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REGULATORY GUIDE

OFFICE OF NUCLEAR REGULATORY RESEARCH

REGULATORY GUIDE 8.30
(Task OH 710-4)

HEALTH PHYSICS SURVEYS IN URANIUM MILLS

A. INTRODUCTION

Section 40.32, "General Requirements for Issuance of Specific Licenses," of 10 CFR Part 40, "Domestic Licensing of Source Material," states that the Commission will approve an application to operate a uranium mill if the applicant is qualified by reason of training and experience to be able to protect health and minimize danger to life and property and if the applicant's proposed equipment, facilities, and procedures are also adequate.

The following sections of 10 CFR Part 20, "Standards for Protection Against Radiation," of the Commission's regulations deal with the protection of mill workers: §20.201 requires adequate surveys, §20.101 limits worker exposure to external radiation, §20.103 limits exposure to airborne radioactive material in restricted areas, §20.202 requires personnel radiation dosimeters in certain instances, §20.203 requires posting of warning signs and controlling access to areas with high radiation levels, §20.401 requires records of radiation surveys and personnel monitoring reports, and §20.405 requires reports of overexposures.

This guide describes health physics surveys acceptable to the NRC staff for protecting uranium mill workers from radiation and the chemical toxicity of uranium while on the job. The guidance can also be applied, in part, to other types of uranium recovery facilities and portions of conversion facilities since some of the processes used in these facilities are similar to those in uranium mills.

The guide does not cover surveys to prevent the release of radioactive material to unrestricted areas or surveys to measure the exposure of the public to radioactive materials in effluents, except for surveys of the skin and clothing of workers leaving the mill and surveys of equipment and packages leaving the mill.

Any guidance in this document related to information collection activities has been cleared under OMB Clearance No. 3150-0019 and No. 3150-0013.

B. DISCUSSION

Regulatory Guide 3.5, "Standard Format and Content of License Applications for Uranium Mills," outlines the type of information that applicants for a uranium mill license should include in their applications and suggests a uniform format for presenting that information. This regulatory guide describes occupational health physics (radiation protection) surveys acceptable to the NRC licensing staff that an applicant may use for describing surveys in Section 5.5, "Radiation Safety," in Regulatory Guide 3.5.

The contents of this guide are based to a significant extent on NRC's current licensing practice. The contents of this guide are also based to a large extent on the International Atomic Energy Agency (IAEA) "Manual of Radiological Safety in Uranium and Thorium Mines and Mills" (Ref. 1). The NRC is also developing a report on occupational radiological monitoring at uranium mills that will describe how many of the surveys in this guide can be performed properly. That report will be available in late 1983.

The subjects of respiratory protection, uranium bioassay, and programs for maintaining occupational exposures to radiation as low as reasonably achievable are not included in this guide. Those subjects are covered in Regulatory Guide 8.15, "Acceptable Programs for Respiratory Protection," Regulatory Guide 8.22, "Bioassay at Uranium Mills," and Regulatory Guide 8.31, "Information Relevant to Ensuring that Occupational Radiation Exposures at Uranium Mills Are As Low As Is Reasonably Achievable."

C. REGULATORY POSITION

1. SURVEYS

1.1 Surveys for Airborne Uranium Ore Dust

Surveys for airborne uranium ore dust are necessary (1) to demonstrate compliance with the quarterly intake limits for workers specified in §20.103(a) of 10 CFR Part 20, (2) to meet the posting requirements for airborne radioactivity areas in §20.203(d), (3) to determine whether precautionary procedures such as process or other engineering controls, increased surveillance, limitation on working times, provision of respiratory protective equipment, or other precautions should be considered to meet §§20.103(b)(1) and (b)(2), and (4) to determine whether exposures to radioactive materials are being maintained as low as is reasonably achievable as stated in §§20.1(c) and 20.103(b)(2).

The concentration applicable to limiting exposure to airborne uranium ore dust in restricted areas is given in paragraph 4 of the Note to Appendix B, "Concentrations in Air and Water Above Natural Background," of Part 20. If gross alpha counting of the air sample is performed, concentration is 1×10^{-10} microcuries (μCi) of alpha activity per milliliter (ml) of air. This concentration applies to the alpha emissions of uranium-238, uranium-235 (negligible), uranium-234, thorium-230, and radium-226. If chemical separation of uranium followed by alpha counting, alpha spectrometry, or fluorometric procedures are used to determine the uranium concentration alone, the concentration is 5×10^{-11} μCi of uranium per ml of air. In mass units the concentration is 75 micrograms (μg) of natural uranium per cubic meter of air.* The uranium ore dust concentration is applicable to areas where ore is handled prior to chemical separation of the uranium from the ore. Where the ore crushing and grinding circuits, chemical leaching areas, and yellowcake areas are physically isolated from each other, the ore dust concentration obviously applies to the ore handling areas.

Where ore handling and yellowcake processing are not physically isolated from each other, the concentration value of 1×10^{-10} μCi/ml may be used provided that gross alpha counting is performed. For other methods of analysis that include only measurements of uranium it is necessary to determine the fraction of the alpha activity that is due to ore dust. For example, in a mill that produces little ore dust because it has a wet ore grinding process but has significant emissions from yellowcake processing equipment, the natural uranium concentration of 1×10^{-10} μCi of natural uranium per ml of air (or 200 μg of soluble natural uranium/m^3**) may be applicable throughout the plant. To know when uranium ore dust concentrations are sufficiently low to allow use of this limit for natural uranium, paragraph 5 of the Note to Appendix B to Part 20 should be consulted. If uranium ore dust concentrations are below 10% of the applicable concentration value in Appendix B of Part 20 (i.e., below 5×10^{-12} μCi/ml), uranium ore dust may be considered to be not present, and the appropriate value for natural uranium (1×10^{-10} μCi/ml) may be used instead. If ore dust concentrations exceed 10% of the Appendix B value, the airborne mixture may either be considered entirely ore dust (for which the concentration value of 5×10^{-11} μCi/ml applies) or a new concentration value for the mixture, MPC_m, may be calculated using the following equation:

$$MPC_m = \left[\frac{f_{nu}}{MPC_{nu}} + \frac{f_{od}}{MPC_{od}}\right]^{-1}$$

where:

MPC_{nu} = regulatory concentration value for natural uranium

MPC_{od} = regulatory concentration value (in radiometric units) for natural uranium in ore dust

f_{nu} = fraction of alpha activity from natural uranium as yellowcake, i.e., $C_{nu}/(C_{nu} + C_{od})$

f_{od} = fraction of alpha activity from natural uranium in ore dust, i.e., $C_{od}/(C_{nu} + C_{nu})$

Since this equation would only be used with the 5×10^{-11} μCi/ml value of C_{od}, f_{od} is calculated as the fraction of the uranium alpha activity only. This equation was derived from, and is thus equivalent to, the inequality shown in paragraph 1 of the Note to Appendix B, 10 CFR Part 20 (see Appendix A of this guide).

In areas that are not "airborne radioactivity areas," an acceptable sampling program for airborne uranium ore dust includes monthly grab samples of 30-minutes duration in worker-occupied areas while ore is being actively handled. As an alternative, weekly grab samples of 5-minutes duration each using a high-volume sampler (roughly 30 cfm) are acceptable as long as the licensee can demonstrate that the volume sampled is accurately known. The quantity of air sampled and the method of analysis should allow a lower limit of detection (LLD) of 5×10^{-12} μCi of natural uranium per ml of air (or 7.5 μg of uranium per m^3 of air). Appendix B to this guide shows how to calculate the LLD when a fluorometric analysis for uranium is used. If any area is an "airborne radioactivity area," as defined in §20.203(d), 30-minute samples should be taken weekly if workers occupy the area. Outdoor areas such as the ore pad should be sampled quarterly.

Only ore dust samples representative of the air inhaled by the workers present are acceptable. Samples taken at a height of about 3 to 6 feet between the source and the worker are normally considered representative. Samples should be taken while normal ore handling is taking place. The state of operation of major equipment during sampling should be recorded. In large rooms, several locations should be sampled. Special breathing zone sampling (lapel sampling or other sampling of the immediate breathing zone of a particular worker) is not necessary for ore dust.

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*Micrograms of uranium can be converted to microcuries by using the specific activity of natural uranium: 6.77×10^{-7} μCi/μg.

**The primary standard for airborne soluble natural uranium is 200 μg/m^3. Multiplying that value by 6.77×10^{-7} μCi/μg gives 1.35×10^{-10} μCi/ml. This is rounded down to give the Appendix B concentration of 1×10^{-10} μCi/ml.

During the first year of operation, new mills will need a more extensive air sampling program than operating mills to determine what locations provide measurements of the concentration representative of the concentration to which workers are exposed.

Sample analysis should usually be completed within two working days after sample collection. Unusual results should be reported promptly to the Radiation Safety Officer (RSO).*

Regulatory limits on the intake of ore dust are discussed in Section C.3 of this guide.

1.2 Surveys for Airborne Yellowcake

It is generally accepted that uranium dissolved in the lung or absorbed by the gastrointestinal tract enters the bloodstream and is excreted or distributed to various body organs. The rate of dissolution for yellowcake appears to depend on its temperature history. Yellowcake dried at low temperature, which is predominantly composed of ammonium diuranate, dissolves more quickly than yellowcake dried at higher temperature; and a relatively large fraction is rapidly transferred to kidney tissues (Refs. 2-4). If the intake of such yellowcake is controlled to protect the kidney from the chemical toxicity of uranium, radiological protection criteria for natural uranium will also be satisfied. For purposes of compliance with 10 CFR Part 20, yellowcake undried or dried at low temperature should be classified as soluble.

