



DRAFT REGULATORY GUIDE

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BIOASSAY AT URANIUM MILLS

A. INTRODUCTION

This guide describes a method that the staff of the U.S. Nuclear Regulatory Commission (NRC) considers acceptable for bioassay programs at uranium mills and applicable portions of uranium conversion facilities where there is a possibility of exposure to dust of uranium compounds. It also provides guidance on the conditions under which bioassay should be performed, minimum quantifiable values for direct and indirect bioassay measurements, and protective guidelines and objectives. The guide does not address measurement techniques and procedures.

Title 10 of the *Code of Federal Regulations* (CFR) Part 20, "Standards for Protection Against Radiation," (Ref. 1), §20.1204 requires that each licensee take suitable and timely measurements of (1) concentrations of radioactive materials in the 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

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This regulatory guide contains information collection requirements covered by 10 CFR Part 50 that the Office of Management and Budget (OMB) approved under OMB control number 3150-0011. 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. This regulatory guide is a rule as designated in the Congressional Review Act (5 U.S.C. 801-808). However, OMB has not found it to be a major rule as designated in the Congressional Review Act.

This regulatory guide is being issued in draft form to involve the public in the early stages of the development of a regulatory position in this area. It has not received final staff review or approval and does not represent an official NRC final staff position. Public comments are being solicited on this draft guide (including any implementation schedule) and its associated regulatory analysis or value/impact statement. Comments should be accompanied by appropriate supporting data. Written comments may be submitted to the Rules, Announcements, and Directives Branch, Office of Administration, U.S. Nuclear Regulatory Commission, Washington, DC 20555-0001; submitted through the NRC's interactive rulemaking Web page at <http://www.nrc.gov>; or faxed to (301) 492-3446. Copies of comments received may be examined at the NRC's Public Document Room, 11555 Rockville Pike, Rockville, MD. Comments will be most helpful if received by May 11, 2012.

Electronic copies of this draft regulatory guide are available through the NRC's interactive rulemaking Web page (see above); the NRC's public Web site under Draft Regulatory Guides in the Regulatory Guides document collection of the NRC's Electronic Reading Room at <http://www.nrc.gov/reading-rm/doc-collections/>; and the NRC's Agencywide Documents Access and Management System (ADAMS) at <http://www.nrc.gov/reading-rm/adams.html>, under Accession No. ML110960333. The regulatory analysis may be found in ADAMS under Accession No. ML110960341.

B. DISCUSSION

The annual dose requirements in 10 CFR Part 20 are based on a 50-year committed dose equivalent (CDE) and committed effective dose equivalent (CEDE). §20.1201, “Occupational Dose Limits for Adults,” requires licensees to control the occupational dose to certain dose limits. In addition, §20.1201(e) requires occupational intake limits of soluble uranium of 10 milligrams (mg) per week in consideration of chemical toxicity. Also, §20.1207 states that the annual occupational dose limits for minors are 10 percent of the annual dose limits for adult workers in §20.1201.

Conditions requiring individual monitoring of external and internal occupational dose are stated in §20.1502. Measurements shall be performed to determine airborne concentrations, as needed, in order to meet the requirements of §20.1204(b) and §20.1703(c) for determination of internal exposure, to verify the effectiveness of respiratory protection devices used, and to determine the actual intake following the use of respiratory protection devices.

In addition, 10 CFR Part 20, Subpart H, “Respiratory Protection and Controls to Restrict Internal Exposure in Restricted Areas,” identifies regulatory requirements to allow for the use of respiratory equipment and use of engineering controls to reduce exposure. In general, licensees using individual respiratory protection devices are required to take measurements of airborne concentrations, as needed, to select the respiratory protection devices used and to determine the actual intake while using the devices.

The purpose of this update to Regulatory Guide 8.22 is to provide better alignment with 10 CFR Part 20, with the dose assessment and bioassay interpretation methodologies recommended by the International Commission on Radiological Protection, (ICRP) Publication 30, (Ref. 2) for uranium, and with recommended interpretation methods for bioassay measurements in ICRP Publication 54, (Ref. 3). The topics discussed in this guide include (1) conditions under which bioassay should be performed, (2) types of bioassay, (3) frequency of routine bioassay, (4) action levels and the actions that should be taken based on bioassay results, (5) quality assurance and control of bioassay measurements, and (6) reporting and notifications. Lung contents and interpretation of urine data with the associated intake by either inhalation or ingestion pathways can be obtained from NUREG/CR-4884, “Interpretation of Bioassay Measurements” (Ref. 4). Additional methods to classify uranium compounds can be found in the U.S. Department of Energy (DOE) Standard, DOE-STD-1136-2009, “Guide of Good Practices for Occupational Radiological Protection in Uranium Facilities,” (Ref. 5). The inhalation classes provided in the DOE standard are listed using the ICRP latest F/M/S system, which is equivalent to the D/W/Y system.

