AN UPDATE ON STANDARDS FOR RADIATION IN THE ENVIRONMENT AND ASSOCIATED ESTIMATES OF RISK

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SUBJECT OF PRESENTATION

(1) Review of current and proposed standards, recommendations, and guidances for limiting routine radiation exposures of the public.

(2) Estimates of risk corresponding to standards, recommendations, and guidances are emphasized.

Estimates provide common basis for comparing different criteria for limiting public exposures to radiation, as well as hazardous chemicals.

RECENT SUMMARIES OF RADIATION STANDARDS

W. A. Mills, D. S. Flack, F. J. Arsenault, and E. F. Conti, "A Compendium of Major U.S. Radiation Protection Standards and Guides: Legal and Technical Facts," ORAU 88/F-111, Oak Ridge Associated Universities (July 1988)

D. C. Kocher, "Review of Radiation Protection and Environmental Radiation Standards for the Public," Nucl. Saf. 29, 463 (1988)

OUTLINE OF PRESENTATION

(1) Radiation Exposures of U.S. Population

Data on exposures to natural and man-made sources.

(2) Radiation Protection Standards for the Public

Recommendations of national and international authorities on radiation protection.

Current and proposed standards of NRC and DOE.

(3) Environmental Radiation Standards for Specific Practices or Sources

Current and proposed standards or guidances of NRC, EPA, and DOE for -

- operations of uranium fuel-cycle facilities;
- radioactivity in drinking water;
- mill tailings and residual radioactivity;
- radioactive waste disposal;
- airborne radioactivity;
- indoor radon.

RADIATION EXPOSURES OF

U.S. POPULATION

ANNUAL EFFECTIVE DOSE EQUIVALENT IN U.S. POPULATION

Data in NCRP Report No. 93 on average annual effective dose equivalent in U.S. population (1 mSv = 0.1 rem) -

Source	Dose (mSv)
Natural sources	
Radon	2.0
Other	1.0
Nuclear fuel cycle	0.0005
Consumer products	0.1
Medical	
Diagnostic x rays	0.39
Nuclear medicine	0.14
Total	3.6

Other natural sources include cosmic rays, cosmogenic and terrestrial radionuclides, and radionuclides in the body.

Consumer products exclude tobacco; estimated annual dose equivalent to segment of bronchial epithelium from smoking is 0.16 Sv (16 rem).

RADIATION PROTECTION STANDARDS

FOR THE PUBLIC

DEFINITION OF RADIATION PROTECTION STANDARD

A radiation protection standard for the public specifies limits on exposure that are regarded as necessary for protection of public health.

Standards for public exposures are concerned primarily with limitation of stochastic risk (risk of fatal cancers and genetic defects).

Standards usually ensure prevention of non-stochastic (acute) radiation effects.

Radiation protection standards for the public are generally applicable to all sources of exposure, exclusive of natural background and deliberate medical practices.

Radiation protection standards must be met, except under unusual circumstances, regardless of cost.

RECOMMENDATIONS OF FEDERAL RADIATION COUNCIL

Federal guidance on radiation protection of the public developed in 1960 -

Limit on annual dose equivalent to whole body for maximally exposed individuals of 0.5 rem;

Limit on annual dose equivalent to whole body for average individuals in population of 0.17 rem;

Limit on dose equivalent to gonads for individuals in large population groups of 5 rem in 30 years (limitation of genetic defects);

Reduction of exposures As Low As Practical (ALAP).

Dose to "whole body" means dose from uniform irradiation of the whole body.

FRC guidance on dose limitation for maximally exposed individuals was adopted in NRC's current radiation protection standards (10 CFR Part 20).

Interagency committee headed by EPA is preparing new Federal guidance on radiation protection of the public.

EARLY RECOMMENDATIONS OF ICRP

Recommendations in ICRP Publications 1 and 2 (1958, 1959), as amended in Publications 6 (1962) and 9 (1965) -

Limits on annual dose equivalent for individuals of -

- 0.5 rem to whole body, gonads, or red marrow;
- 3 rem to bone, thyroid, or skin;
- 1.5 rem to any other critical organ.

Limits apply to sum of 50-year committed dose equivalent from internal exposure and dose equivalent from external exposure, and are one-tenth of limits for radiation workers.

Critical organ is organ receiving highest dose, and dose to critical organ often is limiting for internal exposures involving non-uniform irradiations of the whole body.

Concept of limiting dose to whole body or critical organ is used in NRC's current radiation protection standards (10 CFR Part 20) and in many environmental radiation standards of EPA and NRC for specific practices or sources.

