REGULATORY GUIDE DISTRIBUTION LIST (DIVISION 4)

SUBJECT: Regulatory Guide 4.14, Revision 1, "Radiological Effluent and Environmental Monitoring at Uranium Mills"

Regulatory Guide 4.14 was originally issued for public comment in 1977. That version has now been revised as appropriate in response to public comments. In addition, the scope of the guide has been expanded to include offsite environmental monitoring. The environmental monitoring programs described in this revision were previously included in NRC publication NUREG-0511, "Draft Generic Environmental Impact Statement on Uranium Milling," published for comment in April 1979.

The NRC staff developed the regulatory positions in this Revision 1 of Regulatory Guide 4.14 over a long period of time, taking into account public input as described above. The positions are already being used by the NRC staff in the licensing process. However, this revision represents the first opportunity for public review of the staff position as a consolidated document. For this reason, it is being provided to all addressees on the Division 4 distribution list. Comments on regulatory guides are encouraged at all times, and comments on this guide will be particularly helpful to the NRC staff in evaluating the need for another revision to this guide. Comments will be most useful if they are submitted within two months of the publication of the guide.

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Director  
Office of Standards Development
A. INTRODUCTION

Uranium mill operators are required by Nuclear Regulatory Commission (NRC) regulations and license conditions to conduct radiological effluent and environmental monitoring programs. Regulations applicable to uranium milling are contained in 10 CFR Part 20, “Standards for Protection Against Radiation,” and Part 40, “Domestic Licensing of Source Material.” For example, § 40.65, “Effluent Monitoring Reporting Requirements,” of 10 CFR Part 40 requires the submission to the Commission of semianual reports containing information required to estimate doses to the public from effluent releases.

Information on radiation doses and the radionuclides in a mill’s effluents and environment both prior to and during operations is needed by the NRC staff:

1. To estimate maximum potential annual radiation doses to the public resulting from effluent releases.

2. To ascertain whether the regulatory requirements of the NRC (including 10 CFR Part 20 dose limits, release limits, and the “as low as is reasonably achievable” requirement), mill license conditions, and the requirements of 40 CFR Part 190, “Environmental Radiation Protection Standards for Nuclear Power Operations,” have been met.

3. To evaluate the performance of effluent controls, including stabilization of active and inactive tailings piles.

4. To evaluate the environmental impact of milling operations, both during operations and after decommissioning.

5. To establish baseline data to aid in evaluation of decommissioning operations or decontamination following any unusual releases such as a tailings dam failure.

This guide describes programs acceptable to the NRC staff for measuring and reporting releases of radioactive materials to the environment from typical uranium mills.

The programs described in this guide are not requirements. Licensing requirements are determined by the NRC staff on a case-by-case basis during individual licensing reviews. Individual applicants or licensees may propose alternatives for new or existing monitoring programs that need not necessarily be consistent with this guide. The justification for such alternatives will be reviewed by the NRC staff, and the acceptability of proposed alternatives will be determined on a case-by-case basis during individual licensing reviews. For example, it is anticipated that operational monitoring programs that do not include at least three continuous air samples at the site boundary will include more extensive stack sampling and more sampling locations than are described in this guide as well as meteorological data and additional environmental monitoring requirements.

B. DISCUSSION

The radiation dose an individual receives can be determined only if the radionuclides to which an individual is exposed are known. Therefore, monitoring programs should provide accurate information on the specific radionuclides in effluents from a mill, its ore piles, and its tailings retention system and in the surrounding environment.

Methods of sampling and analysis for the radionuclides associated with uranium milling are discussed in sources listed in the bibliography. The listing of these documents is not meant to be all inclusive, nor does it constitute an endorsement by the NRC staff of all of the methods in all of the listings. Rather, these listings are provided as sources of information to aid the licensee in developing a monitoring program.

The sampling program described below is divided into two parts: preoperational monitoring and operational...
monitoring. Preoperational data is submitted to the NRC as part of the application process. Operational data is reported as required by § 40.65 of 10 CFR Part 40 and specific license conditions and at times of license renewal.

C. REGULATORY POSITION

1. PREOPERATIONAL MONITORING

An acceptable preoperational monitoring program is described below and summarized in Table 1. At least twelve consecutive months of data, including complete soil sampling, direct radiation, and radon flux data, should be submitted to the NRC staff prior to any major site construction. A complete preoperational report with twelve consecutive months of data should be submitted prior to beginning milling operations. Prior to the start of local mining operations, if possible, monitoring data, including airborne radon measurements, should be submitted to the NRC staff.

Applicants may propose alternatives to this preoperational program. However, equivalent alternatives should be proposed for the operational program so that the programs remain compatible.

1.1 Preoperational Sampling Program

1.1.1 Air Samples

Air particulate samples should be collected continuously at a minimum of three locations at or near the site boundary. If there are residences or occupable structures within 10 kilometers of the site, a continuous outdoor air sample should be collected at or near the structure with the highest predicted airborne radionuclide concentration due to milling operations and at or near at least one structure in any area where predicted doses exceed 5 percent of the standards in 40 CFR Part 190. A continuous air sample should also be collected at a remote location that represents background conditions at the mill site; in general, a suitable location would be in the least prevalent wind direction from the site and unaffected by mining or other milling operations.

Normally, filters for continuous ambient air samples are changed weekly or more often as required by dust loading.

The sampling locations should be determined according to the projected site and milling operation. Preoperational sampling locations should be the same as operational locations. The following factors should be considered in determining the sampling locations: (1) average meteorological conditions (windspeed, wind direction, atmospheric stability), (2) prevailing wind direction, (3) site boundaries nearest to mill, ore piles, and tailings piles, (4) direction of nearest occupiable structure (see footnotes of Tables 1 and 2), and (5) location of estimated maximum concentrations of radioactive materials.

