

Health Physics Society



An American National Standard

Design of Internal Dosimetry Programs

Supplement 5
HEALTH PHYSICS 2001

American National Standard –

Design of Internal Dosimetry Programs

Approved: May 24, 2001
Reaffirmed: July 19, 2011

American National Standards Institute, Inc.

Published by

**Health Physics Society
1313 Dolley Madison Blvd.
Suite 402
McLean, VA 22101**

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Printed in the United States of America

ANSI/HPS N13.39-2001

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Design of Internal Dosimetry Programs

1. Introduction

Internal dosimetry is the science of assessing the amount and distribution of radionuclides in the body, and calculating resulting radiation doses to internal organs or tissues over specific time periods. Because the ionizing radiation energy deposited in a particular organ from radionuclides incorporated in the body cannot be measured directly, internal doses are estimated or inferred from in vivo or in vitro bioassay or from air concentration measurements. During work at nuclear facilities, the potential for intake of radionuclides by ingestion, inhalation, wound, or absorption through the skin often exists. Therefore, internal dosimetry programs are instituted to monitor the type and magnitude of such intakes and radiation dose associated with them.

2. Scope, Purpose, and Application

In the past, internal dosimetry standards have focused on providing guidance for detection and dose assessment for specific radionuclides or groups of radionuclides (e.g., tritium, uranium, and fission and activation products). Frequently, however, these standards provided conflicting or uneven treatment of the programmatic elements that are basic to monitoring for and assessing the dose from any radionuclide. Therefore, this standard was developed to provide uniform and consistent guidance on programmatic issues that are universally applicable to all radionuclides and all occupational intake pathways.

This standard contains the essential elements of the internal dosimetry component of a radiation protection program. It provides general policies and the framework for the design and implementation of an acceptable internal dosimetry program. The topics included herein are definitions, organization, staffing and training, program documentation, quality assurance, personnel participation, internal dose assessment, incident response, and records and reports.

Other than those examples necessary for clarification, this standard does not address bioassay or internal dose assessment methodologies for specific radionuclides.^(a) It is intended that the development and implementation of radionuclide-specific dosimetry programs be consistent with the broad-scoped guidance provided herein.

By its very nature, internal dosimetry is a complex task with varying degrees of difficulty, depending upon the radionuclide and the means by which the radionuclide is metabolized. For some radionuclides, such as tritium, it is relatively easy to monitor for and assess intakes that result in small doses. For others, such as

(a) Also excluded is information on dosimetric quantities and units, regulatory interactions, regulatory or administrative dose limits, methods of and recommendations on decorporation therapy, performance requirements for bioassay methodologies, bioassay frequencies, and uncertainties in assessment results. The reader is referred to the References for information on these and related topics.

^{239}Pu , the task is significantly more difficult. Therefore, while this standard provides the minimal acceptable elements of an internal dosimetry program regardless of the radionuclide, it should not be used to restrict the level of excellence readily achievable for some radionuclides.

This standard provides guidance for programs where monitoring for possible intakes by workers is part of the radiation protection program.

Engineered containment and administrative controls are used to minimize the probability of an intake due to normal operations and accident releases. Workplace surveillance practices identify that the containment and administrative controls are effective. Routine bioassay monitoring provides verification that radiological controls are being maintained and work effectively. Special bioassay is performed in response to indications of an abnormal condition that might have resulted in an intake. This standard focuses on establishing intake monitoring programs, identifying intakes, and assessing internal dose. It does not address equally important aspects of radiation protection involving minimizing intakes or implementing as-low-as-reasonably-achievable total dose control programs.

A graded approach is presented to account for programs involving only a small risk of intake through programs with a risk of intake that might result in an exposure above regulatory limits or even potential radiation-induced health effects. Although most of the standard addresses details relevant to programs with known or substantial risks of intakes, it is recognized that one important purpose of internal dosimetry programs is to document that workplace controls are adequate and no recordable intakes are occurring. Therefore, some guidance is

provided for programs (or a part of a program) that would not be expected to involve dose assessment.

2.1 Normative References

The following standards contain provisions that, through reference in this text, constitute provisions of this American National Standard. At the time of publication, the editions indicated were valid. All standards are subject to revisions, and parties to agreements, based on this American National Standard, are encouraged to investigate the possibility of applying the most recent edition(s) of the standards indicated below:

- 1) An American National Standard – Performance Criteria for Radiobioassay, HPS N13.30-1996.
- 2) An American National Standard – Practice for Occupational Radiation Exposure Records System, ANSI/HPS N13.6-1999.