CURRENT RECOMMENDATIONS OF ICRP

System of dose limitation in ICRP Publication 26 (1977) -

(1) Justification of practice;

(2) Reduction of exposures As Low As Reasonably Achievable (ALARA), i.e., optimization of collective dose on basis of cost-benefit analysis;

(3) Limitation of dose to individuals in critical groups of exposed population.

Dose limits for individuals are intended for application to average exposure situations for reference individuals in critical groups, rather than single real individual who receives highest dose.

CURRENT RECOMMENDATIONS OF ICRP

(continued)

Dose limits for individuals in ICRP Publication 45 (1985) -

Principal limit on annual effective dose equivalent (or dose equivalent from uniform whole-body irradiation) of 1 mSv (0.1 rem);

Subsidiary limit on annual effective dose equivalent of 5 mSv (0.5 rem) for some years, provided annual effective dose equivalent averaged over a lifetime does not exceed 1 mSv (0.1 rem);

Limit on annual dose equivalent to skin and lens of the eye of 50 mSv (5 rem) (prevention of non-stochastic effects).

EFFECTIVE DOSE EQUIVALENT

Effective dose equivalent first developed in ICRP Publication 26 is defined as weighted sum of committed dose equivalents to different organs or tissues -

$$H_E = \sum_i w_i H_i, \quad i = \text{organ index}$$

Weighting factor w_i is proportion of stochastic risk resulting from ith organ to total risk, when whole body is irradiated uniformly.

Effective dose equivalent is intended to be proportional to stochastic risk for either uniform or non-uniform irradiations of the whole body. Exposures with equal effective dose equivalents should correspond to equal risks regardless of distribution of dose among different organs or tissues.

EFFECTIVE DOSE EQUIVALENT

(continued)

Weighting factors (w_i) for different organs or tissues -

Gonads	0.25
Breast	0.15
Red marrow	0.12
Lungs	0.12
Thyroid	0.03
Bone surfaces	0.03
Remainder	0.30

Remainder category includes five other organs (excluding skin, lens of the eye, and body extremities), each assigned weighting factor of 0.06.

Whole body is not a tissue at risk and is not included in remainder category.

RISK FACTORS FROM RADIATION EXPOSURE

Total stochastic risk per unit dose equivalent from uniform whole-body irradiation (per unit effective dose equivalent) recommended in ICRP Publication 26 -

Risk factor = 2×10^{-2} Sv^{-1} (2×10^{-4} rem^{-1}).

Risk factor for any organ is obtained as product of risk factor from uniform whole-body irradiation and weighting factor for that organ.

CURRENT RECOMMENDATIONS OF NCRP

Dose limits for individuals in NCRP Report No. 91 (1987) -

Limit on annual effective dose equivalent of 1 mSv (0.1 rem) for continuous or repeated exposures;

Limit on annual effective dose equivalent of 5 mSv (0.5 rem) for infrequent exposures;

Limit on annual dose equivalent to skin, lens of the eye, and extremities of 50 mSv (5 rem).

Limits are consistent with current ICRP recommendations.

NCRP recommendations traditionally have been adopted in radiation protection standards of DOE.

CURRENT RECOMMENDATIONS OF NCRP

(continued)

Exposure levels for undertaking remedial action recommended in NCRP Report No. 91 -

Average annual effective dose equivalent from external exposure, excluding medical practices but including naturally occurring sources, continuously exceeds 5 mSv (0.5 rem).

In unlikely event that internal exposure other than from radon could be significant, it should be included in exposure assessment.

Annual average exposure to radon and its decay products for an individual exceeds 0.007 Jh/m^3 (2 WLM).

1 WLM (Working Level Month) = cumulative exposure equivalent to exposure to 1 Working Level (WL) for a working month (170 hours).

1 WL = 2.08 x 10^{-5} J of potential alpha-particle energy per m^3 of air (1.3 x 10^5 MeV/L) from short-lived radon daughter products.

Remedial action levels take into account that natural sources enhanced by man-made radioactivity can result in annual effective dose equivalents greater than 1 mSv (0.1 rem).

CURRENT NRC RADIATION PROTECTION STANDARDS IN 10 CFR PART 20

Current NRC standards are based on recommendations in FRC guidance and ICRP Publications 1 and 2, as amended.

Permissible levels of radiation in unrestricted areas from licensee's operations and other sources of radiation -

Limit on annual dose equivalent to whole body of 0.5 rem;

Limits on dose equivalent of 2 mrem in any hour and 0.1 rem in any 7 consecutive days.

Limits on radioactivity in effluents to unrestricted areas from licensee's operations -

Maximum permissible concentrations (MPCs) of radionuclides in air and water above background, based on one-tenth of values in ICRP Publication 2, as amended, for 168 hours per week of occupational exposure.

