BIOASSAYS FOR INTERNAL RADIOACTIVITY

PURPOSE

This procedure specifies the requirements, responsibilities and methods for performing and reporting measurements for detecting and verifying the presence or absence of radioactivity in the body.

POLICY

Although the emphasis of a radiation protection program is primarily on prevention of unnecessary exposures, measurement and evaluation of exposures is also necessary. Bioassay is the determination of the kind and amount (and sometimes the location) of radioactive material in the human body by direct (in vivo) measurement or by analysis in vitro of materials excreted or removed from the body. Bioassay is an important tool for evaluating actual or suspected in vivo contamination with radioactive materials.

Monitoring is required for any individual who is likely to receive an annual intake of all nuclides combined of 0.1 ALI or more. The conditions requiring bioassays, as well as the methods and maximum intervals specified in this procedure are designed to assure that an annual intake exceeding 0.1 ALI, whether as a single intake or as chronic or multiple intakes, is not only detected, but determined quantitatively.

Individuals who handle dispersible radioiodine compounds may be required to obtain in vivo measurements of radioiodine in the thyroid, performed by the RSO, at specified intervals. Individuals who handle other radionuclides in dispersible forms may be required to perform assays of radioactivity in urine on a routine basis to document the absence of radioactivity in the body or to determine the magnitude of any intake. Other types of assays may be utilized if, in the judgment of the RSO, such assays will meet the intent of this policy more effectively.

A bioassay is required whenever significant personal contamination or injury caused by a contaminated object occurs, or if airborne radioactivity may have been inhaled. Routine bioassays, at intervals determined by the nuclides used, are required from each user who handles more than minimal quantities of dispersible radionuclides. A routine bioassay may be waived by the RSO when appropriate surveys for contamination, conducted according to recommended procedures during and after each use of radioactive material, demonstrate that there was essentially no exposure to dispersible radioactive materials.

DEFINITIONS

ALI: The annual limit on intake is the quantity of any radionuclide which, if taken into the body, produces an effective dose to internal organs that is equivalent in risk to the annual whole body dose limit of 5 rems. Because of differences in physiological transport mechanisms, the ALIs vary depending on the route of intake. For purposes of contamination control and bioassay procedures, the ALI for ingestion is used, since that is the most common route of accidental intake in research laboratories.

Bioassay interval: The bioassay interval is the maximum time that may elapse between bioassays that will assure detection of the verification level for a given nuclide and assay method. The bioassay interval for a particular nuclide is determined by its physical and metabolic characteristics, and by the instrumentation used for the measurement. For most commonly used nuclides and typical analytical systems, the bioassay interval is 13 weeks (one calendar quarter); for P-32, and a few other very short-lived nuclides, however, the bioassay interval is only 4 weeks.

Elapsed interval: The elapsed interval is the time since an assumed intake of radioactive materials or, if the time of intake is unknown, since the last bioassay. The elapsed interval is used to calculate the intake and the effective dose from a positive bioassay result.

Intake & Uptake: The total quantity of radioactive material entering the body is referred to as the intake, whereas the quantity absorbed into organs, tissues or interstitial fluids is referred to as the uptake.

Minimally exposed: A radiation user who handles a cumulative quantity of radioactive materials in dispersible form of less than 1 ALI per month, averaged over the bioassay interval, is very unlikely to experience an annual intake of 0.1 ALI and does not require routine bioassays. If exposed to contamination exceeding the levels specified under "Conditions Requiring Bioassays", however, a non-routine bioassay will be required.

Potentially exposed: A radiation user who handles a cumulative quantity of radioactive materials in dispersible form of more than 1 ALI per month, averaged over the bioassay interval, is considered to be potentially exposed to an annual intake of more than 0.1 ALI and must perform or obtain bioassays routinely unless the records of contamination surveys of both the user and the RSO verify that there was no exposure to unconfined radioactive materials exceeding the levels specified under "Conditions Requiring Bioassays" (Lab evaluations, RPR50).

Dispersible: In the context of bioassay requirements, "dispersible" refers to radioactive materials in any form that could be taken into the body and potentially transferred to body organs, tissues or fluids.

Screening bioassay: A screening bioassay is performed simply to determine whether radioactivity may be present in the body, but without precise quantification of activity or dose.