Samples should be collected continuously, or for at least one week per month, for analysis of radon-222. The sampling locations should be the same as those for the continuous air particulate samples.

1.1.2 Water Samples

Samples of ground water should be collected quarterly from at least three sampling wells located hydrologically down gradient from the proposed tailings area, at least three locations near other sides of the tailings area, and one well located hydrologically up gradient from the tailings area (to serve as a background sample). The location of the ground-water sampling wells should be determined by hydrological analysis of the potential movement of seepage from the tailings area, and the basis for choosing these locations should be presented when data is reported. Wells drilled close to the tailings for the specific purpose of obtaining representative samples of ground water that may be affected by the mill tailings are preferable to existing wells.

Ground-water samples should also be collected quarterly from each well within two kilometers of the proposed tailings area that is or could be used for drinking water, watering of livestock, or crop irrigation.

Samples of surface water should be collected quarterly from each onsite water impoundment (such as a pond or lake) and any offsite water impoundment that may be subject to seepage from tailings, drainage from potentially contaminated areas, or drainage from a tailings impoundment failure.

Samples should be collected at least monthly from streams, rivers, any other surface waters or drainage systems crossing the site boundary, and any offsite surface waters that may be subject to drainage from potentially contaminated areas or from a tailings impoundment failure. Any stream beds that are dry part of the year should be sampled when water is flowing. Samples should be collected at the site boundary or at a location immediately downstream of the area of potential influence.

1.1.3 Vegetation, Food, and Fish Samples

Forage vegetation should be sampled at least three times during the grazing season in grazing areas in three different sectors having the highest predicted airborne radionuclide concentration due to milling operations.

At least three samples should be collected at time of harvest or slaughter or removal of animals from grazing for each type of crop (including vegetable gardens) or livestock raised within three kilometers of the mill site.

Fish (if any) samples should be collected semiannually from any bodies of water that may be subject to seepage or surface drainage from potentially contaminated areas or that could be affected by a tailings impoundment failure.

1.1.4 Soil and Sediment Samples

Prior to initiation of mill construction (and if possible prior to mining), one set of soil samples should be collected as follows:

a. Surface-soil samples (to a depth of five centimeters) should be collected using a consistent technique at 300-
meter intervals in each of the eight compass directions out to a distance of 1500 meters from the center of the milling area. The center is defined as the point midway between the proposed mill and the tailings area.

b. Surface-soil samples should also be collected at each of the locations chosen for air particulate samples.

c. Subsurface samples (to a depth of 1 meter) should be collected at the center of the milling area and at a distance of 750 meters in each of the four compass directions.

Soil sampling should be repeated for each location disturbed by site excavation, leveling, or contouring.

One set of sediment samples should be collected from the same surface-water locations as described in Section 1.1.2. For surface water passing through the site, sediment should be sampled upstream and downstream of the site. Samples should be collected following spring runoff and in late summer, preferably following an extended period of low flow. In each location, several sediment samples should be collected in a traverse across the body of water and composited for analysis.

1.1.5 Direct Radiation

Prior to initiation of mill construction (and if possible prior to mining), gamma exposure rate measurements should be made at 150-meter intervals in each of the eight compass directions out to a distance of 1500 meters from the center of the milling area. Measurements should also be made at the sites chosen for air particulate samples.

Measurements should be repeated for each location disturbed by site excavation, leveling, or contouring.

Gamma exposure measurements should be made with passive integrating devices (such as thermoluminescent dosimeters), pressurized ionization chambers, or properly calibrated portable survey instruments.

Direct radiation measurements should be made in dry weather, not during periods following rainfall or when soil is abnormally wet.

1.1.6 Radon Flux Measurements

Radon-222 flux measurements should be made in three separate months during normal weather conditions in the spring through the fall when the ground is thawed. The measurements should be made at the center of the milling area and at locations 750 and 1500 meters from the center in each of the four compass directions. Measurements should not be taken when the ground is frozen or covered with ice or snow or following periods of rain.

1.2 Analysis of Preoperational Samples

Air particulate samples should be analyzed for natural uranium, thorium-230, radium-226, and lead-210.

Air samples collected for radon should be analyzed for radon-222.

The results of analyses of air samples should be used to determine the radionuclide concentrations for the sampling locations.

All ground-water samples collected near the tailings area should be analyzed for dissolved natural uranium, thorium-230, radium-226, polonium-210, and lead-210. Ground-water samples from sources that could be used as drinking water for humans or livestock or crop irrigation should also be analyzed for suspended natural uranium, thorium-230, radium-226, polonium-210, and lead-210.

Surface-water samples from water impoundments should be analyzed quarterly for natural uranium, thorium-230, and radium-226 and semiannually for lead-210 and polonium-210. The samples should be analyzed separately for dissolved and suspended radionuclides.

Surface-water samples from flowing surface water should be analyzed monthly for natural uranium, thorium-230, and radium-226 and semiannually for lead-210 and polonium-210. The samples should be analyzed separately for dissolved and suspended radionuclides.

The results of analyses of water samples should be used to determine the radionuclide concentrations for the sampling locations.

Vegetation, food, and fish (edible portion) samples should be analyzed for natural uranium, thorium-230, radium-226, lead-210, and polonium-210.

All soil samples should be analyzed for radium-226. Soil samples collected at air particulate sampling locations and ten percent of all other soil samples (including at least one subsurface set) should be analyzed for natural uranium, thorium-230, and lead-210. Analysis of extra soil samples may be necessary for repeat samples collected at locations disturbed by site excavation, leveling, or contouring.