This guide also makes recommendations based on the nephrotoxic analyses in NUREG-0874, “Internal Dosimetry Model for Applications to Bioassay at Uranium Mills,” (Ref. 6). Either radiochemical bioassay of the urinalysis or in-vivo counting is acceptable to the NRC staff for estimating intake. A program that corroborates estimates from urinalysis data with the in-vivo determinations, or vice versa, is recommended but not required. There are adequate methods in the literature to help devise bioassay sampling and measurement, which are outside the scope of this guide. Each facility should adopt procedures or obtain services best suited to its own needs.

The NRC staff reviewed International Atomic Energy Agency (IAEA) Safety Guide No. RS-G-1.2, “Assessment of Occupational Exposure Due to Intake of Radionuclides,” (Ref.7) in an effort to align with international standards. The guidance therein provides useful related information. However, the IAEA safety guide was not endorsed within the context of this guide, because it does not use definitions and methodologies of ICRP 30 which provide supporting bases for the current 10 CFR Part 20 radiological protection regulations.

C. STAFF REGULATORY GUIDANCE

1. Conditions Under Which Bioassay Is Necessary

All workers who handle and work with uranium substances, or are sufficiently close to the process so that intake is possible (e.g., within a few meters and in the same room as the worker handling the material), should participate in the bioassay programs described below.

2. Types of Bioassay That Should Be Performed

- a. Baseline Bioassay (preemployment or preoperational). Baseline urinary bioassay should be performed for each worker prior to initial assignments for such work.
- b. Routine Bioassay. These bioassays are performed during routine work operations at the frequency specified in Regulatory Position C.3 .
- c. Postoperational and Termination. A bioassay should be performed within 30 days of the last possible exposure to uranium when operations are being discontinued or terminated.
- d. Special Bioassay. Urinary bioassay should also be performed as soon as possible after an inhalation exposure, or suspected exposure, at or above the values provided below:
 - (1) *Urinalysis for Workers from Yellowcake Areas*
For any reason an inhalation exposure exceeding that resulting from an exposure to an average yellowcake concentration of 1×10^{-10} $\mu\text{Ci/mL}$ ($3.7 \mu\text{Bq/mL}$)¹ for a 40-hour workweek is suspected or air sampling data are not available.
 - (2) *Urinalysis for Workers from Ore-Dust Areas Exclusively*
For any reason an inhalation exposure exceeding that resulting from an exposure to an average ore-dust concentration of 1×10^{-10} $\mu\text{Ci/mL}$ ($3.7 \mu\text{Bq/mL}$) (based on the concentration of gross alpha activity in air) for a period of 1 calendar quarter (i.e., 90 days) is suspected.
- e. Following use of respiratory protection devices. Bioassay specimens should be collected and evaluated after a respiratory protection device is used to reduce intake of radionuclides.

1 The value of 1×10^{-10} $\mu\text{Ci/mL}$ ($3.7 \mu\text{Bq/mL}$) is not exactly consistent with the 0.2 mg/m^3 concentration limit for soluble uranium in Footnote 3 of Appendix B to 10 CFR Part 20, because of the rounding of values in Appendix B. Since 1×10^{-10} $\mu\text{Ci/mL}$ is the more restrictive of the two values, it has been used in the calculation of all the action-levels (weekly and quarterly) in this guide. For compliance purposes, Footnote 3 to Appendix B sets the weekly limit for soluble uranium compounds, which can be converted to radiological units using the specific activity of natural uranium (U-nat.) ($0.677 \mu\text{Ci/g}$). The present definition of the curie of U-nat. in 10 CFR Part 20 refers to the total activity of all uranium isotopes in the U-nat. mixture. When U-nat. is defined to be $0.711 \pm 0.1\%$ by weight ^{235}U and the ^{234}U is assumed to be in secular equilibrium with ^{238}U , 1 Ci total of U-nat. is composed of ^{234}U (48.9%), ^{235}U (2.25%), and ^{238}U (48.9%).

