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# REGULATORY GUIDE

## REGULATORY GUIDE 8.20

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# APPLICATIONS OF BIOASSAY FOR RADIOIODINE

## A. INTRODUCTION

### Purpose

This regulatory guide describes methods that the staff of the U.S. Nuclear Regulatory Commission (NRC) considers acceptable for the development and implementation of bioassay programs for adult workers and for licensees handling or processing unsealed materials containing iodine-123 ($^{123}$I), iodine-124 ($^{124}$I), iodine-125 ($^{125}$I), iodine-129 ($^{129}$I), and iodine-131 ($^{131}$I), or a combination of these radionuclides. The title of this guide, therefore, was changed to "Applications of Bioassay for Radioiodine," instead of the previous title, "Applications of Bioassay for I-125 and I-131." However, this guide does not address measurement techniques, radiochemistry analytical procedures, or dose assessment. It applies to both reactor and materials licensees.

### Applicable Rules and Regulations

- Title 10 of the *Code of Federal Regulations* (10 CFR), Part 20, Section 1204, "Determination of internal exposure," paragraph (a) (Ref. 1) states that each licensee shall, when required under 10 CFR 20.1502, "Conditions requiring individual monitoring of external and internal occupational dose," take suitable and timely measurements of: (1) concentrations of radioactive materials in air in work areas, (2) quantities of radionuclides in the body, (3) quantities of radionuclides excreted from the body, or (4) combinations of these measurements.

- Regulations in 10 CFR 20.1201, "Occupational dose limits for adults," provide occupational dose limits for adult workers.

- Regulations in 10 CFR 20.1703, "Use of individual respiratory protection equipment," paragraph (c)(2), require licensees to implement and maintain a respiratory protection program that includes surveys and bioassays, as necessary to evaluate actual intakes.

### Related Rules and Regulations

- Regulations in 10 CFR 20.1101 "Radiation protection programs," paragraph (b), require licensees to use, to the extent practical, procedures and engineering controls based upon sound radiation protection principles to achieve occupational doses and doses to members of the public that are as low as is reasonably achievable (ALARA).

Written suggestions regarding this guide or development of new guides may be submitted through the NRC's public Web site under the Regulatory Guides document collection of the NRC Library at http://www.nrc.gov/reading-rm/doc-collections/reg-guides/contactus.html.

Electronic copies of this regulatory guide, previous versions of this guide, and other recently issued guides are available through the NRC's public Web site under the Regulatory Guides document collection of the NRC Library at http://www.nrc.gov/reading-rm/doc-collections/. The regulatory guide is also available through the NRC's Agencywide Documents Access and Management System (ADAMS) at http://www.nrc.gov/reading-rm/adams.html, under ADAMS Accession No. ML14064A060. The regulatory analysis may be found in ADAMS under Accession No. ML14064A058 and the staff responses to the public comments on DG-8050 may be found under ADAMS Accession No. ML14064A061.

- Regulations in 10 CFR 20.2202, "Notification of incidents," require each licensee to notify the NRC either immediately or within 24 hours of any event involving byproduct, source, or special nuclear material possessed by the licensee that may have caused or threatens to cause an individual to receive a dose meeting the limits specified in this section of the NRC regulations.

- Regulations in 10 CFR 20.2203, "Reports of exposures, radiation levels, and concentrations of radioactive material exceeding the constraints or limits," require a report to be sent to the NRC describing specified reportable events.

- Regulations in 10 CFR 20.2205, "Reports to individuals of exceeding dose limits," require that when a licensee is required by sections 20.2203 or 2204 to send a report to the Commission of any exposure of an identified occupationally exposed individual, or an identified member of the public, to radiation or radioactive material, the licensee shall also provide the individual a report of the data included in the report to the Commission.

**Related Guidance**

- Regulatory Guide 8.9, "Acceptable Concepts, Models, Equations, and Assumptions for a Bioassay Program" (Ref. 2), provides methods and criteria acceptable to the NRC staff for estimating intake of radionuclides using bioassay measurements.

- Regulatory Guide 8.25, "Air Sampling in the Workplace" (Ref. 3), provides methods and criteria acceptable to the NRC staff for air sampling in restricted areas in the workplace.

