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PERFORMANCE OBJECTIVES FOR DISPOSAL OF LOW-LEVEL RADIOACTIVE WASTES ON THE OAK RIDGE RESERVATION*

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ABSTRACT

This paper presents a set of performance objectives for the long-term protection of public health and safety for disposal of low-level radioactive wastes in a new facility on the Oak Ridge Reservation. The principal performance objectives include (1) a limit on annual committed effective dose equivalent averaged over a lifetime of 0.25 mSv (25 mrem) for any member of the general public beyond the boundary of the disposal facility, and (2) a limit on annual committed effective dose equivalent averaged over a lifetime of 1 mSv (100 mrem) and a limit on committed effective dose equivalent in any year of 5 mSv (500 mrem) for any individual who inadvertently intrudes onto the disposal site after loss of active institutional controls. In addition, releases of radioactivity beyond the site boundary (1) shall not result in annual doses to any member of the general public that exceed limits established by Federal regulatory authorities for all sources of exposure, and (2) shall be kept as low as reasonably achievable. The limit on annual committed effective dose equivalent averaged over a lifetime for off-site individuals is based primarily on the judgment of the U.S. Nuclear Regulatory Commission that this level of protection is reasonably achievable for shallow-land disposal of low-level wastes. The dose

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limits for inadvertent intruders are based on radiation protection standards for the general public recommended by the International Commission on Radiological Protection and the National Council on Radiation Protection and Measurements. The use of annual committed effective dose equivalents averaged over a lifetime departs from customary practice in radiation standards in the U.S. of specifying limits on dose received in any year to whole body or the critical organ, but provides a set of performance objectives that are more closely related to the fundamental goal of limiting lifetime risk from chronic radiation exposures.

INTRODUCTION

The U.S. Department of Energy (DOE) is proposing to operate a new facility on the Oak Ridge Reservation in Tennessee that will provide for permanent disposal of low-level radioactive wastes generated at the three DOE plants in Oak Ridge.[1-3] An important step in developing the new facility is the establishment of objectives for overall performance of the disposal system that ensure long-term protection of public health and safety. Such performance objectives provide constraints on acceptable siting and design of the facility and on the quantities and physicochemical properties of radioactive wastes that may be accepted for disposal.

This paper presents a set of performance objectives for the new low-level waste disposal facility in Oak Ridge. The performance objectives are based on the principle that potential risks to members of the general public must be limited to levels that are widely regarded as safe. As is customary in radiation protection (e.g., see refs. 4-6), the performance objectives are expressed in terms of limits on radiation dose to maximally exposed individuals, rather than limits on risk itself. The dose limits can be related to limits on risk using an accepted value for the risk per unit dose (e.g., see ref. 4).

The DOE has established limits on annual dose to members of the general public from DOE operations of 500 mrem to whole body, gonads, or bone marrow and 1500 mrem to any other organ.[7] However, these dose limits apply to all DOE operations that may impact the general public, and considerably lower limits may be more appropriate for a single waste-disposal facility. The performance objectives presented in this paper are based on levels of protection that have been judged by regulatory authorities to be reasonably achievable for low-level waste disposal.

The performance objectives for low-level waste disposal are presented in the next section. The following sections then discuss (1) the time period and the types of processes and events to which the performance objectives are intended to apply, (2) the rationale for the use of limits on annual committed effective dose equivalents averaged over a lifetime as a surrogate for limits on lifetime risk, (3) the rationale for the numerical dose limits chosen as performance objectives, (4) implications of the performance objectives for demonstrations of compliance, and (5) alternatives for relating the performance objectives directly to a limit on risk.

STATEMENT OF PERFORMANCE OBJECTIVES

The performance objectives for low-level waste disposal are directed at limiting (1) releases of radioactivity to the general environment beyond the site boundary and (2) exposures of inadvertent intruders onto the disposal site. The principal performance objectives include separate dose limits for off-site individuals and inadvertent intruders as follows:

[1] a limit on annual committed effective dose equivalent averaged over a lifetime of 0.25 mSv (25 mrem) for any member of the general public beyond the boundary of the disposal facility; and

[2] a limit on annual committed effective dose equivalent averaged over a lifetime of 1 mSv (100 mrem) and a limit on committed effective dose equivalent in any year of 5 mSv (500 mrem) for any individual who inadvertently intrudes onto the disposal site after loss of active institutional controls.