Yellowcake dried at high temperature is a mixture of compounds, which contains a major portion of more insoluble uranium oxides. Radiation dose to the lung and other organs is the limiting consideration rather than chemical toxicity primarily due to the large insoluble component. For compliance purposes, yellowcake dried at 400°C and above should be classified as insoluble (Refs. 5 and 6).

Solubility classification is important with respect to compliance with the Commission's weekly intake regulations for soluble uranium. Paragraph 20.103(a)(2), in connection with footnote 4 of Appendix B to Part 20, imposes a weekly intake limit of 0.0065 μCi (9.6 mg) for soluble uranium. If this limit is exceeded during a calendar week, an overexposure has occurred.** A weekly overexposure limit is imposed because hazardous conditions must be corrected quickly where chemical toxicity to the kidney may be involved.

Solubility classification is not an important consideration from the viewpoint of complying with the Commission's quarterly intake limits for natural uranium. Paragraph 20.103(a)(1), footnote 3, requires that every quarterly intake limit be calculated as the product of the Appendix B, Column 1 concentration and the constant 6.3×10^8 ml (which is the assumed number of milliliters of air inhaled by a worker, while on the job, during one calendar quarter). The concentration value for either soluble or insoluble natural uranium is 1×10^{-10} μCi/ml of air. Thus, the quarterly intake limit for any type of yellowcake is 0.063 μCi (approximately 93 mg) of uranium.* If this value is exceeded, an overexposure has occurred.

The regulations for insoluble uranium do not contain overexposure limits based on the weekly intake. However, a weekly control measure is specified in §20.103(b)(2), which is applicable to insoluble natural uranium, such as yellowcake dried at high temperature. It is not a violation of the NRC's regulations if a worker's intake of insoluble uranium exceeds the equivalent of 40 hours at a concentration of 1×10^{-10} μCi/ml in any period of seven consecutive days, for a single time. However, failure to make an evaluation of an occurrence, take appropriate actions to ensure against recurrence, and maintain the required records is a violation of §20.103(b)(2).

Thus, surveys for airborne yellowcake are necessary to demonstrate compliance with the weekly and quarterly intake limits in §§20.103(a)(1) and (a)(2). Surveys are also necessary to establish the boundaries of airborne radioactivity areas and to determine whether surveillance, limitation on working times, provisions of respiratory equipment, or other precautions should be considered in compliance with §20.103(b).

The recommended survey program for yellowcake uses a combination of general air sampling and breathing zone sampling during operations that may involve considerable intake such as those that require a special work permit.

Grab samples for yellowcake with a duration of 30 minutes should be performed weekly in airborne radioactivity areas and monthly in areas not designated as airborne radioactivity areas. As an alternative, weekly grab samples of 5-minutes duration using a high-volume sampler (roughly 30 cfm) are acceptable in areas that are not airborne radioactivity areas instead of monthly 30-minute samples as long as the licensee can demonstrate that the volume of air sampled is accurately known. The increased duration of surveys in airborne radioactivity areas should be performed to meet the requirement in §20.103(b)(2) for increased surveillance in such areas.

Breathing zone sampling for specific jobs should be used to monitor intakes of individual workers doing special high-exposure jobs if the special jobs are likely to involve more than 10 MPC-hours** in any one week. An example of a job during which such breathing zone sampling may be used is maintenance of yellowcake drying and packaging equipment.

*The title "Radiation Safety Officer" is used by many licensees and, in this guide, means the person responsible for conducting health physics survey programs; other titles are equally acceptable.

**In connection with the 0.0065 μCi weekly limit and the 0.063-μCi quarterly limit, note that 0.0065 multiplied by 13 does not yield 0.063, as would normally be expected. The reason is as follows. The 0.0065 μCi weekly limit is derived from the 200-μg/m^3 value specified in footnote 4 of Appendix B. The 0.063-μCi quarterly limit is derived from the 1×10^{-10} μCi/ml value from Column 1, Appendix B. The 1×10^{-10} value contains a roundoff error that essentially accounts for the anomaly.

*1×10^{-10} μCi/ml x 6.3×10^8 ml/quarter = 0.063 μCi/quarter. 0.063 μCi ÷ 6.77×10^{-7} μCi/μg = 9.3×10^4 μg = 93 mg.

**MPC is the acronym for maximum permissible concentration.

Samples should be representative of the air inhaled by the workers. The state of operation of major equipment during sampling should be recorded.

The quantity of air sampled and the method of analysis should allow a lower limit of detection of at least 1×10^{-11} μCi/ml (10% of the Part 20, Appendix B concentration). Appendix B to this guide shows a calculation of the LLD.

Sample analysis should usually be completed within 2 working days after sample collection to permit prompt corrective action if needed. Unusual results should be reported promptly to the RSO.

1.3 Surveys for Radon-222 and Its Daughters

In uranium mills, significant concentrations in air of radon-222 and its daughters may occur near ore storage bins and crushing and grinding circuits or anywhere large quantities of ore are found, particularly dry ore. In addition, any poorly ventilated room can have high radon* daughter concentrations even if large quantities of ore are not present.

NRC regulations permit measurements of concentrations of either radon itself or the radon daughters. Thus either type of measurement is acceptable. However, at uranium mills, measurements of daughters are considered by the staff to be more appropriate. Measurements of radon daughter concentrations are more appropriate because radon daughter concentrations are both easy to measure and because radon daughter concentrations are the best indicator of worker dose. The dose from radon will be negligible in comparison with the dose from radon daughters (Ref. 7, p. 78, and Ref. 8).

Monthly measurements of radon daughter concentrations should be made where radon daughters routinely exceed 10% of the limit or 0.03 working level (i.e., the radon daughter concentrations are considered to be present according to paragraph 5 of the Note to Appendix B to Part 20). If radon daughter concentrations are normally greater than 0.08 working level (25% of limit) or radon concentrations are above 8×10^{-9} μCi/ml (8 pCi/l), the sampling frequency should be increased to weekly. Sampling should continue to be performed weekly until four consecutive weekly samples indicate concentrations of radon daughters below 0.08 working level or radon below 8×10^{-9} μCi/ml (8 pCi/l). After that radon daughter surveys may be resumed on a monthly basis.

Quarterly sampling for radon daughters should be made where previous measurements have shown the daughters are not generally present in concentrations exceeding 0.03 working level (10% of the limit) but where proximity to sources of radon daughters might allow them to be present. For example, quarterly measurements might be appropriate for a shop area attached to the crushing and grinding circuit building.

*The term "radon" used in this guide means "radon-222."

Radon daughter samples should be representative of worker exposures. Samples should be taken near locations where workers are most often present. The state of operation of major equipment during sampling and the time of day the sample was taken should be recorded.

The lower limit of detection for radon daughter measurements should be 0.03 working level so that concentrations defined as being present in paragraph 5 of the Note to Appendix B to Part 20 can be detected. Appendix B of this guide shows how to calculate the LLD for a radon daughter measurement. Measured values less than the lower limit of detection, including negative values, should still be recorded on data sheets. The lower limit of detection is set high enough to provide a high degree of confidence that 95% of the measured values above the LLD truly represent radon daughters and are not "false positive" values. However, the most accurate average for a sampling location is obtained by averaging all representative values, including values obtained that are below the lower limit of detection.

The modified Kusnetz method for measuring radon daughter working levels is a suitable method for uranium mills. The procedure consists of sampling radon daughters on a high efficiency filter paper for 5 minutes and, after a delay of 40 to 90 minutes, measuring the alpha counts on the filter during a 1-minute interval. The original Kusnetz method measured the alpha count rate. In the modified Kusnetz method, the rate meter is replaced by a scaler. This improves the sensitivity to a practical lower limit of 0.03 working level for a 1-minute count on a 10-liter (0.01 cubic meter) sample. This is about a factor of 10 lower than that originally obtained using the original Kusnetz method. A 4-minute count gives a lower limit of about 0.003 working level (Ref. 1). High efficiency membrane or glass fiber filters should be used to minimize loss of alpha counts by absorption in the filter. However, a correction factor to account for alpha absorption in the filter paper should still be used. Care should be taken to avoid contamination of the alpha counter.

The modified Kusnetz method is discussed in more detail in References 1 and 9. Other acceptable methods discussed in Reference 1 are the original Kusnetz method with greater than 10 liters of air sampled, the modified Tsivoglou method, and the Rolle method. The modified Tsivoglou method is slightly more accurate but is also more complicated than the modified Kusnetz method. The Rolle method is quicker than the Kusnetz method, but is less sensitive. Alpha spectroscopy yields acceptable results, but the instruments are expensive and fragile and lack portability. Recently, "instant working level" meters have been developed, which have the advantage of speed. These are also acceptable if an LLD of 0.03 working level can be achieved.

1.4 Surveys for External Radiation

Most, but not all, mill workers receive external gamma radiation doses of less than 1 rem per year (Ref. 1). Gamma radiation exposure rates are generally below 1 milliroentgen per hour (mR/hr) in contact with incoming ore and are about 1.2 mR/hr in contact with fresh yellowcake (Ref. 1). During the buildup of the uranium daughters thorium-234 and protactinium-234 in fresh yellowcake, the radiation levels increase somewhat for several months following yellowcake production.

