

**Radiological Criteria
for Remedial Actions
at Radioactively Contaminated Sites**

David C. Kocher

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at Radioactively Contaminated Sites**

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Health Sciences Research Division
Oak Ridge National Laboratory
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1. INTRODUCTION

Radiological criteria for determining acceptable remedial actions at radioactively contaminated sites on the Oak Ridge Reservation are presented in this report. The proposed criteria address protection of human health and man's exposure environment but do not address protection of nonhuman biota. In addition, the criteria do not address potential exposures to nonradioactive hazardous chemicals that might be present at contaminated sites; however, as discussed in Sect. 7, the protection principles on which the proposed radiological criteria are based could be used to determine acceptable remedial actions for carcinogenic hazardous chemicals. This proposal was first discussed in a previous report (Kocher 1989).

An important rationale for the proposed remedial action criteria is that many of the contaminated sites of concern were used for deliberate disposals of radioactive waste, principally low-level waste, or the sites contain radioactive materials similar in composition and potential hazard to many low-level wastes. Indeed, the basis for this proposal is the notion that remedial actions at radioactively contaminated sites on the Oak Ridge Reservation should achieve risks to human health consistent with current standards for ongoing, permitted disposals of low-level radioactive waste at Oak Ridge and all other United States Department of Energy (DOE) sites.

Current standards for disposal of low-level radioactive waste, which provide the basis for the proposed remedial action criteria for radioactively contaminated sites, were developed under authority of the Atomic Energy Act. However, the contaminated sites of concern in this report are subject to remediation under authority of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), primarily because standards for low-level waste disposal had not been developed at the time the contamination occurred and therefore the contaminated sites constitute "unpermitted" releases to the environment under CERCLA. This report also describes two different approaches to risk management under the Atomic Energy Act and CERCLA and demonstrates how the proposed remedial action criteria can be reconciled with the requirements of CERCLA.

2. PROPOSED REMEDIAL ACTION CRITERIA

In accordance with the previously stated notion that remedial actions at radioactively contaminated sites should achieve risks to human health consistent with risks that could result from permitted disposals of low-level radioactive waste at any DOE site, the proposed radiological criteria for determining acceptable remedial actions at radioactively contaminated sites on the Oak Ridge Reservation are:

for members of the public beyond any boundary at which active institutional controls over contaminated sites are maintained, a limit on effective dose equivalent from all exposure pathways of 0.25 mSv (25 mrem) per year;

reduction of releases of radioactivity from contaminated sites into the general environment as low as reasonably achievable (ALARA);

for inadvertent intruders onto contaminated sites at any time after loss of active institutional controls over the sites, limits on effective dose equivalent from all exposure pathways from direct intrusion into radioactive materials of 1 mSv (100 mrem) per year for scenarios involving continuous exposure over a lifetime or 5 mSv (500 mrem) for scenarios involving a single, acute exposure; and

to the extent reasonably achievable, protection of groundwater and surface water resources consistent with Federal, State, and local requirements.

The proposed radiological criteria for remedial actions at radioactively contaminated sites essentially are the same as the current performance objectives for permitted disposals of low-level radioactive waste at any DOE site (DOE 1988).

3. DISCUSSION OF PROPOSED CRITERIA

A discussion of the rationale for the proposed remedial action criteria for radioactively contaminated sites on the Oak Ridge Reservation and certain aspects of how the proposed criteria should be implemented is presented in the following subsections.

3.1 PROTECTION OF OFF-SITE MEMBERS OF THE PUBLIC

The proposed criteria for limiting dose to off-site members of the public and reducing releases of radionuclides into the general environment as low as reasonably achievable (ALARA) are based on well-established principles of radiation protection developed, for example, by the International Commission on Radiological Protection (ICRP 1991). In particular, the ICRP has recommended, first, that radiation doses to maximally exposed individuals should not exceed specified limits and, second, that doses should be reduced below the limits using the ALARA principle, which takes into account the costs of reducing exposures in relation to the benefits in health risks averted and other societal concerns.