3. Definitions for this Standard

Definitions are grouped by subject matter and are arranged alphabetically within each grouping.

3.1 Bioassay

Bioassay. In this standard, bioassay is synonymous with radiobioassay; measurement of amount or concentration of radioactive material in the body or in biological material excreted or removed from the body and analyzed for purposes of estimating the intake or amount of radioactive material in the body.

Bioassay, baseline. Measurements performed prior to the commencement of duties involving risk of intake of radioactive material.

Bioassay, in vitro (or indirect). Measurements to determine the presence of or to estimate the amount of radioactive material in excreta or other biological materials removed from the body.

Bioassay, in vivo (or direct). Measurements of radioactive material in the body using instruments that detect radiation emitted from the radioactive material in the body.

Bioassay, termination (or ending work assignment). Measurements performed after the worker has ceased working where there was risk of an intake or because a confirmatory measurement is desired. Termination bioassay is specific for radionuclides to which the worker was at risk of intake, not to radiation work in general. For instance, if a worker ceased work with exposure to one radionuclide (e.g., ^{90}Sr) and was about to begin work with another radionuclide (e.g., ^3H), a termination measurement might be obtained for the exposure to the ^{90}Sr and another measurement might be obtained as the baseline bioassay for the ^3H . (In fact, both measurements might be performed on the same urine sample.)

3.2 Detection Levels

Analytical decision level (critical level), L_C . The amount of a count or final instrument measurement of a quantity of analyte at or above which a decision is made that a positive quantity of the analyte is present.

Minimum detectable activity (or amount) (MDA). The smallest activity (or amount) of a radionuclide (or analyte) that will be detected with a probability β of non-detection (Type II error) while accepting a probability α of erroneously deciding that a positive (non-zero) quantity of analyte is present in an appropriate blank sample (Type I error).

3.3 Dose

This standard adopts the terminology presented in ICRP Publication 60 (ICRP 1991). However, this standard also recognizes that there are two systems of dose units in use at this time. Dose equivalent and equivalent dose are similar in concept but numerically different because they involve different tissue weighting factors. Also, they are associated with different primary dose limits. Recommendations in this standard are intended to be independent of (and can be applied to) whichever system of units and tissue weighting factors are required by the user's regulations. For convenience to the reader, only the equivalent dose system is used in the text of this standard; however, programs required to use the dose equivalent system may substitute that system of units without changing the meaning or magnitude of the recommendations.

Committed effective dose. The sum of the committed equivalent doses to the various organs and tissues in the body, each multiplied by the appropriate tissue weighting factor.

Committed equivalent dose. The time-integral of the equivalent dose rate for 50 years (for adults) after an intake.

Effective dose. The sum of the equivalent doses to the various organs and tissues in the body, each multiplied by the appropriate tissue weighting factor.

Equivalent dose. The product of the absorbed dose averaged over an organ or tissue and the radiation weighting factor summed over the types of ionizing radiations.

3.4 Intake, Limits

Annual limit on intake (ALI). The activity of a radionuclide which taken alone would irradiate a person, represented by Reference Man (ICRP 1974) to the annual regulatory limit.

Confirmed intake. An intake due to occupational sources judged to have a high probability of having occurred, that judgment being based on special bioassay, by association with a known incident, by exposure to known conditions likely to produce an intake, or by investigation. Information about confirming an intake is found in Section 9.7.

Deterministic annual limit on intake (DALI). 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).

Intake. The amount of a radionuclide that enters the body. For inhalation, it is the material inhaled (including material that is subsequently exhaled). For material absorbed through the intact skin, it is the amount absorbed through the skin. For a wound or abraded skin, it is the amount absorbed through the skin; for practical purposes, it does not include material on the skin near the wound or material in the wound that is easily and promptly washed away. However, it does include material that is later removed by medical treatment if the time from deposition to treatment is deemed long enough to allow some material to reach the systemic circulation prior to treatment. Intake is independent of time. Use of the term 'intake' can be confusing unless the time period of intake is specified; in practice it is usually associated with 1) a single event and considered an instantaneous intake, 2) several individual events during a monitoring period, or 3) nearly continuous intakes during a monitoring period.

Stochastic annual limit on intake (SALI). 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, 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.