3. Frequency

- a. Routine bioassay specimens or samples from workers, regardless of whether or not respiratory protection devices were used, should be collected and evaluated at least once per month.
- b. Certain situations may require follow-up bioassays. Licensees should use the guidance on selecting appropriate frequencies available in Appendix A, of "Guidelines for Follow-up Uranium Bioassay Measurements (Action Levels), Based on NUREG-0874 Modeling," Table A-1 and A-2. The prescribed frequency of in-vitro urinalysis and in-vivo lung measurements is a function of the translocation classification of the inhaled uranium compound.
- c. Urinalysis should be performed with sufficient frequency to detect exposures before elimination from the body renders them undetectable. However, special specimens for urinalysis of uranium pertinent to mill operations should usually be collected at least 36 hours after the most recent occupancy in the mill. The 36-hour delay is necessary to avoid uranium that is eliminated without uptake in kidney tissues.

4. Action-Levels and Corresponding Actions

Bioassay data should be promptly and carefully reviewed by a qualified professional and appropriate action should be taken if the results exceed a preselected action-level (PAL). The corrective actions that should be taken depend on the amount of urinary uranium concentration reported. The action-levels and action-protocols in Appendix A are acceptable as protection against uranium intake. Proposals for other PALs and action protocols (other than those in Appendix A) from an applicant will be considered on a specific-case basis, if accompanied by a description of how the information in NUREG-0874 (Ref. 6) was used to derive those different criteria.

- a. It should be assumed that any confirmed positive urinalysis results are an indication of soluble uranium (Inhalation Class D, or W, or both) to which the kidney has been exposed. The corrective actions to be taken depend on the amount of uranium detected and are given in Appendix A. The suggested inhalation Class for soluble uranium compounds is tabulated in Table 1.

Table 1: Inhalation Class of Uranium Compounds (Ref. 2 and Ref. 3)

Chemical Form	Inhalation Class
UF ₆ , UO ₂ F ₂ , and U ₂ O ₂ (NO ₃) ₂	D
UO ₃ , UF ₄ , and UCl ₄	W
UO ₂ and U ₃ O ₈	Y

The information in this table is taken from Appendix B, 10 CFR Part 20, (72 Federal Register 55922, October 1, 2007).

- b. It should also be assumed that positive in-vivo results indicate the quantity of inhalation Class Y uranium retained in the lung. Corrective action should be taken in accordance with Appendix A, Table A-2 of this guide. The suggested inhalation Class for insoluble uranium compounds is tabulated in Table 1 and in Ref. 5.

- c. For unlisted uranium materials licensees should follow:
 - (1) For radiation protection (i.e., dose) purposes, classify the material as inhalation Class W.
 - (2) For chemical toxicity purposes (i.e., 10 CFR 20.1201(e)), classify the material as inhalation Class D.
 - (3) Licensees can update the inhalation class for any specific materials when an appropriate analytical analysis is performed and documented.
- d. Appendix A, Figure A-1, A-2, and A-3 should be used to determine acceptable action-levels for workers who were exposed in any insoluble-yellowcake area, soluble-yellowcake area, and ore-dust area, respectively, based on a single acute intake.
- e. When short-lived components are anticipated in urinalysis, licensees should use the recommendation in NUREG/CR-2268 (Ref. 8) to use two action-levels: at 1 µg/L Monday morning urinary excretion rate and an exposure associated urinary output of 100 µg/L during the first 24 hours after the exposure. (Table A-1 would not necessarily be applicable to these results.)
- f. If an alternative dosimetry model is to be used, an exemption is required, which must satisfy the requirements in §20.2301.

The above constitutes default guidance that may be used in the absence of information that indicates other practices may be preferable at specific licensee facilities. Licensees may adopt practices other than those described in this section if information or analyses are available that justify those alternative practices. It should be recognized that bioassay programs, including who should participate and the frequency of sampling, are prospective, except in cases of intake assessments. That means that these decisions should be based on conservative estimates of what type and quantity of intakes may occur given the kinds of activities expected to take place at the licensee's facility during the next monitoring year. The program is also confirmatory, namely to indicate that the measures in place to control airborne radioactive materials are effective and that no unexpected intakes have occurred. An unchanging process stream and adequate experience with the process may justify adjustments in the bioassay program, such as a reduction or increase in bioassay frequency, or inclusion of fewer or more workers in the program.

