



American National Standard

ANSI/HPS N13.25-2022

Internal Dosimetry Programs for Plutonium Exposure—Basic Requirements

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American National Standards Institute, Inc.



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Foreword

(This foreword is not a part of American National Standard ANSI/HPS N13.25-2022)

This American National Standard provides criteria for the design and implementation of an internal dosimetry program for plutonium. These criteria are intended to provide guidelines concerning the functional operation of bioassay monitoring and internal dose assessment programs for facilities having the potential for occupational exposure to plutonium. These guidelines include the design and setup of a bioassay monitoring program, the selection of individuals to receive monitoring, the interpretation of bioassay monitoring results, the assessment of internal dose, action levels for medical intervention, assessing intakes associated with contaminated wounds, estimating uncertainty associated with assessed intakes, and numerical thresholds for medical intervention. The appendices to this standard provide additional useful information applicable to the design and implementation of a plutonium internal dosimetry program. Suggestion and comments for improvement of this standard are welcome and may be sent to the Health Physics Society Standard Coordinator at 950 Herndon Parkway, Suite 450, Herndon, VA 20170; or by email to: awride-graney@burkinc.com.

Keywords

bioassay, internal dosimetry, plutonium

Internal Dosimetry Programs for Plutonium Exposure – Basic Requirements

1 Introduction

The dominant health physics concern for plutonium is the potential for intake of alpha particle emitters. Individuals who work with unencapsulated plutonium or in areas where plutonium is handled have the potential for intakes of plutonium through inhalation, in contaminated wounds, and by ingestion.

A radiation protection program is essential at a facility that handles unencapsulated plutonium in order to minimize or prevent intakes of plutonium. In addition to quantifying dose, an internal dosimetry program serves to verify that the radiation protection program is effective and to alert the facility of any unplanned intakes, which could indicate a deficiency in workplace monitoring and controls. It is also essential to have a measurement program to estimate the quantity of plutonium taken into the body or to establish a basis for judgment as to whether or not intakes have occurred. These measurements include workplace air monitoring and bioassays such as urine and fecal sampling, nasal swipes, and in vivo counting. The specification, analysis, and interpretation of bioassay measurements and other relevant measurements, such as air monitoring measurements, is referred to as an internal dosimetry program.

This standard incorporates the major recommendations of the International Commission on Radiological Protection (ICRP), with a focus on but not limited to the dosimetry concepts and methods of ICRP 60 (ICRP 1991) and the biokinetic models summarized in ICRP 78 (ICRP 1998). Other standards from the American National Standard Institute (ANSI) and Health Physics Society (HPS) that may be useful to the reader are ANSI/HPS N 13.39-2001 “An American National Standard—Design of Internal Dosimetry Programs” (HPS 2001)

and ANSI/HPS N13.30-2011 “An American National Standard—Performance Criteria for Radiobioassay” (HPS 2011).

2 Purpose

This standard defines the elements needed to establish an internal dosimetry program used to monitor individuals who may be occupationally exposed to plutonium.

3 Scope

This standard includes the following items that define an acceptable plutonium internal dosimetry program:

1. Design and setup of a bioassay program.
2. Selection of individuals for participation in the bioassay program.
3. Interpretation of bioassay measurements with a focus on the biokinetic models established in ICRP publications ICRP 67 (ICRP 1994a), Appendix B; and ICRP 68 (ICRP 1995), 72 (ICRP 1996b) and 78 (ICRP 1998).
4. Guidelines for medical intervention in the case of large intakes.

This standard addresses the evaluation of possible plutonium intakes using the methodologies and philosophies of ICRP publications 60 (ICRP 1991), 66 (ICRP 1994b), 68 (ICRP 1995a), and 78 (ICRP 1998). This standard does not specifically incorporate the methodologies and philosophies previously developed in ICRP publications 26 (ICRP 1977) and 30 (ICRP 1979, 1988a), although these are discussed in Appendices A and B.

4 Definitions

4.1 General

The terminology in this standard is meant to conform to current standard usage in the field of internal dosimetry. The definitions given in references (HPS 2001, 2011; ANS

Subcommittee on Nuclear Terminology and Units 1986; ICRU 1980, ICRP 1984; NCRP 1985) apply and are supplemented by those given below. The word “shall” is used to denote a requirement to meet the purpose or objectives of the standard. The word “should” denotes guidance or indications of recommended good practice.