3.5 Quality

Quality assurance. All planned and systematic actions that are necessary to provide adequate confidence that a product or service satisfies given requirements for quality. Quality assurance usually requires a continuing evaluation of factors that affect the adequacy of the design or specification for intended applications as well as verifications and audits of production, installation, and inspection of operations.

Quality control. The operational techniques and activities that are used to fulfill requirements for quality. Quality control involves operational techniques and activities aimed both at monitoring a process and at identifying causes of unsatisfactory performance at relevant stages of the quality loop in order to result in economic effectiveness.

Quality management. That aspect of the overall management function that determines and implements the quality policy. Quality management includes strategic planning, allocation of resources, training, and other systematic activities for quality such as quality planning, operations, and evaluations.

Quality policy. The overall quality intention and direction of the nuclear facility with regard to quality. Quality policy forms one element of corporate policy and is typically authorized and supported by top management.

Quality system. The organizational structure, responsibilities, procedures, processes, and

resources used to implement quality management.

3.6 Reference Levels

Investigation level. The level of intake at or above which a bioassay or air monitoring result shall be investigated for purposes of confirming intake and assessing dose.

Medical referral level. The level of intake at or above which the medical staff shall be notified.

Reference level. A level used to trigger a course of action when the value of a quantity equals, exceeds, or is predicted to exceed the particular level. In this standard, reference levels are based on intake and are expressed as fractions of the SALI. A **derived reference level** is the expected value of a bioassay result or an air sample result that would result from or lead to an intake at the reference level. Details on reference levels and derived reference levels are provided in Section 5.

Screening level. The level of intake below which a bioassay or air sampling result need not be considered for investigation of intake and assignment of dose.

Verification level. The level of unexpected intake at or above which an attempt to confirm the intake as real should be made.

3.7 Types of Monitoring Program

This standard recognizes three types of intake monitoring programs consistent with those discussed by the ICRP in their Publication 54 (ICRP 1988). A fourth type of monitoring discussed in that publication, operational monitoring, was considered to be a special case applicable to any of the other three programs, depending on the specific situation, and was not adopted as a separate category. Information and requirements on aspects of monitoring are provided in Section 9, and requirements for

when the types of monitoring should be used are provided in Section 10.

Monitoring. In this standard, refers to both bioassay and air monitoring unless specifically stated as one or the other.

Confirmatory monitoring. Monitoring performed to verify exposure conditions for workers thought not likely to be exposed at levels requiring routine monitoring.

Routine monitoring. Regular measurements on individual workers. For bioassay programs, routine monitoring includes baseline bioassay measurements, such as might be obtained on newly hired workers or workers just starting work involving exposure to a new (for the worker) radionuclide and final bioassay measurements before being removed from a routine program, such as might be obtained for a worker terminating employment or terminating work with a specific radionuclide. Routine monitoring can include air sampling when the air sample results can be linked to individual workers. Routine monitoring can also include planned, but not regular, monitoring associated with a specific task, for instance, by obtaining a bioassay measurement at the end of a specific task or by increasing the frequency of measurements during the task.

Special monitoring. Any monitoring that is not required for routine monitoring but is performed for confirmation of a suspected intake or for follow-up evaluation of a confirmed intake.

3.8 Uncategorized Definitions

Assigned respiratory protection factor. The expected workplace level of respiratory protection that would be provided by a properly functioning respirator or class of respirators to properly fit and trained users. Factors are provided in Table 1 of ANSI Z88.2 - 1992 (ANSI 1992).

Decorporation. The chemical acceleration of the removal of radioactive atoms from the body using chelating agents, which bind the atoms and cause them to be excreted.

Radiation protection manager. An individual who has been given the authority to implement the radiation protection program at a facility that uses radioactive material.

Shall. As used in this standard, shall denotes a requirement rather than a recommendation.

Should. As used in this standard, should denotes a recommendation; however, other alternatives may be acceptable and the size of the program and the relative risks of intakes by personnel may be taken into account.

4. Essential Elements of Internal Dosimetry Programs

The internal dosimetry program provides the capability to assess internal radiation doses to workers and others from radioactive materials under jurisdiction of a radiation protection program. This section describes the essential elements of a functional internal dosimetry program. These elements are introduced below with detailed requirements being provided in subsequent sections.