5. Time of Specimen Collection and Availability of Results

All bioassay results should be available, i.e., turn-around-time (TAT), to the person responsible for conducting the bioassay program within 20 days after the specimen is collected. Based on Table A-1 and Table A-2, any measurements exceeding (1) 35 µg/L of uranium in urine and (2) 16 nCi (590 Bq) of uranium in a lung, respectively, should be reported to the responsible individual within 24 hrs following receipt of data from the analytical laboratory.

6. Prevention of Specimen Contamination

Collection

- a. The specimens or samples should be collected before the worker enters the work area and in an area free of uranium contamination. The collection may occur at an area outside the mill specifically designated to be maintained contamination-free. The hands should be carefully washed prior to voiding. Use of disposable collection containers is highly recommended.
- b. Under unusual circumstances where specimens cannot be collected in this manner, the worker should shower immediately prior to voiding. When a shower is not possible, disposable plastic or rubber gloves should be worn during voiding.
- c. Sufficient urine volume should be collected to complete four separate analyses, each of which should be capable of achieving the required minimum quantifiable concentration value.

Laboratory Analysis

- a. All analyses should be performed in a qualified laboratory that is free of uranium contamination.
- b. Both on-site and off-site laboratories should maintain the quality control (QC) procedures specified in Section C.7 of this guide. Use of the laboratory, containers, and equipment for process or environmental samples should be restricted to low-level samples. (Note: The laboratory may be located within the restricted area provided these conditions are met.)
- c. External contamination is a common source of false positive results in in-vivo bioassay measurement. Care should be taken to minimize contamination. An in-vivo measurement that could reasonably indicate external contamination should initiate a repeat measurement following the subjects showering and changing clothes.

7. Quality Control

A quality control (QC) program for bioassay measurements should be established and incorporated in each bioassay program at uranium mills. All QC programs should be consistent with that recommended in Part B of Regulatory Guide 4.15, "Quality Assurance for Radiological Monitoring Programs (Inception Through Normal Operations to License Termination) – Effluent Streams and the Environment." (Ref. 9) Alternatively, the following specific QC program for bioassay at uranium mills is acceptable

a. Urinalysis

Each batch of urine specimens sent to their contracted laboratory for analysis should be accompanied by at least two control specimens. When possible, these control specimens should be taken from individuals who are not and have not been occupationally exposed to uranium; otherwise, simulated controls known to contain a uranium concentration less than 1 µg/L may be used.

The uranium urinalyses sensitivity and detection shall be achieved at a minimum quantifiable concentration (MQC) of less than 15 µg/L. The analytical laboratory should measure and document its own chemical reagent, urine blanks, and spiked standards as appropriate to check its own procedures, provide its own calibration factors, and evaluate its results for each batch. The laboratory should report the results of its urine blank and associated performance evaluation samples along with the other results reported to the mill.

b. Direct Bioassay for Lung and Thorax Measurements

For direct bioassay measurements, a QC program using persons known to have no lung or systemic uranium burdens and phantoms spiked with known amounts of uranium should be used to test the counting system before performing measurements on each group of employees.

For assuring positive bioassay measurements, the measurement quality objective of uranium contents in lung and in thorax for workers shall be better than 9 nCi (330 Bq), with Type I and Type II errors each equal to 5%.

8. Reports and Notifications

If an overexposure occurs, immediate notification and subsequent reporting must be made as required by §20.2202. In addition, §20.2203 describes requirements for routine reportable events.

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. The NRC does not intend or approve any imposition or backfit in connection with its issuance.

In some cases, applicants or licensees may propose or use a previously established acceptable alternative method for complying with specified portions of the NRC's regulations. Otherwise, the methods described in this guide will be used in evaluating compliance with the applicable regulations for license applications, license amendment applications, and amendment requests.

GLOSSARY

Annual Limit on Intake (ALI) – Means 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 rems (0.05 Sv) or a committed dose equivalent of 50 rems (0.5 Sv) to bone surface.

Bioassay – Means 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) – Means the concentration of a given radionuclide in air that, if breathed by Reference Man for a working year of 2,000 hours under conditions of light work (inhalation rate 1.2 cubic meters of air per hour), results in an intake of one ALI.

Derived Air Concentration-hour (DAC-hour) – Means the product of the average concentration of radioactive material in air during a specified period of time, 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 intake, and 2,000 DAC-hours represent an intake of one ALI, equivalent to a committed effective dose equivalent of 5 rems (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 excreted or removed from the human body, usually urine and feces.