Gamma radiation surveys should be performed semi-annually throughout the mill at locations representative of where workers are exposed in order to allow determination of "radiation area" boundaries in accordance with §20.203(b) and to determine external radiation dosimetry requirements, in accordance with §20.202. At new mills, a gamma radiation survey should be performed shortly after plant operation starts.

If the semiannual survey reveals any areas accessible to personnel where the gamma exposure rates are high enough that a major portion of the body of an individual could receive a dose in excess of 5 mrem in any hour or a dose in excess of 100 mrem in any 5 consecutive days, the area must be designated a "radiation area," as defined in §20.202(b)(2). For example, if the maximum time any individual worker spends in a room in a 5-day period is 40 hours, the room will be a "radiation area" if the exposure rate exceeds 2.5 mR/hr. Few mills will have radiation dose rates this high, but such dose rates have been found where radium-226 builds up in part of the circuit.

The survey frequency in radiation areas should be quarterly. Survey measurements should be representative of where workers might stand so that their whole-body radiation exposures can be estimated. Thus, measurements should generally be made at about 12 inches from the surfaces.* Use of surface "contact" exposure rate measurements are not required for establishing radiation area boundaries or estimating personnel whole-body exposures because these exposures would not be representative of the exposures workers would receive.

A list of the radiation levels in each area of the plant should be prepared after each survey. The number of areas on the list should be held to a manageable number. In general, a minimum of 20 survey locations is necessary to characterize the radiation levels in the mill.

To determine the need for personnel monitoring, quarterly radiation exposures expected for each category of plant worker should be calculated from the measured radiation levels and predicted occupancy times. If the calculated quarterly gamma ray dose for any individual worker exceeds 0.31 rem, §20.202 of 10 CFR Part 20 requires that the worker wear a personnel radiation dosimeter (e.g., film badge or TLD). In addition, personnel monitoring should be used for at least a 1-year period to verify the survey results even if predicted levels are below 0.31 rem. When feasible, the personnel monitoring results should be correlated with the gamma survey results as a cross-check on each.

*See § 20.204(a) and Item 6(a) of Regulatory Guide 10.6, "Guide for the Preparation of Applications for Use of Sealed Sources and Devices for Performing Industrial Radiography."

In addition to gamma surveys, beta surveys of specific operations that involve direct handling of large quantities of aged yellowcake are advised to ensure that extremity and skin exposures for workers who will perform those operations are not unduly high. Beta surveys should be used to determine the need for protective clothing for these operations (e.g., thick rubber gloves). Beta surveys should also be used to determine if procedures could be changed to reduce beta dose while still allowing the worker to do the operation efficiently. Because of these needs, beta dose rates, unlike gamma dose rates, are usually measured on the surface and at short distances rather than at 12 inches. Beta surveys need be done only once for an operation but should be repeated for an operation any time the equipment or operating procedure is modified in a way that may have changed the beta dose that would be received by the worker.

The beta dose rate on the surface of yellowcake just after separation from ore is negligible, as shown in Figure 1; but this dose rate rises steadily thereafter. The beta dose rate from yellowcake aged for a few months after chemical separation from the ore so that equilibrium with protactinium-234 and thorium-234 has been reached is about 150 mrem/hr (Ref. 10). Figure 2 shows the beta dose rate from aged yellowcake as a function of distance from the surface (Ref. 10). The diameter of the yellowcake source used to measure the dose rates shown in Figure 2 was 9.5 cm. Rubber work gloves (thickness: 0.04 cm or 50 mg/cm^2) will reduce the beta dose to the hands from aged yellowcake by about 15%. Extremity monitoring is required by §20.202(a) for any worker whose hand dose would exceed 4.68 rems in a quarter.

In the case of beta surveys, it is usually acceptable to substitute evaluations of beta doses based on Figures 1 and 2 in place of surveys using radiation survey instruments.

It should be noted that commercially available film badge and TLD services often have not been able to measure beta radiation in the mixed beta-gamma field of a uranium mill (see, for example, Tables A-11 and A-12 of Reference 11 and Tables 6 and 9 of Reference 12). Workers' beta doses should be estimated from the beta surveys described above rather than from personnel monitoring reports.

1.5 Surveys for Surface Contamination

NRC regulations provide no specific limit on surface contamination levels in restricted areas. However, yellowcake or ore dust lying on surfaces can become resuspended and contribute to the intake of radionuclides, which is limited by §20.103(a).

In ore handling areas, surface contamination is not a problem because of the very low specific activity of the ore. In fact, cleanup attempts by methods such as sweeping are

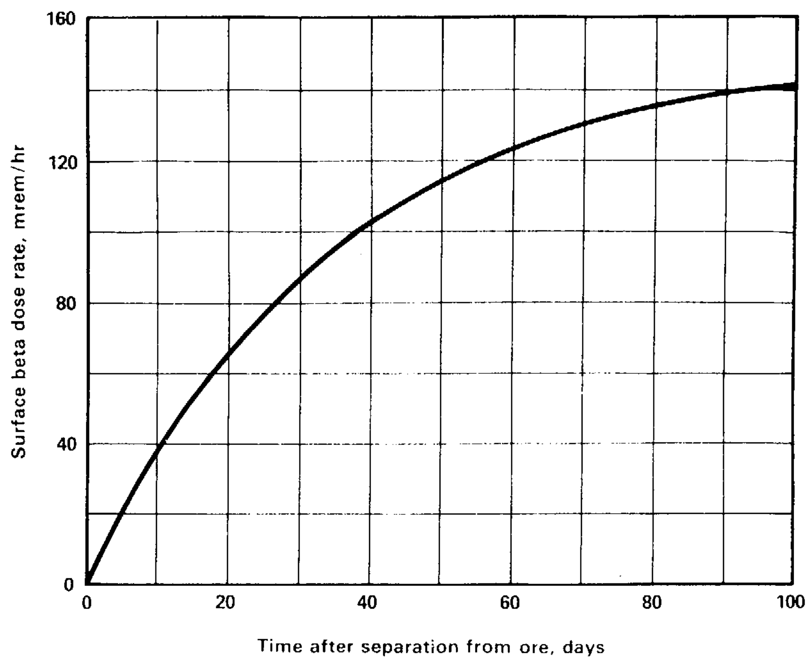


FIGURE 1. BETA DOSE RATE ON THE SURFACE OF YELLOWCAKE

This curve was prepared by S. McGuire, NRC staff, by calculating the buildup of thorium-234 and protactinium-234 from the parent uranium-238, and the buildup of thorium-231 from the parent uranium-235. The surface beta dose rate was normalized to 150 mrem/hr (Figure 2 shows the measured value on the surface). Since measurements show that less than 1% of the thorium, radium, and lead initially present in the ore remains after the chemical separation process, betas from thorium-234, lead-210, and lead-214 in the ore before separation are negligible in the yellowcake after se[illegible]on (Ref. 13).

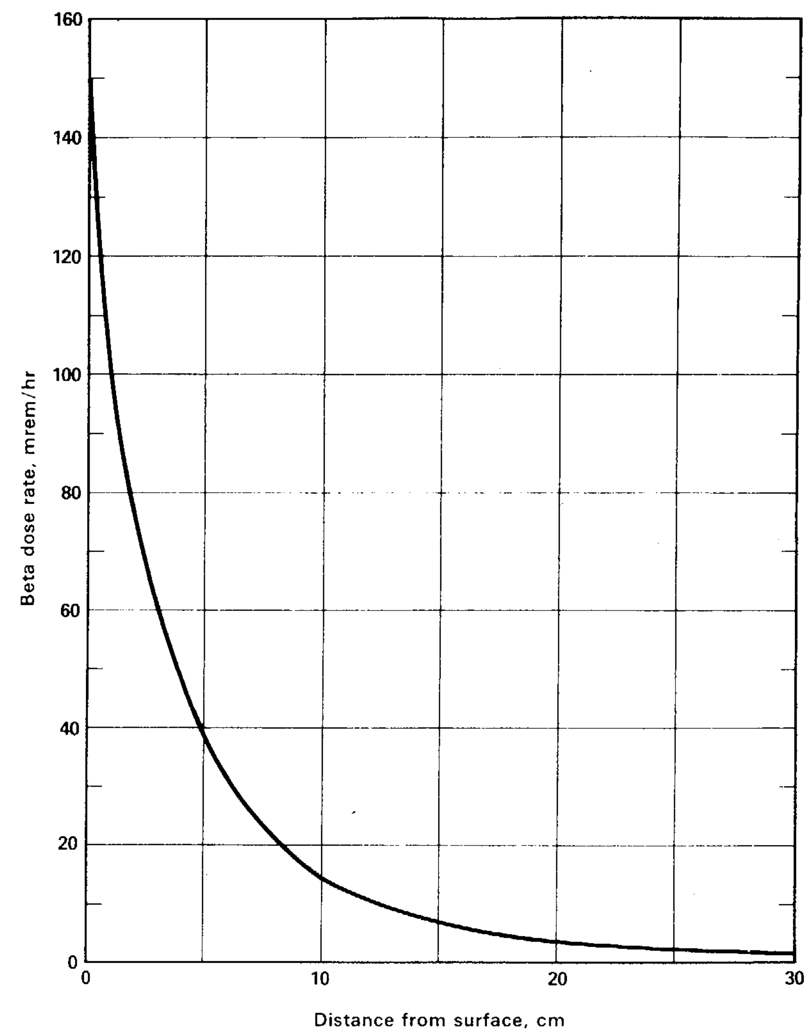


FIGURE 2. BETA DOSE RATE FROM YELLOWCAKE SEPARATED FROM ORE FOR MORE THAN 100 DAYS (from Reference [illegible])

likely to produce a more serious hazard through resuspension in the air than if the ore dust were allowed to remain where it lies. When necessary, cleanup may be performed by hosing down the ore dust into floor sumps or by using vacuum suction systems with filtered exhausts.