For individual members of the public, the ICRP (1991) has recommended a limit on dose equivalent from all man-made sources of 1 mSv (100 mrem) per year, and this dose limit is specified in radiation protection standards for the public established by the DOE (1990) and the Nuclear Regulatory Commission (NRC 1991). However, because individuals could receive exposures from more than one man-made source, regulatory authorities have established lower dose limits for specific sources of exposure to ensure that the dose limit for all man-made sources will be met (Kocher 1988). A limit on dose equivalent of 0.25 mSv (25 mrem) per year for a single source, i.e., one-fourth of the dose limit for all man-made sources, conforms with current recommendations of the National Council on Radiation Protection and Measurements (NCRP 1993) on control of individual sources, and essentially the same dose limit has been established by the NRC (1982) for disposal of civilian low-level radioactive waste.

In applying the dose limit for off-site members of the public to remediation of radioactively contaminated sites on the Oak Ridge Reservation, the boundary between contaminated sites and off-site locations must be defined. At facilities which are permitted in accordance with NRC (1982) or DOE (1988) requirements for disposal of low-level radioactive waste, the site boundary normally is defined as the edge of a buffer zone extending no more than 100 m from any disposed waste; e.g., see Wood et al. (1994). A 100-m buffer zone should provide sufficient land area for any monitoring, maintenance, or remedial action activities that might be required at disposal sites, and such a buffer zone would be appropriate for defining the location of off-site individuals at contaminated sites remediated under CERCLA.

3.2 PROTECTION OF INADVERTENT INTRUDERS

The proposed criterion for limiting dose to inadvertent intruders addresses the possibility that, at any time after loss of active institutional controls over contaminated sites, individuals could come onto the sites and, without prior knowledge of the contamination, receive exposures as a result of activities involving direct intrusion into radioactive materials. This criterion is based directly on current radiation protection standards for the public (ICRP 1991, DOE 1990, NRC 1991) which include a primary limit on dose equivalent of 1 mSv (100 mrem) per year for continuous exposure and a subsidiary limit on dose equivalent of 5 mSv (500 mrem) for infrequent exposure. For radioactively contaminated sites on the Oak Ridge Reservation, scenarios for continuous exposure of inadvertent intruders are expected to be more important in determining limits on acceptable residual concentrations of radionuclides than scenarios for a single, acute exposure (ORNL 1994).

The proposed criteria allow higher doses and risks to inadvertent intruders than to off-site individuals. This approach is based on established precedents for low-level waste disposal (NRC 1981a) and takes into account several considerations. First, even if lifetime exposures of inadvertent intruders would occur as postulated, e.g., according to a standard homesteader scenario, the resulting dose and risk would still be within the acceptable bounds recommended by the ICRP (1991). Second, even if inadvertent intruders would receive higher doses than off-site individuals, the collective dose in the exposed population and the expected number of health effects would not be increased significantly, due to the small number of potential inadvertent intruders. Third, scenarios for inadvertent intrusion which assume chronic exposure over a lifetime undoubtedly are somewhat conservative in the sense that the postulated scenarios would occur only with a probability somewhat less than one for any individual at any site. Therefore, the risk to inadvertent intruders, given by the product of the conditional risk assuming that an exposure scenario occurs and the probability of occurrence of that scenario, would be correspondingly reduced. Finally, although inadvertent intruders could receive exposures from more than one source, it is unlikely that exposures to sources other than the contaminated site would result in doses exceeding more than a small fraction of the dose limit of 1 mSv (100 mrem) per year for all man-made sources.

Exposures of inadvertent intruders at radioactively contaminated sites are assumed to be credible only in the absence of active institutional controls, and no special protection is provided for individuals who might deliberately intrude onto contaminated sites during the institutional control period. In accordance with the usual assumption for permitted low-level waste disposal facilities regulated under the Atomic Energy Act (NRC 1982, DOE 1988), it would be reasonable to assume

maintenance of active institutional controls over contaminated sites subject to remediation under CERCLA for up to 100 years after cessation of operations on the Oak Ridge Reservation.

The criterion for protection of inadvertent intruders could apply at any time after loss of active institutional controls over the contaminated sites, and assuming an active institutional control period of 100 years allows radioactive decay to be taken into account in determining limits on acceptable residual concentrations of radionuclides that decay appreciably over that time. For almost all radionuclides, the limits on acceptable residual concentrations could be based on analyses of scenarios for inadvertent intrusion at the time active institutional controls are lost, because the concentrations, and therefore the dose, decrease monotonically with time thereafter. However, the dose to an inadvertent intruder from long-lived isotopes of uranium (^{234}U , ^{235}U , and ^{238}U) increases with time, due to the buildup of their radiologically more significant radioactive decay products (^{226}Ra and ^{231}Pa). For these isotopes, it would be reasonable to evaluate exposures of inadvertent intruders for times up to 10,000 years after disposal, in accordance with a recent recommendation on a time limit for applying performance objectives for low-level waste disposal (Wood et al. 1994).