In addition, releases of radioactivity to the general environment beyond the site boundary –

- shall not result in annual doses to any member of the general public that exceed limits established by Federal regulatory authorities for all sources of exposure, exclusive of natural background and deliberate medical practices; and

- shall be kept as low as reasonably achievable, economic and social factors being taken into account.

The latter two requirements ensure that the performance objectives conform to radiation protection standards for the general public established by the U.S. Nuclear Regulatory Commission (NRC)[8] in 10 CFR Part 20 and to similar standards for DOE operations.[7] In view of proposed revisions of the NRC and DOE radiation protection standards,[9,10] the limit on annual dose to individuals from all sources of exposure is expected to become 5 mSv (500 mrem) committed effective dose equivalent. The requirement that off-site releases of radioactivity shall be kept as low as reasonably achievable (ALARA) involves an optimization of population exposures by means of a cost-benefit analysis.[4] Thus, the ALARA requirement ensures protection of population groups as well as individuals.

APPLICABILITY OF PERFORMANCE OBJECTIVES

Time Period for Performance Objectives

The performance objectives for protection of off-site individuals and inadvertent intruders are intended to apply at any time following closure of the facility. The absence of a time cutoff agrees with the approach in the NRC's low-level waste standards[11] in 10 CFR Part 61. However, since the effects of radioactive decay and the dispersibility of radionuclides in the environment over time are expected to result in maximum doses to off-site individuals and inadvertent intruders that occur well within 10,000 years,[3,12,13] assessments of doses to maximally exposed individuals probably will not be required for unreasonably long time periods in the future.

The time period over which institutional controls are assumed to prevent inadvertent intrusion onto the disposal site is not specified in the performance objectives, but is important for determining concentrations of radionuclides that are acceptable for disposal when the half-life for radioactive decay is comparable to or less than the control period. On the basis of the NRC's conclusion that an institutional control period of 100 years is the most reasonable assumption for low-level waste disposal,[11] and the same conclusion of the U.S. Environmental Protection Agency (EPA) for high-level waste disposal,[14] we recommend that an institutional control period of 100 years be assumed in applying the performance objectives for protection of inadvertent intruders. However, this approach does not preclude the use of technologies (e.g., engineered barriers) that may be assumed to prevent intrusion into the wastes for time periods beyond the institutional control period, e.g., for 500 years.[11]

In applying the ALARA principle, it is reasonable to consider a time cutoff for calculation of population dose. Otherwise, dose estimates for very long-lived radionuclides (e.g., ^{129}I and natural uranium) are obtained primarily by accruing very small individual doses over very large populations for millions of years or more, but the estimated risk to most individuals is trifling compared with accepted risks from normal activities. Thus, such calculations do not provide a reasonable basis for optimization of population exposures. However, instead of specifying an explicit time cutoff that would necessarily be somewhat arbitrary, a lower cutoff on dose to individuals to be included in the calculations can be specified. This approach provides an effective time cutoff for population dose assessments, but one that is directly related to control of health risks in the population. On the basis of recent proposals,[6,9] we recommend that calculations of population dose for application of the ALARA principle include only annual committed effective dose equivalents to individuals that exceed 0.01 mSv (1 mrem).

<u>Processes and Events of Concern</u>

The performance objectives, including application of the ALARA principle, are intended to apply only to expected or reasonably foreseeable processes and events that could affect the long-term performance of the disposal system and lead to exposures of off-site individuals or inadvertent intruders; they are not intended to apply to low-probability processes and events that might lead to doses above the specified limits. This approach is consistent with the NRC's low-level waste standards,[11] and is a customary feature of performance objectives for other practices that involve limits on dose (e.g., see ref. 15). Thus, performance assessments will require scientific judgment in determining those processes and events that are reasonably foreseeable and those that are not. Again, however, this evaluation probably can be limited to a time period less than 10,000 years, because the effects of radioactive decay and environmental dispersion of radionuclides will tend to reduce doses to maximally exposed individuals over time.

Although the performance objectives do not apply to unexpected processes and events, such occurrences can be taken into account in developing criteria for siting and design of the facility and for the acceptability of wastes and waste forms. Such criteria presumably would not involve limits on dose or health risk. Alternatives for taking unexpected processes and events into account in the performance objectives, including expressing the performance objectives directly in terms of a limit on risk, are discussed later in this paper.