Sediment samples should be analyzed for natural uranium, thorium-230, radium-226, and lead-210.

2. OPERATIONAL MONITORING

An acceptable monitoring program to be conducted during construction and after the beginning of milling operations is described below and summarized in Table 2. The results of this program should be summarized quarterly and submitted to NRC semiannually pursuant to § 40.65 of 10 CFR Part 40. An acceptable reporting format is shown in Table 3.

2.1 Operational Sampling Program

2.1.1 Stack Sampling

Effluents from the yellowcake dryer and packaging stack should be sampled at least quarterly during normal operations. The sampling should be isokinetic, representative,
and adequate for determination of the release rates and concentrations of uranium. The sampling should also be adequate for the determination of release rates and concentrations of thorium-230, radium-226, and lead-210 if this data cannot be obtained from other sources.

Other stacks should be sampled at least semiannually. The samples should be representative (not necessarily isokinetic) and adequate for the determination of the release rates and concentrations of uranium, thorium-230, radium-226, and lead-210.

All stack flow rates should be measured at the time of sampling.

2.1.2 Air Samples

Air particulate samples should be collected continuously at (1) a minimum of three locations at or near the site boundary, (2) the residence or occupiable structure within 10 kilometers of the site with the highest predicted airborne radionuclide concentration, (3) at least one residence or occupiable structure where predicted doses exceed 5 percent of the standards in 40 CFR Part 190, and (4) a remote location representing background conditions. The sampling locations should be the same as those for the preoperational air samples (see Section 1.1.1). The sampling should be adequate for the determination of natural uranium, thorium-230, radium-226, and lead-210.

Normally, filters for continuous ambient air samples are changed weekly or more often as required by dust loading.

Samples should be collected continuously at the same locations, or at least one per month, for analysis of radon-222.

2.1.3 Water Samples

Samples of ground water should be collected from at least three sampling wells located hydrologically down gradient from the tailings area and from one background well located hydrologically up gradient. The samples should be collected monthly through the first year of operation and quarterly thereafter from the same downslope and background wells that were used for preoperational samples (see Section 1.1.2).

Samples should be collected at least quarterly from each well within two kilometers of the tailings area that is or could be used for drinking water, watering of livestock, or crop irrigation.

Samples should be collected at least quarterly from each onsite water impoundment (such as a pond or lake) and any offsite water impoundment that may be subject to seepage from tailings, drainage from potentially contaminated areas, or drainage from a tailings impoundment failure.

Samples should be collected at least monthly from any surface water crossing the site boundary and offsite streams or rivers that may be subject to drainage from potentially contaminated areas or from a tailings impoundment failure. Stream beds that are dry part of the year should be sampled when water is flowing. Operational samples should be collected upstream and downstream of the area of potential influence.

Any unusual releases (such as surface seepage) that are not part of normal operations should be sampled.

2.1.4 Vegetation, Food, and Fish Samples

Where a significant pathway to man is identified in individual licensing cases, vegetation, food, and fish samples should be collected as described below.

Forage vegetation should be sampled at least three times during the grazing season in grazing areas in three different sectors having the highest predicted airborne radionuclide concentration due to milling operations.

At least three samples should be collected at the time of harvest or slaughter or removal of animals from grazing for each type of crop (including vegetable gardens) or livestock raised within three kilometers of the mill site.

Fish (if any) samples should be collected semiannually from any bodies of water that may be subject to seepage or surface drainage from potentially contaminated areas or that could be affected by a tailings impoundment failure.

2.1.5 Soil and Sediment Samples

Surface-soil samples should be collected annually using a consistent technique at each of the locations chosen for air particulate samples as described in Section 2.1.2.

Sediment samples should be collected annually from the surface-water locations described in Section 2.1.3.

2.1.6 Direct Radiation

Gamma exposure rates should be measured quarterly at the sites chosen for air particulate samples as described in Section 2.1.2. Passive integrating devices (such as thermoluminescent dosimeters), pressurized ionization chambers, or properly calibrated portable survey instruments should be used (see Regulatory Guide 4.13).

2.2 Analysis of Operational Samples

Samples from the yellowcake dryer and packaging stack should be analyzed for natural uranium. Samples should also be analyzed for thorium-230, radium-226, and lead-210 if this data cannot be obtained from other sources such as isotopic analysis of yellowcake product. Samples from other stacks should be analyzed for natural uranium, thorium-230, radium-226, and lead-210.

Air particulate samples should be analyzed for natural uranium, thorium-230, radium-226, and lead-210.

Air samples collected for radon should be analyzed for radon-222.
The results of analyses of air samples should be used to determine the radionuclide release rates for the stacks and the radionuclide concentrations for the stacks and other sampling locations.

Water samples should be analyzed for natural uranium, thorium-230, radium-226, polonium-210, and lead-210.

Ground-water samples from sources not expected to be used as drinking water should be analyzed for dissolved radionuclides. Ground-water samples from sources that could be used as drinking water for humans or livestock and all surface-water samples should be analyzed separately for dissolved and suspended radionuclides. These results should be used to determine radionuclide concentrations for ground water and natural bodies of water.

All vegetation, food, and fish (edible portion) samples should be analyzed for radium-226 and lead-210.

All soil samples should be analyzed for natural uranium, radium-226, and lead-210.

All sediment samples should be analyzed for natural uranium, thorium-230, radium-226, and lead-210.