Radiation exposures and releases to unrestricted areas should be maintained ALARA.

PROPOSED REVISIONS OF NRC RADIATION PROTECTION STANDARDS

NRC has published proposed revisions of radiation protection standards for the public in 10 CFR Part 20.

Final standards will differ somewhat from Proposed Rule but probably will incorporate -

- risk-based dose limitation system (i.e., effective dose equivalent) recommended by ICRP;
- dose limits for individuals from licensee's operations which are consistent with current ICRP and NCRP recommendations;
- derived limits on radionuclide concentrations in unrestricted areas based on metabolic and dosimetric parameters recommended in ICRP Publications 30 and 48;
- reductions in derived concentration limits for adults to provide adequate protection of younger age groups.

DOE RADIATION PROTECTION STANDARDS

Current radiation protection standards for DOE operations in Order 5480.1A -

Limit on annual effective dose equivalent of 0.5 rem (5 mSv) for occasional exposures;

Limit on annual effective dose equivalent of 0.1 rem (1 mSv) for exposures lasting longer than 5 years;

Limit on annual dose equivalent to any organ of 5 rem (50 mSv);

Exposures of the public shall be maintained ALARA.

Limits are consistent with current ICRP and NCRP recommendations and represent first use in U.S. of effective dose equivalent.

DOE RADIATION PROTECTION STANDARDS

(continued)

Impending revisions of DOE standards in Order 5400.3 -

Limit on annual effective dose equivalent of 0.1 rem (1 mSv);

If avoidance of higher exposures is impractical, temporary limit on annual effective dose equivalent not to exceed 0.5 rem (5 mSv) may be authorized;

Limit on annual dose equivalent to any organ of 5 rem (50 mSv);

Concentration guides for radionuclides in air and water in uncontrolled areas, based on internal dosimetry data in ICRP Publications 30 and 48, plus concentration guides for external exposure from immersion in contaminated air;

Exposures of the public shall be maintained ALARA.

DOE Order also contains requirements for control of specific practices or sources.

ENVIRONMENTAL RADIATION STANDARDS FOR

SPECIFIC PRACTICES OR SOURCES

DEFINITION OF ENVIRONMENTAL RADIATION STANDARD

An environmental radiation standard applies only to a specific practice or source of exposure.

Environmental radiation standards for specific practices or sources are based primarily on -

- considerations of best available control technologies; or
- reduction of environmental radioactivity to levels near ambient background.

Thus, environmental radiation standards represent judgments regarding levels of public exposure that are reasonably achievable, rather than a need for limitation of risk per se.

Standards for specific practices or sources provide practical basis for ensuring that radiation protection standards for all sources of exposure will be met.

CURRENT RECOMMENDATIONS OF NCRP

Recommendation on control of individual sources of public exposure in NCRP Report No. 91 -

> If individual could exceed 25% of annual effective dose equivalent limit from exposure to single source, then operator should ensure that annual effective dose equivalent to maximally exposed individual from all sources would not exceed 1 mSv (0.1 rem) on a continuous basis.

Recommendation assumes it is unlikely that individuals would receive significant exposure from more than four sources.

Recommendation essentially provides limit on annual effective dose equivalent of 0.25 mSv (25 mrem) per source.

Recommendation on control of individual sources is being considered by interagency committee preparing new Federal guidance on radiation protection of the public.

JURISDICTION OF ENVIRONMENTAL RADIATION STANDARDS

For a regulated practice or source -

- NRC standards generally apply only to NRC licensees;
- DOE standards generally apply only to DOE or contractor organizations;
- EPA standards generally take precedence over NRC and DOE standards, but NRC or DOE standards can apply if (1) they are more restrictive than EPA standards or (2) they include requirements not addressed in EPA standards.

Many of EPA's environmental radiation standards are enforced by NRC or DOE, i.e., those developed under authority of Atomic Energy Act of 1954, as amended.

EPA enforces its environmental radiation standards developed under authority of other statutes, e.g., Safe Drinking Water Act and Clean Air Act.

NRC STANDARDS IN 10 CFR PART 50

ALARA, DESIGN OBJECTIVES FOR NUCLEAR REACTORS

Standards specify that releases of radioactivity from nuclear power reactors shall be kept ALARA.

Appendix I - Numerical guides for design objectives and ALARA

Design objectives (i.e., dose limits for whole body or particular organs or tissues) for liquid effluents, gaseous effluents, and releases of iodine and particulates -

Limits on annual dose equivalent of 3-15 mrem;

Dose limits are not an environmental radiation standard for operating reactors.