4.2 Specific terms

ABSORPTION TYPE: An ICRP 66 (ICRP 1994b) respiratory tract model concept describing the relative speed of dissolution and translocation to blood of material within the respiratory tract. It is related to the physical chemistry of the material. The ICRP 66 (ICRP 1994b) model defines three absorption types: Type F (fast absorption), Type M (moderate rate of absorption), and Type S (slow absorption).

ALI: Annual Limit on Intake, the activity of a radionuclide which, taken alone, would irradiate a person, represented by Reference Man (ICRP 2003) to the annual regulatory limit.

AMAD: Activity Median Aerodynamic Diameter, the diameter of a unit density sphere with the same terminal settling velocity in air as that of the aerosol particle whose activity is the median for the entire aerosol.

AMTD: Activity Median Thermodynamic Diameter, for particles with an AMAD less than about 0.5 μm , when the deposition depends primarily on diffusion.

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

BURDEN: The instantaneous quantity of material in an organ or tissue of interest (e.g., lung, bone surfaces, whole body, and wound site)—same as retained quantity.

CHELATION: A method of accelerating the removal of transuranic materials, such as plutonium, from the body by administration of specific chemicals known as chelation agents. For metals like plutonium, americium,

and curium, the preferred chelation agent is diethylenetriamine pentaacetate (DTPA), which will form a complex that is very efficiently excreted in urine.

COMMITTED EFFECTIVE DOSE, E_{50} : The effective dose calculated for a 50-year period following an acute intake or onset of a chronic intake. It does not include contributions from external dose.

COMMITTED EQUIVALENT DOSE, $H_{T,50}$: The equivalent dose to an organ or tissue calculated for a 50-year period following an acute intake or onset of a chronic intake. It does not include contributions from external dose.

DAC: Derived Air Concentration, the air concentration that, if breathed under normal working conditions for one year, results in one ALI intake. Workers are assumed to spend 2000 hours (50 weeks at 40 hours per week) in light activity. Under these conditions, the annual breathing volume for an average worker is 2400 m^3 (ICRP 1974). Therefore,

$$DAC = \frac{ALI}{2400 \text{ m}^3}$$

DALI: Deterministic Annual Limit on Intake, the ALI based solely on the regulatory limit for deterministic effects, i.e., on the committed equivalent dose at the regulatory limit. Depending on the radionuclide, the DALI may be more restrictive than the stochastic annual limit on intake (SALI) and will be listed in its place in regulations or standards. The DALI is not the limiting ALI under the system recommended by the ICRP in their Publication 60 and hence is not used in that system (ICRP 1991).

DOSE COEFFICIENT: Either the committed equivalent dose in an organ or tissue per intake ($h_{T,50}$), or the committed effective dose per intake (e_{50}). For adult workers, the dose commitment period is 50 years.

DL: Decision Level, the measurement result that would be judged to differ from background, and therefore would lead to a decision that the count or sample contains a net activity greater than 0.

EFFECTIVE DOSE, E : The summation of the products of the equivalent doses (H_T) received by organs or tissues of the body and the appropriate tissue weighting factors (w_T). For adult workers, the dose commitment is over a 50-year period (E_{50}).

EQUIVALENT DOSE, H_T : The product of the average absorbed dose to an organ or tissue and the appropriate radiation weighting factor (w_R). The total equivalent dose is the sum over all radiation types. For adult workers, the dose commitment is over a 50-year period ($H_{T,50}$).

INTAKE: The quantity of material that enters the body. For plutonium, the primary intake pathways are via inhalation through the nose or mouth, directly into the blood through a contaminated wound, or by ingestion.

MDA: Minimum Detectable Amount or MDC Minimum Detectable Concentration, the smallest amount of an analyte in a sample that will be detected with a probability of non-detection (type II error) while accepting a probability of erroneously deciding that a positive (non-zero) quantity of analyte is present in an appropriate blank sample (type I error).

SALI: Stochastic Annual Limit on Intake, the ALI based solely on a committed effective dose at the regulatory limit for effective dose. It is not always the most limiting ALI and, therefore, is not always the value listed in tables in regulatory documents. For instance, in ICRP 30 (ICRP 1979), the SALIs are listed in parentheses if the DALI is more limiting.

UPTAKE: The passage of material introduced as intake (for example, inhaled into the lungs) and absorbed into systemic circulation and available for deposit in body organs or tissues. For inhalation of highly insoluble material, the systemic uptake may be small even though the intake (and dose to lung tissues) is large.