Verification level: A verification level is a result of a screening bioassay that indicates a possible intake exceeding **0.002 ALI multiplied by the elapsed interval in weeks**. A screening assay result that exceeds the verification level must be verified.

Verification assay: A verification assay is performed to obtain a reasonable estimate of the actual quantity of radioactivity taken into or present in the body.

Dosimetric assay: A dosimetric assay is performed by an accredited laboratory to provide data for annual dose determination. The need for a dosimetric assay will be determined by the RSO, but it is generally required for any individual whose cumulative annual intake is likely to exceed 0.1 ALI.

Investigation level: An assay result that indicates a possible intake of **0.05 ALI or more** will be investigated by the RSO to determine the cause of the exposure and corrective measures to prevent or reduce exposures in the future.

Removable Contamination Limit (RCL): A quantity of removable radioactive contamination related to its relative radiotoxicity used to prescribe corrective action for contamination situations, specified in “CONTAMINATION LIMITS AND ACTION LEVELS” (RPR 10B)

CONDITIONS REQUIRING BIOASSAYS

Refer to RPR 50D, “Radioisotope Laboratory Evaluation Report”.

1 A screening bioassay is required promptly [P] (within 5 days) for each individual having contamination of the skin or hair exceeding 10 RCL.

2 A screening bioassay is required within the normal bioassay interval [B] for any individual having skin or hair contamination exceeding 1 RCL.

3 A screening bioassay is required promptly [P] (within 5 days) for each individual who was present in an area during a time when removable contamination exceeding 100 RCL was present on any readily accessible surface.

4 A screening bioassay is required within the normal bioassay interval [B] for each individual who was present in an area during a time when removable contamination exceeding 10 RCL was present on any readily accessible surface.

5 A screening bioassay is required within the normal bioassay interval for each "potentially exposed" radiation user, unless the routing lab

evaluations show a pattern of no significant contamination and no significant deviations from proper radioactivity handling procedures. The determination of the cumulative quantity handled will be based primarily on records of receipts and disposals of radioactive materials, with adjustments made for individual work assignments as defined by the responsible user.

The optimum time for performing a bioassay is within a few days after a potential exposure. Each user should perform a screening assay within a few days after handling any unusually large quantities, or after performing any procedure involving a greater than usual opportunity for intake. Subsequent routine bioassays would not be required again until the end of another full bioassay interval unless another unusual exposure situation occurred.

The RSO will notify users when a routine bioassay is due, i.e. the expiration of the bioassay interval, but it is the responsibility of the user to complete the bioassay promptly. Routine bioassays may be waived at the discretion of the RSO if the records of contamination surveys of both the user and the RSO verify that there was no exposure to unconfined radioactive materials exceeding the levels specified above and no incidents of personal contamination since the last bioassay.

If no work with radioactive materials was performed since the last bioassay, or if survey records verify that there was no exposure to contamination exceeding the levels indicated below, this may be reported by checking the appropriate statement on the "URINALYSIS SCREENING ASSAY" report form (RPR 12A).

RADIOIODINE ASSAYS

The preferred bioassay method for gamma-emitting radioiodines is by in vivo measurement of the thyroid gland. These assays are performed by the RSO at preannounced locations on a regular schedule. It is the responsibility of the user to obtain the thyroid assay whenever appropriate. Records of the results of these assays are maintained by the RSO, but are available to the monitored individuals upon request.

SCREENING URINALYSIS

A screening assay is one performed simply to determine if radioactivity is present in the body, but without precise quantification of activity or dose. For radionuclides other than iodines, routine bioassays are most easily performed by in vitro analyses of urine. The same instruments that are used to measure radioactivity in research samples may be used to detect the same radioisotopes in urine samples. Screening assays are to be performed by or for each potentially exposed individual and reported to the RSO on the "URINALYSIS SCREENING ASSAY" form (RPR 12A).

For the nuclides used recently, determine the verification level (dpm/mL of urine) for the elapsed interval. For several commonly-used nuclides, the "BIOASSAY GUIDELINES" that follow list the action levels for various elapsed times up to the maximum elapsed interval. For other nuclides, or other elapsed times, the action levels must be obtained from the RSO.