In leaching and chemical separation areas there is usually little dust and little difficulty with surface contamination.

In the precipitation circuit and the yellowcake drying and barrelling areas, surface contamination can be a problem because of the concentrated nature of the yellowcake. The International Atomic Energy Agency (IAEA) recommends (Ref. 1) a limit for alpha contamination on such areas as walls, floors, benches, and clothing of 10^{-3} μCi/cm^2 (220,000 dpm/100 cm^2), which is equivalent to about 2 mg/cm^2 of natural uranium. Based on experience, the IAEA concluded that if surface contamination levels are kept below this value, the contribution to airborne radioactivity from surface contamination will be well below applicable limits. The British National Radiological Protection Board also recommends a limit of 10^{-3} μCi/cm^2 for uranium alpha contamination in active areas of plants (Ref. 14), based on calculations using resuspension factors rather than experience.

The NRC staff considers surface contamination levels of 10^{-3} μCi/cm^2 acceptable to meet the ALARA concept in uranium mills. The levels are low enough to ensure little contribution to airborne radioactivity, yet are practical to meet. Such an amount of yellowcake surface contamination is readily visible because of the low specific activity of uranium and does not require a survey instrument for detection. It is recommended that surfaces where yellowcake may accumulate be painted in contrasting colors because surveys for surface contamination in work areas are visual rather than by instrument. Surfaces painted prior to the implementation date of this guide need not be repainted merely to meet this recommendation. However, when such surfaces are repainted they should be painted in contrasting colors.

In yellowcake areas daily visual inspections should be made for locating yellowcake contamination on surfaces. Visible yellowcake should be cleaned up promptly, especially where contamination will be disturbed and resuspended on walkways, railings, tools, vibrating machinery, and similar surfaces. Spills should be cleaned up before the yellowcake dries so that resuspension during cleanup will be lessened.

In rooms where work with uranium is not performed, such as eating rooms, change rooms, control rooms, and offices, a lower level of surface contamination should be maintained. These areas should be spot-checked weekly for removable surface contamination using smear tests. The areas should be promptly cleaned if surface contamination levels exceed the values shown in Table 1.

TABLE 1

Surface Contamination Levels for Uranium and Daughters on Equipment To Be Released for Unrestricted Use, Clothing, and Nonoperating Areas of Mills*

Average	5,000 dpm alpha per 100 cm^2	Averaged over no more than 1 m^2
Maximum	15,000 dpm alpha per 100 cm^2	Applies to an area of not more than 100 cm^2
Removable	1,000 dpm alpha per 100 cm^2	Determined by smearing with dry filter or soft absorbent paper, applying moderate pressure, and assessing the amount of radioactive material on the smear

Note: The contamination levels are given in units of dpm/100 cm^2 because this is the minimum area typically surveyed. When performing a smear or wipe test, the area should very roughly approximate 100 cm^2. However, there is no need to be very precise about the area to be smeared.

*These values are taken from: Regulatory Guide 1.86, "Termination of Operating Licenses for Nuclear Reactors," and "Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for Byproduct Source, or Special Nuclear Material," Division of Fuel Cycle and Material Safety, USNRC, Washington, D.C. 20555, November 1976. Available in NRC Public Document Room for inspection and copying for a fee.

1.6 Surveys for Contamination of Skin and Personal Clothing

Contamination of skin and personal clothing should be controlled to prevent the spread of contamination to unrestricted areas (e.g., the workers' cars and homes). Alpha radiation from uranium on the skin or clothing is not a direct radiation hazard because the alpha particles do not penetrate the dead layer of the skin. Rather, uranium is primarily a hazard if it is inhaled or swallowed.

Visual examination for yellowcake is not sufficient evidence that the worker's skin or clothing is sufficiently free of contamination to permit the workers to leave the work environment. Normally such contamination can be adequately controlled if yellowcake workers wash their hands before eating, shower before going home, and do not wear street clothes while working with yellowcake in the mill. Prior to leaving the restricted area, everyone who has worked with yellowcake during the day should either shower or monitor their skin after changing clothes. If the worker does not change clothes, the clothes should also be monitored. The soles of the shoes of anyone entering the yellowcake area of the mill should either be brushed or monitored before leaving the mill. An alpha survey instrument should be available at the exit of the employee change room. In addition, the licensee should at least quarterly use a calibrated alpha survey instrument to perform an unannounced spot survey for alpha contamination on selected yellowcake workers leaving the mill.

Limits on acceptable levels of alpha contamination of skin and clothing are those in Table 1, but used in the following manner. All alpha contamination on skin and clothing should be considered to be removable so that the limit of 1,000 dpm alpha per 100 cm^2 applies.* Additional showering or washing should be done if the limit is exceeded. The value of 5,000 dpm alpha contamination per 100 cm^2 should be used for the soles of shoes using a portable alpha survey instrument to measure total alpha activity. If alpha levels exceed the value in Table 1, the clothing should be laundered before leaving the site. If the soles of shoes exceed the value in Table 1, the shoes should be brushed or scrubbed until they are below the limit.

1.7 Surveys of Equipment Prior to Release to Unrestricted Areas

Surface contamination surveys should be conducted before potentially contaminated equipment is released to unrestricted areas. The surface contamination limits listed in Table 1 are recommended.** If contamination above these limits is detected, the equipment should be decontaminated until additional efforts do not significantly reduce contamination levels.

The licensee should develop methods to prevent potentially contaminated equipment from leaving the restricted area without being monitored. In some cases this is facilitated if parking for workers and visitors is outside the restricted area.

1.8 Surveys of Packages Prepared for Shipment

After being filled, yellowcake packages should be washed down to remove surface contamination. Surveys of external surfaces of yellowcake packages prepared for shipment should be carried out before shipment. The surveys conducted should be adequate to ensure that the wash-downs are reducing surface contamination levels to less than Department of Transportation (DOT) limits, but do not necessarily include a survey of each package. The bottoms of some, but not all barrels, should be surveyed to determine the effectiveness of the wash downs.

Contamination on packages should not exceed Department of Transportation limits in 49 CFR §173.397. The average measured removable alpha contamination determined by wiping the external surface of the package with an absorbent material should be below 2200 dpm/100 cm^2 if a non-exclusive-use vehicle is to be used (49 CFR §§173.397(a) and (a)(1)) or 22,000 dpm/100 cm^2 if an exclusive-use vehicle is to be used (49 CFR §§173.397(b) and (a)(1)). Packages having higher contamination levels should be cleaned and resurveyed prior to shipment. Visible yellowcake should be cleaned off.

1.9 Ventilation Surveys

A properly operating ventilation system is the most effective means of worker protection from inhalation hazards at a uranium mill. The operation of the ventilation system should be checked each day by the radiation safety staff during the daily walk-through of the mill.

Whenever equipment or procedures in the mill are changed in a manner that affect ventilation, a survey should be made of the ventilation rates in the area to ensure that the ventilation system is operating effectively.

1.10 Surveys for Contamination on Respirators

Before being reused, respirator face pieces and hoods should be surveyed for alpha contamination by a standard wipe or smear technique. Removable alpha contamination levels should be less than 100 dpm/100 cm^2 (Ref. 16, Section 9.6).

1.11 Summary of Survey Frequencies

Table 2 summarizes the survey frequencies given in this guide.

2. INTAKE AND EXPOSURE CALCULATIONS

2.1 Uranium Ore Dust and Yellowcake

In 10 CFR Part 20, §20.103(a)(1) establishes a quarterly intake limit on airborne uranium in yellowcake and in ore dust, §20.103(a)(2) establishes a weekly intake limit on airborne soluble uranium (low-temperature dried yellowcake), and §20.103(b)(2) establishes a weekly control measure for ore dust and airborne insoluble uranium (high-temperature dried yellowcake).

This guide presents two equivalent methods for calculating worker intake. The first method expresses intake in terms of microcuries or micrograms. The second method expresses intake in terms of MPC-hours of exposure. The methods are equivalent and either may be used.

Method 1: The Intake Method (Microcuries or Micrograms)

The intake of uranium ore dust or yellowcake during the weekly or quarterly period being evaluated may be estimated using the following equation:

$$I_u = b \sum_{i=1}^{n} \frac{X_i t_i}{PF}$$

where:

I_u = uranium intake, μg or μCi

*This value is comparable to the limit of 10^{-5} $\mu Ci/cm^2$ or 2,200 dpm per 100 cm^2, recommended by the International Atomic Energy Agency on page 15 of Reference 1 and the United Kingdom Atomic Energy Authority in Reference 15.

**See Regulatory Guide 1.86, "Termination of Operating Licenses for Nuclear Reactors," and "Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for Byproduct Source, or Special Nuclear Material," Division of Fuel Cycle and Material Safety USNRC, Washington, D.C. 20555, November 1976. Available in NRC Public Document Room for inspection and copying for a fee.

