A Summary of NRC's Interim Radiological Cleanup Criteria and Current Dose Bases

Decommissioning and Regulatory Issues Branch, NOMA
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Implementation of residual contamination criteria is dependent on the establishment of acceptable dose or risk criteria for unrestricted use of nuclear facilities. The NRC has been using a patchwork of remediation criteria to define acceptable levels for cleanup of radioactive contamination. However, these criteria are not currently binding on licensees and are generally not consistent with one another or with comparable requirements being established and imposed by other agencies (e.g., Environmental Protection Agency (EPA)). In addition, the scientific basis for some of the criteria established in the 1970s and early 1980s is out of date. Further, some of the criteria are only indirectly related to the protection of the public health and safety and the environment.

In the mid-1980s, NRC staff initiated development of the technical basis to support a rulemaking to codify final cleanup standards for radiological contamination. This rulemaking was an outgrowth of the NRC's long-term effort to establish decommissioning requirements (53 FR 24018; June 27, 1988). However, the rulemaking to establish radiological criteria for decommissioning may not be completed for another two years or so, posing the problem of what criteria should the NRC use in the interim to determine whether sites have been sufficiently decontaminated so that they may be released for unrestricted use.

In preparing this paper, the NRC staff identified the full range of existing cleanup criteria used by the NRC and estimated the doses associated with the criteria.

1.1 NRC Cleanup Criteria

NRC has developed or used the criteria in the following references coupled with the concept of maintaining exposures from residual radioactive material as low as is reasonably achievable (ALARA) for guiding the cleanup of contaminated soils, structures, and equipment for unrestricted use:

1. *Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for Byproduct, Source, and Special Nuclear Material*, Policy and Guidance Directive FC 83-23, November 4, 1983; *Termination of Operating Licenses for Nuclear Reactors*, Regulatory Guide 1.86, June 1974 -- These two documents provide criteria in terms of fixed and

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removable contamination and acceptable radiation exposures associated with beta- and gamma-emitting surface contamination. The FC 83-23 guidance also provides acceptable volumetric concentrations of uranium, thorium, americium and plutonium in soil. The uranium and thorium criteria are identical to the option 1 position in the Branch Technical Position described in item 2. Regulatory Guide 1.86 has been combined with a 5 uR/hr at 1 meter external dose criterion for ^{60}Co, ^{137}Cs, and ^{152}Eu that may exist in concrete, components, and structures at nuclear reactor research facilities, with an overall dose objective of 10 millirem/year (cf. Letter to Stanford University from James R. Miller, Chief, Standardization and Special Projects Branch, Division of Licensing, Office of Nuclear Reactor Regulation, U.S. Nuclear Regulatory Commission, April 21, 1982, Docket No. 50-141).

2. *Disposal or Onsite Storage of Thorium and Uranium Wastes from Past Operations*, Branch Technical Position, October 23, 1981, 46 FR 52061 -- This document provides acceptable activity concentrations of uranium and thorium (with and without decay products) in soil under a variety of conditions.

3. The Environmental Protection Agency's (EPA's) *Interim National Primary Drinking Water Regulations*, 40 CFR Part 141, July 9, 1976, 41 FR 38404 -- This EPA regulation provides maximum contaminant limits for radionuclides in public drinking water, which can be extended to apply as acceptable activity concentrations in groundwater and surface water (see FC 83-23). Drinking water standards have been established for radium-226/228, gross-alpha particle emissions, and man-made radionuclides emitting beta particles and photons. The Environmental Protection Agency recently (July 18, 1991) proposed adding standards for uranium and radon and revising the existing standards for radium and gross-alpha (56 FR 33050).

4. The EPA's *Persons Exposed to Transuranium Elements in the Environment*, November 30, 1977, 42 FR 60956 -- This document provides draft radiation dose guidelines recommended by EPA for acceptable levels of transuranium elements contamination in soil.