4.1 Program Organization

The internal dosimetry program is part of the overall radiation protection program at a nuclear facility. Its purpose is to provide the functional capability to monitor workers for potential intakes of radionuclides, to identify when they occur, and to appropriately assess and record internal doses after confirmed intakes. Program organization elements are briefly described below. Further requirements for organization, staffing, and training are described in Section 6.

4.1.1 Management

The radiation protection manager is responsible for ensuring that the internal dosimetry program is adequately staffed by internal dosimetry specialists capable of performing the program functions.

4.1.2 Staffing

Technical direction of the internal dosimetry program is provided by a competent specialist having the requisite education, expertise, and experience to manage the program. This person is supported by such staff as may be required to conduct the program, which depends largely on the size of the work force monitored and the potential for radionuclide intakes.

4.1.3 Qualifications, Training, and Resources

Internal dosimetry specialists require a broad educational foundation in mathematics, physics, biology, computer science, and chemistry. Other more specific educational requirements include specific training in general health physics, nuclear radiation physics, anatomy, physiology, and radiation biology.

Management provides the computational resources needed for internal dose assessment. These include computer equipment and software for dose assessment and record-keeping, and the scientific reference materials needed to maintain appropriate and adequate capabilities in internal dose assessment. Capable staff are familiar with the major scientific metabolic models, including those used for the respiratory tract, the gastro-intestinal tract, skeletal tissues, and other soft tissues, as recommended by various national and international scientific organizations. Staff also maintain familiarity with current literature describing preferred models and methods for internal dose assessment.

Experience and practice sharpen the skills of internal dosimetry specialists. New internal

dose evaluators are usually trained by an established internal dosimetry specialist. A period of apprenticeship is also desirable, depending on the complexity of anticipated dose assessments. Opportunities for continuing education, commensurate with job requirements and depending on individual staff needs, are provided by management.

4.2 Program Documentation

Three elements constitute the minimum documentation for the internal dosimetry program:

- (1) program description,
- (2) procedures, and
- (3) technical basis documentation.

This documentation describes the program purpose and organization, the methods by which program goals are carried out, and the scientific and technical bases for the methods and objectives. A brief description of this documentation is given below. Further requirements for program documentation are described in Section 7.

4.2.1 Program Description

A general description of the site-specific internal dosimetry program, together with programmatic goals, is documented and may be part of the site radiation safety manual or comparable document. The functional objectives of the program are described and include worker protection and compliance with regulatory requirements. The program description also addresses responsibilities of management and program staff.

4.2.2 Procedures Documentation

The procedures specify all methods and materials required for workplace monitoring, bioassay, data collection, calculation of internal dose, and record-keeping. Methods for evaluating specific radionuclides, mixtures of radionuclides, and materials of variable chemical characteristics are also described. Dosimetry models and software are described. A descrip-

tion of the quality assurance/quality control procedures to be applied to dose assessment is given. It includes guidelines for the prompt follow-up of potentially exposed workers. It also describes the actions to be considered in the medical management of workers with excessive intakes of radionuclides. Procedures for maintaining records and historical documents generated by the program are also included. These procedures are updated periodically, particularly with respect to new data on facility conditions or the chemical and radiological characteristics of radioactive material in the workplace.

4.2.3 Technical Basis Documentation

The technical basis documentation provides the scientific principles upon which the internal dosimetry program is based. It describes the radionuclides monitored in the workplace, their chemical form and other characteristics pertinent to dose assessment. It provides the theoretical basis for evaluating bioassay data and air-monitoring data, estimating intakes, and calculating internal dose. It includes a description of the most appropriate biokinetic models, model parameters, and other assumptions needed for intake assessment and dosimetry. The implementation of these models and model parameters in computer programs or software is also described, and parameters for evaluating data and confirming intakes are addressed. The documentation also provides action levels, which are based on bioassay results. These values are derived from calculations employing the specific models and parameters described in the document. The technical basis documentation is updated periodically to stay current with respect to changing standards and requirements and the evolution and improvement of scientific models and biokinetic parameters.

4.3 Monitoring for Intakes

This section briefly describes the essential elements of a worker monitoring program for internal dose assessment. Further requirements for workplace monitoring and bioassay are given in Section 9.

Air sampling and other workplace monitoring are methods for identifying when an intake has occurred. Workplace monitoring and breathing zone air sampling also provide data for estimating intakes of radionuclides.