3.3 PROTECTION OF GROUNDWATER AND SURFACE WATERS

The proposed criterion for protection of groundwater and surface water resources is deliberately left unspecified, because Federal standards for acceptable levels of radioactivity in groundwater and surface waters have not been promulgated. However, in accordance with the requirements of CERCLA and the usual interpretation of the performance objective for protection of groundwater resources at DOE low-level waste disposal sites [e.g., see ORNL (1994)], it would be reasonable to interpret this criterion in terms of standards established by the United States Environmental Protection Agency for radioactivity in public drinking water supplies (EPA 1976). These standards apply at the tap, rather than at the source, and therefore are not directly applicable to protection of groundwater or surface water resources. However, applying drinking water standards to protection of groundwater or surface waters near contaminated sites, to the extent reasonably achievable, would help avoid the need for costly cleanups of drinking water should affected sources ever be used for this purpose.

The EPA's interim drinking water standards for radionuclides (EPA 1976) are currently being revised (EPA 1991). For most radionuclides of concern at radioactively contaminated sites on the Oak Ridge Reservation, the revised standards are expected to specify a limit on effective dose equivalent of 0.04 mSv (4 mrem) per year, assuming consumption of 2 liters per day of drinking water. This dose limit has been applied to all radionuclides in protecting groundwater and surface water resources at some DOE low-level waste disposal sites (ORNL 1994).

Application of the criterion for protection of groundwater and surface water resources also requires an assumption about the need to protect potential sources in the immediate vicinity of contaminated sites. For new low-level waste disposal facilities, DOE is considering a recommendation that drinking water standards need be met in potential sources only outside the 100-m buffer zone (Wood *et al.* 1994). Thus, for remediation of contaminated sites, the goal of protecting groundwater and surface water resources in accordance with drinking water standards for

radionuclides would apply only in the same regions as the requirement for protection of off-site members of the public. At most sites, however, levels of contamination in water inside the 100-m buffer zone should not greatly exceed levels immediately outside the buffer zone.

3.4 INTERPRETATION OF CRITERIA AS LIMITS OR GOALS

The proposed remedial action criteria include both limits and goals, and it is important to recognize the difference between the two. A limit is a criterion that must be met regardless of cost and therefore is regarded as necessary for protection of public health. On the other hand, a goal is a criterion that must be met only if it is reasonable to do so. Considerations of whether a goal is reasonably achievable take into account such factors as costs, benefits, and other societal concerns.

The criteria for protection of off-site members of the public and inadvertent intruders are intended to be interpreted as limits. However, because of the additional criterion that releases of radioactivity from contaminated sites into the general environment should be as low as reasonably achievable (ALARA), remedial actions could result in maximum doses to off-site members of the public considerably less than the limit. The ALARA criterion also could be applied to inadvertent intruders, i.e., in determining allowable residual concentrations of radionuclides at contaminated sites, but this approach probably would not result in meaningful risk reduction when the collective dose and risk that could be experienced by this small population group should be much less than the collective dose and risk in the off-site population.

The criterion for protection of groundwater and surface water resources is intended to be interpreted as a goal, rather than a limit. This interpretation is consistent with the provisions of CERCLA that drinking water standards are applicable or relevant and appropriate requirements (ARARs) for cleanup of contaminated sites but that there are many conditions under which remedial actions need not comply with ARARs, e.g., if compliance is technically infeasible or would not balance the cost against the benefit in protecting public health and the environment.