3. QUALITY OF SAMPLES

Provisions should be made to ensure that representative samples are obtained by use of proper sampling equipment, proper locations of sampling points, and proper sampling procedures (see bibliography).

Air samples may be composited for analysis if (1) they are collected at the same location and (2) they represent a sampling period of one calendar quarter or less. Air samples should not be composited if (1) they represent a sampling period of more than one calendar quarter, (2) they are from different sampling locations, or (3) the samples are to be analyzed for radon-222.

Samples collected for analysis of radon-222 should be analyzed quickly enough to minimize decay losses.

Samples other than air samples should not be composited.

4. SOLUBILITY OF AIRBORNE RADIOACTIVE MATERIAL

Table II of Appendix B, "Concentrations in Air and Water Above Natural Background," to 10 CFR Part 20 lists separate values for soluble and insoluble radioactive materials in effluents. In making comparisons between airborne effluent concentrations and the values given in Table II of Appendix B to 10 CFR Part 20, the maximum permissible concentrations for insoluble materials should be used.

5. LOWER LIMIT OF DETECTION

The lower limits of detection for stack effluent samples should be 10% of the appropriate concentration limits listed in Table II of Appendix B to 10 CFR Part 20.

The lower limits of detection for analysis of other samples should be as follows:

<table>
<thead>
<tr>
<th>Sample Type</th>
<th>Lower Limit of Detection</th>
</tr>
</thead>
<tbody>
<tr>
<td>U-natural, Th-230, Ra-226 in air</td>
<td>$1 \times 10^{-16}$ μCi/ml</td>
</tr>
<tr>
<td>Pb-210 in air</td>
<td>$2 \times 10^{-15}$ μCi/ml</td>
</tr>
<tr>
<td>Rn-222</td>
<td>$2 \times 10^{-10}$ μCi/ml</td>
</tr>
<tr>
<td>U-natural, Th-230, Ra-226 in water</td>
<td>$2 \times 10^{-10}$ μCi/ml</td>
</tr>
<tr>
<td>Po-210 in water</td>
<td>$1 \times 10^{-9}$ μCi/ml</td>
</tr>
<tr>
<td>Pb-210 in water</td>
<td>$1 \times 10^{-9}$ μCi/ml</td>
</tr>
<tr>
<td>U-natural, Th-230, Ra-226, Pb-210 in soil and sediment (dry)</td>
<td>$2 \times 10^{-7}$ μCi/g</td>
</tr>
<tr>
<td>U-natural, Th-230 in vegetation, food, and fish (wet)</td>
<td>$2 \times 10^{-7}$ μCi/kg</td>
</tr>
<tr>
<td>Ra-226 in vegetation, food, and fish (wet)</td>
<td>$5 \times 10^{-8}$ μCi/kg</td>
</tr>
<tr>
<td>Po-210, Pb-210 in vegetation, food, and fish (wet)</td>
<td>$1 \times 10^{-6}$ μCi/kg</td>
</tr>
</tbody>
</table>

Obviously, if the actual concentrations of radionuclides being sampled are higher than the lower limits of detection indicated above, the sampling and analysis procedures need only be adequate to measure the actual concentrations. In such cases, the standard deviation estimated for random error of the analysis should be no greater than 10% of the measured value.

An acceptable method for calculating lower limits of detection is described in the appendix to this guide.

6. PRECISION AND ACCURACY OF RESULTS

6.1 Error Estimates

The random error associated with the analysis of samples should always be calculated. The calculation should take into account all significant random uncertainties, not merely counting error.

If the analyst estimates that systematic errors associated with the analysis are significant relative to the random error, the magnitude of the systematic error should be estimated.

6.2 Calibration

Individual written procedures should be prepared and used for specific methods of calibrating all sampling and measuring equipment, including ancillary equipment. The procedures should ensure that the equipment will operate with adequate accuracy and stability over the range of its intended use. Calibration procedures may be compilations...
of published standard practices, manufacturers' instructions that accompany purchased equipment, or procedures written in-house. Calibration procedures should identify the specific equipment or group of instruments to which the procedures apply.

To the extent possible, calibration of measuring equipment should be performed using radionuclide standards certified by the National Bureau of Standards or standards obtained from suppliers who participate in measurement assurance activities with the National Bureau of Standards (see Regulatory Guide 4.15).

Calibrations should be performed at regular intervals, at least semiannually, or at the manufacturer's suggested interval, whichever is more frequent. Frequency of calibration should be based on the stability of the system. If appropriate, equipment may be calibrated before and after use instead of at arbitrarily scheduled intervals. Equipment should be recalibrated or replaced after any repairs or whenever it is suspected of being out of adjustment, excessively worn, or otherwise damaged and not operating properly. Functional tests, i.e., routine checks performed to demonstrate that a given instrument is in working condition, may be performed using sources that are not certified by the National Bureau of Standards.

6.3 Quality of Results

A continuous program should be prepared and implemented for ensuring the quality of results and for keeping random and systematic uncertainties to a minimum. The procedures should ensure that samples and measurements are obtained in a uniform manner and that samples are not changed prior to analysis because of handling or because of their storage environment. Tests should be applied to analytical processes, including duplicate analysis of selected effluent samples and periodic cross-check analyses with independent laboratories (see Regulatory Guide 4.15).

7. RECORDING AND REPORTING RESULTS

This section provides guidelines for recording all results. Reports submitted to NRC should be prepared using these guidelines and the format shown in Table 3 of this guide.