The bioassay program provides important data that may be needed to determine the time and amount of a radionuclide intake. The primary methods of bioassay are in vivo counting, and urine and fecal analyses. Other methods of bioassay may include analysis of breath, tissue, blood, sputum, or hair.

The method of bioassay measurement should be appropriate for the specific type of data needed for dose assessment. These data are collected in a manner that does not compromise the quality of the samples. The frequency of bioassay measurements is often based on an estimate of the internal dose that could go undetected between measurements.

4.3.1 Criteria for Selecting Workers and Others for Monitoring of Intakes

Monitoring is conducted for workers, visitors, students, and the embryo-fetus of declared pregnant workers who are likely to receive intakes of radionuclides, if these intakes could result in internal doses in excess of values presented in this standard. (Participation in internal dosimetry programs is discussed in Section 10.)

4.3.2 Minimum Detection Levels for Bioassay Measurements

Laboratory measurements are performed to determine the amounts of radionuclides present in bioassay samples or in the body. Facilities, equipment, and radiochemical methods for in

vivo measurements and in vitro bioassay are designed for analysis of the specific radionuclide. When technically feasible, the detection limits of these measurements are less than the derived reference levels described in the technical basis documentation. (Section 5 discusses reference levels.)

4.4 Investigating Potential Intakes

Intakes of radionuclides may be detected during routine bioassay or workplace monitoring, and are then confirmed after special bioassay. Following suspected intakes, additional measurements or other sampling are usually conducted, often while awaiting initial results, to ensure that there is an adequate amount of data at early times after intake for dose assessment. These may include further bioassay, analysis of air samples, contamination surveys, and other sources of exposure information.

4.5 Assessing Internal Dose

Internal doses are calculated, documented, and reported in a timely manner to enable appropriate follow-up action to take place. This section briefly describes the essential elements of internal dose assessment. Further requirements are defined in Section 11.

Bioassay data are interpreted using metabolic and biokinetic models appropriate to the radionuclide involved and its particle-size distribution, chemical form, and solubility. It is not essential that pre-selected models be used for all cases; rather, a scientific approach is preferred for modeling the intake, retention, translocation, clearance, and excretion of radionuclides based on careful analysis of the data and characteristics of the internally deposited materials. The effort invested in dose assessment is proportional to the complexity of the calculation, the magnitude of the projected dose, accuracy of dose value desired, and the reasonableness of the costs involved.

4.6 Recording and Reporting

All internal dosimetry records are maintained in permanent, retrievable files. These records include all measurement data, methods of calculation, and results of calculated internal doses. Recording and reporting requirements are further described in Section 13.

4.7 Quality Assurance and Quality Control

The internal dosimetry program's quality assurance procedures help reduce errors to sustain the quality of the service provided to the facility and its workers. Quality control procedures serve to ensure the reliability of data collection, data analysis, dose assessment, record-keeping, and compliance with this and other performance standards. Quality assurance and quality control procedures apply to measurement and analytical laboratory techniques, calculational techniques for dose assessment, computer programs, record-keeping systems, and other processes subject to inadvertent errors. Quality assurance and quality control requirements are further described in Section 8.

4.8 Evaluating Compliance

The internal dosimetry program is periodically reviewed by management and the site radiation protection organization to evaluate continuing compliance with this and other standards, good practices, and regulatory requirements. External peer review by qualified persons will also help maintain the scientific proficiency of the internal dosimetry program.

5. Reference Levels

For interpreting data used as indicators of a potential or probable intake, including workplace or bioassay data (usually both), this standard

endorses the concept referred to as reference levels by the ICRP (ICRP Publications 26 [1977] and 54 [1988]) and action points by the NCRP (NCRP Report No. 87 [1987]). A reference level is used to determine a course of action when the value of a quantity exceeds or is predicted to exceed the reference level (ICRP 1988). A reference level is not a limit. Such levels provide a graded response to a potential intake based on its magnitude relative to some measure of the importance of the intake.

Although the dose resulting from a deposition of radionuclides in the body is a commonly used measure of the severity of an intake, regulatory limits, recommendations of scientific bodies, and administrative or As-Low-As-Reasonably-Achievable (ALARA) levels expressed in dose vary significantly and are subject to change. Consequently, this standard adopts the stochastically based annual limit on intake (SALI) as the measure for establishing reference levels. The numerical values of the SALI may differ between countries, institutions, or companies, or vary through time, depending on the applicable dose limit upon which the SALI is based. However, the framework of reference levels as factors of SALI provided in this section applies regardless of the actual values of the SALI in use.