1.2 Doses Associated with Existing NRC Criteria

NMSS Policy and Guidance Directive FC 83-23

NMSS Policy and Guidance Directive FC 83-23 provides guidelines for acceptable average and maximum surface contamination levels for a wide variety of radionuclides. It also provides average and maximum radiation levels of 0.2 and 1.0 millirad per hour at 1 centimeter for beta- and gamma-emitters. In addition, the Directive provides an acceptable external radiation exposure rate for soil contamination of 10 microroentgen above background per hour at 1 meter. An enclosure to the Directive lists acceptable soil contamination levels based on the 1981 Branch Technical Position and includes concentration values for plutonium and americium compounds. For byproduct materials, the Directive states that acceptable soil concentration levels will be determined on a case-by-case basis. The criteria in FC 83-23 and their associated doses are summarized in Table 1. The right hand column indicates "dose bases" calculated using the computer code RESRAD that contains contemporary dosimetry and exposure assumptions.

Regulatory Guide 1.86

NRC issued Regulatory Guide 1.86 in 1974. This guide provides the same basis for the acceptable surface contamination levels described in Policy and Guidance Directive FC 83-23. When combined with an exposure rate limit of 5uR/hr above background at 1 meter, this guide has been used in decommissioning and terminating licenses for a number of research reactors. The 5 uR/hr criterion for indoor contamination corresponds to an annual whole body dose of about 10 millirem for an assumed indoor occupancy period of 2000 hours per year. The 5 uR/hr criterion has been applied to ^{60}Co, ^{137}Cs, and ^{152}Eu that may exist in concrete, components, and structures at nuclear reactor research facilities, with an overall dose objective of 10 millirem/year (cf. Letter to Stanford University from James R. Miller, Chief, Standardization and Special Projects Branch, Division of Licensing, Office of Nuclear Reactor Regulation, U.S. Nuclear Regulatory Commission, April 21, 1982, Docket No. 50-141).

Table 1. Acceptable Contamination Criteria and Associated Dose Bases in NMSS Policy and Guidance Directive FC 83-23

Contamination	Criterion	Stated Dose Basis+	Estimated Dose Basis (EDE)+
Average, fixed U-nat, ^{235}U, ^{238}U, and decay products	5000 dpm/100 cm^2	None	~13mrem/yr#
Average, fixed ^{226}Ra, ^{228}Ra, transuranics, etc.	100 dpm/100 cm^2	None	~0.2mrem/yr#
Average, fixed Th-nat, ^{232}Th, ^{90}Sr, etc.	1000 dpm/100 cm^2	None	~28 mrem/yr#
Avg. and max. external beta-gamma dose	0.2-1 mrad/hr at 1 cm	None	~20 mrem/yr*
U-nat with decay products in soil	10 pCi/gm	~500 mrem/yr (based on 5 pCi ^{226}Ra per gram standard in 40 CFR 192; lifetime risk of 0.02)	~2.4 to 260 mrem/yr@ ~1.8 to 49 mrem/yr@
Depleted Uranium in soil	35 pCi/gm	1 mrad/yr (lung) 3 mrad/yr (bone)	~2.4 to 8 mrem/yr@ ~1.8 to 18 mrem/yr@

Table 1. Acceptable Contamination Criteria and Associated Dose Bases in NMSS Policy and Guidance Directive FC 83-23 (Continued)

Contamination	Criterion	Stated Dose Basis+	Estimated Dose Basis (EDE)+
Th-nat with decay products in soil	10 pCi/gm	35 mrem/yr	~35 to 82 mrem/yr@
Enriched Uranium in soil	30 pCi/gm	1 mrad/yr (lung) 3 mrad/yr (bone)	~2.4 to 5 mrem/yr[a] ~1.8 to 16 mrem/yr[a]
^{239}Pu in soil	25 pCi/gm	None	~15mrem/yr[a]
^{241}Am in soil	30 pCi/gm	None	~19 to 325 mrem/yr[&]
External radiation	10 uR/hr at 1 meter above background	None	~24mrem/yr^

+. Dose bases generally expressed in terms of potential dose to the maximum reasonably exposed individual.

#. Calculated using draft NUREG/CR-5512. FC 83-23 criteria are based more on technological capabilities (i.e., levels of detectability) than on an explicit dose basis.

*. Estimate based on dose at 1 meter for 2000 hour occupancy.

[a]. Lower estimate represents conversion or repetition of stated dose basis, while upper estimate based on RESRAD calculation (default values used for input parameters).

[&]. Based on RESRAD calculations without and with water pathways considered, respectively.

^. Estimate based on effective, unshielded occupancy of about 2360 hours for outside exposure.