Inhalation Class – Solubility studies have revealed notable differences in the dissolution rates of yellowcake produced under different temperature (i.e., drying and calcining) conditions due to the variation of the density, which is associated with temperature of the unit operation. For the purpose of this guide, for bioassay interpretation and dose assessment, the following distinction is made:

- Soluble yellowcake is defined as yellowcake dried under 400° C.
- Insoluble yellowcake is defined as yellowcake dried at 400° C or higher.
- Uranium ore is defined as naturally occurring earthen material that may be processed in industry to concentrate uranium minerals that it contains.
- Ore-dust areas, under normal conditions, are defined as those areas beginning with the transfer of ore from the ore-pad to the crusher through the final thickening stage of the leaching operation.
- Yellowcake areas are defined as those areas that contain uranium extracted from the ore in a liquid solution form from the ion exchange or solvent extraction stage through final packaging.

Intake – Activity that enters the body through the respiratory tract, gastrointestinal tract, or skin. Intake may be acute, meaning a single intake occurring over a very short time period, usually taken to be instantaneous, or chronic, occurring over a specified time period. Common units used in this guide for intake are μCi and Bq (e.g., $1 \mu\text{Ci} = 3.7 \times 10^4 \text{ Bq}$).

Uptake – The quantity of material that enters the body fluids through the respiratory tract, gastrointestinal tract, or skin. The term is also sometimes used to indicate material taken into a tissue or organ from circulation. Common units used in this guide for intake are μCi and Bq.

Yellowcake – The final precipitate formed in the milling process; the composition is variable and depends on the precipitating conditions.

REFERENCES¹

1. 10 CFR Part 20, “Standards for Protection Against Radiation,” U.S. Nuclear Regulatory Commission, Washington, DC.²
2. ICRP Publication 30, “Limits for Intakes of Radionuclides by Worker: Part 1,” International Commission on Radiation Protection, Pergamon Press, Oxford. (www.icrp.org)
3. ICRP Publication 54, “Individual Monitoring for Intakes of Radionuclides by Workers: Design and Interpretation,” Page 209: International Commission on Radiation Protection, Pergamon Press, Oxford. (www.icrp.org)
4. NUREG/CR-4884, “Interpretation of Bioassay Measurements,” U.S. Nuclear Regulatory Commission, Washington, DC.
5. DOE-STD-1136-2009, “Guide of Good Practices for Occupational Radiological Protection in Uranium Facilities,” U.S. Department of Energy, Washington DC. (http://www.hss.doe.gov/healthsafety/wshp/radiation/std_1136_2009.pdf)
6. NUREG-0874, “Internal Dosimetry Model for Applications to Bioassay at Uranium Mills,” U.S. Nuclear Regulatory Commission, Washington, DC. (ADAMS Accession No.ML093240418)
7. IAEA Safety Standards Series, “Assessment of Occupational Exposure Due to Intake of Radionuclides,” Safety Guide No. RS-G-1.2, International Atomic Energy Agency, Vienna. (www.iaea.org)
8. NUREG/CR-2268, “Metabolic Fate and Evaluation of Injury in Rats and Dogs Following Exposure to the Hydrolysis Products of Uranium Hexafluoride,” U.S. Nuclear Regulatory Commission, Washington, DC.
9. Regulatory Guide 4.15, “Quality Assurance for Radiological Monitoring Programs (Inception Through Normal Operations to License Termination)-Effluent Streams and the Environment.” U.S. Nuclear Regulatory Commission, Washington, DC.

¹ Publicly available NRC-published documents are available electronically through the NRC Library on NRC’s public Web site at: <http://www.nrc.gov/reading-rm/doc-collections/>. The documents also can be viewed online or printed for a fee in 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.

² Copies of the non-NRC documents included in these references may be obtained directly from the publishing organizations at the link provided.