It also should be emphasized that drinking water standards for radionuclides were based on judgments about levels of radioactivity in public drinking water supplies that are reasonably achievable, taking into account costs of water treatment in relation to health risks averted, rather than an assumed limit on risk to public health that must be met regardless of cost (EPA 1976). Furthermore, levels of radioactivity that are reasonably achievable in public drinking water supplies are not necessarily reasonably achievable in groundwater or surface waters near contaminated sites. However, even if protection of groundwater and surface water resources in accordance with drinking water standards, i.e., a dose limit of 0.04 mSv (4 mrem) per year for the drinking water pathway, is not reasonably achievable, the dose limit of 0.25 mSv (25 mrem) per year from all exposure pathways for off-site individuals would ensure that levels of radioactivity in groundwater or surface waters at any locations outside the 100-m buffer zone would not exceed drinking water standards by more than a factor of about six (the ratio 0.25/0.04).

3.5 LEVEL OF ASSURANCE IN DEMONSTRATING COMPLIANCE WITH CRITERIA

The proposed criteria for defining acceptable remedial actions at radioactively contaminated sites are stated in unqualified terms in regard to the level of assurance that would be required in demonstrating compliance. However, demonstrations of compliance with the criteria, either at the

present time or over long time periods in the future, can only be based on measurements and models that involve irreducible and, in some cases, unquantifiable uncertainties.

The nature of uncertainties in predicting health risks due to contamination at any site leads to the conclusion that absolute assurance of compliance with any remedial action criteria cannot be achieved and that the concept of reasonable assurance should be used in demonstrating compliance with criteria, e.g., see NRC (1981b) and Wood et al. (1994). Indeed, there appears to be no other standard of assurance that can be applied in reaching safety decisions on the basis of uncertain technical information. Use of the concept of reasonable assurance in decision making for site remediation would be completely consistent with its present applications to radioactive waste disposal.

3.6 USE OF INSTITUTIONAL CONTROLS IN COMPLYING WITH CRITERIA

Approaches to remediation of contaminated sites normally consider cleanup of contamination in environmental media to an extent sufficient to permit unrestricted use of the site and the surrounding area by members of the public. However, given the types of institutional controls presently maintained over contaminated sites on the Oak Ridge Reservation, and given that such controls are expected to be maintained for some time in the future, acceptable remedial actions also could include the continued use of some form of institutional controls to prevent public access to the sites and contaminated areas beyond site boundaries.

Appropriate institutional controls could include such active measures as fences and guards, as at the present time, or such passive controls as restrictions on land use, permanent marker systems, and public records of activities at the contaminated sites. Use of active or passive institutional controls could be a cost-effective option at sites where the contamination levels are reduced appreciably over time by radioactive decay or at sites where removal of radioactive material to an extent sufficient to meet the proposed criteria for conditions of unrestricted use of the site is not practical.

4. RISKS CORRESPONDING TO REMEDIAL ACTION CRITERIA

The doses in the proposed radiological criteria can be expressed in terms of equivalent risks by using a risk factor (i.e., risk per unit dose) recommended by the ICRP (1991). For chronic lifetime exposures of members of the public, the ICRP recommends a risk factor for fatal cancers of 5.0×10^{-2} per Sv. Therefore, for continuous exposure over an average lifetime of 70 years, the lifetime risk of fatal cancers corresponding to the dose limit of 0.25 mSv per year for off-site members of the public is 9×10^{-4} . Similarly for inadvertent intruders, the lifetime risk corresponding to the dose limit of 1 mSv per year for continuous exposure is 3.5×10^{-3} , and the risk corresponding to the dose limit of 5 mSv for a single, acute exposure is 2.5×10^{-4} . Finally, if the goal for protection of groundwater and surface water resources is assumed to be a dose of 0.04 mSv per year, the corresponding lifetime risk is 1.4×10^{-4} .

Conversion of the dose criteria to equivalent lifetime risks facilitates a comparison with the risk goals for remediation of contaminated sites under CERCLA as discussed in the following section.

5. REMEDIAL ACTION GOALS UNDER CERCLA

Remediation of radioactively contaminated sites on the Oak Ridge Reservation will be regulated under the authority of CERCLA. This law and its implementing regulations (EPA 1990) specify that remediation goals for contaminated sites shall be developed taking into account 1) applicable or relevant and appropriate requirements (ARARs) established under other Federal or State environmental laws, with Federal drinking water standards specified as ARARs for cleanup of groundwater and surface water; 2) other information to be considered (TBCs) which is not ARARs (e.g., DOE Orders); and 3) for known or suspected carcinogens (e.g., radionuclides), an upper bound on lifetime cancer risk of 10^{-4} – 10^{-6} from all substances and all exposure pathways.