Branch Technical Position (BTP) on Disposal or Storage of Thorium and Uranium Wastes

On October 20, 1981, NRC published this technical position (46 FR 52061) to provide guidance on decommissioning and cleanup of fuel cycle and other facilities contaminated with relatively large volumes of wastes with low activity concentrations of uranium and thorium. In combination with the disposal provisions in 10 CFR 20.302, the technical position provides four "options" for disposal of uranium and thorium wastes, which vary in activity concentration and corresponding potential radiological dose. As directed in the Commission's April 6, 1992, staff requirements memorandum, only the lower-activity concentration limits and disposal methods provided in Options 1 and 2 of the technical position can be applied as criteria for the release of a site for unrestricted use. Options 3 and 4 require deed restrictions that would be inconsistent with the Commission's regulations that require sites to be cleaned up so that they may be released for unrestricted use.

Under Option 1 of the Branch Technical Position, licensees may dispose of wastes containing natural thorium, depleted or enriched uranium, and natural uranium without restrictions for burial method or post-termination land use. The activity concentrations for this option are consistent with the levels identified in Policy and Guidance Directive FC 83-23. The maximum activity concentration for natural uranium is based on EPA standards for cleanup and stabilization of uranium mill tailings for ^{226}Ra (5 pCi/g) including its decay products (42 FR 2556-2563). The activity concentrations for natural thorium and depleted or enriched uranium are based on internal radiation dose guidelines recommended by EPA for protection against transuranium elements present in the environment as a result of unplanned contamination (42 FR 60956-60959). As shown in Table 1, committed doses were expected to be on the order of one millirad per year to the lung or three millirad per year to the bone from inhalation and ingestion. The resulting concentrations would also limit external exposures to less than 10 microroentgens per hour above background.

Under Option 2 of the 1981 BTP, concentrations of natural thorium and depleted or enriched uranium are required to be buried under prescribed conditions without requiring land use restrictions after license termination. Disposals performed under Option 2 guidelines must be covered by four feet or more of clean soil. Acceptable activity concentrations for burial were calculated based on the criteria that (1) radiation doses to members of the public should not exceed Option 1 levels when the waste is buried in an approved manner under routine exposure conditions, and (2) radiation doses to an inadvertent intruder should not exceed 170 millirems to a critical organ or whole body.

When applying Option 2 of the technical position, the staff evaluates the human intruder pathway. In addition, consistent with the technical position, groundwater considerations are also evaluated, when necessary, because of site specific hydrogeologic features and groundwater use. Dose from the ground water pathway should not exceed 3 mrad/yr to the bone (approximately 1.8 mrem/yr committed EDE) consistent with the stated dose basis for the Option 1 concentration values. Dose from the human intruder pathway should not exceed 170 mrem/yr to the critical organ. For soluble uranium, the critical organ is the bone. For insoluble uranium, the critical organ is the lung. For thorium, both soluble and insoluble, the critical organ is the whole body.

The dose of 170 mrem/yr to the whole body, from Option 2 concentrations of thorium, via the human intruder pathway, may be unacceptably high. Further, this 170 mrem/yr whole body dose assumes a 0.8 occupancy factor and a 0.5 shielding factor. If the occupancy and shielding factors are set to 1, the dose from thorium may be as high as 420 mrem/yr to the whole body. Therefore, for thorium concentrations above the Option 1 limit, the 10 CFR 20 limit of 100 mrem/yr TEDE may be the appropriate unrestricted-use release limit. The intruder exposure pathway could possibly be ignored when the disposal method makes the chance of future human access very remote, such as via deep disposal, or disposal by mine backfill.

Disposals under Option 2 that involve depleted or enriched uranium, are evaluated for buildup of decay products for a period of 1000 years. The original dose assessments to determine the Option 2 limits for depleted and enriched uranium did not include decay products because the decay products are removed in processing the uranium. Significant ingrowth of the decay products requires more than one thousand years and has not been routinely considered in assessing the acceptability of the disposals under Option 2 even though potential doses may increase considerably with time (i.e., beyond 10,000 years).

Table 2 lists the Option 2 concentrations along with their stated dose bases and estimated current dose bases calculated using the RESRAD computer code that contains contemporary dosimetry and exposure assumptions. It should be noted that the use of RESRAD and its default parameter assumptions may not be appropriate for specific regulatory decisions depending on site conditions and characteristics, which may render RESRAD estimates too conservative or nonconservative.