APPENDIX A

Guidelines for Follow-up Uranium Bioassay Measurements (Action Levels), Based on NUREG-0874 Modeling

Table A-1. Corrective Actions Based on Monthly Urinary Uranium Results^a

URINARY URANIUM CONCENTRATION	INTERPRETATION	ACTIONS
Less than 15 µg/L	Uranium confinement and air sampling programs are indicated to be adequate. ^b	None. Continue to review further bioassay results.
15 to 35 µg/L	Uranium confinement and air sampling may not provide an adequate margin of safety. ^b	<ol style="list-style-type: none"> 1. Confirm results (repeat urinalysis). 2. Identify the cause of elevated urinary uranium and initiate additional control measures if the result is confirmed. 3. Examine air sampling data to determine the source and concentration of intake. If air sampling results are anomalous, investigate sampling procedures. Make corrections if necessary. 4. Determine whether other workers could have been exposed and perform bioassay measurements for them. 5. Consider work assignment limitations until the worker's urinary uranium concentration falls below 15 µg/L. 6. Improve uranium confinement controls or respiratory protection program as investigation indicates.
Greater than 35 µg/L	Uranium confinement and/or air sampling programs are not acceptable. ^c	<ol style="list-style-type: none"> 1. Take the actions stated above. 2. Continue operations only if it is virtually certain that no other worker will exceed a urinary uranium concentration of 35 µg/L. 3. Establish work restrictions for affected employees or increase uranium confinement controls if ore dust or high-temperature-dried yellowcake are involved. 4. Analyze bioassay samples weekly.
Confirmed to be greater than 35 µg/L for two consecutive specimens, confirmed to be greater than 130 µg/L for any single specimen or air sampling indication of more than a quarterly limit of intake	Worker may have exceeded regulatory limit on intake.	<ol style="list-style-type: none"> 1. Take the actions stated above. 2. Have urine specimen tested for albuminuria. 3. Obtain an in-vivo count if the worker may have been exposed to Class Y material or ore dust. 4. Evaluate exposures. 5. Establish further uranium confinement controls or respiratory protection requirements as indicated. 6. Consider continued work restrictions on affected employees until urinary concentrations are below 15 µg/L and laboratory tests for albuminuria are negative.

- a. Use Figures A-1 and A-3 to adjust action-levels for other frequencies of bioassay sampling. The model used in NUREG-0874 (Ref. 6) employs fractional composition values (F₁, F₂, F₃) for Class D, Class W, and Class Y components of yellowcake compounds. The assigned values in NUREG-0874 are based on data from available literature. The use of alternative values of F₁, F₂, and F₃ specific for a particular operation are acceptable provided that (1) details regarding their determination are described and mentioned in employee exposure records (see 10 CFR §20.2106(a)(4)) and (2) the model as published in NUREG-0874 is then used in the determination of alternative urinalysis frequencies and action-levels.
- b. However, if a person is exposed to uranium ore dust or other material of Class W or Y alone, refer to Section 6 of NUREG-0874 regarding the possible need for conducting in-vivo lung counts on selected personnel or using alternative urine sampling times and associated action-levels computed using NUREG-0874.
- c. Unless the result was anticipated and caused by conditions already corrected.

Table A-2. Corrective Actions Based on In-Vivo Results^a

AMOUNT OF URANIUM DETECTED	INTERPRETATION	ACTIONS
Below 9 nCi (330 Bq)	May be below detection limit. This result does not necessarily indicate that uranium confinement and air sampling programs are validated.	Rely on urinalysis results to determine corrective actions (unless air sampling indicates quarterly intake limits are exceeded for ore dust).
9 to 16 nCi (330 to 590 Bq)	Confinement and air sampling programs should be examined. ^b Uranium activity in lungs could be too high.	<ol style="list-style-type: none"> 1. Confirm result (repeat measurement within 6 months). Ensure that results are not caused by body surface activity. 2. Examine air sampling data to determine source and concentrations of intake. If air sampling results are anomalous, investigate air sampling procedures. Make corrections, if necessary. 3. Identify the cause of elevated activity and initiate additional uranium confinement control measures. 4. Determine whether other workers could have been exposed and perform special bioassay measurements for them. 5. Consider work assignment limitations that will permit the lung burden to be reduced through natural elimination; ensure that the lung burden does not exceed 16 nCi (590 Bq).
More than 16 nCi (590 Bq)	Uranium confinement and air sampling probably are not acceptable. ^b Uranium activity in the lungs should be reduced by increased protection measures for the workers involved.	<ol style="list-style-type: none"> 1. Within 90 days, take the actions listed above for 9 to 16 nCi (330 to 590 Bq). 2. Establish work restrictions for affected workers or increased uranium confinement control measures. (Normally workers with a lung burden greater than 16 nCi (590 Bq) are not allowed by their employer to resume work in airborne activity areas until the burden is reduced to less than 9 nCi or 330 Bq.) 3. Perform individual case studies (bioassays) for affected workers. 4. Continue operations only when it is virtually certain no additional workers will exceed 16 nCi (590 Bq).