The sample volume and minimum counting time must be selected so as to achieve a lower limit of detection (LLD) at least equal to the required verification level. The "BIOASSAY GUIDELINES" provide examples for several common nuclides and liquid scintillation counting conditions, and may be used, if appropriate. The minimum counting time may be calculated as illustrated later in this procedure or it may also be requested from the RSO.

For urinalysis by liquid scintillation counting, select a fluor that is suitable for large aqueous samples; Cherenkov counting may be used for P-32 or other high-energy beta emitters.

For urinalysis by gamma counting, as well as by liquid scintillation counting, proceed as follows:

1 To assure adequate sensitivity of the measurement, use the largest vial and sample volume that the counting system can accommodate.

2 Prepare urine and tap water samples of equal volumes. Count both the urine and the tap water samples for the same times.

3 Record the sample data and results on the "URINALYSIS SCREENING ASSAY" form (RPR 12A). 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 Compare the assay result with the verification Level for the nuclide(s) of interest, based on the elapsed interval since last use (or last bioassay). If the assay result in less than the verification level, send the signed form to the RSO. If the assay result exceeds the verification level, perform a "Verification Assay".

VERIFICATION ASSAYS

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. A verification assay for a urine sample involves spiking the urine and water samples with a known amount of activity to obtain the true efficiency of the counting system for the samples. Follow the steps on the "URINALYSIS VERIFICATION ASSAY" form (RPR 12B). If the bioassay result exceeds the investigation level or indicates a potential annual intake exceeding 0.1 ALI, the RSO will determine appropriate corrective measures. Send the signed form to the RSO. If the assay result exceeds the verification level, perform a "Verification Assay".

REFERENCES

International Commission on Radiological Protection:

Report of the Task Group on Reference Man, ICRP Publ. 23, 1975.

Limits for Intakes of Radionuclides by Workers, ICRP Publ. 30, Parts 1, 2 and 3 with Supplements, 1979-82.

General Principles of Monitoring for Radiation Protection of Workers, ICRP Publ. 35, 1982.

Individual Monitoring for Intakes of Radionuclides by Workers: Design and Interpretation, ICRP Publ. 54, 1988.

National Council on Radiation Protection and Measurements:

General Concepts for the Dosimetry of Internally Deposited Radionuclides, Report No. 84, 1984.

Use of Bioassay Procedures for Assessment of Internal Radionuclide Deposition, NCRP Report No. 87, 1987.

U.S. Nuclear Regulatory Commission:

Acceptable Concepts, Models, Equations and Assumptions for a Bioassay Program, Reg. Guide 8.9, Rev. 1, 1993.

Applications of Bioassay for I-125 and I-131, Reg. Guide 8.20, Rev. 1, 1979.

Information for Establishing Bioassay Measurements and Evaluations of Tritium Exposure, NUREG-0938, 1983.

MINIMUM COUNTING TIME CALCULATION

The lower limit of detection (LLD) for which the risks of false negative results and of false positive results are each 5% is defined as follows:

$$LLD = 4.66(SD_b)/Eff$$

where:

- LLD = disintegrations in sample in time T = VL x Vol x T
- 4.66 = the product of the distribution parameters needed to establish the 5% error limits
- SD_b = standard deviation of the background (tap water) count
  - = $N_b^{0.5} = (R_b x T)^{0.5}$
- N_b = total background counts in time T
- R_b = background count rate, in cpm
- Eff = detection efficiency, in counts/dis
  (a nominal efficiency may be used for screening assays, whereas it should be determined experimentally for verification assays)
- VL = verification level for elapsed interval since last bioassay, in dpm/mL
- Vol = volume of urine in sample, in mL
- T = minimum counting time required, in minutes
  - = $R_b(4.66/VL \times Vol \times Eff)^2$

BIOASSAY GUIDELINES

URINALYSIS CRITERIA FOR SELECTED RADIONUCLIDES[1]

Nuclide	Elapsed Interval (weeks)	Action Levels (dpm/mL) Verification[2]	Action Levels (dpm/mL) Investigation[3]	Minimum Count Time (minutes)[4]
H-3	1	5,800	145,000	1
	4	5,400	33,700	1
	8	1,500	4,800	1
	13	220	420	1
C-14	1-3	<5	>30	NA
	4-7	5	25	90
	8-10	6	20	70
	11-13	5	12	90
P-32	1	16	400	4
	2	13	160	6
	3	10	90	10
	maximum: 4	7	48	20
S-35	1	64	1,600	1
	4	100	660	1
	8	65	200	1
	13	25	48	5