5 Bioassay Monitoring and Internal Dosimetry

A bioassay and internal dosimetry program shall be provided if quantities of plutonium are present or handled at a facility meeting the requirements for monitoring. Criteria for

monitoring workers differ depending on the governing regulation. ANSI/HPS N13.39-2001 (HPS 2001) contains recommended guidance, however, the Nuclear Regulatory Commission, Department of Energy and other regulatory bodies may mandate differing levels. Any bioassay monitoring program would be supplemental to normal workplace surveillances such as general air sampling, breathing zone or personal air sampling, area contamination surveys, and personal contamination surveys.

Bioassay programs shall be capable of detecting intakes resulting in doses of 50 mSv committed effective dose or 500 mSv committed equivalent dose in the course of a year and an order of magnitude or better for special measurements made shortly after a potential intake is identified. There is no single best bioassay method for monitoring for plutonium intakes. The detection of plutonium intakes at or below 5 mSv using conventional routine monitoring techniques, such as periodic radiochemical alpha spectrometry analysis of urine samples, is difficult (US DOE 2007). Detection of a plutonium intake resulting in a 5-mSv committed effective dose by special urine monitoring (see Section 6.4) is usually possible if samples are collected close in time to the time of the suspected intake, and additional measurement information may be utilized, such as air monitor readings, nose swipes, etc. Fecal analysis is typically much more sensitive than urine for intake detection, but it has potential drawbacks, including worker acceptance, biological variability, and increased analytical costs. Mass measurement techniques such as inductively coupled plasma mass spectrometry (ICPMS) or thermal ionization mass spectrometry (TIMS) can provide greater sensitivity than radiochemical alpha spectrometry for analysis of ^{239}Pu in urine (Inkret et al. 1998), but are not sensitive to detection of higher specific activity isotopes such as ^{238}Pu or ^{241}Pu , and may have limited commercial availability due to cost and laboratory specifications. Beta particle counting, typically by liquid scintillation, is required for monitoring of ^{241}Pu , but may not be warranted if dose contributions from ^{241}Pu and its decay progeny ^{241}Am are addressed by isotopic ratios from characterization data.

5.1 Characterizing the Material

Characterization of plutonium within the workplace is the first step in the design of a bioassay program. This characterization should include, as applicable:

- Identifying the physical and chemical forms expected to be present or generated.
- Identifying the expected range of particle size distributions and particle solubility (e.g., by measurement, process knowledge, and literature search) for anticipated low-level or chronic intakes.
- Identifying the isotopic mixes of plutonium expected.
- Determining the activity ratios to be expected (e.g., $^{241}\text{Am}/^{239,240}\text{Pu}$)—particularly if those ratios are going to be used for interpreting in vivo counting results.
- Reviewing available documents to identify plutonium mixtures previously used in the area.

In identifying the physical and chemical forms of plutonium in the workplace, ICRP 68 (ICRP 1995) assigned insoluble plutonium oxides to absorption Type S and all other plutonium compounds to Type M. No plutonium compounds were assigned to Type F. These default absorption types are adequate for program design; however, caution should be used in applying these categorizations to actual intakes because variations have been observed (Moody et al. 1994; La Bone and Findley 1999; Romanov et al. 2003; Hahn et al. 2004; Kathren 1994; Kathren and McInroy 1991; Carbaugh and La Bone 2003). In an intake scenario, additional bioassay measurements may be required to better characterize the intake.

For particle sizes, a detailed discussion of the deposition of particles in the respiratory tract can be found in ICRP 66 (ICRP 1994b) and 78 (ICRP 1998). The deposition model provides for deposition of an aerosol in each of the five respiratory regions as a fraction of intake for particle sizes ranging from 0.0006 to 100 μm . The ICRP (ICRP 1998, 1994b) recommends a default particle size of 5 μm AMAD for occupational exposure settings. Where members of the public are exposed to

fallout and radioactivity in the general environment, a 1- μm particle size is the standard that has been recommended by ICRP (ICRP 1998, 1994b). AMADs are typically measured using a multistage cascade impactor to collect the aerosol. Different stages collect different aerodynamically equivalent diameter particles, which are then separately counted and used to describe the AMAD. Particle size analysis is most useful under steady-state chronic intake conditions, such as at a processing facility.