- NUREG-1556, Vol. 9, "Consolidated Guidance about Materials Licenses: Program-Specific Guidance about Medical Use Licenses" (Ref. 4), provides methods for the development and implementation of radioiodine bioassay programs in medical facilities.

- National Council on Radiation Protection and Measurements (NCRP) Report 159, "Risk to the Thyroid from Ionizing Radiation" (Ref. 5), provides protection guidance and global data on $^{131}I$ exposures from atmospheric testing of nuclear fallouts.

- NCRP Report 161, "Management of Persons Contaminated with Radionuclides: Handbook" (Ref. 6), provides guidance for emergency treatment if a severe intake of radioiodine was to occur.

- U.S. Environmental Protection Agency (EPA), Federal Guidance Report No. 11, "Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion" (Ref. 7), provides the technical basis and values for setting upper bounds on the inhalation, ingestion, and submersion in radioactive materials.

**Purpose of Regulatory Guides**

The NRC issues regulatory guides to describe to the public methods that the staff considers acceptable for use in implementing specific parts of the agency's regulations, to explain techniques that the staff uses in evaluating specific problems or postulated accidents, and to provide guidance to applicants. Regulatory guides are not substitutes for regulations, and compliance with them is not required. Methods and solutions that differ from those set forth in regulatory guides will be deemed acceptable if they provide a basis for the findings required for the issuance or continuance of a permit or license by the Commission.

**Paperwork Reduction Act**

This regulatory guide contains information collection requirements covered by 10 CFR Part 20, "Standards for Protection against Radiation," that the Office of Management and Budget (OMB) approved under OMB control number 3150-0014. The NRC may neither conduct nor sponsor, and a person is not required to respond to, an information collection request or requirement unless the requesting document displays a currently valid OMB control number.

# B. DISCUSSION

**Reason for Revision**

The NRC revised this guide to achieve better alignment with: (1) 10 CFR Part 20, and (2) the internal dose assessment methods recommended by the International Commission on Radiological Protection (ICRP) Publication 30, "Limits for Intakes of Radionuclides by Workers" (Ref. 8). New predetermined action levels (PALs) are specified in the Staff Regulatory Guidance section of this guide. This regulatory guide revision also provides new guidance for $^{123}$I, $^{124}$I, and $^{129}$I, and updates the content of the guide and its references.

**Background**

The guide provides methods and criteria acceptable to the NRC staff for the development and implementation of a bioassay program for any licensee handling or processing one or a combination of the five selected radionuclides. It also provides guidance regarding the selection of workers who should participate in a program to detect and measure possible internal radiation exposure.

The decisions on the type of monitoring, who is to be monitored, the frequency of monitoring, and other aspects of the program must be based on estimates of what types and quantities of intakes may occur given the kinds of activities that are expected to take place at the licensee's facility during the monitoring year. Based on operational experience, licensees may also justify adjustments in the bioassay program, such as reduction or increase in bioassay frequency or the use of alternative bioassay dosimetry models due to medical, prenatal, or other reasons, but the adjusted program shall meet NRC requirements and satisfy the requirements in 10 CFR 20.2301, "Applications for exemptions," and 10 CFR 20.2302, "Additional requirements." This guide does not include bioassay measurement techniques and procedures.

The basic criteria in Table 1, "Radioiodine Protection Properties," are specified for the development of a bioassay program. Table 1 provides the radiological half-life, annual limits on intake (ALI), derived air concentration (DAC), and the maximum bioassay duration from the beginning of an operation for the iodine isotopes. The values of radiological half-life are based on those in Federal Guidance Report No. 11. The ALI and DAC values are based on those in Column 2 and Column 3 of 10 CFR Part 20, Appendix B, "Annual Limits on Intake (ALIs) and Derived Air Concentrations (DACs) of Radionuclides for Occupational Exposure; Effluent Concentrations; Concentrations for Release to Sewerage." The duration specified in the last column of the Table 1, "Maximum Bioassay Duration from Beginning of an Operation," provides information for bioassay frequency. Specific guidance on the frequency of bioassays is found in section C of this guide.

The required bioassay criteria are specified in Table 2, "Radioactivity Levels above which Bioassay for Radioiodine is Necessary." The criteria are presented in dual radioactivity units.