THYROID MONITORING CRITERIA FOR RADIOIODINES

Elapsed Interval (weeks)	I-125 Action Levels (nCi in thyroid) Verification[2]	I-125 Action Levels (nCi in thyroid) Investigation[3]	I-131 Action Levels (nCi in thyroid) Verification[2]	I-131 Action Levels (nCi in thyroid) Investigation[3]
1	21	530	9.4	235
2	38	470	9.9	120
4	59	370	5.4	34
8	72	230	0.8	3
13	64	120	0.05	1

1 For nuclides that are not listed, contact the RSO for appropriate analytical criteria.
2 Verification levels are based on chronic intake of 0.2% of the ALI per week during the elapsed interval.
3 Investigations levels are based on a single intake of 5% of the ALI at the beginning of the elapsed interval.
4 Minimum count times are based on a sample volume of 1 mL counted with a typical liquid scintillation counter.

RPR 12A. URINALYSIS SCREENING ASSAY

Name: _____ Soc. Sec. No. _____ UNID : _____

☐ Check here if you have used no dispersible radioactive materials since your last bioassay.

☐ Check here if all records of contamination surveys, both by the user and the RSO, indicate no personal contamination and no exposure to unconfined radioactive materials exceeding the levels specified under "CONDITIONS REQUIRING BIOASSAYS" in the procedure.

If you checked either of the above exemption statements, provide the signatures and return the form to the RSO.

Radionuclides used since last bioassay:

			Action Levels	
Nuclide	How Much?	How Long Ago?	Verification	Investigation
_____	_____ mCi	_____ weeks	_____ dpm/mL	_____ dpm/mL
_____	_____ mCi	_____ weeks	_____ dpm/mL	_____ dpm/mL

Assay Data: Sample collection date: _____ Date counted: _____

Instrument used (make, model, S.N.):

_____

Volume of Samples: _____ mL Fluor: _____ mL Count time: _____ minutes

Use the same volumes of urine and tap water for the samples. If not counted for the minimum time required for the critical nuclide and the elapsed time, the assay will not be valid.

Total counts from samples - Urine: _____ Water: _____

Nominal counting efficiency for the assay = _____ counts/dis

Concentration in dpm/mL:

$$\frac{\text{(Urine sample counts) - (Water sample counts)}}{\text{(Sample volume, mL) x (Count time, min) x (Efficiency, counts/dis)}}$$

☐ = _____ dpm/mL Less than verification level? Yes No

If less than the verification level, sign the form and obtain the signature of the responsible user; then send the form promptly to the Radiological Health Department, 322 RAB (Campus Address)

If the result exceeds the verification level, proceed with a verification assay, using the following form (RPR 12B) for reporting.

Signatures: Counted by: _____ Responsible User: _____

RSO verification of assay data: _____ (Analyst or RSO)

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RPR 12B. URINALYSIS VERIFICATION ASSAY

Name: _____ Soc. Sec. No. _____ UNID:_____

Sample collection date: _____ Date counted: _____

Instructions:

1. Complete the "Screening Assay" procedure.

2. Add a known activity of the nuclide of greatest concern to each sample (urine and water) and count again to determine the true efficiency. The volume of the spike must be small enough so that it does not change the original counting characteristics of the sample. If the appropriate nuclide is not available in a solution of known concentration from which a spike can be obtained, discuss the requirement with the RSO.

3. Calculate the counting efficiency and convert the final results to disintegrations per minute per milliliter of sample (dpm/mL).

Assay Data: Instrument used: _____

Sample: _____ mL Fluor: _____ mL Count time: _____ minutes

If not counted for the minimum time required for the critical nuclide and the elapsed time, the assay will not be valid.