ALARA - Additional effluent controls shall be used if cost is less than $1,000 per person-rem avoided to whole body or thyroid for population within 50 miles.

EPA STANDARDS IN 40 CFR PART 190
URANIUM FUEL-CYCLE OPERATIONS

Standards apply to normal operations in milling of uranium ore, chemical conversion, fuel fabrication, electricity generation in nuclear power plants, and fuel reprocessing but not to mining, waste disposal operations, transportation, and reuse of recovered special nuclear and byproduct materials.

Limits on annual dose equivalent from all radionuclides except radon and its daughters of -

- 25 mrem to whole body;
- 75 mrem to thyroid;
- 25 mrem to any other organ.

Release limits per GW-year of electrical energy produced of -

- 50,000 Ci for ^{85}Kr;
- 5 mCi for ^{129}I;
- 0.5 mCi for ^{239}Pu plus other alpha-emitting transuranic radionuclides with half-lives greater than 1 year.

40 CFR Part 190 is first environmental radiation standard for specific practice or source based on considerations of best available effluent control technologies.

EPA STANDARDS IN 40 CFR PART 141

RADIOACTIVITY IN COMMUNITY DRINKING WATER SYSTEMS

Standards apply to public or private water systems with at least 15 service connections or serving at least 25 persons.

Limits on concentrations of radionuclides at the tap of -

- 5 pCi/L for ^{226}Ra plus ^{228}Ra;
- 15 pCi/L for gross alpha-particle activity, including ^{226}Ra but excluding radon and uranium.

Limit on annual dose equivalent from man-made, beta/gamma-emitting radionuclides at the tap of -

- 4 mrem to whole body or any organ.

Standards for radium and gross alpha-particle activity are based on consideration of costs of reducing ambient levels in community drinking water systems in relation to health risks averted (application of ALARA principle).

For ingestion of 2 L per day of water, 5 pCi/L of ^{226}Ra plus ^{228}Ra corresponds to annual effective dose equivalent of about 5 mrem.

Standard for beta/gamma-emitting radionuclides is based on maximum levels of ^{90}Sr and ^{137}Cs from fallout in community drinking water systems.

EPA STANDARDS IN 40 CFR PART 141
RADIOACTIVITY IN COMMUNITY DRINKING WATER SYSTEMS
(continued)

EPA standards are being revised and may include -

Separate concentration limit for ^{228}Ra about 2-3 times less than present limit of 5 pCi/L for ^{226}Ra;

Concentration limit for uranium somewhat greater than present limit for ^{226}Ra;

Concentration limit for radon about an order of magnitude greater than limits for radium or uranium;

Use of concentration limit for gross alpha-particle activity only as screening tool in monitoring requirements;

Alternative of single limit on annual effective dose equivalent from all radionuclides.

Standards in 40 CFR Part 141 are increasingly being applied to limitation of radioactivity in potential sources of drinking water that may be contaminated by past or future practices.

DOE STANDARDS FOR RADIOACTIVITY IN DRINKING WATER

Requirements in impending DOE Order 5400.3 -

Limit on annual effective dose equivalent from drinking water supplies operated by or for DOE of 4 mrem (0.04 mSv), excluding naturally occurring radionuclides;

Liquid effluents from DOE activities will not cause private or public drinking water systems downstream of facility discharge to exceed concentration and dose limits in EPA drinking water standards (40 CFR Part 141).

EPA STANDARDS IN 40 CFR PART 440

MINING EFFLUENT LIMITS FOR U AND RA

Standards apply to liquid discharges from mines or mills used to produce or process uranium, radium, and vanadium ores.

Limit on concentrations in effluents for any day -

- 10 pCi/L for dissolved ^{226}Ra;
- 30 pCi/L for total ^{226}Ra;
- 4 mg/L for U.

Limit on average concentrations in daily effluents for 30 consecutive days -

- 3 pCi/L for dissolved ^{226}Ra;
- 10 pCi/L for total ^{226}Ra;
- 2 mg/L for U.

Standards are based on best available effluent control technologies.