RATIONALE FOR USE OF ANNUAL COMMITTED EFFECTIVE DOSE EQUIVALENTS AVERAGED OVER A LIFETIME

The principal performance objectives for low-level waste disposal are expressed in terms of limits on annual committed effective dose equivalents averaged over the lifetime of an exposed individual. This approach differs from current practice in the U.S. of expressing radiation standards, including those for low-level waste disposal, in terms of limits on dose equivalents received to whole body or the critical organ (generally the organ or tissue that receives the highest dose) for each year of exposure.[7,8,11,14-16] This section discusses the rationale for the manner in which the performance objectives in this paper are expressed.

Effective Dose Equivalent

Use of the dose equivalent to whole body or the critical organ in radiation standards has three important drawbacks: (1) a given dose limit for two different tissues generally does not correspond to the same limit on risk; (2) potentially important doses and risks to tissues other than the critical organ are ignored; and (3) "whole body" is not a definable tissue at risk from radiation exposure, but it is particular organs or tissues in which health effects are expressed. In response to these difficulties, the International Commission on Radiological Protection (ICRP) has developed the concept of the _effective_ dose equivalent.[4]

The effective dose equivalent is defined by the ICRP as a weighted average of dose equivalents received by several different organs or tissues, excluding whole body; the weighting factor assigned to each organ is proportional to the stochastic risk per unit dose equivalent for that organ.[4] Thus, any exposures with equal effective dose equivalents should correspond to the same risk, regardless of the particular distributions of doses among different organs, and a limit on effective dose equivalent is directly related to the fundamental goal of risk limitation.

Use of the effective dose equivalent recently has been endorsed by the National Council on Radiation Protection and Measurements (NCRP),[6] and limits on effective dose equivalent are an essential feature of proposed revisions of radiation protection standards of the NRC and DOE.[9,10] The effective dose equivalent also appears in recent EPA standards for airborne releases of radionuclides.[16]

Committed Dose Equivalent

The committed dose equivalent (also called the dose commitment) is a concept used in estimating dose from inhaled or ingested activity that takes into account that an acute intake of some radionuclides (e.g., long-lived radionuclides that deposit in bone) results in significant doses received in future years, even with no further intakes, until the activity is removed from the body by radioactive decay and biological elimination.[4] The dose commitment from an acute intake is defined as the time integral of the dose equivalent rate, taking into account not only radioactive decay and biological retention of the inhaled or ingested radionuclide but also the buildup, decay, and retention in the body of any radioactive daughter products. The dose rate from an acute intake normally is integrated over a time period of 50 years, which is the average lifespan of an adult,[4] but 70-year dose commitments may be considered for exposures of the general public.

Many exposures of the general public, including expected exposures from low-level waste disposal, involve chronic rather than acute intakes of radionuclides. For any retention function of radionuclides in the body that decreases monotonically with time, is independent of the age of the individual, and for which the integral over infinite time is finite, the following important relationship holds:

> The dose received over any time t following an acute intake of a radionuclide is numerically equal to the dose rate at time t from a chronic intake of the same quantity of the radionuclide per unit time.

This relationship provides the basis for use of the committed dose equivalent for each year of exposure, rather than doses received in each year, in radiation standards. For chronic exposures, the dose received in any year will be less than or equal to the dose commitment from each year's intakes.

The advantage of expressing radiation standards for the general public in terms of limits on committed dose equivalent is that the resulting allowable intake of a radionuclide by an adult is constant with time. For radionuclides with long retention times in the body, the usual practice of specifying a limit on dose received in each year results in an allowable intake in any year after the first that is only a small fraction of the allowable intake in the previous year. For routine public exposures to environmental radioactivity, it clearly is highly impractical to use a dose-limitation system that requires knowledge of prior intakes of radionuclides in determining allowable intakes at present and future times. In addition, there are radionuclides for which an intake during the first year that meets a limit on dose received during that year would result in doses in all subsequent years that greatly exceed the dose limit even with no further intakes, due to the buildup and decay in the body of radiologically more significant daughter products. For example, on the basis of models and parameter values recommended by the ICRP,[17] an acute ingestion intake of ^{241}Pu results in a maximum annual dose to bone at about 40 years after intake that is nearly 25 times greater than the dose received during the first year, due to the buildup and decay of ^{241}Am. Again, use of a limit on committed dose equivalent alleviates this problem and leads to an allowable intake rate of ^{241}Pu by an adult that is constant with time.