7.1 Sampling and Analysis Results

7.1.1 Air and Stack Samples

For each air or stack sample, the following should be recorded:

1. Location of sample.
2. Dates during which sample was collected.
3. The concentrations of natural uranium, thorium-230, radium-226, lead-210, and radon-222 for all samples except stack samples.
4. The concentration of natural uranium, thorium-230, radium-226, and lead-210 for stack effluent samples.
5. The percentage of the appropriate concentration limit as shown in Table II of Appendix B to 10 CFR Part 20.
6. The estimated release rate of natural uranium, thorium-230, radium-226, and lead-210 for stack effluent samples.
7. The flow rate of each stack.

7.1.2 Liquid Samples

For each liquid sample, the following should be recorded:

1. Location of sample.
2. Type of sample (ground or surface water).
3. Date of sample collection.
4. The concentrations of natural uranium, thorium-230, radium-226, polonium-210, and lead-210. (If separate analyses were conducted for dissolved and suspended radionuclides, report each result separately.)

7.1.3 Other Samples

For other samples, the following should be recorded:

1. Location of sample.
2. Date of sample collection.
3. Type of sample (vegetation, soil, radon-222 flux, gamma exposure rate, etc.).
4. Analytical result (radionuclide concentration, gamma exposure rate, radon flux rate, etc.).

7.1.4 Error Estimates

Reported results should always include estimates of uncertainty. The magnitude of the random error of the analysis to the 95% uncertainty level should be reported for each result. If significant, an estimate of the magnitude of the systematic error should also be reported.

7.2 Supplemental Information

The following information should be included in each monitoring report submitted to NRC:

1. Name of facility, location, docket number, and license number.
2. Description of sampling equipment and discussion of how sampling locations were chosen.
3. Description of sampling procedures, including sampling times, rates, and volumes.

4. Description of analytical procedures.

5. Description of calculational methods.

6. Discussion of random and systematic error estimates, including methods of calculation and sources of systematic error.

7. The values of the lower limits of detection, along with a description of the calculation of the lower limit of detection.

8. The values of maximum permissible concentration from Table II of Appendix B to 10 CFR Part 20 used in any calculations.

9. Discussion of the program for ensuring the quality of results.

10. Description of calibration procedures.

11. Discussion of any unusual releases, including the circumstances of the release and any data available on the quantities of radionuclides released.

7.3 Units

Radionuclide quantities should be reported in curies. Radionuclide concentrations should be reported in microcuries per milliliter for air and water, microcuries per gram for soil and sediment, and microcuries per kilogram for vegetation, food, or fish. Direct radiation exposure rates should be reported in milliroentgens per calendar quarter. Radon flux rates should be reported in picocuries per square meter per second. Stack flow rates should be reported in cubic meters per second. (In the International System of Units, a curie equals $3.7 \times 10^{10}$ becquerels, a microcurie equals $3.7 \times 10^4$ becquerels, and a milliliter equals $10^{-6}$ cubic meters.)

Estimates of random error should be reported in the same units as the result itself. Estimates of systematic error should be reported as a percentage of the result.

Note: The Commission has discontinued the use in 10 CFR Part 20 of the special curie definitions for natural uranium and natural thorium (39 FR 23990, June 28, 1974). Reports to the Commission should use units consistent with this change.

7.4 Significant Figures

Results should not be reported with excessive significant figures, so that they appear more certain than they actually are. The reported estimate of error should contain no more than two significant figures. The reported result itself should have the same number of decimal places as the reported error.

7.5 Format

Reports should be submitted according to the format shown in Table 3.

The term “not detected,” “less than the lower limit of detection (LLD),” or similar terms should never be used. Each reported result should be a value and its associated error estimate, including values less than the lower limit of detection or less than zero.
### TABLE 1
PREOPERATIONAL RADIOLOGICAL MONITORING PROGRAM FOR URANIUM MILLS

<table>
<thead>
<tr>
<th>Type of Sample</th>
<th>Sample Collection</th>
<th>Sample Analysis</th>
<th>Type of Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type</strong></td>
<td><strong>Number</strong></td>
<td><strong>Location</strong></td>
<td><strong>Method</strong></td>
</tr>
<tr>
<td><strong>AIR</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Particulates</td>
<td>Three</td>
<td>At or near the site boundaries</td>
<td>Continuous&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>One</td>
<td>At or close to the nearest(b) residence(s) or occupable offsite structure(s) (if within 10 km of site)</td>
<td>Continuous</td>
<td>Weekly filter change or more frequently as required by dust loading</td>
</tr>
<tr>
<td>One</td>
<td>At a control or background location remote from site(c)</td>
<td>Continuous</td>
<td>Weekly filter change or more frequently as required by dust loading</td>
</tr>
<tr>
<td>Radon Gas(d)</td>
<td>Five or more</td>
<td>Same locations as for air particulates</td>
<td>Continuous or at least one week per month representing about the same period each month</td>
</tr>
<tr>
<td><strong>WATER</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ground Water(e)</td>
<td>Six or more</td>
<td>Wells located around future tailings disposal area. At least three wells hydrologically down gradient from disposal area. At least three located on other sides of tailings disposal area.(f)</td>
<td>Grab</td>
</tr>
<tr>
<td>One from each well</td>
<td>Wells within 2 km of tailings disposal area, that are or could be used for potable water supplies, watering of livestock, or crop irrigation.</td>
<td>Grab</td>
<td>Quarterly</td>
</tr>
<tr>
<td>One</td>
<td>Well located hydrologically up gradient from tailings disposal area to serve as control or background location.</td>
<td>Grab</td>
<td>Quarterly</td>
</tr>
</tbody>
</table>
**TABLE 1 (Continued)**