## Table 1. Radioiodine Protection Properties

| Isotope | Radiological half-life[†] | ALI by inhalation: μCi (MBq) | | DAC[‡] μCi/mL (Bq/mL) | Maximum bioassay duration from beginning of an operation |
|---|---|---|---|---|---|
| | | Stochastic | Non-stochastic | | |
| $^{123}$I | 13 hours | 20,000 (740) | 6,000 (220) | 3E-6 (9E-2) | 1 day |
| $^{124}$I | 4.2 days | 300 (11) | 80 (3.0) | 3E-8 (1E-3) | 1 week |
| $^{125}$I | 60 days | 200 (7.4) | 60 (2.2) | 3E-8 (9E-4) | 2 weeks |
| $^{129}$I | 1.6 E+7 years | 30 (1.1) | 9 (0.30) | 4E-9 (1E-4) | 2 weeks |
| $^{131}$I | 8.0 days | 200 (7.4) | 50 (1.9) | 2E-8 (7E-4) | 2 weeks |

[†] Half-life values have been rounded to two significant digits.

[‡] ALI and DAC values in the Table include one significant figure, which reflects the convention used in Appendix B of 10 CFR Part 20, Table 1, Column 2 and Column 3. When a mixture of radioiodine is present, the ALI and DAC values for the mixture should be established following the methods stated in 10 CFR 20.1204(e), (f), and (g).

## Table 2. Radioactivity Levels above Which Bioassay for Radioiodine is Necessary

| Types of Operations | Radioactivity Levels in Unsealed Form above Which Bioassay is Necessary[†] | |
|---|---|---|
| | Volatile or Dispersible | Bound to Nonvolatile Agent |
| Column 1 | Column 2 | Column 3 |
| Processes in open room or bench, with possible escape of iodine from process vessels | 1 mCi (37 MBq) | 10 mCi (370 MBq) |
| Processes with possible escape of iodine carried out within well-controlled and ventilated areas (i.e., fume hood of adequate design, face velocity, and performance reliability)[‡] | 10 mCi (370 MBq) | 100 mCi (3.7 GBq) |
| Processes carried out within gloveboxes, ordinarily closed, but with possible release of iodine from process and occasional exposure to contaminated box and box leakage | 100 mCi (3.7 GBq) | 1 Ci (37 GBq) |

[†] (1) Quantities should consider the cumulative amount of the radioactivity in the process handled by a worker during a 3-month period. When the cumulative amount of radioactivity of iodine in unsealed forms during any 3-month period exceeds the specified quantities in Column 2 and Column 3 above, then bioassay is necessary. (2) the quantities in Column 3 may be used when it can be shown that the radioactive materials in the process are always chemically bound and processed in such a manner that all iodine compounds will remain in a nonvolatile form and will be diluted to a concentration of less than 100 mCi/g (3.7 GBq/g) of nonvolatile agent. (3) Capsules (such as gelatin capsules given to patients for diagnostic tests) may be considered to contain the iodine in sealed form, and bioassay would not be necessary unless a capsule were inadvertently opened (e.g., dropped and crushed). (4) If there is a breech in normal procedures during the administration of $^{131}$I, for example, spillage from the vial that exceeds the capacity of the absorbent pad, a bioassay would be necessary. (5) Certain compounds where radioiodine is normally bound are known to release radioiodine when the material is processed, and in this scenario Column 2 may be applicable. (6) For laboratories that only work with $^{125}$I in radioimmunoassay (RIA) kits, the quantities of $^{125}$I are very small and in less volatile forms; thus, Column 3 may be used for bioassay requirements. (7) In field operations, where reagent containers are opened outdoors for simple operations such as pouring liquid solutions, the above table does not apply; however, bioassay should be performed whenever an individual employee handles an unsealed source (e.g., an open bottle or container) of more than 50 millicurie (mCi) (1.8 gigabecquerel (GBq)) at any one time.

[‡] Ventilated fume hoods with face velocities that meet the design criteria in the American Conference of Governmental Industrial Hygienists (ACGIH) Industrial Ventilation Manual designed criteria, or equivalent.