Although radiation standards in the U.S. normally do not refer explicitly to limits on committed dose equivalents, dose commitments often are used in calculations for demonstrating compliance with the standards. However, we still believe it is preferable to express dose limits directly in terms of committed dose equivalents, in order to ensure consistency between the performance objectives and calculations used to assess compliance. Proposed revisions of radiation protection standards of the NRC and DOE explicitly specify limits on committed dose equivalents.[9,10]

Annual Doses Averaged over a Lifetime

Radiation standards usually specify a limit on dose to individuals for each year of exposure. However, the performance objectives in this paper are expressed in terms of annual doses averaged over a lifetime. This approach allows higher doses in some years provided they are compensated by lower doses in other years, and is based on consideration of the risk resulting from chronic exposures over a lifetime, including the age dependence of dose and risk. Chronic lifetime exposures, rather than acute exposures, are expected to occur with low-level waste disposal for both off-site individuals and inadvertent intruders.

Limits on dose are used in radiation standards as a surrogate for the fundamental goal of providing a limit on risk, so the dose limits should be expressed in a manner that corresponds closely to a limit on lifetime risk. The customary use in radiation standards for the general public of equal annualized increments of dose as a surrogate for a limit on lifetime risk is based on accepted practice for workers.[4,7,8] However, this practice may not be the most appropriate for chronic exposures of the general public.

An important difference between exposures of workers and exposures of the general public is that the latter involve age groups other than adults. Younger age groups may experience higher doses and risks than adults for some types of acute exposures, due to such factors as greater absorption of ingested activity from the gastrointestinal (GI) tract into blood for radionuclides with low GI-tract absorption in adults, increased deposition of absorbed activity in the skeleton for many elements, smaller organ masses, and greater risks per unit dose for some types of cancers (e.g., see ref. 18 and references therein). Thus, exposures of infants and children should be considered in establishing performance objectives for low-level waste disposal.

The most obvious way of accounting for different age groups would be to specify a limit on dose for each year of exposure that applies to all ages, and this is the approach that customarily is taken in radiation protection standards for the general public.[7,8] However, for practices that are expected to result in chronic exposures over a lifetime, this approach may not achieve a close correspondence with a desired limit on lifetime risk when the age dependence of dose and risk is taken into account. For low-level waste disposal, exposures of off-site individuals and inadvertent intruders are expected to vary slowly with time,[3,12,13] so that total intakes of radionuclides over a lifetime should be greater for adults than for younger age groups. Furthermore, for radionuclides with long retention times in the body, a substantial portion of the committed dose from intakes by infants or children may be received during adult years.[18]

The arguments presented above show that specifying a limit on dose commitment for each year of exposure for low-level waste disposal is largely a matter of custom, and may have the undesirable effect that acceptable system performance will be controlled by potential exposures of infants and children, even though the risk from chronic lifetime exposures will be determined primarily by intakes and doses received during adult years. Thus, a limit on annual dose commitment averaged over a lifetime corresponds more closely to a given limit on lifetime risk than does a limit on dose commitment for each year of exposure.

Although the approach adopted here leads to a primary focus on exposures of adults in evaluating system performance, exposures of younger age groups still should be considered in evaluating compliance with the performance objectives. We emphasize that if the limit on annual dose commitment averaged over a lifetime is sufficiently low, then any higher doses that might be received by infants and children still should result in an acceptable lifetime risk. Furthermore, annual doses to infants and children from all sources of exposure, including low-level waste disposal, are limited by the requirements in radiation protection standards of the NRC and DOE,[7,8] and we have included such a dose limit explicitly in the performance objectives for low-level waste disposal to ensure adequate protection of all age groups.

Finally, there is the practical matter that proper age-dependent internal dose calculations are available only for a few radionuclides of importance to low-level waste disposal, e.g., for ^{3}H, ^{14}C, ^{131}I, ^{137}Cs, and a number of bone-seeking radionuclides.[19–22] Proper calculations take into account the age dependence of organ masses and their shapes and locations within the body, radionuclide absorption in the GI tract, deposition and retention of inhaled radionuclides in the lung, and the distribution and retention of absorbed activity in different organs and tissues. For most radionuclides, however, calculations of internal dose for infants and children are based to some extent on models and parameters that are appropriate for adults.