**PREOPERATIONAL RADIOLOGICAL MONITORING PROGRAM FOR URANIUM MILLS**

<table>
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<tr>
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<tr>
<td><strong>Type of Sample</strong></td>
<td><strong>Number</strong></td>
<td><strong>Location</strong></td>
</tr>
<tr>
<td><strong>Surface Water</strong></td>
<td>One from each body of water</td>
<td>Large permanent onsite water impoundments or offsite impoundments that may be subject to direct surface drainage from potentially contaminated areas or that could be affected by a tailings impoundment failure.</td>
</tr>
<tr>
<td><strong>Surface Water</strong></td>
<td>One from each body of water</td>
<td>Surface waters passing through the site(n) or offsite surface waters that may be subject to drainage from potentially contaminated areas or that could be affected by a tailings impoundment failure.</td>
</tr>
<tr>
<td><strong>Vegetation, Food, and Fish</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Vegetation</strong></td>
<td>Three</td>
<td>Grazing areas near the site in different sectors that will have the highest predicted air particulate concentrations during milling operations.</td>
</tr>
<tr>
<td><strong>Food</strong></td>
<td>Three of each type</td>
<td>Crops, livestock, etc. raised within 3 km of mill site</td>
</tr>
<tr>
<td><strong>Fish</strong></td>
<td>Each body of water</td>
<td>Collection of fish (if any) from lakes, rivers, and streams in the site environs that may be subject to seepage or direct surface runoff from potentially contaminated areas or that could be affected by a tailings impoundment failure</td>
</tr>
</tbody>
</table>
# Table 1 (Continued)

## Preoperational Radiological Monitoring Program for Uranium Mills

<table>
<thead>
<tr>
<th>Type of Sample</th>
<th>Sample Collection</th>
<th>Sample Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Soil and Sediment</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surface Soil</td>
<td>Up to forty 300-meter intervals to a distance of 1500 meters in each of 8 directions from center of milling area</td>
<td>Grab</td>
</tr>
<tr>
<td>Subsurface Soil Profile</td>
<td>Five At center reference location and at distances of 750 meters in each of 4 directions.</td>
<td>Grab</td>
</tr>
<tr>
<td>Sediment</td>
<td>Two from each stream Up and downstream of surface waters passing through site or from offsite surface waters that may be subject to direct runoff from potentially contaminated areas or that could be affected by a tailings impoundment failure</td>
<td>Grab</td>
</tr>
<tr>
<td>ONSITE WATER IMPOUNDMENTS</td>
<td>One from each water impoundment ONSITE WATER IMPOUNDMENTS</td>
<td>Grab</td>
</tr>
<tr>
<td>Direct Radiation</td>
<td>Up to eighty 150-meter intervals to a distance of 1500 meters in each of 8 directions from center of milling area or at a point equidistant from milling area and tailings disposal area.</td>
<td>Grab</td>
</tr>
</tbody>
</table>
### TABLE 1 (Continued)
PREOPERATIONAL RADIOLOGICAL MONITORING PROGRAM FOR URANIUM MILLS

<table>
<thead>
<tr>
<th>Type of Sample</th>
<th>Sample Collection</th>
<th>Sample Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>Location</td>
<td>Method</td>
</tr>
<tr>
<td>Five or more</td>
<td>At same locations used for collection of particulate samples</td>
<td>Once prior to site construction</td>
</tr>
<tr>
<td>RADON FLUX (n)</td>
<td>Up to ten</td>
<td>At center reference location and at distances of 750 and 1500 meters in each of 4 directions</td>
</tr>
<tr>
<td>Type of Sample</td>
<td>Sample Collection</td>
<td>Sample Analysis</td>
</tr>
<tr>
<td>---------------</td>
<td>------------------</td>
<td>----------------</td>
</tr>
<tr>
<td></td>
<td>Number</td>
<td>Location</td>
</tr>
<tr>
<td><strong>STACKS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Particulates</td>
<td>One for each stack</td>
<td>Yellowcake dryer and packaging stack(s)</td>
</tr>
<tr>
<td>Particulates</td>
<td>One for each stack</td>
<td>Other stacks</td>
</tr>
<tr>
<td><strong>AIR</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Particulates</td>
<td>Three</td>
<td>Locations at or near the site boundaries and in different sectors that have the highest predicted concentrations of airborne particulates(b)</td>
</tr>
<tr>
<td></td>
<td>One or more</td>
<td>At the nearest residence(s) or occupiable structure(s)</td>
</tr>
<tr>
<td></td>
<td>One</td>
<td>Control Location(s)(c)</td>
</tr>
<tr>
<td>Radon Gas</td>
<td>Five or more</td>
<td>Same locations as for air particulates</td>
</tr>
<tr>
<td><strong>WATER</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ground Water</td>
<td>Three or more</td>
<td>Hydrologically down gradient and relatively close to the tailings impoundment(f)</td>
</tr>
<tr>
<td></td>
<td>At least one control sample</td>
<td>Hydrologically up gradient (i.e., not influenced by seepage from tailings)</td>
</tr>
<tr>
<td>Type of Sample</td>
<td>Sample Collection</td>
<td>Sample Analysis</td>
</tr>
<tr>
<td>------------------------------------</td>
<td>-------------------</td>
<td>-----------------</td>
</tr>
<tr>
<td><strong>Operational Radiological Monitoring Program for Uranium Mills</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Table 2 (Continued)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Number</strong></td>
<td><strong>Location</strong></td>
<td><strong>Method</strong></td>
</tr>
<tr>
<td>One from each well</td>
<td>Each well used for drinking water or watering of livestock or crops within 2 km of the tailings impoundment</td>
<td>Grab</td>
</tr>
<tr>
<td><strong>Surface Water</strong></td>
<td>Two from each water body</td>
<td>Surface waters passing through the mill site or offsite surface waters that are sufficiently close to the site to be subject to surface drainage from potentially contaminated areas or that could be influenced by seepage from the tailings disposal area. (h) One sample collected upstream of mill site and one sample collected at the downstream site boundary or at a location immediately downstream of location of potential influence.</td>
</tr>
<tr>
<td>One from each water body</td>
<td>Large water impoundments (i.e., lakes, reservoirs) near the mill site that are sufficiently close to the site to be subject to drainage from potentially contaminated areas or that could be influenced by seepage from the tailings disposal area.</td>
<td>Grab</td>
</tr>
<tr>
<td><strong>Vegetation, Food, and Fish</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vegetation or Forage (o)</td>
<td>Three or more</td>
<td>From animal grazing areas near the mill site in the direction of the highest predicted airborne radionuclide concentrations</td>
</tr>
</tbody>
</table>