TABLE 2

SUMMARY OF SURVEY FREQUENCIES

Type of Survey	Type of Area	Survey Frequency	Lower Limit of Detection
1. Uranium ore dust	Airborne radioactivity areas Other indoor process areas Outdoor areas	Weekly grab samples Monthly grab samples Quarterly grab samples	5×10^{-12} μCi/ml (uranium)
2. Yellowcake	Airborne radioactivity areas Other indoor process areas Special maintenance involving high airborne concentrations of yellowcake	Weekly grab samples Monthly grab samples Extra breathing zone grab samples	1×10^{-11} μCi/ml
3. Radon daughters	Areas that exceed 0.08 working level Areas that exceed 0.03 working level Areas below 0.03 working level	Weekly radon daughter grab samples Monthly radon daughter grab samples Quarterly radon daughter grab samples	0.03 WL
4. External radiation: Gamma	Throughout mill Radiation areas	Semiannually Quarterly	0.1 mR/hr
Beta	Where workers are in close contact with yellowcake	Survey by operation done once plus whenever procedures change	1 mrad/hr
5. Surface contamination	Yellowcake areas Eating rooms, change rooms, control rooms, offices	Daily Weekly	Visual 500 dpm alpha per 100 cm^2
6. Skin and personal clothing	Yellowcake workers who shower Yellowcake workers who do not shower	Quarterly Each day before leaving	500 dpm alpha per 100 cm^2
7. Equipment to be released	Equipment to be released that may be contaminated	Once before release	500 dpm alpha per 100 cm^2
8. Packages containing yellowcake	Packages	Spot check before release	500 dpm alpha per 100 cm^2
9. Ventilation	All areas with airborne radioactivity	Daily	Not applicable
10. Respirators	Respirator face pieces and hoods	Before reuse	100 dpm alpha per 100 cm^2

t_i = time of exposure to average concentration X_i (hr)

X_i = average concentration of uranium in breathing zone air during the time t_i, $\mu g/m^3$ or $\mu Ci/m^3$

b = breathing rate, 1.2 m^3/hr

PF = the respirator protection factor, if applicable*

n = the number of exposure periods during the week or quarter

Method 2: The MPC-hour Method

The intake of uranium ore dust or yellowcake during the weekly or quarterly period being evaluated may be estimated using the following equation:

$$I_u = \sum_{i=1}^{n} \frac{X_i t_i}{MPC \times PF}$$

where:

I_u = uranium intake, MPC-hours

t_i = time that the worker is exposed to concentrations X_i (hr)

X_i = average concentration of uranium in the air near the worker's breathing zone, $\mu Ci/ml$

MPC = the concentration value for the radioactive material from Appendix B of Part 20, $\mu Ci/ml$

X_i/MPC = the number of MPCs

PF = the respirator protection factor, if applicable*

n = the number of exposure periods during the week or quarter

2.2 Radon Daughters

In 10 CFR Part 20, §20.103(a)(1) establishes an annual limit on the intake of radon daughters. Radon daughter intake may be estimated using either of the two following equations:

Method 1: The Intake Method (Working-Level Months)

$$I_r = \frac{1}{170} \sum_{i=1}^{n} \frac{W_i t_i}{PF}$$

where:

I_r = radon daughter intake, working-level months

t_i = time of exposure to W_i (hr)

170 = number of hours in a working month

W_i = average number of working levels in breathing zone air during the time (t_i)

PF = the respirator protection factor, if applicable *

n = the number of exposure periods during the year

Method 2: The MPC-hour Method

$$I_r = \sum_{i=1}^{n} \frac{W_i t_i}{MPC \times PF}$$

where:

I_r = radon daughter intake, MPC-hours

t_i = time of exposure to W_i (hr)

W_i = average number of working levels in breathing zone air during the time (t_i)

MPC = the Appendix B (Part 20) concentration value for radon daughters (0.33 working levels)

W_i/MPC = the number of MPCs of radon daughters

PF = respirator protection factor, if applicable*

n = the number of exposure periods during the year

The values of t_i may be determined by actual timing and recording for each exposure, or t_i values may be derived from a time study of worker occupancy in the various mill areas. Such studies should be updated annually and after any significant change in mill equipment, procedures, or job functions. When nonroutine maintenance or cleanup operations are performed, accurate time records should be kept, and the results of special area or breathing zone samples taken over this period should be added to the calculations of employee exposures.

3. REPORTS OF OVEREXPOSURES TO AIRBORNE MATERIALS

Any overexposure of a person to airborne radioactivity must be reported to the NRC. Section 20.405 requires

*If the licensee's respiratory protection program is being conducted in conformance with Regulatory Guide 8.15, "Acceptable Programs for Respiratory Protection," and the appropriate NRC Regional Office has been notified that the licensee plans to use respirators, the prescribed protection factor (PF) may be used in the calculation of I_u and I_r.

overexposure reports to the appropriate NRC regional office if the intake of uranium ore dust or yellowcake exceeds the quantities specified in §20.103 or if the exposure to radon daughters exceeds the working-level values specified in footnote 3 to Appendix B to 10 CFR Part 20. Many uranium mill workers are exposed to a combination of these materials. In such cases, Appendix B to 10 CFR Part 20 specifies the method for determining whether NRC exposure limits have been exceeded. Overexposure reports are also required for combined exposures that exceed NRC limits.

A listing of exposure limits follows:

1. Soluble uranium, weekly determination.

If during a period of 1 calendar week a worker has an intake of soluble uranium (yellowcake dried at a temperature below 400°C) exceeding 9.6 mg, an overexposure has occurred.*

2. Airborne radioactivity, quarterly determination.

For a worker exposed to uranium ore dust, yellowcake, or both, it is necessary to determine whether an overexposure has occurred during the quarter. Either one of the two following methods may be used for this purpose.

Method 1: The Intake Method (Microcuries or Milligrams). The ore dust uranium intake in microcuries (or milligrams) is divided by 0.03 μCi** (or 47 mg) to calculate the fraction of the limit that has been taken in. The yellowcake intake for the quarter in microcuries (or milligrams) is divided by 0.063 μCi (or 93 mg). Add the two fractions. If the sum exceeds unity, an overexposure has occurred.

Method 2: MPC-hour Method. Add the exposures, in MPC-hours, of uranium ore dust and yellowcake. If the total for any worker exceeds 520 MPC-hours*** an overexposure has occurred.

3. Radon daughters, annual determination.

Exposure to radon daughters is limited on an annual basis. If the intake method is used, an intake exceeding 4 working-level months in a calendar year is an overexposure. If the MPC-hour method is used, an exposure exceeding 2080 MPC-hours in a calendar year is an overexposure.

4. ACTION LEVELS

4.1 The 40-Hour Control Measure

The 40-hour control measure, specified in §20.103(b)(2), is an action level of concern to the uranium mill operator. If during a week a worker is subjected to an intake exceeding 40 MPC-hours, §20.103(b)(2) requires that the cause must be determined, corrective action to prevent another such occurrence must be taken, and a record of the corrective action must be maintained.

Use either of the two methods in Section C.2 of this guide to calculate a worker's weekly intake. If the microcurie (or milligram) method is used, a weekly intake of uranium ore dust plus yellowcake exceeding 1/13 of the quarterly limit given in Section C.3 of this guide exceeds the 40-hour control measure. Do not include radon daughters because these are considered only on an annual basis. If the sum of the two fractions for the weekly intake exceeds 1/13, the 40-hour control measure has been exceeded.

If the MPC-hour method is used, the MPC-hours from ore dust and yellowcake are added. If the sum exceeds 40 MPC-hours, the 40-hour control measure has been exceeded.

4.2 Administrative Action Levels

In addition, the licensee should establish administrative action levels to protect workers. Action levels should be established as shown below. A record of each investigation made and the actions taken, if any, should be kept.

1. *Uranium ore dust.* The RSO should establish an action level for each ore dust sampling location. The action level for the location should be set somewhat above the normal fluctuations that occur when the mill is operating properly. If any sample is above the action level for that location, the RSO should find out why and should take corrective action if appropriate.

2. *Yellowcake.* Similarly, for yellowcake the RSO should establish an action level for each sampling location. In addition, action levels should be established for maintenance activities where breathing zone sampling is used. The action level for maintenance activities can be expressed either in airborne concentration or in MPC-hours. If any action level is exceeded, the RSO should find out why and should take corrective action if appropriate.

3. *Radon daughters.* The RSO should establish an action level for radon daughters for each sampling location. If the action level for any location is exceeded, the RSO should find out why and should take corrective action, if appropriate.

4. *Time-weighted exposure to airborne radioactivity.* If any worker's time-weighted exposure, calculated by either of the two methods in Section C.2 of this guide, exceeds 25% of the exposure limits, as listed in Section C.3 of this guide, the RSO should determine the causes of the exposure, should investigate why the exposure was higher than previous exposures in performing the work, and should take corrective action if appropriate. This action level will be on a weekly basis for soluble uranium (yellowcake dried at less than 400°C), a quarterly basis for uranium ore dust and yellowcake combined, and an annual basis for radon daughters.

*40 hours at a concentration of 0.2 mg/m^3 and a breathing rate of 1.2 m^3/hr.