a. The model used in NUREG-0874 (Ref. 6) employs fractional composition values (F_1 , F_2 , F_3) for Class D, Class W, and Class Y components of yellowcake compounds. The assigned values in NUREG-0874 are based on data from available literature. The use of alternative values of F_1 , F_2 , and F_3 specific for a particular operation are acceptable provided that (1) details regarding their determination are described and mentioned in employee exposure records (see 10 CFR §20.2106(a)(4)) and (2) the model as published in NUREG-0874 is then used in the determination of alternative urinalysis frequencies and action-levels.

b. Unless the result was anticipated and caused by conditions already corrected.

Data Supporting Corrective Action Levels Following a Single Acute Intake

Figure A-1
Uranium Concentration in Urine Following Inhalation Exposure of 1 ALI
to Calcining-Yellowcake (NUREG-0874)
(1 ALI = 160,000 $\mu\text{g U}$)

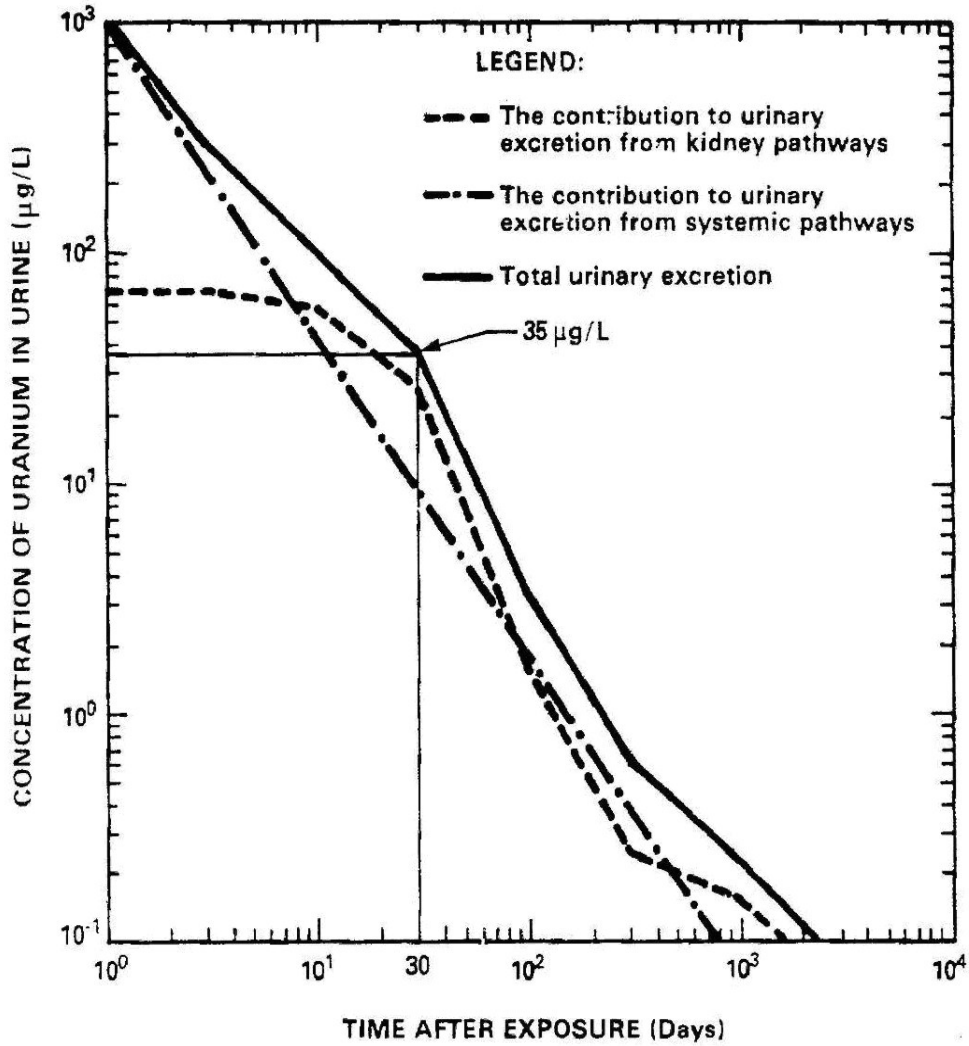


Figure A-2
Uranium Concentration in Urine Following Inhalation Exposure
of 1 ALI to Drying-Yellowcake (NUREG-0874)
(1 ALI = 260,000 $\mu\text{g U}$)