RATIONALE FOR NUMERICAL DOSE LIMITS

Dose Limit for Off-Site Exposures

The choice of an annual[*] committed effective dose equivalent averaged over a lifetime of 0.25 mSv (25 mrem) as the principal performance objective for off-site exposures of individuals is based primarily on the judgment by the NRC that such a level of protection is reasonably achievable for low-level waste disposal, given the current state of disposal technology and its associated costs.[11] The EPA also has indicated that this dose limit should be encompassed by any standard that the EPA might derive.[11] Thus, low-level waste disposal on the Oak Ridge Reservation would conform to generic health-protection standards for this practice established by Federal regulatory authorities. We also note that the DOE has issued guidance that all planning for new low-level waste disposal facilities should assume an interim performance objective for off-site exposures of 0.25 mSv (25 mrem) per year.[23]

If we assume a risk factor for radiation exposure of 2×10^{-2} per Sv (2×10^{-4} per rem),[4] then an average annual dose commitment of 0.25 mSv (25 mrem) corresponds to an average annual risk of 5×10^{-6} and to a lifetime risk of 3.5×10^{-4} from continuous exposure over an average lifespan of 70 years. Thus, the dose limit for off-site exposures corresponds to a risk that is about 0.2% of the current risk of fatal cancers in the U.S.[24] We note, however, that continuous lifetime exposures of off-site individuals at the dose limit are highly unlikely for a disposal facility that meets the requirements on dose limitation and application of the ALARA principle.[4] Furthermore, the assumed risk factor may provide conservative overestimates of risks at very low doses and dose rates.[4] Thus, actual risks to off-site individuals should be consistent with levels that are regarded as negligible by most members of the general public.

Dose Limits for Inadvertent Intruders

The use of higher dose limits for inadvertent intruders than for off-site individuals is consistent with the NRC's standards for low-level waste disposal.[11] Higher doses to inadvertent intruders can be justified on the grounds that relatively few individuals are likely to intrude onto the site, so that intruder exposures will have little effect on population dose, and postulated exposure scenarios for inadvertent intruders probably will not occur with a probability of unity at any time after loss of institutional controls.

The choice of a committed effective dose equivalent of 5 mSv (500 mrem) as a limit for any year of exposure is consistent with the NRC's low-level waste standards,[11] and is based on current and proposed radiation protection standards of the NRC and DOE for all sources of exposure.[7-10] However, for prolonged exposures of inadvertent intruders, we follow the recommendations of the ICRP[4,25] and NCRP[6] that the limit on annual committed effective dose equivalent should be reduced to 1 mSv (100 mrem) in order to provide an acceptable lifetime risk. The lower dose limit for prolonged exposures also is contained in proposed revisions of the DOE's radiation protection standards.[10]

Continuous exposure over a 70-year lifetime at an average rate of 1 mSv (100 mrem) per year corresponds to an estimated lifetime risk of 1.4×10^{-3}. Again, however, for a disposal facility that meets the performance objectives on dose to an inadvertent intruder, it is unlikely that any individuals would experience a lifetime risk as large as this.

IMPLICATIONS FOR DEMONSTRATIONS OF COMPLIANCE

Formulation of the performance objectives for low-level waste disposal in terms of annual committed effective dose equivalents averaged over a lifetime has important implications for dose assessments used in demonstrations of compliance, some of which have been discussed previously in this paper.

[1] The performance assessments need consider only expected or reasonably foreseeable processes and events that lead to human exposures.

[2] Annual doses to maximally exposed individuals would be evaluated over a lifetime's exposure, which encourages consideration of reductions in radionuclide inventories in environmental media over a lifetime due to radioactive decay and environmental transport processes.

[3] Available information on dose and risk from intakes of radionuclides as a function of age at exposure (e.g., see refs. 18, 22 and references therein) suggests that dose assessments can focus primarily on intakes and doses received during adult years in evaluating annual doses averaged over a lifetime, because these are expected to be the most important in determining lifetime risk from chronic exposures. However, proper consideration of the age dependence of exposure and dose in determining compliance with the performance objectives is strongly encouraged, not only in evaluating annual committed doses averaged over a lifetime but also in ensuring that committed doses received in any year do not exceed specified limits, particularly for those radionuclides for which the committed dose per unit intake is considerably higher in infants and children than in adults (e.g., see ref. 22).

[4] Dose assessments for inadvertent intruders need not consider ephemeral exposure scenarios, such as the so-called intruder-construction scenario,[26] because chronic exposures again will be the most important in determining annual committed doses averaged over a lifetime and ephemeral exposures are not likely to exceed the dose limit for each year of exposure if compliance with the dose limit for chronic exposures is achieved.