EPA STANDARDS IN 40 CFR PART 192
URANIUM AND THORIUM MILL TAILINGS

Standards for (1) control and cleanup of residual radioactive materials at inactive uranium processing sites or (2) management of uranium and thorium byproduct materials at active processing sites include -

Limit on (1) annual average release rate of ^{222}Rn to atmosphere of 20 $pCi/m^2/s$ or (2) annual average concentration of ^{222}Rn in air above background outside disposal site of 0.5 pCi/L;

Limit on ^{226}Ra concentration in soil above background of (1) 5 pCi/g averaged over first 15 cm below surface and (2) 15 pCi/g averaged over 15-cm thick layers more than 15 cm below surface;

Limit on radon decay-product concentration (including background) in any occupied or habitable building of 0.03 WL, with objective for remedial action of 0.02 WL;

Limit on gamma radiation level above background in any occupied or habitable building of 20 $\mu R/h$;

1 R ≈ 0.7 rem effective dose equivalent

EPA STANDARDS IN 40 CFR PART 192
URANIUM AND THORIUM MILL TAILINGS
(continued)

Standards (continued) -

Limits on concentrations of ^{226}Ra plus ^{228}Ra and gross alpha-particle activity, excluding radon and uranium, in ground water as given in drinking water standards (40 CFR Part 141);

Limit on annual dose equivalent from thorium processing operations of 25 mrem to whole body, 75 mrem to thyroid, or 25 mrem to any other organ;

Limits for uranium, ^{222}Rn, and ^{226}Ra also apply to thorium, ^{220}Rn, and ^{228}Ra, respectively;

Standards for control of radon emissions shall be effective for up to 1,000 years, to extent reasonably achievable, and in any case for at least 200 years.

EPA STANDARDS IN 40 CFR PART 192

URANIUM AND THORIUM MILL TAILINGS

(continued)

Estimates of limits on annual effective dose equivalent corresponding to standards -

Outdoor ^{222}Rn concentration of 0.5 pCi/L - 0.026 rem, based on mean annual effective dose equivalent per unit concentration for outdoor residence time of 15% given in ICRP Publication 50.

^{226}Ra concentrations in soil - 0.06 rem, assuming continuous external exposure, decay products in equilibrium, indoor and outdoor residence times of 85% and 15%, and indoor shielding factor of 0.7.

Indoor radon decay-product concentration of 0.03 WL from ^{222}Rn - 0.8 rem, based on mean annual effective dose equivalent per unit exposure for indoor residence time of 85% given in ICRP Publication 50.

Indoor gamma radiation level of 20 μR/h - 0.1 rem, assuming indoor residence time of 85%.

^{226}Ra concentration in ground water of 5 pCi/L - 0.005 rem, assuming ingestion of 2 L per day of water.

EPA STANDARDS IN 40 CFR PART 192
URANIUM AND THORIUM MILL TAILINGS
(continued)

Standards are based primarily on ambient levels of radioactivity in western U.S. where ore deposits exist and residual materials were obtained; i.e., to extent reasonably achievable, mill tailings disposal should be as safe as unmined ore from which tailings were produced.

Proposed revision of standards -

Limit on concentration of ^{234}U plus ^{238}U in ground water near inactive uranium processing sites of 30 pCi/L.

Limit would provide risk from uranium in drinking water equivalent to risk associated with current limit of 5 pCi/L for radium.

NRC STANDARDS IN 10 CFR PART 40, APPENDIX A

URANIUM MILL TAILINGS

NRC standards conform in most respects to current EPA standards in 40 CFR Part 192.

Remaining differences with EPA standards -

External photon exposures from tailings or wastes should be reduced to background levels;

Indoor concentrations of radon decay products are not addressed.

NRC standards also contain -

- technical criteria for siting and design of disposal facilities and protection of ground water;
- requirement that airborne effluents from milling operations shall be ALARA.

DOE STANDARDS FOR RESIDUAL RADIOACTIVITY

Standards for residual radioactive material in impending DOE Order 5400.3 address (1) release of contaminated property for unrestricted use by the public, (2) interim storage of residual radioactive material, and (3) long-term management of uranium, thorium, and their decay products.

Standards involve hierarchy of -

- requirements for radiation protection, i.e., limit on annual effective dose equivalent from routine DOE operations and exposure to residual radioactive material of 0.1 rem (1 mSv) and reduction of levels of residual radioactivity ALARA;

- generic guidelines for levels of residual radioactivity, based primarily on EPA standards in 40 CFR Part 192 and NRC guidelines for radioactivity on surfaces of structures and equipment, or derived guidelines based on prescribed site-specific procedures and data;

- authorized limits set equal to generic or derived guidelines, except where site-specific data clearly show that radiation protection requirements will not be met.

EPA RULEMAKING 40 CFR PART 194

CLEANUP OF RESIDUAL RADIOACTIVITY

EPA intends to develop standards for cleanup of land and facilities contaminated with residual radioactive materials.

Standards would apply to -

- licensees of NRC or Agreement States;
- sites owned or used by DOE, DOD, former AEC, and former Manhattan Engineering District;
- sites where natural and accelerator-produced radioactive materials have been used.

EPA GUIDANCE ON TRANSURANIUM ELEMENTS IN THE ENVIRONMENT

Proposed guidance was first published in 1977.