Because $^{123}I$ has a half-life of 13 hours, indirect (in vitro) bioassay methods may not be practical. Therefore, a direct (in vivo) thyroid count is recommended and should be performed within 24 hours of the event, and each workday thereafter. The total 40 hours (weekly) thyroid content should also be documented for dose estimates and for ALARA purposes.

Because of the low specific activity of $^{129}I$, the low-energy gamma radiations, and the limited capacity of the thyroid gland for iodine (as described in Book, S.A., "Iodine-129 Uptake and Effects of Lifetime Feeding in Rats" (Ref. 9), which determined that the relative risk (radiological) from $^{129}I$ is less than $^{131}I$ in the thyroid), only indirect (in vitro) measurements are practical and acceptable to the NRC staff for $^{129}I$ bioassay. In addition, NCRP Report 75, "Iodine-129: Evaluation of Releases from Nuclear Power Generation" (Ref. 10), provides a complete evaluation of $^{129}I$ (i.e., physical properties, biological behavior, production sources, environmental transport, and waste management).

**Harmonization with International Standards**

The NRC has a goal of harmonizing its guidance with international standards, to the extent practical. The International Atomic Energy Agency (IAEA) has issued a significant number of standards, guidance, and technical documents, and the ICRP has issued recommendations addressing good practices in most aspects of radiation protection. The criteria and guidance of this regulatory guide are generally consistent with the guidance in these documents. These documents include:

- ICRP Publication 30, "Limits for Intakes of Radionuclides by Workers"
- IAEA Safety Guide RS-G-1.2, "Assessment of Occupational Exposure Due to Intake of Radionuclides" (Ref. 11)

The NRC encourages licensees to consult these international documents and implement good practices that are consistent with NRC regulations. It should be noted that some of the international recommendations do not correspond to the requirements specified in the NRC's regulations. In such cases, the NRC's requirements take precedence.

# C. STAFF REGULATORY GUIDANCE

## 1. Conditions under which Bioassay is Necessary

a. Conditions under which Routine Bioassay is Necessary[1]—Routine bioassay is necessary when an individual handles or works near unsealed quantities of a radioiodine substance that exceed those values specified in Table 2, "Radioactivity Levels above Which Bioassay for Radioiodine is Necessary," of this guide. The quantities shown in Table 2 apply to both the quantity handled at any one time or integrated as the total amount of activity introduced into a process by an employee over a period of 90 days.

b. Conditions under which Routine Bioassay May Be Necessary—When an individual routinely handles and works near unsealed radioiodine quantities greater than 10 percent but less than 100 percent of the Table 2 values, a routine bioassay should still be

[1] *Routine*, as used in this guide, means that an individual is assigned on a scheduled and repeatable basis to submit specimens for indirect bioassay or to report for in vivo measurements, i.e., direct bioassay, at the frequency specified in section C of this guide. Either radiochemical urinalysis or in vivo thyroid counting is acceptable to the NRC staff. In some cases, a licensee may wish to corroborate estimates from urinalysis data with in vivo determinations. Since there are adequate references in the literature to help devise bioassay measurements, this guide does not include analytical procedures. Each installation should adopt procedures or obtain services best suited to its own needs.

performed unless justification is provided for not performing routine bioassay (e.g., licensees could demonstrate by ALARA records or use of protection devices at the facility that the frequency of bioassay could be reduced/eliminated). Written justification for not performing normally required bioassay should be prepared and documented in auditable form on site for NRC inspections. When an individual routinely handles and works near unsealed quantities of less than 10 percent of those in Table 2, routine bioassay is not necessary.

c. Routine Bioassay at Reactor Facilities—In nuclear power installations, employees should receive a bioassay within 30 days after the end of exposure in work locations where concentrations exceeded, or might have exceeded, 1.0 DAC of radioiodine, averaged over any 40-hour period. Table 1, regarding frequency of bioassays, and Table 2 are not applicable to power reactor licensees.

d. Special Bioassay—A bioassay measurement should be performed within 24 hours of notification. Special bioassay measurements should be performed to verify the effectiveness of respiratory protection devices and protective clothing. If an individual wearing a respiratory protective device or protective clothing is subjected to a concentration of radioiodine (in any form) in air such that his or her intake with no protection would have resulted in a dose that would have exceeded the limits specified in 10 CFR 20.1201, perform bioassays as necessary to verify that the actual intake will not result in a dose in excess of the limits. These special bioassay procedures should also be conducted for personnel wearing respirators or other protective clothing if for any reason the radioiodine concentration(s) in air or the duration of the exposure are unknown or cannot be conservatively estimated by calculation.