Activity added to sample for efficiency determination: Inventory No. _____

Concentration: _____ dpm/mL Volume added: _____ mL Activity: _____ dpm

Total counts obtained from samples:	Untreated	Spiked
Urine samples:	_____	_____
Tap water samples:	_____	_____

Efficiency in counts/dis:

$$\frac{\text{(Spiked urine sample counts) - (Untreated urine sample counts)}}{\text{(Count time, min) x (Spike activity, dpm)}} = \_\_\_\_\_ \text{ counts/dis}$$

Concentration in dpm/mL:

$$\frac{\text{(Untreated urine sample counts) - (Untreated water sample counts)}}{\text{(Sample volume, mL) x (Count time, min) x (Efficiency, counts/dis)}} = \_\_\_\_\_ \text{ dpm/mL}$$

☐ Less than investigation level? Yes No

If less than the investigation level, complete the signatures and mail the form to the RSO. If the result exceeds the investigation level, confer with the RSO to determine appropriate follow-up assays.

Signatures: Counted by: _____ Responsible User: _____

RSO verification of assay data: _____ (Analyst or RSO)

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RPR 12C. I-125 THYROID MONITORING REPORT

Name: _____ Soc. Sec. No. _____ UNID_____

Instructions: Record successive counts for one individual as long as the same instrument is used and the calibration is still valid. Use the same counting time for all counts.

Instrument and calibration data:

Scaler - model: _____ Ser. No. _____

Detector - model: _____ Ser. No. _____

Calibration date: _____ I-129 source activity (A) = _____ μCi

Count time (t) = _____ min or sec Net counts in phantom (C) = _____ counts

I-125 efficiency = 0.00189 x C(counts) / A(μCi) = _____ net counts/nCi I-125 in time t

(1.462 I-125 photons of 27.5-35.5 keV/dis) / (0.775 I-129 photons of 29.5-39.6 keV/dis) (1,000 nCi/μCi) = 0.00189

Screening assay data:

Date	Elapsed Interval (weeks)	Verif. Level (nCi)	Phantom Counts I-129 (counts)	Phantom Counts Bkgd. (counts)	Phantom Counts Net (counts)	Thyroid Data Gross (counts)	Thyroid Data Net (counts)	Thyroid Data (nCi)	Counted By

Submit the form for filing after the above spaces have been filled, or after one verification assay has been recorded, or at the end of the calendar year, whichever comes first.

Verification assay data:

If screening assay exceeds the verification level, make a measurement on the thigh to determine contribution from blood pool. Use the thigh measurement as the background to determine net activity in thyroid:

$$\frac{\text{(Total counts from thyroid) - (Total counts from thigh)}}{\text{(Efficiency, net counts per nCi)}} = \_\_\_\_\_ \text{ nCi}$$

If the verification assay result does not exceed the investigation level, submit the form although no further action is required. If the investigation level is exceeded, report to the RSO and initiate an investigation.

Reviewed by: _____ Date: _____

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RPR 12D. I-131 THYROID MONITORING REPORT

Name: _____Soc. Sec. No. _____UNID;_____

Instructions: Record successive counts for one individual as long as the same instrument is used and the calibration is still valid. Use the same counting time for all counts.

Instrument and calibration data:

Scaler - model: _____ Ser. No. _____

Detector - model: _____ Ser. No. _____

Calibration date: _____ I-131 source activity (A) = _____ μCi

Count time (t) = _____ min or sec Net counts in phantom (C) = _____ counts

Efficiency = 0.001(μCi/nCi) x C(counts) / A(μCi) = _____ net counts/nCi in time t

Screening assay data:

Date	Elapsed Interval (weeks)	Verif. Level (nCi)	Bkgd. (counts)	Thyroid Data Gross (counts)	Net (counts)	(nCi)	Counted By

Submit the form for filing after the above spaces have been filled, or after one verification assay has been recorded, or at the end of the calendar year, whichever comes first.

Verification assay data:

If screening assay exceeds the verification level, make a measurement on the thigh to determine contribution from blood pool. Use the thigh measurement as the background to determine net activity in thyroid:

$$\frac{\text{(Total counts from thyroid) - (Total counts from thigh)}}{\text{(Efficiency, net counts per nCi)}} = \_\_\_\_\_ \text{ nCi}$$

If the verification assay result does not exceed the investigation level, submit the form although no further action is required. If the investigation level is exceeded, report to the RSO and initiate an investigation.

Reviewed by: _____ Date: _____

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