Pure isotopes of plutonium are seldom encountered. Instead, plutonium is usually encountered as a mixture of isotopes. For specific intake cases where the isotopic composition of a mixture is known, that composition should be used for dosimetry purposes (e.g., bioassay data, smear samples, and air samples). In situations where mixtures are unknown, or for bioassay planning purposes, assumptions regarding the mixture should be made based on characterization data or the most conservative isotope.

5.2 In Vitro and In Vivo Bioassays

Bioassay monitoring techniques fall into two broad categories: analysis of material removed from the body (in vitro analysis), and direct measurement of radioactive material within the body (in vivo counting). Available in vitro and in vivo bioassay techniques are discussed in Appendices C and D. Consideration of the radioisotopes to be measured factors significantly into the decision as to monitoring techniques and specific measurement types. The most common isotopes of plutonium and plutonium decay mode are shown in Table 1 along with selected decay data.

Urine samples are the most common type of in vitro measurements, although fecal samples are also used. Analysis is mostly done using chemical separation of plutonium and radiochemical alpha spectrometry. For ^{239}Pu , TIMS techniques may be advantageous (Inkret et al. 1998); however, only a few laboratories are capable of performing the analysis as opposed to the majority of commercial laboratories capable of performing radiochemical alpha spectrometry.

Table 1: Plutonium and decay data.

Isotope	Decay mode	Half-life		Decay constant		Specific activity Bq g ⁻¹
		Year ^a	Day	Year ⁻¹	Day ⁻¹	
²³⁸ Pu	Alpha	87.7	3.20E+04	7.90E-03	2.16E-05	6.34E+11
²³⁹ Pu	Alpha	24,110	8.80E+06	2.87E-05	7.87E-08	2.29E+09
²⁴⁰ Pu	Alpha	6,564	2.40E+06	1.06E-04	2.89E-07	8.39E+09
²⁴¹ Pu	Beta	14.35	5.24E+03	4.83E-02	1.32E-04	3.82E+12
²⁴² Pu	Alpha	375,000	1.37E+08	1.85E-06	5.06E-09	1.46E+08

^a Based on ICRP 107 (ICRP 2008) nuclear decay data.

Lung, wound, liver, and skeleton counting are examples of in vivo monitoring most commonly used for plutonium and its progeny (see Appendix D for a discussion of in vivo counting techniques). The objective of lung counting is to provide a direct measurement of material retained within the lung following an inhalation intake or to monitor potential long-term buildup of lung activity. Lung measurements, although relatively insensitive, can provide early upper limit estimates of the magnitude of the intake. Energies most commonly used for plutonium monitoring are the 17 keV and 20 keV L x rays and the 60 keV gamma emitted in the decay of ²⁴¹Am. Specific data on the proportions of ²⁴¹Am and ²⁴¹Pu in the mixture, and the age of material to account for ingrowth of ²⁴¹Am, are necessary to accurately quantify the counting result. Mixtures of spent fuel material can lend themselves to whole body counting if the ratio of a readily detectable high-energy gamma emitter to plutonium is known.

Facilities with a potential for intakes via wounds with resulting committed effective doses at or above 1 mSv should have the capability to detect and assess depositions of plutonium in wounds (see Appendix D for a discussion of wound counting techniques). Rapid wound counting is important to allow timely medical decisions regarding surgical excision of the wound and administration of chelation therapy.

6 Types of Monitoring Programs

6.1 Baseline Bioassay

Baseline bioassays establish pre-intake conditions for new employees or new work assignments. For most plutonium bioassay techniques, baseline measurements made prior to any occupational intake can be expected to yield no detectable results; that is, background plutonium levels in the general population (from atmospheric testing of nuclear weapons) are undetectable (The urinary excretion of ²³⁹Pu in the general population is on the order of 1 µBq d⁻¹ (Wrenn et al. 1994; Ibrahim et al. 1999)).

Requirement of baseline measurements can potentially impact the schedule of short-term jobs; the time required to obtain a chest count and a large volume urine sample may add a day or two delay to entry procedures. It is an acceptable practice to begin work once the baseline sample has been collected but prior to receipt of results.

6.2 Air Monitoring

Intakes can be estimated by tracking time exposed and the concentrations of airborne radioactive material measured with personal (lapel) air samplers or, less reliably, other air samples. This method is appropriate only when bioassay data are unavailable or measurements are not sufficiently sensitive, as great uncertainty accrues from any assumption that an air sample is representative of presumptive intakes.