**If total alpha activity is measured instead of uranium activity, divide by 0.06 μCi.

***40 hours/week x 13 weeks = 520 hours.

5. *Gamma dose rates.* The RSO should establish an action level for each location where the gamma dose rate is periodically measured. If the action level for any location is exceeded, the RSO should find out the cause of the elevation and should take corrective action, if appropriate.

6. *Dosimeter results.* The RSO should establish action levels for the monthly dosimeter results. If the action level for any person is exceeded, the RSO should find out the cause and take corrective action, if appropriate.

7. *Contamination on skin and clothing.* If alpha contamination of the skin or clothing of workers leaving the mill is found to exceed 1000 dpm/100 cm^2, an investigation of the cause of the contamination should be made and corrective action taken, if appropriate.

8. *Low airborne radioactivity readings.* Abnormally low readings of airborne radioactivity (uranium ore dust, yellowcake, and radon daughters) should also be investigated since very low readings may indicate an equipment malfunction or procedural error. The RSO should establish action levels for low readings of airborne radioactivity. If readings are below these action levels, the RSO should find out why and should take corrective action, if appropriate.

5. ESTABLISHMENT OF "AIRBORNE RADIOACTIVITY AREAS"

In general, yellowcake drying and packaging rooms and enclosures should always be considered to be airborne radioactivity areas because of the high concentrations that can result if any equipment malfunctions. On the other hand, ore crushing and grinding areas and areas outside yellowcake drying and packaging areas will not normally need to be classified as airborne radioactivity areas when normal engineering controls are used.

Any area, room, or enclosure is an "airborne radioactivity area," as defined in §20.203(d), if (1) at any time the uranium concentration exceeds 0.5×10^{-10} μCi/ml in the case of ore dust or 1×10^{-10} μCi/ml in the case of yellowcake (i.e., the values in Appendix B to 10 CFR Part 20) or (2) the concentration exceeds 25% of the values in Appendix B to 10 CFR Part 20 averaged over the number of hours in any one week in which individuals are present in such area, room, or enclosure. For example, an area that is occupied 20 hours per week (out of the 40 hours used as a basis for the limits) is an airborne radioactivity area if the concentration of uranium in yellowcake exceeds 0.5×10^{-10} μCi/ml of air. The licensee should maintain records to show that occupancy is in fact thus limited.

If combinations of radon daughters, ore dust, and yellowcake are present (see Section C.1.3 of this guide), their concentrations divided by the appropriate Table 1 Appendix B value should be added. If the sum of these fractions exceeds unity or if the sum exceeds 0.25 after adjustment for the occupancy factor, the area is an airborne radioactivity area.

6. POSTING OF CAUTION SIGNS, LABELS, AND NOTICES TO EMPLOYEES

The radiation protection staff should periodically survey to ensure that signs, labels, required notices to employees, copies of licenses, and other items are properly posted as required by 10 CFR §19.11 and §20.203.

The mill and tailings area should be fenced to restrict access, and the fence should be posted with "Caution, Radioactive Material" signs as required in §20.203(e)(2). If the fence and all entrances are posted and in addition contain the words "Any area within this mill may contain radioactive material," the entire area is posted adequately to meet the requirement in §20.203(e)(2). Additional posting of each room with "Radioactive Material" signs is not necessary.

"Radiation Areas" and "Airborne Radioactivity Areas" must be posted in accordance with §§20.203(b) and (d). The licensee should avoid posting radiation area signs and airborne radioactivity area signs in areas that do not require them. The purpose of the signs is to warn workers where additional precautions to avoid radiation exposure are appropriate. Posting all areas in the mill with such signs defeats this purpose.

7. CALIBRATION OF SURVEY INSTRUMENTS

Portable survey instruments should be placed on a routine maintenance and calibration program to ensure that properly calibrated and operable survey instruments are available at all times for use by the health physics staff.

Survey instruments should be checked for constancy of operation with a radiation check source prior to each usage. If the instrument response to the radiation check source differs from the reference reading by more than 20%, the instrument should be repaired if necessary and recalibrated (Ref. 17, paragraph 4.6).

This constancy check should be supplemented by calibrations at 12-month intervals or at the manufacturer's suggested interval, whichever is shorter (Ref. 17, paragraph 4.7.1). An adequate calibration of survey instruments cannot be performed solely with built-in check sources. Electronic calibrations that do not involve a source of radiation will not determine the proper functioning and response of all components of an instrument. However, an initial calibration with a gamma source and periodic tests using electronic input signals may be considered adequate for the high dose ranges on survey instruments if those ranges are not used routinely. Each instrument should be calibrated at two points at about one-third and two-thirds of each linear scale routinely used or with a calibration at one point near the midpoint of each decade on logarithmic scales that are routinely used. Digital readout instruments with either manual or automatic scale switching should be calibrated in the same manner as are meter-dial instruments. Digital readout instruments without scale switching should be calibrated in the same manner as are logarithmic readout instruments. Survey instruments should be calibrated following repair. A survey instrument may be considered properly calibrated when the instrument readings are within ±20% of the calculated or known values for each point checked (see Regulatory Guide 10.6, Appendix A).

Calibration for beta dose rate measurements may be performed in the following manner. A usual technique for making a beta survey is to note the difference between the open-window and closed-window reading on a GM or ionization chamber survey meter. The difference is considered to be the beta dose rate. This approach is incorrect if the survey meter has been calibrated with a gamma source alone. A correction factor must be applied to determine the beta dose rate.

To determine the calibration factor, use Figure 2 in this guide. Place the detector of the survey meter at the surface of an extended yellowcake source that has been separated from ore for at least 100 days. Use a piece of paper or thin plastic between the detector and yellowcake to avoid contaminating the detector. Note the difference between the open-window and closed-window readings. Compute a calibration factor that applies to the surface dose rate that will make the difference between the open-window and closed-window readings equal to the surface beta dose rate of 150 mrem/hr, as shown in Figure 2. To determine the calibration factor that applies at a distance from the surface, place the axis of the detector at 2 cm from the surface. Note the difference between the open-window and closed-window readings. Compute a calibration factor that will make the difference between the open-window and closed-window readings equal to 75 mrem/hr, as shown in Figure 2. A sample calculation is shown in Appendix C.

Errors in estimates of the volume of air that has passed through filters should be avoided by accurate calibration of the flow rate and by preventing or correcting for the loss of flow caused by accumulation of material on the filter. As material accumulates on filter paper the air flow rate will drop. Thus less air volume will be sampled. Air flow rates through filters should be determined by calibrating pumps with the filter paper in place once every 6 months to ±20% accuracy. These calibrations should be done in accordance with manufacturer's recommendations. Further information on these calibrations is contained in Regulatory Guide 8.25, "Calibration and Error Limits of Air Sampling Instruments for Total Volume of Air Sampled."

The fluorometric analysis system should be calibrated by processing a known standard uranium solution and a blank sample with each batch. Every quarter, the fluorometer response should be checked by a complete serial dilution.

Alpha counting systems used for radon daughter measurements should be calibrated at least monthly by using a known standard alpha source.

Alpha survey meters used to detect contamination on skin and equipment should receive a constancy check each week and a calibration annually.

8. PROTECTIVE CLOTHING

Workers working with yellowcake should be provided with protective clothing such as coveralls and shoes or shoe covers. Rubber work gloves should be used when aged yellowcake will be handled to reduce the beta dose rate and to avoid contamination of the skin with uranium.

Protective clothing should be changed and discarded or laundered weekly or whenever yellowcake is visible on the clothing. Potentially contaminated clothing should not be sent to a laundry that is not specifically authorized by the NRC or an Agreement State to process clothing contaminated with uranium unless the clothing has been surveyed and found to have less uranium contamination than the values in Table 1 of this guide.

9. QUALITY ASSURANCE PROGRAM

The licensee should ensure the accuracy of survey measurements by having a quality assurance program. Regulatory Guide 4.15, "Quality Assurance for Radiological Monitoring Programs (Normal Operations)—Effluent Streams and the Environment," should be consulted for guidance on quality assurance.

D. IMPLEMENTATION

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

Except in those cases in which an applicant proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, applications for new uranium mills and renewal applications submitted after July 1, 1983, should follow the recommendations in this guide.

APPENDIX A

DERIVATION OF EQUATION FOR MPC_m

The equation for MPC_m is derived here. The equation for mixtures in paragraph 1 of the Note to Appendix B of Part 20 is:

$$\frac{C_a}{MPC_a} + \frac{C_b}{MPC_b} + \frac{C_c}{MPC_c} \leq 1$$

Consider a mixture of natural uranium as yellowcake with a concentration of C_{nu} and ore dust with a concentration C_{od}. If the sum of the concentrations equals the MPC for the mixture

$$C_{nu} + C_{od} = MPC_m$$

$$\frac{C_{nu} + C_{od}}{MPC_m} = 1$$

the equality in the first equation will apply.

Therefore:

$$\frac{C_{nu}}{MPC_{nu}} + \frac{C_{od}}{MPC_{od}} = \frac{C_{nu} + C_{od}}{MPC_m}$$

Solve for MPC_m

$$MPC_m = \frac{C_{nu} + C_{od}}{\frac{C_{nu}}{MPC_{nu}} + \frac{C_{od}}{MPC_{od}}}$$

Divide the numerator and denominator of the right-hand side by $C_{nu} + C_{od}$

$$MPC_m = \frac{1}{\frac{C_{nu}}{(C_{nu} + C_{od})(MPC_{nu})} + \frac{C_{od}}{(C_{nu} + C_{od})(MPC_{od})}}$$

The term

$$\frac{C_{nu}}{C_{nu} + C_{od}}$$

can be recognized as f_{nu}, the fraction of activity from natural uranium as yellowcake.