However, as noted in Subsect. 3.4, CERCLA also specifies several conditions under which remedial actions need not comply with ARARs, TBC guidance, or the upper bound on lifetime cancer risk. Therefore, the CERCLA criteria for site remediation clearly should be interpreted as goals to be met only if it is reasonable to do so, rather than limits that must be met regardless of cost or other considerations. Indeed, in no instances have cleanups at CERCLA sites achieved the goal for a lifetime cancer risk of 10^{-4} – 10^{-6} . Rather, lifetime cancer risks embodied in cleanup decisions to date generally have been in the range 10^{-2} – 10^{-4} (EPA 1994).

The lifetime cancer risk of 1.4×10^{-4} that would result from applying proposed revisions of drinking water standards for radionuclides (EPA 1991) to cleanup of groundwater and surface water (refer to Sect. 4) is consistent with the goal for an upper bound on lifetime cancer risk at CERCLA sites. Again, however, achieving levels of contamination in groundwater and surface water at CERCLA sites that comply with drinking water standards is a goal rather than a requirement.

In addition, current standards for disposal of low-level radioactive waste presumably would be ARARs for cleanup of old waste disposal sites that were not subject to the current standards. The risks corresponding to the dose limits for off-site individuals (0.25 mSv per year) and inadvertent intruders (1 mSv per year) in these standards, given in Sect. 4, are at least an order of magnitude greater than the risk goal for cleanup of CERCLA sites. However, these doses are intended to be applied as limits, not goals, in remediating radioactively contaminated sites, and the corresponding limits on lifetime cancer risk are within the range of risks (10^{-2} – 10^{-4}) that have been achieved in all cleanups of CERCLA sites to date. Furthermore, in the proposed remediation criteria, the ALARA principle would be used to reduce doses and risks to below the limit for off-site individuals.

6. RISK MANAGEMENT UNDER CERCLA AND ATOMIC ENERGY ACT

The radiological criteria proposed in this report for radioactively contaminated sites on the Oak Ridge Reservation are based on current standards for disposal of low-level radioactive waste

developed under authority of the Atomic Energy Act but these sites are subject to remediation under authority of CERCLA; therefore, it is important to understand the different regulatory approaches to risk management under the two laws and how these approaches can be reconciled.

As described in other reports (Kocher and Hoffman 1991), radiation exposures of the public subject to control under authority of the Atomic Energy Act are regulated using a "top-down" approach to risk management. As indicated in Subsect. 3.1, this approach, which is referred to as the radiation paradigm, essentially follows specific steps. First, a limit on radiation exposure corresponding to an upper bound on acceptable risk is established. Exposures above the upper bound are regarded as unacceptable, meaning intolerable, and the limit must be met regardless of cost. Then, exposures must be reduced below the limit as low as reasonably achievable (ALARA).

Regulation of public exposures under authority of CERCLA is an example of the "bottom-up" approach to risk management embodied in a variety of laws other than the Atomic Energy Act. This approach, which is referred to as the chemical paradigm and is the opposite of the "top-down" approach in the radiation paradigm described previously, essentially follows specific steps. First, a goal for acceptable risk is established, e.g., the lifetime cancer risks of 10^{-4} – 10^{-6} under CERCLA. Then, the goal for acceptable risk may be increased (i.e., relaxed upward) for specific exposure situations based on, for example, consideration of the costs of risk reduction in relation to the benefits in health risks averted. Therefore, it is clear that risks above the statutory or regulatory goals are not necessarily unacceptable (i.e., intolerable).

An important difference between the chemical paradigm for risk management embodied in CERCLA and the radiation paradigm under the Atomic Energy Act is that the former does not yet incorporate the notion of an intolerable risk, i.e., a risk so high that it must be reduced regardless of cost for any reasonably foreseeable circumstance. The CERCLA risk goals clearly do not define a lower bound on unacceptable (i.e., intolerable) risk, because risks exceeding these levels are allowable (acceptable) in specific situations, e.g., if the goals are not reasonably achievable. Furthermore, there is no requirement under CERCLA, or any other laws which embody the chemical paradigm, to reduce risks below the stated goals using the ALARA principle. Therefore, any risk goals in the chemical paradigm clearly should be interpreted as upper bounds on *de minimis* (i.e., negligible or trivial) risks, rather than risks above which action to reduce risk is required.