5.1 Applicability

5.1.1 Reference levels apply to routine and special monitoring programs. For confirmatory monitoring programs, any unexpected bioassay or air monitoring result should be investigated.

5.1.2 Because there are categories of exposed individuals that have different recommended or regulatory equivalent dose limits, the reference levels provided in this standard are numerically different for the categories of exposed individuals. The numerical levels are listed in Table 1, and the meanings and actions

Table 1. Reference Levels

Level	Radiological Worker		Member of the public ^(a)
	Adult, except declared pregnant worker	Minor or declared pregnant worker	
Screening Verification Investigation Medical referral	0.002 SALI 0.02 SALI 0.1 SALI 1 SALI	0.002 SALI 0.005 SALI 0.01 SALI 1 SALI or exceeds regulatory gestation limit	The radiation protection organization shall establish a special program for monitoring for intakes and reviewing data.

(a) When entering facility boundaries. The intent is to recognize that members of the public visiting facilities that contain radioactive materials are subject to different dose limits.

associated with the reference levels are discussed below.

5.1.3 If more than one radionuclide is involved in a real or potential intake, the SALI factors listed in Table 1 refer to the total SALI for the mixture.

Alternatively, the sum of the fraction rule can be used:

$$\sum_{i=1}^n \frac{A_i}{\text{SALI}_i} < \text{REF. LEVEL}$$

where A_i = activity of radionuclide i , and n is the number of radionuclides in the mixture.

5.2 Derived Reference Levels

Seldom do measurements performed for intake monitoring programs actually measure intake. Normally the measurement result is interpreted in terms of intake through the use of a mathematical formula or series of formulas constituting a mathematical model. For each reference level, derived reference levels, which

are the results of the various monitoring measurements equated to the reference level through the mathematical formulas, are established. For instance, derived reference levels can be established for air monitoring data based on the physical and chemical nature of the radioactive material, the worker's breathing rate, the representativeness of the air sample relative to radioactive material concentration at the worker's face, the duration of the exposure, and the assigned respiratory protection factor, if appropriate. Such derived reference levels would most likely be expressed as the concentration of the radioactive material in the air.

Similarly, derived reference levels can be established for bioassay measurements. Starting with the reference level intake, assumptions are made concerning the physical and chemical nature of the radioactive material. Biokinetic models are used to determine the value of the bioassay measurement at the applicable time after an acute intake or onset of chronic intake. (See Section 11 for discussion about the use of biokinetic models.) When expressed in the

same units as the bioassay measurement result, that value is the derived reference level for that particular bioassay measurement.

5.2.1 For routine monitoring programs, default assumptions for the various parameters needed to establish the derived reference levels should be established and documented. If there are choices for default assumptions for conditions applicable to the worker or set of workers, the default assumptions should be chosen to optimize (according to usage in ICRP Publication 60 [1991]) the derived reference level.

5.2.2 For routine monitoring of potential acute intakes, the bioassay reference level may be based on an assumption of intake at the midpoint of the bioassay interval. However, if there is insufficient workplace monitoring to provide reliable indications of potential intake, the day after the last bioassay measurement should be used.

5.2.3 For some radionuclides in some types of bioassay, the concentration of a radionuclide may exceed the analytical decision level and the derived reference level due to non-occupational sources (e.g., natural sources in food, water, or the air.)

If bioassay results because of non-occupational sources normally or often exceed the derived reference level, and are confirmed to be due to non-occupational sources, the derived reference level may be increased if

- the statistical population of the bioassay results due to non-occupational sources are established using controls with similar non-occupational exposure but no potential for occupational exposure;
- the adjusted derived reference level is set no higher than the 99 percentile of the control population;

- under the above conditions, if non-occupational levels exceed the derived investigation level, then alternate methods of intake monitoring or of data analysis should be used, if at all possible.

5.3 Screening Level

The screening level is the level of intake below which a bioassay result need not be considered for investigation of intake and assignment of dose.

5.3.1 If a bioassay or air monitoring measurement result exceeds the analytical decision level and the derived screening level, the committed effective dose^(a) should be determined. Default assumptions are acceptable for assignment of dose, but actual conditions should be used if known. (See Section 13 for recording and reporting practices.)

5.4 Verification Level

The verification level is the level of unexpected intake at or above which an attempt to confirm the intake as real should be made.