Therefore:

$$MPC_m = \left[\frac{f_{nu}}{MPC_{nu}} + \frac{f_{od}}{MPC_{od}}\right]^{-1}$$

APPENDIX B

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 that has a 95% probability of being detected.* Radioactive material is "detected" if the value measured on an instrument is high enough to conclude that activity above the system background is probably present.

For a particular measurement where radioactive disintegrations are detected (which may include a radiochemical separation):

$$LLD = \frac{4.66 S_b}{3.7 \times 10^4 EVY e^{-\lambda t}}$$

where:

LLD = the lower limit of detection (μCi/ml)

S_b = the standard deviation of background count rate (counts per second)

3.7×10^4 = the number of disintegrations/sec/μCi (this term is omitted if S_b is given in terms of microcuries)

E = the counting efficiency (counts per disintegration)

V = the sample volume (ml)

Y = the fractional radiochemical yield (if applicable)

λ = the decay constant for the particular radionuclide

t = the elapsed time between sample collection and counting.

Example: LLD for uranium when fluorometric analysis is used.

Work this example in terms of microcuries of natural uranium. The LLD could just as well be calculated in terms of micrograms of uranium. A conversion factor of 6.77×10^{-7} μCi/μg for natural uranium can be used if the uranium quantity is known in micrograms.

First, determine the standard deviation of the background count rate S_b. To do this perform a fluorometric analysis for several clean filter papers that have not been used to collect air samples. At least 5 filter papers would have to be analyzed over many months. The value of S_b will be in terms of microamperes because fluorometers usually give readings in microamperes.

The value of S_b can then be converted either to microcuries or to counts per second by using a calibration factor.

A sample calculation is shown here. The fluorometric readings for 10 clean filter papers are as follows:

Sample number	Fluorometric reading (X_i) (microamperes)
1	0.062
2	0.072
3	0.050
4	0.050
5	0.050
6	0.040
7	0.086
8	0.088
9	0.088
10	0.018

Calculate the standard deviation S_b by the equation (or by pocket calculator):

$$S_b^2 = \frac{1}{n-1} \sum_{i=1}^{n} (X_i - \bar{X})^2$$

where:

n = the number of samples

X_i = the reading for sample i

$\bar{X}$ = the average of the readings

For the data above, the standard deviation is:

$S_b = 0.023\ \mu A$

Convert S_b to micrograms of uranium. On this fluorometer 0.1 μg of U_3O_8 gives a reading of 0.67 μA. The fluorometer will read 6.7 μA/μg of U_3O_8. This compound is 85% uranium by weight (238 x 3 = 714, 16 x 8 = 128, 714/842 = 0.85). Therefore, the fluorometer will read 7.9 μA/μg of uranium (6.7/0.85 = 7.9).

Now calculate the standard deviation in micrograms of uranium:

$$S_b = \frac{0.023\ \mu A}{7.9\ \mu A/\mu g}$$

*This definition of LLD was chosen to be consistent with the NRC position previously stated in Tables 1 and 3 of Regulatory Guide 4.8, "Environmental Technical Specifications for Nuclear Power Plants." The basis for the definition is given in References 18 and 19 of this guide. The definition is also used in other regulatory guides, among them 4.14, "Radiological Effluent and Environmental Monitoring at Uranium Mills," and 8.14, "Personnel Neutron Dosimeters."

$= 0.0029\ \mu g$ of uranium

To convert to microcuries, use a conversion factor of $6.77 \times 10^{-7}\ \mu Ci/\mu g$ of uranium.

Therefore:

$$S_b = 0.0029\ \mu g \times 6.77 \times 10^{-7}\ \mu Ci/\mu g$$

$$= 1.97 \times 10^{-9}\ \mu Ci$$

In the equation for LLD, the counting efficiency E will be 1. (The term E is not applicable to a fluorometric analysis.)

The sample volume V will be equal to the collection rate of the air sampler times the sample collection time. Assume a low-volume air sampler with an air flow rate of 10 liters per minute and a 30-minute sample collection time.

$$V = 10 \text{ liters/min} \times 30 \text{ minutes}$$

$$= 300 \text{ liters}$$

$$= 300{,}000 \text{ ml}$$

For a fluorometric analysis, the radiochemical yield is not applicable, and Y may be set equal to 1.

The exponential term for radioactive decay $e^{-\lambda t}$ will also be equal to 1 because the half-life of uranium is so long that the amount of decay between collection and analysis will be negligible.

Therefore

$$LLD = \frac{4.66 \times 1.97 \times 10^{-9}\ \mu Ci}{300{,}000 \text{ ml}}$$

$$= 3 \times 10^{-14}\ \mu Ci \text{ of uranium/ml of air}$$

This LLD is about 150 times more sensitive than recommended in the guide as an acceptable lower limit of detection.

Example: LLD for radon daughters when the modified Kusnetz method is used

The background standard deviation is established by using blank filters. Assume the alpha counts on 10 blank filters counted for 1 minute each are as shown below:

Sample Number	Alpha Counts
1	2
2	3
3	1
4	3
5	2
6	2
7	2
8	3
9	2
10	4

For these filters S_b can be calculated to be 0.84 counts for a 1-minute count.

Assume the counting efficiency E is 0.27. Consider a low-volume sampler with a flow rate of 5 liters per minute and a 5-minute collection time. Therefore, the sample volume will be 25,000 ml. The radiochemical yield Y is not applicable, and is set equal to 1.

To calculate radioactive decay the value of λ can be taken to be roughly 0.026 per minute (for lead-214, the radon daughter with the longest half-life). The value of t is taken to be 60 minutes. It will be accurate enough to use 60 minutes for this value even though it could be as short as 40 minutes or as long as 90 minutes. Therefore $e^{-\lambda t}$ equals 0.21. The lower limit of detection can now be calculated:

$$LLD = \frac{4.66 \times 0.84 \text{ counts/min}}{0.27 \text{ counts/dis} \times 25 \text{ liters} \times 1 \times 0.21}$$

$$= 2.8 \text{ dpm/liter}$$

To convert this LLD to working levels (WL), divide by the factor from Figure 1 in ANSI N13.8-1973 (Ref. 9). The factor is 110 dpm/liter/WL for a sample counted 60 minutes after collection. Therefore:

$$LLD = 0.025 \text{ WL}$$

This is below the LLD for radon daughters recommended in this guide.

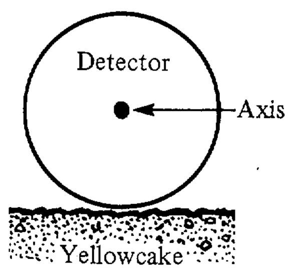
APPENDIX C

BETA CALIBRATION OF SURVEY INSTRUMENT

Here is an example for calibrating the survey instrument.

At the surface:

The closed-window reading is 3 mR/hr. The open-window reading is 28 mR/hr. The difference is 25 mR/hr. Since the beta dose rate at the surface is 150 mrem/hr, the calibration factor CF_{sur} can be calculated from the equation below:



Observed dose rate x CF = actual dose rate

$$25\ mR/hr \times CF_{sur} = 150\ mrem/hr$$

$$CF_{sur} = \frac{150\ mrem/hr}{25\ mR/hr}$$

$$CF_{sur} = 6\ mrem/mR \text{ (at the surface)}$$

At 2 cm: Place the axis of the detector at 2 cm from the surface of the yellowcake. The closed-window reading is 3 mR/hr. The open-window reading is 23 mR/hr. The difference is 20 mR/hr. Since the beta dose rate at 2 cm is 75 mrem/hr, the calibration factor CF_{2cm} can be calculated:

$$CF_{2cm} = \frac{75\ mrem/hr}{20\ mR/hr}$$

$$CF_{2cm} = 3.75\ mrem/mR \text{ (at 2 cm)}$$

The value obtained at 2 cm will generally be accurate enough to use at all distances greater than 2 cm.

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[2]Available from National Technical Information Service (NTIS), Springfield, Virginia 22161.

[3]Available from American National Standards Institute, 1430 Broadway, New York, New York 10018.

10. D. Haggard, Battelle-Pacific Northwest Laboratory, letter to Dr. Stephen A. McGuire, U.S. Nuclear Regulatory Commission, June 29, 1982.[4]

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13. M. H. Momeni et al., "Radioisotopic Composition of Yellowcake," NRC Report NUREG/CR-1216, 1979.[2]

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17. American National Standards Institute, "Radiation Protection Instrumentation Test and Calibration," ANSI N323-1978.[3]

18. J. H. Harley, Editor, "EML Procedures Manual," DOE Report HASL-300, p. D-08-01, revised annually.[2]

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VALUE/IMPACT STATEMENT

1. PROPOSED ACTION

1.1 Description

Applicants for a uranium milling license must submit a license application containing the information specified in Regulatory Guide 3.5, "Standard Format and Content of License Applications for Uranium Mills." The purpose of this proposed action is to describe health physics surveys that are acceptable to the NRC staff to protect workers. Information about health physics surveys is covered under Section C.5, "Operations," in Regulatory Guide 3.5.

