficiency is 33% based on ^{129}I efficiency of 18%.**



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Appendix C – Urinalysis Assay Procedure



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Urinalysis Assay Procedure

Required Materials

- Bioassay Container
- RPR-12C – Urinalysis Assay Workbook
- LSC or Gamma-Well Counter

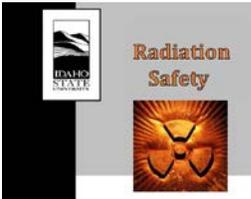
1. Sample Collection

- 1.1. Obtain a bioassay container to provide to the individual.
- 1.2. Assign the container a unique Chain of Custody ID to protect the workers Personal Identifiable Information.
- 1.3. Instruct the worker to provide a urine sample during the workday, approximately 500 to 1000 mL.
 - 1.3.1. The sample will need to be normalized using the methods published in Reg. Guide 8.9 – Section 4.3.1 since it is less than the 1400 mL daily excretion of Reference Man.

2. Derivation of Evaluation Levels

Evaluation levels, as defined in Reg. Guide 8.9, are 0.02 ALI observed in a bioassay sample. Evaluation levels are re-defined as “Investigation Levels and Derived Investigation Levels” in NUREG/CR-4884. Evaluation levels for a select few radionuclides are shown in NUREG/CR-4884 – Section 5.3. A secondary method of calculating these levels is provided in NUREG/CR-4884 Section 5.1, however this method has not been recommended by the NRC. Therefore, the approved method for calculating the Evaluation Level is presented in ANSI/HPS N13.42-1997 – Appendix A and shown below:

- 2.1. Obtain the following data and input into the RPR-12C Workbook – Assay tab:
 - Estimated days post intake
 - ALI for radionuclide of interest
 - IRF value for the day post intake and bioassay compartment of interest (Lungs or Whole-Body). Data tabulated in NUREG-4884
- 2.2. Multiply the ALI by 0.02, then multiply the result by the IRF value.



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2.3. Convert the units from μCi to dpm and divide by the sample volume.

3. Derivation of Investigation Levels

Investigation levels, as defined in Reg. Guide 8.9, are 0.1 ALI observed in a bioassay sample. Investigation levels are calculated using the same methodology as shown in Section 2.1, however the ALI is multiplied by 0.1 instead of 0.02.

4. Counting Procedure

The urinalysis is performed by either gamma counting or liquid scintillation counting.

- 4.1. Use the largest vial and sample volume that the system can accommodate to assure adequate sensitivity of the measurement. For liquid scintillation counting, select a cocktail that is suitable for large aqueous samples.
- 4.2. Prepare urine and distilled water samples of equal volumes. Count both the urine and the distilled water samples for the same times.
- 4.3. Consult the RSO for the appropriate Liquid Scintillation Counting Protocol.
- 4.4. Record the sample data and results in the RPR-12C - Urinalysis Assay Workbook.
- 4.5. Calculate the activity concentration (dpm/ml) in the urine sample using a nominal counting efficiency (as provided by the vendor) for the nuclide of greatest concern.
- 4.6. Compare the assay result with the evaluation level for the nuclide(s) of interest, based on the elapsed interval since last use or negative bioassay.
- 4.7. If the assay result is less than the evaluation level, send the signed form to the RSO. If the assay result exceeds the evaluation level
- 4.8. If the bioassay result exceeds the Evaluation Level or Investigation Level, the intake should be estimated using methods in NUREG/CR-4884, and a committed effective dose equivalent assigned to the workers dose for the calendar year. Consult the with the RSO for the best course of action.

5. Records

- 5.1. An electronically signed copy of the RPR-12C Workbook should be placed in the Radiation Worker files.

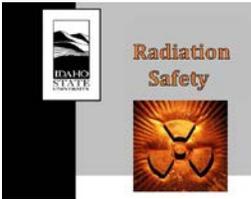


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6. References

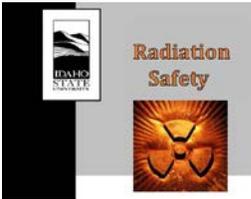
USNRC. Regulatory Guide 8.9, Acceptable concepts, models, equations, and assumptions for a bioassay program. Rev. 1; 1993.

USNRC. NUREG/CR-4884, Interpretations of bioassay measurements. 1988.



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Appendix D – Technical Basis for Dispersible RAM Handling Bioassay Threshold



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Technical Basis for Dispersible RAM Handling Bioassay Threshold

The following methodology is used to determine the quantities of material that require bioassay, either in vivo or in vitro, for Condition iii listed above:

Guidance for determining an initial screening level provided in NUREG-1400 - Air Sampling in the Work Place, states that radiological workers handling dispersible material in quantities of 10^4 ALI in a year are unlikely to receive an intake of more than 0.01 ALI or that a worker receives an inhalation intake of less than 10^{-6} of the material handled in a year. Jobs at Idaho State University involving handling dispersible radioactive materials are usually completed in a single day. Using the NUREG-1400 screening level, a daily radioactive material handling limit may be established which will ensure the annual exposure is likely to remain below the 0.1 ALI monitoring threshold of 10 CFR 20. Computationally this is shown below:

$$200 \frac{\text{days}}{\text{year}} \cdot 200 \frac{\text{ALI}}{\text{day}} \cdot 10^{-6} = 0.04 \frac{\text{ALI}}{\text{year}}$$

This predicted intake is a factor of 2.5 below the criteria for monitoring in 10 CFR 20 and uses only the conservative screening criteria from NUREG-1400 without additional modifying factors. Based on this analysis, ISU will perform internal dose measurements by bioassay or lapel air sampling for workers who handle more than 200 ALI in a day.

Occasional confirmatory air sampling or in-vivo/in-vitro measurements will be used to verify this approach is protective of worker health in accordance with 10 CFR 20. Minors and pregnant workers are unlikely to be involved with dispersible radioactive material operations and will be evaluated on a case-by-case basis to ensure that predicted doses would be expected to remain below the 100 mrem CEDE threshold.