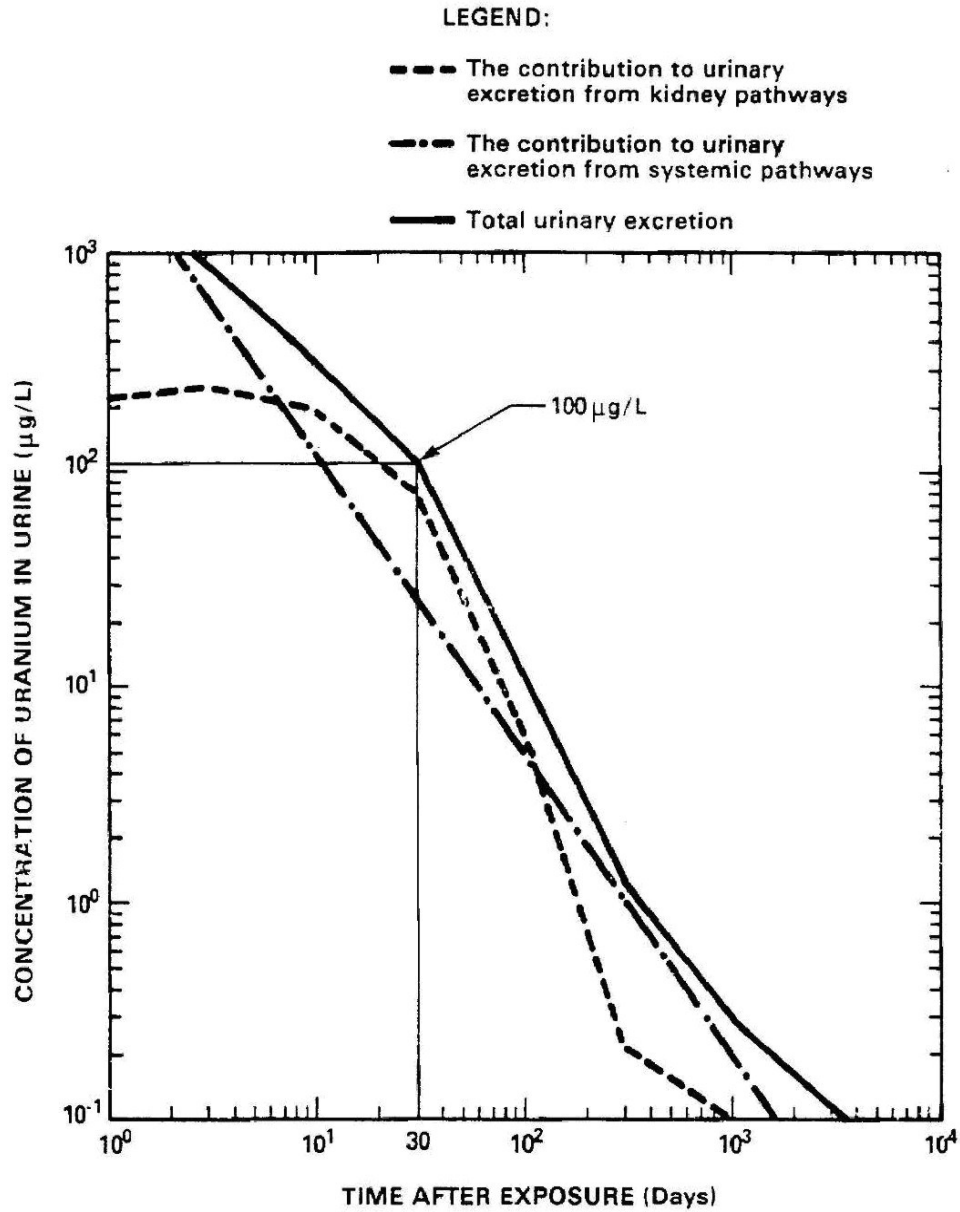


Figure A-3
Uranium Concentration in Urine Following Inhalation Exposure
of 1 ALI to Ore Dust (NUREG-0874)
(1 ALI = 46,000 $\mu\text{g U}$)