6.3 Routine Monitoring

A routine bioassay program consists of a periodic series of bioassay sample collections and measurements. The purposes of routine bioassay monitoring include the following:

1. Provide data for evaluating the effectiveness of engineered and administrative controls at the workplace.
2. Demonstrate compliance with appropriate standards and regulations.
3. Identify potential intakes which might have gone undetected by normal workplace monitoring.

The routine bioassay measurement frequency is based on the probability of an intake occurring and the sensitivity of a bioassay program for detecting potential intakes. Further details of the selection process are given in Section 8.3. The rationale for the selected bioassay measurement frequency should be documented. It is appropriate to evaluate the probability of intake and to modify the sampling frequency based on that probability. Note that the detection of plutonium intakes at 50 mSv from routine urine monitoring can be difficult using conventional techniques such as radiochemical alpha spectrometry. Determine and demonstrate that the routine monitoring program will reasonably identify intakes that would result in assigned doses in excess of regulatory limits and facility specific action levels.

6.4 Special Monitoring

Special monitoring is implemented as follow-up to unusual routine monitoring results or suspected intakes. Special monitoring is performed to confirm an intake and to assess the resulting dose. Owing to the biokinetics of plutonium, special monitoring may be required for an extended time period following intake (e.g., months).

6.5 Confirmatory Monitoring

Confirmatory bioassay monitoring is used to demonstrate that administrative and technical controls limiting the release of radioactive materials are effective and that a stringent routine bioassay program is not

warranted (HPS 2001). Confirmatory monitoring programs are typically applied in situations where workers have the potential for intakes exceeding the verification level (e.g., 2% of annual exposure limit), but less than the investigation level (e.g., 10% of annual exposure limit). As these levels are difficult to achieve for insoluble plutonium, confirmatory monitoring should not be considered for conditions where plutonium exposure potentially exists.

Confirmatory bioassay monitoring may be performed by randomly sampling a subgroup of similarly exposed workers, or sampling individual workers less frequently than required for routine monitoring. Because confirmatory monitoring is not associated with a presumptive intake, policies concerning the handling of positive bioassay results (including bioassay result verification, worker intake assessment and dose assignment, and the identification of other affected individuals if conducted as representative sampling) shall be developed.

6.6 Ending-Task and Termination Bioassay

Ending-task bioassay measurements are obtained upon the completion of a work assignment for which bioassay monitoring was required. Termination measurements are performed after a worker has ceased working in an area where there was potential for an intake of plutonium and has no further potential for exposure.

6.7 Long-term Follow-up

Long-term follow-up monitoring may be performed to verify and revise intake and dose assessments for individuals having confirmed intakes of plutonium. The selection of monitoring techniques as well as the frequency and duration of monitoring depends on the magnitude and nature of the intake. Follow-up monitoring may be warranted as long as detectable results are obtained and potential exists for additional exposure. Continued monitoring may be offered to individuals who terminate employment.

Follow-up monitoring results can be compared to bioassay projections derived from the most current intake estimate. This is

particularly important for individuals who return to plutonium work, because biological and sampling-related fluctuations hamper the ability to identify new intakes via routine monitoring. Detection of new intakes at 50 mSv by urine monitoring can be difficult for workers having long-term urine excretion from previous intakes. For these workers, routine bioassay monitoring may not be feasible, thus reliance must be placed on workplace indicators and air sampling (DAC-hours) for potential intakes.

7 Timely Receipt of Bioassay Results

Bioassay measurement results should be provided in a manner timely for the purpose for which they are obtained. Factors to consider in determining timeliness include:

1. Use of results for preliminary intake and dose assessment, reporting, and initiation of follow-up measures.
2. Use of results to initiate or determine the efficacy of dose reduction therapy.
3. Confirmation of an occupational intake based on a positive routine monitoring result prior to the loss of detection capabilities due to normal biokinetics.
4. Trade-offs in sensitivity (due to analytical shortcuts and reduced counting times) for rapid results.

Because in vivo measurement data are usually available almost immediately upon completion of the measurement, the response times discussed in this section will generally apply to in vitro bioassay measurements.

Confirmatory bioassay measurements are not expected to show any significant detection of nuclides of concern. Because the purpose of these measurements is to provide general information that significant intakes are not occurring and that radiological controls are effective, the time between obtaining a bioassay sample (or measurement) and receipt of the results need not be rapid (e.g., one or two months). Likewise, where routine periodic measurements are not likely to show significant intakes with regard to dose control and work administration, a one- or two-month

analytical response time is not likely to have any significant impact.