Draft interim recommendations on acceptable levels of transuranium elements above background (1987) -

To extent practical, annual alpha dose from transuranium elements should be limited to 1 mrad (0.01 mGy) to pulmonary lung or 3 mrad (0.03 mGy) to bone, endosteal bone surfaces, or red bone marrow - Range I.

Doses above Range I and less than annual effective dose equivalent of 0.1 rem (1 mSv) from all sources, excluding natural background and medical practices, are acceptable provided risks to population are justified, general surveillance and routine monitoring are implemented, and doses are maintained ALARA - Range II.

Doses above Range II and less than annual effective dose equivalent of 0.5 rem (5 mSv) from all sources on intermittent basis require continuing monitoring and evaluation of individuals and limitations on access or use pending remedial actions - Range III.

Recommendations also contain detailed guidance on applicability and implementation.

EPA STANDARDS IN 40 CFR PART 191
MANAGEMENT AND DISPOSAL OF HIGH-LEVEL WASTES

Standards apply to management (except for transportation), storage, and disposal of spent fuel, high-level waste, and transuranic waste.

Standards for management and storage (Subpart A) -

For facilities regulated by NRC or Agreement States -

Limit on annual dose equivalent, including all operations covered by 40 CFR Part 190, of 25 mrem to whole body, 75 mrem to thyroid, or 25 mrem to any other organ.

For facilities operated by DOE and not regulated by NRC or Agreement States -

Limit on annual dose equivalent of 25 mrem to whole body or 75 mrem to any organ; or

Upon application for alternative standard, limit on annual dose equivalent from all sources, excluding natural background and medical practices, of 0.1 rem for continuous exposure and 0.5 rem for infrequent exposure.

Difference between two standards provides clear example of limits based on doses judged to be reasonably achievable.

EPA STANDARDS IN 40 CFR PART 191
MANAGEMENT AND DISPOSAL OF HIGH-LEVEL WASTES
(continued)

Standards for disposal (Subpart B) -

Containment requirements - For 10,000 years after disposal, cumulative releases of radionuclides to accessible environment shall have likelihood of (1) less than one chance in 10 of exceeding specified limits and (2) less than one chance in 1,000 of exceeding ten times the limits.

Cumulative release limits correspond to population risk of 1,000 health effects per repository over 10,000 years, and result from application of ALARA principle.

Containment requirements are probabilistic; i.e., predictions of cumulative releases will be expressed as probability distributions based on uncertainties in model parameters and likelihood of release scenarios.

Assurance requirements - qualitative requirements to provide confidence that containment requirements will be met.

Individual and ground water protection requirements (as well as containment requirements) were vacated by First Circuit Court and remanded to EPA for further proceedings.

EPA has not published proposal for modifying requirements.

NRC STANDARDS IN 10 CFR PART 60
WASTE DISPOSAL IN GEOLOGIC REPOSITORIES

Standards contain performance, siting, and design criteria intended to provide reasonable assurance that containment requirements in EPA standards (40 CFR Part 191) for disposal of high-level wastes will be met.

Post-closure performance criteria -

Substantially complete containment of waste within waste packages for 300-1,000 years;

Limit on release rate of any radionuclide from engineered barrier system following containment period of (1) 10^{-5} per year of inventory of that radionuclide at 1,000 years following permanent closure or (2) 10^{-5} per year of inventory of all radionuclides placed in disposal facility that remains after 1,000 years of decay;

Pre-waste-emplacement ground-water travel time along fastest path of likely radionuclide travel from edge of disturbed zone to accessible environment of at least 1,000 years.

NRC STANDARDS IN 10 CFR PART 61
NEAR-SURFACE LAND DISPOSAL OF RADIOACTIVE WASTE

Performance objectives for disposal include -

Limit on annual dose equivalent beyond facility boundary of 25 mrem to whole body, 75 mrem to thyroid, or 25 mrem to any other organ;

Releases beyond facility boundary should be maintained ALARA;

Requirement for protection of inadvertent intruders into site at any time after active institutional controls are removed (assumed to be 100 years after closure).

Technical requirements for disposal include -

Requirements on site suitability and design, facility operation and site closure, and waste characteristics;

Limits on radionuclide concentrations that are generally acceptable for near-surface land disposal, i.e., Class-A and -C limits for longer-lived radionuclides and Class-A, -B, and -C limits for shorter-lived radionuclides.

Waste classification system provides protection of inadvertent intruders and is based on limit on annual dose equivalent of 0.5 rem to whole body and bone or 1.5 rem to any other organ.