If the differences between the two risk management paradigms are recognized, particularly between a limit and a goal for health risk, then the proposed remedial action criteria for radioactively contaminated sites on the Oak Ridge Reservation, which involve limits on radiation exposure and reduction of exposures and levels of environmental contamination using the ALARA principle, are seen to be consistent with the current regulatory approach under CERCLA. This approach includes goals for risk and levels of environmental contamination but permits risks and levels of contamination above the stated goals. The consistency between the two regulatory approaches results essentially from the fact that both approaches emphasize reduction of risks to the extent reasonably achievable, i.e., using the ALARA principle. Therefore, risks can be acceptable under either paradigm even if they are greater than levels generally regarded as negligible.

7. APPLICATION OF PROPOSED CRITERIA TO HAZARDOUS CHEMICALS

The proposed criteria for remedial actions at radioactively contaminated sites also could be applied to chemical carcinogens in a straightforward manner. For exposures of off-site members of the public and inadvertent intruders, limits on risk from exposure to chemical carcinogens consistent with the risks corresponding to the proposed dose limits from exposure to radionuclides could be established. In addition, risk goals for contamination of groundwater and surface waters by chemical carcinogens could correspond to current drinking water standards. If one recognizes the difference between limits and goals, then, as described in Sect. 6, such criteria would be consistent with the current regulatory approach to site remediation under CERCLA.

Applying the proposed criteria to noncarcinogenic hazardous chemicals would be less straightforward, primarily because the dose-response relations for noncarcinogens, which are assumed to involve a threshold, are quite different from the dose-response relations for carcinogens, which are assumed to be linear with no threshold. Remedial action criteria for noncarcinogens presumably could be based on Reference Doses (RfDs), which are estimated on the basis of observed thresholds for induction of adverse health effects in animals and application of large safety factors which take into account uncertainties in extrapolating animal data to sensitive human populations (EPA 1989). However, because of the careful distinction between limits and goals in the proposed remedial action criteria for radionuclides, consideration would need to be given to the question of whether RfDs are appropriate for defining limits that must be met regardless of cost or whether, because of the large safety factors used in their derivation, RfDs should be used to define remediation goals. Some multiple of the RfDs would be more appropriate for defining exposure limits.

8. SUMMARY

This report has presented a proposed set of radiological criteria for determining acceptable remedial actions at radioactively contaminated sites on the Oak Ridge Reservation. Compliance with the criteria could be achieved by removal of radioactive contaminants to an extent sufficient to permit unrestricted use of the sites or, if cleanup to acceptable levels of contamination would be impractical, by use of long-term active or passive institutional controls to preclude unrestricted use of the sites.

The proposed criteria are based on the notion that remedial actions at these sites should achieve risks to human health and the environment consistent with risks that will be achieved at permitted sites for disposal of low-level radioactive waste. This approach is assumed to be reasonable because radioactively contaminated sites and permitted sites for disposal of low-level waste involve similar practices and potential radiological impacts. If essentially the same criteria were applied to contaminated sites and permitted waste disposal facilities, the two should be virtually indistinguishable in regard to their impacts on human health and the environment.

The proposed radiological criteria for radioactively contaminated sites are based essentially on the radiation paradigm for risk management, as applied under authority of the Atomic Energy Act,

although these sites will be remediated in accordance with the chemical paradigm for risk management under authority of CERCLA. However, the two risk management paradigms can be reconciled by distinguishing clearly between *limits* for exposure and environmental contamination, which are central to the radiation paradigm, and *goals*, which are central to the chemical paradigm, and by recognizing that both paradigms emphasize reduction of health risks and environmental contamination to levels that are as low as reasonably achievable (ALARA). On the other hand, it also should be recognized that certain of the proposed criteria in the form of dose limits, which must be met regardless of cost, do not represent a regulatory concept presently acknowledged under CERCLA or in other applications of the chemical paradigm.

This report also included a brief discussion on how the proposed remedial action criteria for radioactively contaminated sites might be applied to carcinogenic and noncarcinogenic hazardous chemicals. However, this discussion is somewhat more speculative, particularly for noncarcinogens, and is intended only to indicate that it would be possible to apply the concepts of limits and goals for exposure and environmental contamination in a reasonably consistent way for all contaminants.

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