414-13
### TABLE 2 (Continued)

**OPERATIONAL RADIOLOGICAL MONITORING PROGRAM FOR URANIUM MILLS**

<table>
<thead>
<tr>
<th>Type of Sample</th>
<th>Sample Collection</th>
<th>Sample Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Food</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type</td>
<td>Number</td>
<td>Location</td>
</tr>
<tr>
<td>Food</td>
<td>Three of each type</td>
<td>Crops, livestock, etc. raised within 3 km of mill site</td>
</tr>
<tr>
<td>Fish</td>
<td>Each body of water</td>
<td>Collection of fish (if any) from lakes, rivers, and streams in the site environs that may be subject to seepage or direct surface runoff from potentially contaminated areas or that could be affected by a tailings impoundment failure</td>
</tr>
</tbody>
</table>

**SOIL AND SEDIMENT**

<table>
<thead>
<tr>
<th>Type</th>
<th>Number</th>
<th>Location</th>
<th>Method</th>
<th>Frequency</th>
<th>Type of Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil</td>
<td>Five or more</td>
<td>Same as for air particulate samples (k)</td>
<td>Grab</td>
<td>Annually</td>
<td>Natural uranium, Ra-226, and Pb-210</td>
</tr>
<tr>
<td>Sediment</td>
<td>One or two from each water body</td>
<td>Same as surface water samples (m)</td>
<td>Grab</td>
<td>Annually</td>
<td>Natural uranium, Th-230, Ra-226, and Pb-210</td>
</tr>
</tbody>
</table>

**DIRECT RADIATION**

<table>
<thead>
<tr>
<th>Type</th>
<th>Number</th>
<th>Location</th>
<th>Method</th>
<th>Frequency</th>
<th>Type of Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>DIRECT RADIATION</td>
<td>Five or more</td>
<td>Same as for air particulate samples</td>
<td>Continuous passive integrating device</td>
<td>Quarterly change of passive dosimeters</td>
<td>Gamma exposure rate</td>
</tr>
</tbody>
</table>
Footnotes for Tables 1 and 2:
(a) Continuous collection means continuous sampler operation with filter change weekly or as required by dust loading, whichever is more frequent.
(b) The term "nearest" as used here means the location with the highest predicted airborne radionuclide concentrations during milling operations.
(c) Care should be taken in selection of the control sampling location so that it is representative of the site conditions. In general, a location in the least prevalent wind direction from the site should provide a suitable location for a control sampling site.
(d) Various methods are acceptable; for example: (1) Continuous collection of a gaseous air sample with samples being changed about every 48 hours for a 1-week period or (2) continuous sampling.
(e) If the sample contains appreciable suspended material, it should be filtered as soon as possible following collection through a membrane filter and the filtrate acidified to 1% hydrochloric acid.
(f) The location of the ground-water sampling wells should be determined by a hydrological analysis of the potential movement of seepage from the tailings disposal area. In general, the objective is to place monitor wells in all directions around the tailings area with the emphasis on the down gradient locations.
(g) Surface-water samples to be analyzed for dissolved and suspended fractions should be filtered as soon as possible following collection through a membrane filter and the filtrate acidified to 1% hydrochloric acid.
(h) Natural drainage systems (dry washes) that carry surface runoff from the site following a precipitation event should be sampled following the event but at a frequency not greater than monthly.
(i) The milling area refers to the area that includes ore storage pads, mill buildings, and other processing areas.
(j) Thermoluminescent dosimeters should contain two or more chips or otherwise provide for two readings per exposure period (see Regulatory Guide 4.13).
(k) Surface soil samples should be collected using a consistent technique to a depth of 5 cm.
(l) Subsurface soil profile samples should be collected to a depth of one meter. Samples should be divided into three equal sections for analysis.
(m) Several samples should be collected at each location and composited for a representative sample.
(n) Radon exhalation measurements should not be taken during periods when the ground is frozen or covered with ice or snow or following periods of rain. It is recommended that these measurements be taken in the spring through the fall during normal weather conditions.
(o) Vegetation or forage sampling need be carried out only if dose calculations indicate that the ingestion pathway from grazing animals is a potentially significant exposure pathway (an exposure pathway should be considered important if the predicted dose to an individual would exceed 5% of the applicable radiation protection standard).
## TABLE 3(a)

**SAMPLE FORMAT FOR REPORTING MONITORING DATA**

1. **STACK SAMPLES**
   
   For each sample analyzed, report the following information:
   
   a. Date sample was collected
   b. Location of sample collection
   c. Stack flow rate (m³/sec)