DOE ORDER 5820.2A, CHAPTER III

MANAGEMENT OF LOW-LEVEL WASTE

Performance objectives and requirements for new low-level waste disposal facilities at DOE sites -

Limit on annual effective dose equivalent beyond facility boundary of 25 mrem;

Releases beyond facility boundary should be maintained ALARA;

Limit on annual effective dose equivalent for inadvertent intruders after loss of active institutional controls (at 100 years) of 0.1 rem for continuous exposure or 0.5 rem for single acute exposure;

Protection of ground water in accordance with Federal and State standards;

Demonstrations of compliance with performance objectives shall be based on site-specific performance assessments.

EPA RULEMAKING 40 CFR PART 193

MANAGEMENT AND DISPOSAL OF LOW-LEVEL WASTE

Draft proposed standards for management and storage -

Limit on annual effective dose equivalent beyond facility boundary of 25 mrem;

Limit on annual effective dose equivalent to any member of the public of 4 mrem defines waste which is Below Regulatory Concern (BRC); BRC waste does not require disposal in facilities regulated according to standards in this Part.

Draft proposed standards for disposal -

Limit on annual effective dose equivalent beyond facility boundary of 25 mrem;

Ground-water protection requirements -

No increase in levels of radioactivity in Class I ground waters;

Limit on annual effective dose equivalent of 4 mrem from ingestion of 2 L per day of drinking water from Class II ground waters.

Standards do not address protection of inadvertent intruders.

EPA RULEMAKING 40 CFR PART 764

MANAGEMENT AND DISPOSAL OF NATURALLY OCCURRING AND ACCELERATOR-PRODUCED RADIOACTIVE MATERIALS (NARM)

Standards are being developed under authority of Toxic Substances Control Act; i.e., NARM is not regulated under Atomic Energy Act.

Definitions -

NARM means any radioactive material except source, byproduct, or special nuclear material.

Regulated NARM waste has specific activity greater than 2 nCi/g, but does not include specified consumer products containing small quantities of activity.

Draft proposed standards for management and disposal -

NARM waste must be classified as Class-A, -B, or -C waste, based on waste classification system developed by NRC in 10 CFR Part 61 but modified to include long-lived isotopes of radium, thorium, and uranium.

Regulated NARM waste is subject to disposal according to requirements in 40 CFR Part 193.

EPA STANDARDS IN 40 CFR PART 61
AIRBORNE EMISSIONS OF RADIONUCLIDES

Standards for airborne releases of radionuclides from DOE facilities and NRC-licensed and non-DOE Federal facilities, except underground uranium mines and facilities regulated under 40 CFR Parts 190, 191, or 192 -

Limit on annual dose equivalent of 25 mrem to whole body or 75 mrem to any organ, exclusive of doses from radon and decay products;

Upon application for alternative standard, limit on annual effective dose equivalent from all sources, excluding natural background and medical practices, of 0.1 rem for continuous exposure and 0.5 rem for noncontinuous exposure.

Standard for elemental phosphorus plants -

Limit on annual emissions of ^{210}Po to air of 21 Ci.

Standard for ^{222}Rn emissions from underground uranium mines -

Requirements on installation and maintenance of bulkheads to isolate abandoned and temporarily abandoned areas of mines.

EPA STANDARDS IN 40 CFR PART 61
AIRBORNE EMISSIONS OF RADIONUCLIDES
(continued)

EPA has published proposed revision of standards for different source categories which present four alternatives based on various assumptions regarding (1) acceptable risk to individuals or populations and (2) an ample margin of safety.

DOE facilities (excluding radon emissions) and NRC-licensed and non-DOE Federal facilities -

Limit on annual effective dose equivalent ranging from 10 mrem to 0.03 mrem.

Elemental phosphorus plants -

Limit on annual emissions of ^{210}Po to air ranging from 10 Ci to 0.006 Ci.

Radon emissions from DOE facilities and phosphogypsum stacks -

Limit on emanation rate of ^{222}Rn into the air ranging from 20 $pCi/m^2/s$ to 0.02 $pCi/m^2/s$.

Radon emissions from surface uranium mines -

Limit on emanation rate of ^{222}Rn into the air of 0.02 $pCi/m^2/s$.

EPA STANDARDS IN 40 CFR PART 61
AIRBORNE EMISSIONS OF RADIONUCLIDES
(continued)

Proposed revision of standards (continued) -

Radon emissions from underground uranium mines -

Limit on annual release of ^{222}Rn into the atmosphere ranging from 5,000 Ci to 5 Ci.

Radon emissions from disposal of uranium mill tailings -

Limit on emanation rate of ^{222}Rn into the air ranging from 6 $pCi/m^2/s$ to 0.02 $pCi/m^2/s$.