**2. Participation**

All workers handling radioactive iodine or sufficiently close to the process so that intake is possible (e.g., within a few meters or in the same room as the worker handling the material, as appropriate) should participate in bioassay programs described in staff regulatory guidance C.1.

**3. Types of Bioassay that are Performed**

a. Baseline (pre-employment or preoperational). Before beginning work with radioactive iodine in sufficient quantity that bioassay is necessary, as specified in C.1.a through C.1.c.

b. Routine. As described in C.1.a through C.1.c, at the frequency specified in C.4.

c. Emergency. As soon as possible after any incident that might cause thyroid uptakes to exceed the PAL specified in C.5.b., bioassays (including the initial post-event bioassays and all subsequent diagnostic bioassays) should be performed as discussed in C.5.b.

d. Post-operational and physical separation. A bioassay should be performed within the maximum bioassay duration specified in Table 1 when operations are being discontinued or when the worker is terminating. A contingency plan should be developed to ensure the collection of the post-operational or termination bioassay measurements, to the extent practicable.

e. Diagnostic. Follow-up bioassay should be performed within the maximum bioassay duration specified in Table 1 of any measurements exceeding PAL levels given as action points in C.5 in order to confirm the initial results and, in the case of a single intake, to allow an estimate of the effective half-life of radioiodine in the thyroid.

f. Special. As described in C.1.d.

**4. Frequency of Routine Bioassay**

The basis for adjusting an individual's bioassay frequency should be documented and retained on site in an auditable form.

a. Initial Routine (within First 3 Months). Except in situations where thyroid contents may exceed the PAL level specified in C.5.a, a bioassay should be performed within the maximum bioassay duration specified in Table 1 following initial entry of an individual into an area where bioassay is performed in accordance with C.1 and C.2 or more frequently thereafter as long as the conditions described in C.1 and C.2 exist. When work with radioactive iodine is on an infrequent basis (less frequently than every 2 weeks), bioassay should be performed within the maximum bioassay duration specified in Table 1 (but not sooner than 6 hours unless emergency actions to obtain an early prognosis and thyroid blocking treatment are appropriate (Ref. 5)).

b. Routine after 3 Months. When a periodic measurement frequency has been selected in accordance with C.4.a, it may be changed to quarterly if, after 3 months, all the following conditions are met:

(1) The average thyroid content for each individual working in a given area was less than the PAL specified in C.5.a.

(2) The 3-month average radioiodine concentration in air breathed by the worker (as obtained when measurements of radioiodine concentrations in air are required) did not exceed 25 percent of the DAC values specified in Table 1.

(3) There is no reasonable expectation that the criteria in C.4.b(1) and C.4.b(2) above will be exceeded during the period in which the quarterly bioassay frequency will be employed.

**5. Predetermined Action Level**

If the thyroid contents exceed PAL values, specific actions should be performed. These values and the associated recommended actions are described as follows:

a. Whenever the thyroid content at the time of measurement exceeds 1.0 μCi (37 kBq)[2], the following actions should be taken:

[2] PAL is based on $^{131}$I and the product of the 10 percent of ALI (stochastic) and the intake retention fraction of 0.07 as iodine in the thyroid 8-hours post-intake presented in NUREG/CR-4884, "Interpretation of Bioassay Measurement" (Ref. 12).

(1) An investigation of the operations involved, including air and other in-plant surveys, should be carried out to determine the causes of exposure and to evaluate the potential for further exposures.

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

(3) A repeat direct (in vivo) bioassay for thyroid measurement should be performed within 24 hours of the last measurement, in order to confirm the presence of intake. Where direct bioassay is not feasible, indirect (in vitro) bioassay should be performed within 2 weeks of the last measurement or within the maximum bioassay duration specified in Table 1, whichever is less.

b. Whenever the thyroid content at the time of measurement exceeds 5.0 μCi (185 kBq), the following actions should be taken:

(1) Carry out all steps described under C.5.a.