<table>
<thead>
<tr>
<th>Radionuclide</th>
<th>Concentration (μCi/ml)</th>
<th>Error Estimate(b) (μCi/ml)</th>
<th>Release Rate (Ci/hr)</th>
<th>Error Estimate (Ci/hr)</th>
<th>LLD(c) (μCi/ml)</th>
<th>% MPC(c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>U-nat</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Th-230</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ra-226</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pb-210</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rn-222</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. **AIR SAMPLES**

   For each sample analyzed, report the following information:
   
   a. Date sample was collected
   b. Location of sample collection

<table>
<thead>
<tr>
<th>Radionuclide</th>
<th>Concentration (μCi/ml)</th>
<th>Error Estimate(b) (μCi/ml)</th>
<th>% LLD(c)</th>
<th>% MPC(c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>U-nat</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Th-230</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ra-226</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pb-210</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rn-222</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(a) This table illustrates format only. It is not a complete list of data to be reported. (See text of guide and Tables 1 and 2.)

(b) Error estimate should be calculated at 95% uncertainty level, based on all sources of random error, not merely counting error. Significant systematic error should be reported separately. See Sections 6.1, 7.1.4, and 7.3.

(c) All calculations of lower limits of detection (LLD) and percentages of maximum permissible concentration (MPC) should be included as supplemental information.
### TABLE 3 (Continued)

**SAMPLE FORMAT FOR REPORTING MONITORING DATA**

#### 3. LIQUID SAMPLES

For each sample analyzed, report the following information:

- a. Date sample was collected
- b. Location of sample collection
- c. Type of sample (for example: surface, ground, drinking, stock, or irrigation)

<table>
<thead>
<tr>
<th>Radionuclide</th>
<th>Concentration (μCi/ml)</th>
<th>Error Estimate (μCi/ml)</th>
<th>LLD (μCi/ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>U-nat (dissolved)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>U-nat (suspended)(d)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Th-230 (dissolved)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Th-230 (suspended)(d)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ra-226 (dissolved)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ra-226 (suspended)(d)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pb-210 (dissolved)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pb-210 (suspended)(d)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Po-210 (dissolved)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Po-210 (suspended)(d)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### 4. VEGETATION, FOOD, AND FISH SAMPLES

For each sample analyzed, report the following information:

- a. Date sample was collected
- b. Location of sample collection
- c. Type of sample and portion analyzed

<table>
<thead>
<tr>
<th>Radionuclide</th>
<th>Concentration (μCi/kg wet)</th>
<th>Error Estimate (μCi/kg)</th>
<th>LLD (μCi/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>U-nat</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Th-230</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ra-226</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pb-210</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Po-210</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(d) Not all samples must be analyzed for suspended radionuclides. See Sections 1.2 and 2.2 of this guide.
TABLE 3 (Continued)
SAMPLE FORMAT FOR REPORTING MONITORING DATA

5. SOIL AND SEDIMENT SAMPLES
For each sample analyzed, report the following information:
   a. Date sample was collected
   b. Location of sample collection
   c. Type of sample and portion analyzed

<table>
<thead>
<tr>
<th>Radionuclide</th>
<th>Concentration (μCi/g)</th>
<th>Error Estimate (μCi/g)</th>
<th>LLD (μCi/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>U-nat</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Th-230</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ra-226</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pb-210</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Po-210</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6. DIRECT RADIATION MEASUREMENTS
For each measurement, report the dates covered by the measurement and the following information:

<table>
<thead>
<tr>
<th>Location</th>
<th>Exposure Rate (mR/qr)</th>
<th>Error Estimate (mR/qr)</th>
</tr>
</thead>
</table>

7. RADON FLUX MEASUREMENTS
For each measurement, report the dates covered by the measurement and the following information:

| Location | Flux (pCi/m²·sec) | Error Estimate (pCi/m²·sec) |
BIBLIOGRAPHY


Handbook of Radiochemical Analytical Methods, EPA-680/4-75-001, USEPA, 1975.


Operational Health Physics, Proceedings of the Ninth Midyear Topical Symposium of the Health Physics Society, Central Rocky Mountain Chapter, Health Physics Society, P.O. Box 3229, Boulder, Colorado 80303, 1976.


APPENDIX

LOWER LIMIT OF DETECTION

For the purposes of this guide, the Lower Limit of Detection (LLD) is defined as the smallest concentration of radioactive material sampled that has a 95% probability of being detected, with only a 5% probability that a blank sample will yield a response interpreted to mean that radioactive material is present. (Radioactive material is “detected” if it yields an instrument response that leads the analyst to conclude that activity above the system background is present.)

For a particular measurement system (which may include radiochemical separation):

\[
LLD = \frac{4.66 S_b}{3.7 \times 10^4 E Y \exp(-\lambda \Delta t)}
\]

where

- **LLD** is the lower limit of detection (microcuries per milliliter);
- **\( S_b \)** is the standard deviation of the instrument background counting rate (counts per second);
- **\( 3.7 \times 10^4 \)** is the number of disintegrations per second per microcurie;
- **\( E \)** is the counting efficiency (counts per disintegration);
- **\( Y \)** is the fractional radiochemical yield (when applicable);
- **\( \lambda \)** is the radioactive decay constant for the particular radionuclide; and
- **\( \Delta t \)** is the elapsed time between sample collection and counting.

The value of \( S_b \) used in the calculation of the LLD for a particular measurement system should be based on the actual observed variance of the instrument background counting rate rather than an unverified theoretically predicted variance.

Since the LLD is a function of sample volume, counting efficiency, radiochemical yield, etc., it may vary for different sampling and analysis procedures. Whenever there is a significant change in the parameters of the measurement system, the LLD should be recalculated.*