Table 2. Concentrations and Dose Bases for Option 2 of the 1981 Branch Technical Position (BTP).

Contamination	Criterion	Stated Dose Basis	Estimated Dose Basis (EDE)
Natural Thorium	50 pCi/gm	170 mrem/yr	170 - 420 mrem/yr
Depleted Uranium	100 pCi/gm (soluble)	170 mrem/yr (bone)	5 - 50 mrem/yr
	300 pCi/gm (insoluble)	170 mrem/yr (lung)	20 - 68 mrem/yr
Enriched Uranium	100 pCi/gm (soluble)	170 mrem/yr (bone)	5 - 52 mrem/yr
	250 pCi/gm (insoluble)	170 mrem/yr (lung)	20 - 42 mrem/yr

EPA's National Primary Drinking Water Standards for Radionuclides

NRC staff has applied EPA's National Primary Drinking Water Standards on a case-by-case basis to the cleanup and decommissioning of contaminated sites to ensure adequate protection of groundwater and surface water resources. These standards could be applied as criteria for limiting radiation exposures via the ingestion pathway. This approach is explicitly recognized in NMSS Policy and Guidance Directive FC 83-23. EPA promulgated interim drinking water standards for radionuclides in 1976 at 40 CFR 141.15 and 141.16 for combined $^{226}Ra/^{228}Ra$ (5 pCi/l), gross-alpha particle activity (15 pCi/l, excluding radon and uranium), and beta particle and photon emitters (4 mrem/yr for "man-made" radionuclides). The standards are applicable to public drinking water systems and are enforced at the tap. Although they are not strictly applicable to the protection of groundwater and surface water resources, NRC and other agencies (including EPA and States) have applied these standards as objectives and guides for water resource protection. This extension of the applicability of the drinking water standards has been justified based on the paucity of other suitable criteria for water resource protection and on the health and technological feasibility basis of the drinking water standards. This approach is also consistent with EPA policy for groundwater protection. In recent years, EPA has actually adopted the drinking water standards for groundwater and surface water protection purposes at uranium mill tailings sites (40 CFR Part 192, Subparts D and E and proposed Subparts A - C). The dose associated with the standard for beta and photon emitters is 4

mrem/yr. Assuming ingestion of 2 liters of drinking water per day over a 50-year period, the dose associated with the 5 pCi/l standard for ^{226}Ra would be about 5 mrem/yr using the dose conversion factors provided in EPA's Federal Guidance Report No. 11. It is difficult to convert the 15 pCi/l standard for gross-alpha particle activity to dose because gross-alpha is a screening parameter for a variety of alpha-emitting radionuclides and the dose is a function of the energy and characteristics of the alpha decay and biological parameters for each radionuclide.

On July 18, 1991, EPA proposed an increase in the drinking water standard for radium from 5 pCi/l combined $^{226}Ra/^{228}Ra$ to 20 pCi/l for each radionuclide (56 FR 33050). EPA has also proposed in the same rulemaking new drinking water standards for uranium (20 ug/l or 30 pCi/l) and for radon-222 (300 pCi/l). The values of the beta/photon and gross-alpha standards would remain the same, except that the gross-alpha standard would now exclude alpha activity contributed by radium-226. NRC's October 16, 1991 comments to EPA on the proposed rulemaking raised significant concerns about the proposed revisions to the drinking water standards, including ambiguity associated with the documented risk and radiological dose assessments that support the proposed drinking water standards; the need for EPA to assess indirect impacts of the new drinking water standards caused by their applications to other program areas (e.g., decommissioning and waste management); and the need for guidance on how to apply the uranium standard in situations where the uranium has been depleted or enriched. Consequently, there is considerable uncertainity associated with the content of the proposed drinking water standards.

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#. Calculated using draft NUREG/CR-5512. FC 83-23 criteria are based more on technological capabilities (i.e., levels of detectability) than on an explicit health basis.

*. Estimate based on dose at 1 meter for 2000 hour occupancy.

@. Lower estimate represents conversion or repetition of stated dose basis, while upper estimate based on RESRAD calculation (default values used for input parameters).

&. RESRAD calculation - without and with water pathways considered, respectively.

^. Estimate based on effective, unshielded occupancy of about 2360 hours for outside exposure.