Special bioassay measurements are expected to have much faster turnaround time. This is particularly important if the results are being used to determine the need for, or efficacy of, dose reduction therapy. Rapid availability of special results is also needed for preliminary intake and dose assessments used to classify intakes for reporting purposes. Preliminary bioassay measurements should be available within 24 to 48 hours following intake (e.g., in vivo counts or crude radiochemistry). The need for precision and accuracy in these early estimates is much less than for the measurements which will be used for the final dose assessment.

Provisions for assuring that a worker has received the appropriate in vivo measurements or has provided the scheduled in vitro sample should not be overlooked in designing a program. A reasonable grace period (e.g., 30 to 60 days) is appropriate to deal with workers who forget measurements or who are unable to meet the schedule. However, administrative actions (e.g., work restriction) may be appropriate for a worker who is substantially overdue for measurement.

Where air sample results form the basis for identifying intakes and making preliminary dose assessments, preliminary results (e.g., gross alpha or gross beta concentration) should be available within a few hours of obtaining the sample (possible interference from radon decay progeny needs to be taken into account). This is particularly important for samples used to monitor for unknown or changing work conditions. Routine air samples for well-established processes and facilities may have longer turnaround times (e.g., as much as a few days), provided they are not the sole method of monitoring workplace conditions.

8 Participation in the Worker Monitoring Program

8.1 Baseline Bioassay Program Participation

Exempting workers from baseline bioassay may result in accepting any detectable results as attributable to current occupational intake, therefore, baseline bioassay measurements should be obtained before performing work requiring routine bioassay if (1) the worker has had prior exposure to plutonium, or (2) the intake history is missing or inconclusive. Baseline monitoring should be considered if (1) bioassay techniques that are capable of detecting plutonium at environmental levels, that is, non-occupational levels (these levels were discussed in Section 6.1) are being used or (2) the detection level of the current bioassay method is substantially lower than the detection level of the previous employer.

- Example: A new employee in a plutonium facility may not require a baseline bioassay if there was no prior potential occupational intake of plutonium. However, a new employee coming from a plutonium processing facility should undergo baseline bioassay if (1) the individual's work history indicates occupational exposure to plutonium, or (2) the work history information is absent or incomplete.

Employees whose bioassay results show detectable levels of activity from previous intakes shall be evaluated relative to the ability of the routine bioassay program to detect additional intakes (see Section 6.7).

8.2 Air Monitoring Program Participation

Air monitoring should be performed for workers who may be subject to multiple or chronic low-level inhalation intakes. In plutonium facilities, air monitoring is particularly appropriate when dealing with acute intakes resulting in committed effective doses of 0.025–1 mSv, which could go undetected by routine bioassay. Multiple intakes resulting in a cumulative committed effective dose of up to 5 mSv are also suitable for this practice. Air sample data used for assigning intakes to individual

workers shall be traceable to the worker. ALI, DAC and DAC-hr values are typically based on the deterministic bone surface dose limit rather than the stochastic limit as a conservative basis for bioassay monitoring actions. Calculations of committed effective dose from such quantities must account for the actual solubility or absorption type of the inhaled material and the ratio of stochastic to deterministic dose coefficients.

- Example: 1 DAC-hour, based on the bone surface deterministic DAC and Type M material, will correspond approximately to an E_{50} of 0.0072 mSv for 5- μ m particles of ^{239}Pu . Thus, the implied dose of 10–40 DAC-hours is nominally an E_{50} of 0.07 to 0.30 mSv.

8.3 Routine Bioassay Program Participation

Workers considered to have the potential to receive intakes in excess of the investigation level shall participate in a routine bioassay program. Criteria for identifying participants shall be established based on knowledge of the radionuclides, facilities, processes, and anticipated work. Criteria may be expressed in many forms, including quantity and form of material handled, type of work, or category of worker. There is no single, most cost effective and technically correct method to use for identifying these workers. Some examples of methods used to determine the need for routine bioassay program participation and their applications are described below.

- Example 1: Long-term chronic exposure to air concentrations exceeding 10% of the DAC. In cases of continuous occupancy over a year (or occupancy such that the average air concentration exceeds 10% of the DAC), participation in a routine bioassay program is indicated.
- Example 2: Short-term chronic airborne exposure, or multiple acute airborne exposures. This example and the following example may be particularly useful for addressing exposures of supervisory, walk-through, and inspection staff who do