5.4.1 Confirmation should be obtained through special bioassay, unless the dosimetry organization can demonstrate that the circumstances are understood well enough to make an acceptable dose assessment with existing data.

5.4.2 When verification of an unexpected intake is initiated, the worker shall be informed. (Often an interview of the worker will be part of the verification process.) The worker shall also be informed of the results of the verification process. If dose assessment is routine and no verification is conducted, it is sufficient to report

(a) If the dose is being calculated to the embryo/ fetus, then the dose is calculated for the gestation period.

the results of the dose assessment to the worker through normal reporting mechanisms.

5.5 Investigation Level

The investigation level is the level of intake at or above which a bioassay or air monitoring result shall be investigated for purposes of confirming intake and assessing dose.

5.5.1 The actual conditions of the intake, as opposed to default assumptions, shall be determined to the extent possible.

5.5.2 Special bioassay data shall be obtained (unless it is technically infeasible, e.g., because of a short effective half-life). Individual retention or excretion patterns, or both, should be used.

5.5.3 The worker shall be notified that an investigation or a dose assessment is being performed and shall be informed of the results when completed.

5.5.4 Temporary radiation work restriction should be imposed if additional exposure could interfere with the investigation.

5.5.5 Measurements should continue until sufficient data exist to determine the level of intake and resulting dose.

5.5.6 Committed equivalent dose to organs and tissues shall be calculated and recorded.

5.5.7 An investigation is not required if the bioassay result is consistent with an expected pattern of bioassay results due to one or more previous intakes that have already been investigated.

5.6 Medical Referral Level

The medical referral level is the level of intake at or above which the medical staff shall be notified. The notification should be made as

promptly as possible. (This is not to be construed as a requirement for therapy.)

5.6.1 Unless an intake exceeding the medical referral level is not possible under credible accident conditions, levels of bioassay or workplace measurements that indicate the possibility of an intake exceeding the medical referral level shall be established. For instance, levels of facial, nasal, or mouth contamination should be established that result in prompt notification of the medical staff even before or while bioassay measurements are being obtained. (See also Section 12 for guidance on accident response.)

5.6.2 The worker shall be temporarily restricted from work involving potential intakes of radionuclides that could interfere with the ongoing investigation. If the worker is undergoing treatment because of the intake, the worker shall also be restricted from further radiological work until released by the physician in charge, the worker's line management, and the radiation protection organization.

5.6.3 A worker's exposure to a radionuclide should be eliminated or reduced to as low as practical if the intake monitoring program cannot detect a new intake that would exceed the medical referral level because of interference from a prior intake(s). This does not preclude work with different radionuclides where new intakes are readily detectable.

5.7 Flowchart

Figure 1 provides a flowchart for applying the reference levels. Dotted lines indicate "should" recommendations. For convenience the internal dosimetrist may determine the committed effective dose values corresponding to the reference SALI factors and use them in the framework discussed above.

6. Organization

6.1 Organizational Requirements

The management of the organization responsible for the radiation protection program should ensure implementation of an internal radiation protection and dose assessment program designed to minimize the combined external and internal dose (i.e., total effective dose). The structure of this organization should facilitate communication between those assessing internal doses, the operational health physicists, and management.

6.2 Staffing Requirements

The management of the radiation protection organization shall ensure that the internal dosimetry program is adequately staffed to fulfill its function. Staff must either meet the requirements outlined in Section 6.3 or have access to the services of experts who meet these requirements. Some relaxation in the rigor of these requirements may be allowed for very small programs handling a few radionuclides for which the internal dosimetry is simple and which are covered by other radionuclide-specific N13 standards. For instance, if the chemical and physical form of the radionuclide are well known and not likely to change and if the program was initially designed by a qualified internal dosimetrist, the daily maintenance of the program may be performed by staff without meeting all the requirements in Section 6.3. The internal dosimetry staff shall be qualified to recognize conditions that warrant follow-up bioassay and dose evaluation. Staff shall also be familiar with and have ready access to internal dosimetry technical references, literature, and computational tools.

6.3 Staff Qualifications

The management of the radiation protection organization shall establish minimum qualifica-

tions for those staff with internal dosimetry duties. The qualification should include both experience and education requirements.