1.2 Need

Licensees are now uncertain what the NRC staff will accept in the way of a health physics survey program to protect workers. As a consequence, a wide variety of programs are submitted. In order to meet minimum acceptable standards, much correspondence between the applicant and NRC is required. A guide will reduce the amount of correspondence needed, save manpower for both NRC and the applicant, show clearly how NRC regulations apply to uranium mills, and establish a uniform standard for an acceptable survey program for worker protection.

1.3 Value/Impact

1.3.1 NRC

The impact of the proposed guidance will be primarily to reduce licensing staff effort expended in reviewing applications and corresponding with applicants in areas where the application does not meet acceptable NRC licensing standards. One staff-year was required to develop the guide.

1.3.2 Other Government Agencies

The proposed guidance will impact on the Mine Safety and Health Administration (MSHA) because they also regulate occupational health protection at uranium mills and on Agreement State regulatory agencies that regulate mills, primarily agencies in New Mexico, Colorado, Texas, Washington, and Florida. A Memorandum of Understanding (MOU) signed by NRC and MSHA states that each agency will coordinate the development of standards with the other agency. The MOU was published in the *Federal Register* (45 FR 1315) on January 4, 1980.

1.3.3 Industry

Industry will benefit from having clear guidance on what constitutes NRC licensing policy. The total cost of the occupational health physics program (surveys plus other parts of the program) is estimated to be roughly 4 staff-years per year or about $300,000 per year per mill when the costs of overhead, supplies, equipment, and contracted services are included. This does not include the cost of the environmental and effluent monitoring program nor does it include amortization costs on equipment in the mill installed to limit occupational exposure. Equipment design is not covered in this guide, therefore, costs are not estimated here. However, the annual amortization and operating costs of equipment installed to protect workers is not negligible.

1.3.4 Workers

Workers' protection should improve from having clearly stated and consistent standards for health physics survey programs. Workers and workers' representatives will now have access to a clearly defined standard health physics survey program. This will help them understand whether their employer has an adequate program and why some things are done as they are.

1.3.5 Public

The guidance pertains to worker protection programs. It will not directly affect the public.

1.4 Decision

The NRC should develop guidance on standard health physics survey programs for worker protection that are acceptable to the NRC licensing staff.

2. TECHNICAL APPROACH

The technical approach in the guidance is based on (1) NRC licensing policy as expressed in Safety Evaluation Reports (SER) written by the NRC licensing staff, especially the recent SER for Minerals Exploration Company Sweetwater Uranium Project; (2) the IAEA Manual on Radiological Safety in Uranium and Thorium Mines and Mills, IAEA Safety Series No. 43, 1976; (3) public comments received on Draft Guide OH 710-4; and (4) other references cited in the guide.

The most important technical question raised by the public comments concerned the duration of grab samples for uranium ore dust and yellowcake. The draft guide recommended 60-minute samples.

Mr. William Shelley of Kerr-McGee, speaking for the American Mining Congress (AMC), wrote that sampling for uranium ore dust in non-airborne radioactivity areas should be weekly with 5-minute high-volume samples rather than monthly with 60-minute samples as in the guide. The AMC, in a subsequent letter intended to supplement Mr. Shelley's comments, stated that 60-minute samples at 20 to 25 operator-occupied sites would require 3 to 4 days for sample collection, which is excessive. The AMC recommended monthly 30-minute samples with a stipulation requiring additional sampling in the area if an action level were exceeded. The AMC said weekly 5-minute high-volume samples "are not deemed preferable in this context." The AMC recommended weekly 15-minute high-volume samples with a flow rate of 30 cfm when more frequent sampling was needed and said such sampling would satisfy the LLD values in the guide. The AMC stated that filters could clog during long sampling times, thereby reducing the accuracy of the measurement.

Mr. Gerald Sinke of Kerr McGee, in a subsequent letter to clarify the AMC objection to 60-minute samples, stated that the Kerr-McGee mill sampled weekly at 36 locations in ore handling areas. Mr. Sinke said that 5-minute samples would be more accurate than 60-minute samples because the technician would be present during sample collection, whereas he would not be present during a 60-minute sample. Mr. Sinke showed by calculation that an LLD of 2.7×10^{-12} μCi/ml was obtained using a 5-minute sample with a flow rate of 760 liters/min. This meets the recommended LLD of 5×10^{-12} μCi/ml. Sinke's method is based on alpha counting after radon decay. Alpha counting will not work well for ore dust with long sampling times because the dust loading on the filter paper will cause self-absorption of the alpha particles. The State of New Mexico Environmental Improvement Agency said that 30-minute samples seemed excessively long.

The above comments claim that 60-minute samples are too long and state that the recommended LLD can be obtained with shorter samples. Based on NRC's calculations such as those shown in the new appendix to the guide, it is correct that an acceptable LLD can be met with samples of far less than 60-minute duration as long as the air flow is sufficient and the analysis background is low enough.

The NRC agrees that excessive dust loading is likely to be deposited on filters of high-volume samplers during a 60-minute sample. On the other hand, monthly 5-minute samples seem too short to account for short-term variations in air concentrations. A time longer than 5 minutes is believed to be necessary because the grab samples are taken at a fairly low frequency – weekly or monthly depending on the levels of airborne radioactivity present. The NRC accepts the fairly low weekly or monthly frequency because concentrations of ore dust are generally low in ore dust areas (typically 10% of the Appendix B values) and because the concentrations have been observed to fall within fairly narrow ranges, except for seasonal variations due to increased ventilation during warmer months. Concentrations of yellowcake when equipment is not operating are also low and fall within limited ranges. More extensive sampling is required for maintenance operations and in certain operations when yellowcake is actively handled.

In view of this, the recommended sample duration is lowered to 30 minutes at an adequate air flow rate to meet the recommended LLD of 5×10^{-12} μCi/ml. However, in areas that are not airborne radioactivity areas, weekly 5-minute samples are acceptable instead of monthly 30-minute samples.

The second most important technical question raised by the public comments concerned the recommended limits on surface contamination in work areas, namely the value for alpha activity of 0.001 μCi/cm^2. Mr. L. M. Cook of Chevron Resources Company said that the limit on contamination levels of 0.001 μCi/cm^2 may not keep ingestion low enough and that bioassays would routinely be high.

The NRC response is that surface alpha contamination levels of 0.001 μCi/cm^2 are generally recognized as being adequate to maintain the inhalation of resuspended particles to very low levels. Experimental work in a uranium facility showed that surface contamination of this magnitude contributed less than 1% of the exposures received by employees.[1] Experience in plants led the International Atomic Energy Agency to recommend this value for uranium mills.[2] Theoretical calculations based on resuspension factors led the British National Radiological Protection Board to recommend the same limit.[3] In the words of the International Commission on Radiological Protection (ICRP), "Experience has shown that there is not necessarily a correlation between surface contamination in the workplace and the exposure of workers."[4]

There are several physical factors that reduce the resuspension of small respirable particles. Fine dusts (<50 microns) are extremely resistant to resuspension by wind because these particles lie in the laminar layer next to the ground and do not protrude much into the turbulent air layers.[5] In addition, respirable particles (<10 microns) tend to agglomerate in a process called weathering and their resuspension depends on a mechanical impact to break the agglomerate.[6]

A more complete "Response to Public Comments on Health Physics Surveys in Uranium Mills" is available from the author of the guide: Dr. Stephen A. McGuire, Office of Nuclear Regulatory Research, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555.

3. PROCEDURAL APPROACH

In its preliminary value/impact assessment, the staff considered several procedural approaches for carrying out the proposed action and selected the publication of a regulatory guide.

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[1] A. J. Breslin, A. C. George, P. C. LeClare, and H. Glauberman, "The Contribution of Uranium Surface Contamination to Inhalation Exposures," AEC Report HASL-175, 1966.

[2] International Atomic Energy Agency, *Manual on Radiological Safety in Uranium and Thorium Mines and Mills*, IAEA Safety Series No. 43, Vienna, 1976.

[3] A. D. Wrixon et al., "Derived Limits for Surface Contamination," British National Radiological Protection Board Report NRPB-DL2, November 1979.

[4] International Commission on Radiological Protection, "General Principles of Monitoring for Radiation Protection of Workers," ICRP Publication 12, Pergamon Press, Oxford, Paragraph 54, 1969.

[5] See for example, J. E. Newman et al., "Wind as Related to Critical Flushing Speed Versus Reflotation Speed by High-Volume Sampler Particulate Loading," *Atmosphere–Surface Exchange of Particulate and Gaseous Pollutants*, ERDA Symposium Series 38, 1974.

[6] See for example, G. A. Sehmel, "Particle Resuspension from an Asphalt Road Caused by Car and Truck Traffic," in footnote 5.

3.1 Decision on Procedural Approach

Developing a regulatory guide is the favored procedural approach.

4. STATUTORY CONSIDERATIONS

4.1 NRC Authority

NRC authority for issuance of this guide derives from the Atomic Energy Act of 1954, as amended, through those portions of the Commission's regulations in Title 10 of the Code of Federal Regulations cited in the introduction to the guide.

4.2 Need for NEPA Assessment

The proposed action is not a major action significantly affecting the quality of the human environment as defined by paragraph 51.5(a)(10) of 10 CFR Part 51 and does not require an environmental impact statement.

5. CONCLUSION

The regulatory guide on health physics survey programs for worker protection in uranium mills should be issued.

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