(2) As soon as possible, refer the case to appropriate medical consultation for recommendations regarding therapeutic procedures that may be carried out to accelerate removal of radioactive iodine from the body. This should be done within 2-3 hours after exposure when the time of exposure is known so that any prescribed thyroid-blocking agent may be effective. NCRP Report 161 could provide guidance for emergency treatment if a severe intake of radioiodine were to occur.

(3) Carry out repeated measurements at approximately 1-week intervals or within the maximum bioassay duration specified in Table 1, whichever is less, until the thyroid content is less than 1 μCi (37 kBq). If there is a possibility of radioiodine retention in certain parts of the body that requires evaluation, continue bioassay as long as necessary to ensure that appreciable exposures do not go undetected.

(4) If the investigation indicates that further work in the area might result in exposure of a worker to concentrations that would cause the dose limits in 10 CFR 20.1201 to be exceeded, the licensee should restrict the worker from further work until the source of exposure is discovered and corrected.

c. Quarterly Measurements[3]. Carry out actions at levels as indicated under C.5.a. If measurements and surveys indicate an appreciable likelihood that a worker will receive further exposures that do not meet the criteria of C.4.b(1) and C.4.b(2), reinstitute biweekly or more frequent bioassays.

[3] For individuals placed on a quarterly schedule, bioassay should be randomly distributed over the quarter but should be done within one week after a procedure involving the handling of radioiodine (except that if $^{123}I$ is the isotope of concern, bioassay should be performed within 1 day after a procedure, due to its short physical half-life.). This will provide a more representative assessment of exposure conditions.

### 6. Reports and Notifications to the NRC and Exposed Individual

If an overexposure occurs, immediate or 24-hour notifications shall be made to the NRC as required by 10 CFR 20.2202. In addition, a report of the exposure shall be submitted to the NRC as required by 10 CFR 20.2203, and a report shall be sent to the individual as required by 10 CFR 20.2205.

## D. IMPLEMENTATION

The purpose of this section is to provide information to applicants and licensees regarding the NRC's plans for using this regulatory guide.

Methods or solutions that differ from those described in this regulatory guide may be deemed acceptable if they provide sufficient basis and information for the NRC staff to verify that the proposed alternative demonstrates compliance with the appropriate NRC regulations. Current licensees may continue to use guidance the NRC found acceptable for complying with the identified regulations as long as their current licensing basis remains unchanged**.** Backfit and issue finality considerations do not apply to licensees and applicants under 10 CFR Part 20.

# GLOSSARY

| | |
|---|---|
| **annual limit on intake (ALI)** | The derived limit for the amount of radioactive material taken into the body of an adult worker by inhalation or ingestion in a year. ALI is the smaller value of intake of a given radionuclide in a year by the Reference Man that would result in a committed effective dose equivalent of 5 roentgen equivalent man (rem) (0.05 sievert (Sv)) or a committed dose equivalent of 50 rem (0.5 Sv) to any individual organ or tissue. |
| **assessment** | A planned and documented task performed to determine whether various elements within a quality management system are effective in achieving the stated quality objectives. |
| **bioassay** | The determination of kinds, quantities, or concentrations and, in some cases, the locations of radioactive material in the human body, whether by direct measurement (in vivo counting) or by analysis and evaluation of materials excreted or removed from the human body (in-vitro analysis). |
| **derived air concentration (DAC)** | The concentration of a given radionuclide in air which, if breathed by the reference man for a working year of 2,000 hours under conditions of light work (inhalation rate of 1.2 cubic meters of air per hour), results in an intake of 1 ALI. |
| **derived air concentration-hour (DAC-hour)** | The product of the average concentration of radioactive material in air during a specified period (expressed as a fraction or multiple of the derived air concentration) and the duration of exposure to that radionuclide in hours. The DAC-hour expresses an exposure, and 2,000 DAC-hours represent an intake of 1 ALI, equivalent to a committed effective dose equivalent of 5 rem (0.05 Sv). |
| **direct bioassay (in vivo)** | Measurement of gamma or x-radiation emitted from radioactive material located within the body for the purpose of detecting or estimating the quantity (and sometimes the location) of radioactive material present. |
| **indirect bioassay (in vitro)** | Measurement of radioactivity in samples of material (usually urine and feces) excreted or removed from the human body. |
| **intake** | Radioactivity that enters the body through the respiratory tract, the gastrointestinal tract, or the skin. Intake may be acute, meaning a single intake occurring over a very short time, usually taken to be instantaneous, or chronic, occurring over a specified time. Common units used in this guide for intake are microcuries (μCi) and kilo-becquerel (kBq). |
| **overexposure** | Individual doses received in excess of the annual limits listed in Title 10 of the *Code of Federal Regulations* (10 CFR) 20.1201(a). |
| **uptake** | The quantity of material that enters the body fluids from the respiratory tract, the gastrointestinal tract, or through the skin. The term also is sometimes used to indicate material taken into a tissue or organ from circulation. Common units used in this guide for uptake are μCi and kBq. |
| **Volatile/volatility** | A measure of the tendency of a substance to vaporize. |