6.3.1 Education and formal training requirements for those responsible for dose assessment should include the following:

- advanced mathematical methods, such as calculus, differential equations, and statistical analyses;
- radiochemistry and radiometric methodology and concepts;
- computer technology applicable to dose assessment;
- anatomy and physiology of the human body and effects of ionizing radiation on biological systems;
- nuclear radiation physics;
- principles of internal dosimetry including national and international guidance;
- communication of risk to workers;
- operational health physics;
- technical writing.

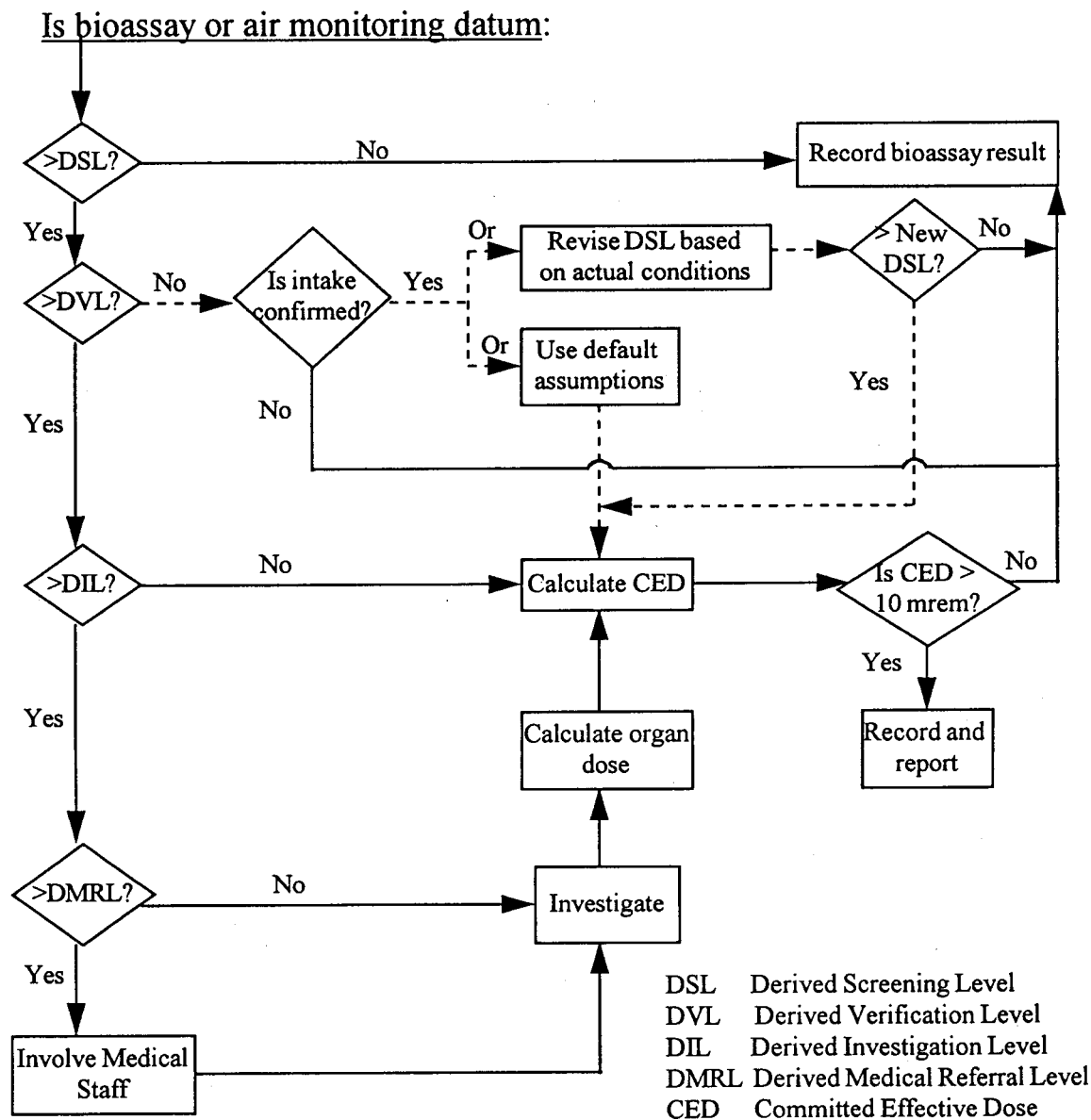


Figure 1. Flowchart showing reference levels for interpreting or responding to intake monitoring results. Dotted lines indicate “should” recommendations.