PERFORMANCE OBJECTIVES EXPRESSED AS A LIMIT ON RISK

An expert group of the Nuclear Energy Agency has developed a recommendation that criteria for protection of individuals from radioactive waste disposal be expressed directly in terms of limits on risk, which is defined as the product of the probability of exposure and the probability that doses received from the exposure will result in deleterious health effects.[27] This approach takes into account that some processes and events that could affect long-term system performance and result in human exposures have probabilities of occurrence that are less than unity and vary with time. A limit on risk thus has the potential advantage that all such processes and events would be treated on the same basis in performance assessments, without the need to make somewhat arbitrary distinctions between those that are expected and those that are not.

Two primary considerations have led us not to express the performance objectives for low-level waste disposal directly in terms of limits on risk. First, this approach implies that there is a known relationship between exposure and risk for all radionuclides and all levels of exposure, whereas the use of limits on dose can be based on an assumed relationship between dose and risk. Only in a few cases, however, is the relationship between exposure and risk known from observations in human populations,[28] and the exposures far exceed those that would be acceptable for low-level waste disposal. This consideration also was important to the NCRP's recent decision not to express radiation protection standards in terms of limits on risk.[6] Second, estimates of probabilities of processes and events that lead to human exposures may be quite contentious and difficult to defend, particularly for occurrences of relatively low probability that would correspond to acceptable doses considerably above dose limits for expected processes and events or that would exceed the threshold for nonstochastic radiation effects in some organs and tissues.[4] The concept of risk as the product of a probability and a consequence is poorly understood by the general public, and there will be a tendency to focus on the high doses that are acceptable and to ignore their probabilities of occurrence.

An alternative approach that expresses the performance objectives as limits on dose but also takes into account probabilities that doses will be received is to specify several dose limits that increase as the probability of receiving the dose decreases.[29] For example, one could specify that the annual committed effective dose equivalent averaged over a lifetime for an inadvertent intruder shall (1) be expected to be less than 1 mSv (100 mrem), (2) be quite unlikely to be more than 5 mSv (500 mrem), and (3) not exceed 50 mSv (5 rem) in any credible circumstances. Thus, the dose limit would be a step function of the probability of receiving the dose, and one then must decide what probabilities correspond to the subjective expressions "quite unlikely" and "in any credible circumstances." Again, however, a potential disadvantage of this approach is that acceptable doses associated with exposures with low probability may not be accepted by the general public.

SUMMARY

This paper has presented a set of performance objectives for a new low-level waste disposal facility on the Oak Ridge Reservation. Consistent with the requirements of radiation protection standards for the general public that have been promulgated by Federal regulatory authorities,[7,8] the primary goal of the performance objectives is to ensure protection of both individuals and population groups. This goal is accomplished by establishing limits on radiation dose for off-site individuals and inadvertent intruders and by the ALARA requirement for optimizing population exposures. The use of dose limits for maximally exposed individuals as a surrogate for a limit on lifetime risk conforms to recommendations of the ICRP[4] and NCRP[5,6] and to conventional radiation protection practice in the U.S.[7-10]

The principal performance objective for protection of off-site individuals is a limit on annual committed effective dose equivalent averaged over a lifetime of 0.25 mSv (25 mrem). This dose limit is based primarily on the judgment of the NRC that it represents a reasonably achievable level of protection for shallow-land disposal of low-level wastes.[11] The principal performance objective for protection of individuals who inadvertently intrude onto the disposal site after loss of institutional controls is a limit on annual committed effective dose equivalent averaged over a lifetime of 1 mSv (100 mrem) and a limit on committed effective dose equivalent in any year of 5 mSv (500 mrem). These dose limits are based primarily on the judgment of the NRC that higher limits are acceptable for inadvertent intruders than for off-site individuals,[11] and on recommendations of the ICRP[4,25] and NCRP[6] for limits on acceptable dose to individuals from all sources of exposure, excluding natural background and medical practices.

The use of limits on annual committed effective dose equivalents averaged over a lifetime differs from customary practice in radiation standards in the U.S.[7,8,11,14-16] Use of the committed effective dose equivalent follows the recommendations of the ICRP[4] and NCRP,[6] and is embodied in proposed revisions of radiation protection standards of the NRC[9] and DOE.[10] The specification of limits on annual dose commitments averaged over a lifetime, rather than dose commitments for each year of exposure, results in performance objectives that are closely related to the fundamental goal of limiting lifetime risk from chronic exposures while still encouraging proper consideration of the age dependence of dose and risk for exposures of the general public in evaluating compliance with the dose limits. This approach is embodied in recent recommendations of the ICRP[25] and NCRP,[6] which specify separate limits on annual dose commitments for chronic and occasional exposures.

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