FEDERAL GUIDANCE ON RADON IN HOMES

EPA and Department of Health and Human Services recommend maximum indoor radon concentration in homes of 4 pCi/L (about 0.02 WL) as guidance on need for mitigation of exposures.

Guidance is <u>not</u> a standard for limiting public exposures to indoor radon.

Estimates of 70-year lifetime risk corresponding to Federal guidance -

$1\text{-}5 \times 10^{-2}$ - EPA's estimate of mean risk of death from lung cancer, assuming indoor residence time of 75%;

8×10^{-3} - Based on mean annual effective dose equivalent per unit exposure for indoor residence time of 85% given in ICRP Publication 50 and risk factor for uniform whole-body irradiation from ICRP Publication 26;

2×10^{-2} - Based on risk factor for death from lung cancer given in BEIR IV report and indoor residence time of 85%;

1×10^{-2} - Based on annual risk of death from lung cancer after age 40 given in NCRP Report No. 77 extrapolated over a lifetime and indoor residence time of 85%.

SUMMARY OF ENVIRONMENTAL RADIATION STANDARDS

Standards based primarily on considerations of best available control technologies -

Design objectives for nuclear reactors (10 CFR Part 50, Appendix I);

Uranium fuel-cycle operations (40 CFR Part 190);

Mining effluent limits for radium and uranium (40 CFR Part 440);

Thorium processing operations (40 CFR Part 192);

Management and disposal of high-level wastes (40 CFR Part 191; 10 CFR Part 60);

Near-surface land disposal of radioactive waste (10 CFR Part 61; DOE Order 5820.2A, Chapter III; draft proposed 40 CFR Parts 193 and 764);

Airborne emissions of radionuclides (40 CFR Part 61).

A limit on annual effective dose equivalent of 25 mrem (0.25 mSv) is a de facto environmental radiation standard for many practices.

SUMMARY OF ENVIRONMENTAL RADIATION STANDARDS

(continued)

Standards or guidances based primarily on considerations of ambient background levels of radioactivity and application of ALARA principle to reductions in environmental levels -

Radioactivity in drinking water (40 CFR Part 141; impending DOE Order 5400.3);

Uranium and thorium mill tailings (40 CFR Part 192; 10 CFR Part 40, Appendix A);

Residual radioactivity in the environment (impending DOE Order 5400.3);

Transuranium elements in the environment (draft EPA interim guidance).

Standards for radioactivity in drinking water and containment requirements for disposal of high-level wastes essentially limit population risks; other standards and guidances essentially limit risks to maximally exposed individuals.

RISKS ASSOCIATED WITH ENVIRONMENTAL RADIATION STANDARDS

Estimates of lifetime risk associated with (1) selected radiation protection standards and environmental radiation standards and guidances and (2) natural background -

3×10^{-2} - Guidance on radon in homes

1×10^{-2} - Uranium mill tailings standards

7×10^{-3} - Annual dose equivalent to whole body of 0.5 rem

4×10^{-3} - Annual effective dose equivalent of 0.3 rem (average natural background)

3×10^{-3} - Annual effective dose equivalent of 0.2 rem (average indoor radon)

1×10^{-3} - Annual effective dose equivalent of 0.1 rem

4×10^{-4} - Annual dose equivalent to whole body or effective dose equivalent of 25 mrem

6×10^{-5} - Ra-226 plus Ra-228 in drinking water

6×10^{-5} - Annual dose equivalent to whole body or effective dose equivalent from drinking water of 4 mrem

3×10^{-5} - Annual dose equivalent to thyroid of 75 mrem

1×10^{-5} - Annual dose equivalent to bone of 25 mrem

5×10^{-6} - Annual dose equivalent to bone from Sr-90 in drinking water of 4 mrem

2×10^{-6} - Annual dose equivalent to thyroid from I-129 in drinking water of 4 mrem

5×10^{-8} - Containment requirements for high-level waste disposal (average risk in U.S. population)

RISKS ASSOCIATED WITH ENVIRONMENTAL RADIATION STANDARDS

(continued)

Conclusions -

Excluding containment requirements for high-level waste disposal, lifetime risks associated with different environmental radiation standards vary by nearly four orders of magnitude.

Risks associated with guidance on radon in homes and uranium mill tailings standards exceed risks associated with all generally applicable radiation protection standards, but the former include contributions from natural background.

Average risks in U.S. population from all natural sources, or from indoor radon only, are at least an order of magnitude greater than risks associated with all environmental radiation standards except for mill tailings and residual radioactivity.

Risks associated with some environmental radiation standards are less than negligible individual risk level of about 10^{-5} recommended in NCRP Report No. 91.