# REFERENCES


1. Title 10 of the *Code of Federal Regulations,* 10 CFR Part 20, "Standards for Protection against Radiation." U.S. Nuclear Regulatory Commission, Washington, DC.[4]

2. Regulatory Guide 8.9, "Acceptable Concepts, Models, Equations, and Assumptions for a Bioassay Program." U.S. Nuclear Regulatory Commission, Washington, DC.

3. Regulatory Guide 8.25, "Air Sampling in the Workplace." U.S. Nuclear Regulatory Commission, Washington, DC.

4. NUREG/CR-1556, "Consolidated Guidance about Materials Licenses: Program-Specific Guidance about Medical Use Licenses." U.S. Nuclear Regulatory Commission, Washington, DC, 2008.

5. National Council on Radiation Protection and Measurements (NCRP) Report 159, "Risk to the Thyroid from Ionizing Radiation." Bethesda, MD, 2008.[5]

6. NCRP Report 161, "Management of Persons Contaminated with Radionuclides." Bethesda, MD, 2008.

7. Environmental Protection Agency, Federal Guidance Report No. 11, "Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion." Office of Radiation Program, Washington, DC 20460, September 1988.[6]

8. International Commission on Radiological Protection (ICRP) Publication 30, "Limits for Intakes of Radionuclides by Workers: Part 1." Pergamon Press, Oxford, England, 1979.[7]

9. Book, S.A., "Iodine-129 Uptake and Effects of Lifetime Feeding in Rats." *Health Physics* 1983 July; 45(1):61-66.[8]

10. National Council on Radiation Protection and Measurements Report 75, "Iodine-129: Evaluation of Releases from Nuclear Power Generation." Bethesda, MD, 2008.

11. International Atomic Energy Agency, Safety Guide No. RS-G-1.2, "Assessment of Occupational


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[4] Publicly available NRC published documents are available on line through the NRC Library on the NRC's public Web site at http://www.nrc.gov/reading-rm/doc-collections/. The documents can also be viewed online or printed for a fee in the NRC's Public Document Room (PDR) at 11555 Rockville Pike, Rockville, MD; the mailing address is USNRC PDR, Washington, DC 20555; telephone 301-415-4737 or (800) 397-4209; fax (301) 415-3548; and e-mail pdr.resource@nrc.gov.

[5] NCRP reports may be purchased from the publishing organization at http://www.ncrponline.org/Publications/Publications.html.

[6] Publication is available at http://www.epa.gov/radiation/docs/federal/520-1-88-020.pdf or may be obtained through the EPA Web site at: http:www.EPA.org.

[7] ICRP documents may be purchased from the publishing organization at http://www.icrp.org.

[8] Copies of *Health Physics* publication may be purchased through their Web site at http://www.hps.org

Exposure Due to Intake of Radionuclides." Safety Standards Series, Vienna, Austria, 1999.[9]

12. NUREG/CR-4884, "Interpretation of Bioassay Measurements." U.S. Nuclear Regulatory Commission, Washington, DC, July 1987.

[9] Copies of International Atomic Energy Agency (IAEA) documents may be obtained through the agency's Web site at: http:www.iaea.org or by writing the International Atomic Energy Agency, P.O. Box 100 Wagramer Strasse 5, A-1400Vienna, Austria. Telephone (+431) 2600-0, Fax (+431) 2600-7, or e-mail at Official.Mail@IAEA.Org